NASA's Never-Ending Mission

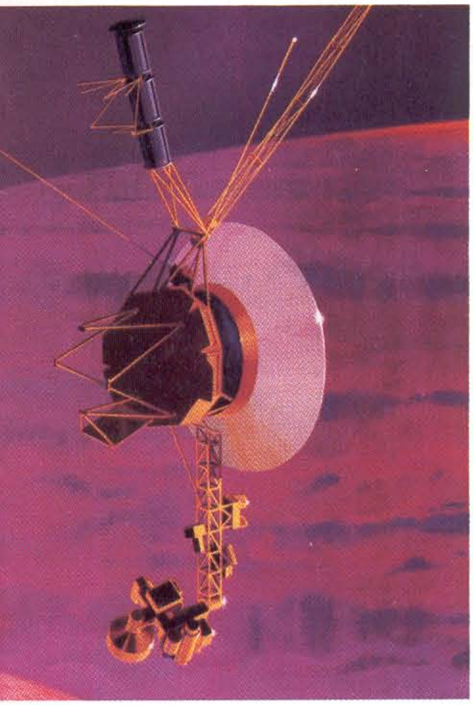
Discoveries in the solar system often result from a second or third look at old spacecraft data and sometimes provide startling insight into the character of moons and planets.

By John Williams

If only the walls at NASA could speak. Within the archives of the institution a small mountain of information sits largely unexamined, waiting to share its secrets. The NASA archives hold warehouses full of magnetic tapes and rooms full of CD-ROM disks containing billions of bytes of data from planetary science missions, much of which has never been thoroughly explored. The problem is time and money: scientists receive only so much funding and have only so much time. It is an enviable situation — possessing too much data to handle.

This condition points up a curious aspect of science. Discoveries sometimes wait until second or third or fourth looks at the data, and they often involve more than a little human intuition, ingenuity and, yes, luck. Let's ride along on four spacecraft missions to Venus, Jupiter, Neptune, and Saturn, and look at the nature of the discoveries scientists made both during and after the fact.

PLUMES OF VOLCANIC ASH lie silhouetted against black space along the limb of Jupiter's moon Io. Volcanic activity was recorded in data from Voyager (below), but noticed long after the spacecraft encounter. NASA photos.



Spark of Controversy

All space missions produce a mountain of data. Much of this data fits neatly into existing theories. However, some new ideas spark controversies requiring the defenders to go back and re-examine their data to prove their points. That's how science works. Chris Russell of UCLA, Joe Grebowsky of the Goddard Space Flight Center, Bob Strangeway of NASA, and D.A. Gurnett of the University of Iowa think science is working well at Venus.

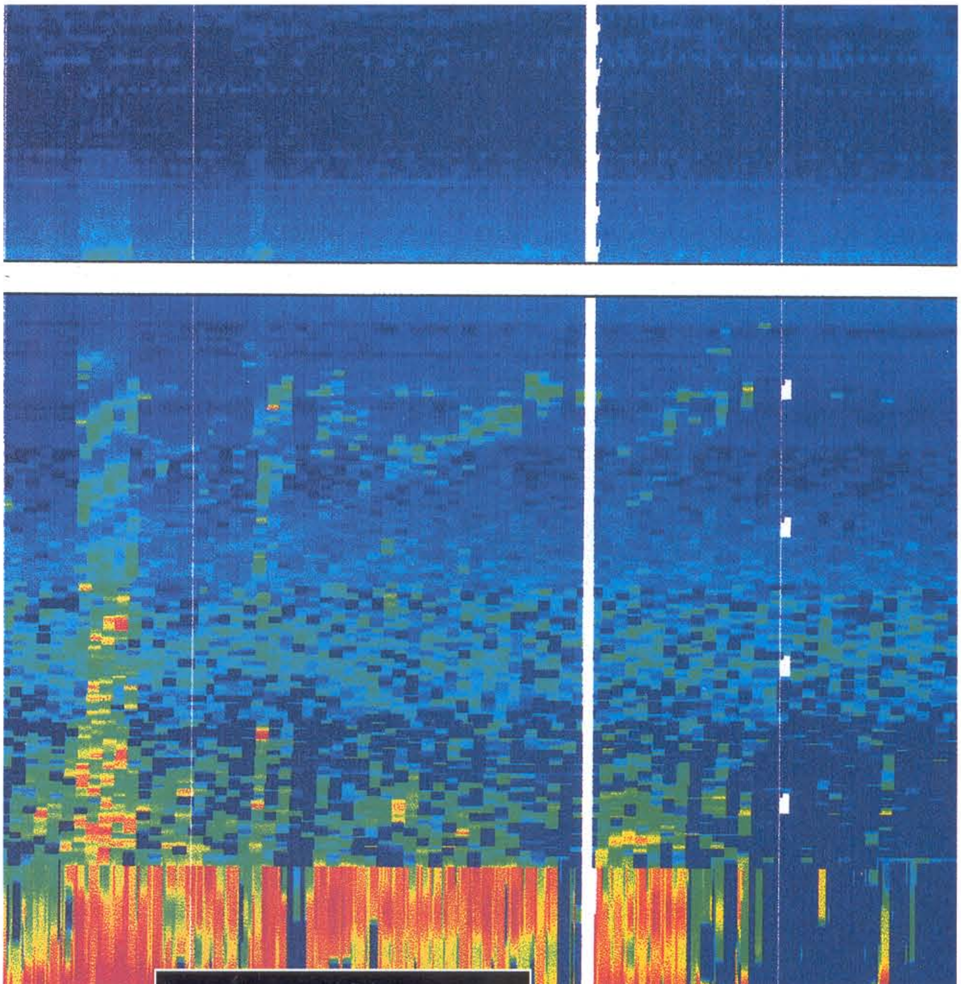
The history of spacecraft exploration of Venus is full of exciting, immediate discoveries. Little was known about this cloud-cloaked sister world until spacecraft first visited it in the 1960s. The Mariner 5 spacecraft discovered in 1967 that the Venusian atmosphere was an incredibly high-pressure environment dominated by carbon dioxide. Soviet spacecraft measured temperatures hot enough to melt lead and zinc. In 1975 two Soviet Venera craft sent back the first pictures of the surface of Venus, revealing a rocky desertlike world with boulders up to 33 feet across.

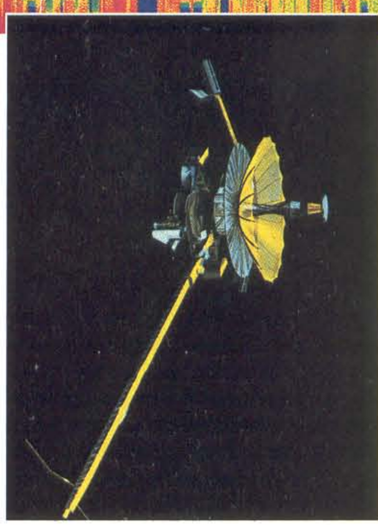
Three years later, Soviet Venera 11 and 12 spacecraft and probes detected electromagnetic waves and flashes that appeared similar to lightning on Earth. In the same year, Pioneer Venus detected similar signals when it started its mapping and observing mission.

Lightning on Earth occurs when air particles ionize due to the presence of strong electric fields. The ionization creates a channel from an area of high charge to low charge, and — Flash! BOOM! — electricity zaps between the two points, usually the sky and the ground but sometimes from cloud to cloud. Lightning has been discovered on Jupiter, Saturn, Uranus, and recently Neptune. But does lightning exist on Venus? The answer lies in the mass of data returned by the Pioneer Venus spacecraft.

Today Russell and the other scientists are busy working with the data collected by the Pioneer Venus Orbiter, one of the four craft launched in 1978. Echoes of the mission continue to spark controversy. From the moment the probe touched down, Russell was certain that the magnetometer on board had detected lightning on Venus. Not everyone was convinced. Grebowsky is searching through the Pioneer Venus data hoping to show that something near the spacecraft produced the curious Pioneer Venus data. Grebowsky does not dispute the existence of lightning on Venus, but he doesn't believe it is the cause of all the electrical discharges that show up in the Pioneer Venus data.

Grebowsky's local events resemble aurorae on Earth. The effects take place in the plasma of Venus' ionosphere instead of the atmosphere. Something is moving





LIGHTNING ON VENUS, visible as ripples in this magnetogram, seems to have been recorded in the data collected by Galileo (left). Magnetogram courtesy D.A. Gurnett.

the plasma, Grebowsky explains, and the electromagnetic waves launched from lightning bolts lack the energy to produce what the astronomers see in the data. He speculates the plasma's movement is caused by cross currents along the planet's magnetic field lines. A charge builds up and launches the 100-hertz bursts observed by the spacecraft.

Strangeway, principal investigator of Pioneer Venus' plasma wave experiment, agrees with Russell and maintains that the evidence supports lightning. "We know what lightning sounds like on Earth. On Venus we're trying to deduce whether or not this is lightning seen from a distance."

Meanwhile, the Galileo spacecraft, en route to Jupiter, is adding fuel to the fire. During its encounter with Venus in February 1990, the spacecraft recorded the whine, pop, and hiss of something that sounds like lightning, according to Gurnett, principal investigator of the craft's plasma wave package.

Galileo zipped by the planet at a distance of 19,000 kilometers (11,900 miles), and its sensitive antenna detected several bursts. The signals it picked up punched right through Venus' ionosphere and resembled static on a car radio during a terrestrial lightning storm. In contrast, Pioneer Venus' Very Low Frequency (VLF) antenna — a product of earlier technology — picked up only whistlers. Whistlers are very-low-frequency radio waves that propagate along magnetic field lines. They are probably not caused by lightning.

With his long history of work on the teams that detected lightning at Jupiter, Saturn, Uranus, and Neptune, Gurnett doubts Galileo's data will settle the 13-year-old debate. He says the craft was just too far away to gather completely believable data about lightning on Venus.

Therefore, scientists will be combing the much greater volume of the 13-year-old data. "Because data is old does not lessen its value," says Strangeway. "Lots of knowledge emerges well after the data has been acquired. Pioneer Venus represents an extremely valuable database that will remain useful for years to come."

A Hot Slice of Pizza

It looks just like a pepperoni pizza! That was the initial thought of scientists after their first close look at Io, one of the four Galilean moons of Jupiter. As Voyager 1 flew past Io, some scientists went out on a limb by proclaiming the surface features appeared to be much younger than the four billion years previously believed. These scientists believed features on the landscape of Io could be as young as one million years.

The immediate science at Io was startling enough. Io was known to be the strangely different Jovian moon: unlike the others, it orbits within an ionized plasma torus and receives a continuous bombardment of charged particles from Jupiter. Voyager revealed Io's landscape as a young world devoid of water but covered with yellow and orange blotches and pockmarked with black. Its surface resembled a crispy pepperoni pizza. "The initial discoveries at Jupiter shook entire points of view," says Candy Hansen, a member of Voyager's imaging team. "Io's surface was so dramatic, like nothing we planned on seeing."

But a later look at an image showed a faint splotch off Io's limb, barely brighter than the inky black background. The image wasn't a good one, but the grainy frame made history. It showed a plume of material shooting away from a volcano near Io's limb. Io had active volcanos, which explained the young landscape features and splotchy surface.

The second look at Io proved to be the key. "We probably would have found the volcanos eventually," Hansen says, "but in real time the eruptions just blended into the background. It wasn't until we enhanced the image and brought the plume out of the background noise that we got our first good look at a volcano on Io."

After closely examining the frames, the astronomers found eight plumes spitting material 43 to 175 miles into space. Voyager 1's discovery sent controllers scrambling to change Voyager 2's trajectory to further study the eruptive moon. When Voyager 2 zipped through the Galilean system four months later, six of the volcanos were still erupting and two more had started. Io was turning itself inside out at an astonishing rate. Violent eruptions occur only rarely on Earth, but Jupiter and its mini-solar system's constant gravitational tug of war make it an everyday affair on Io.

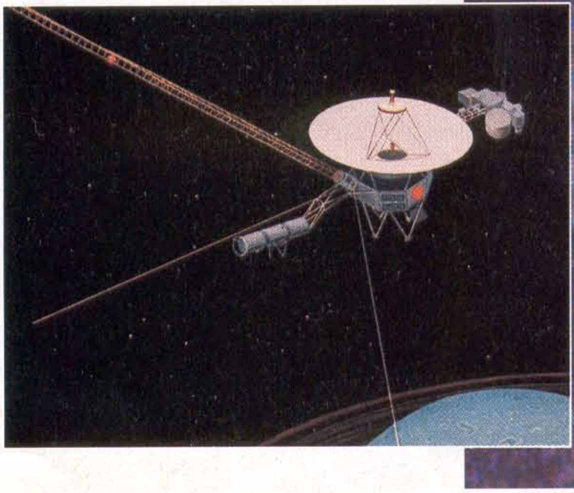
Shaken Points of View

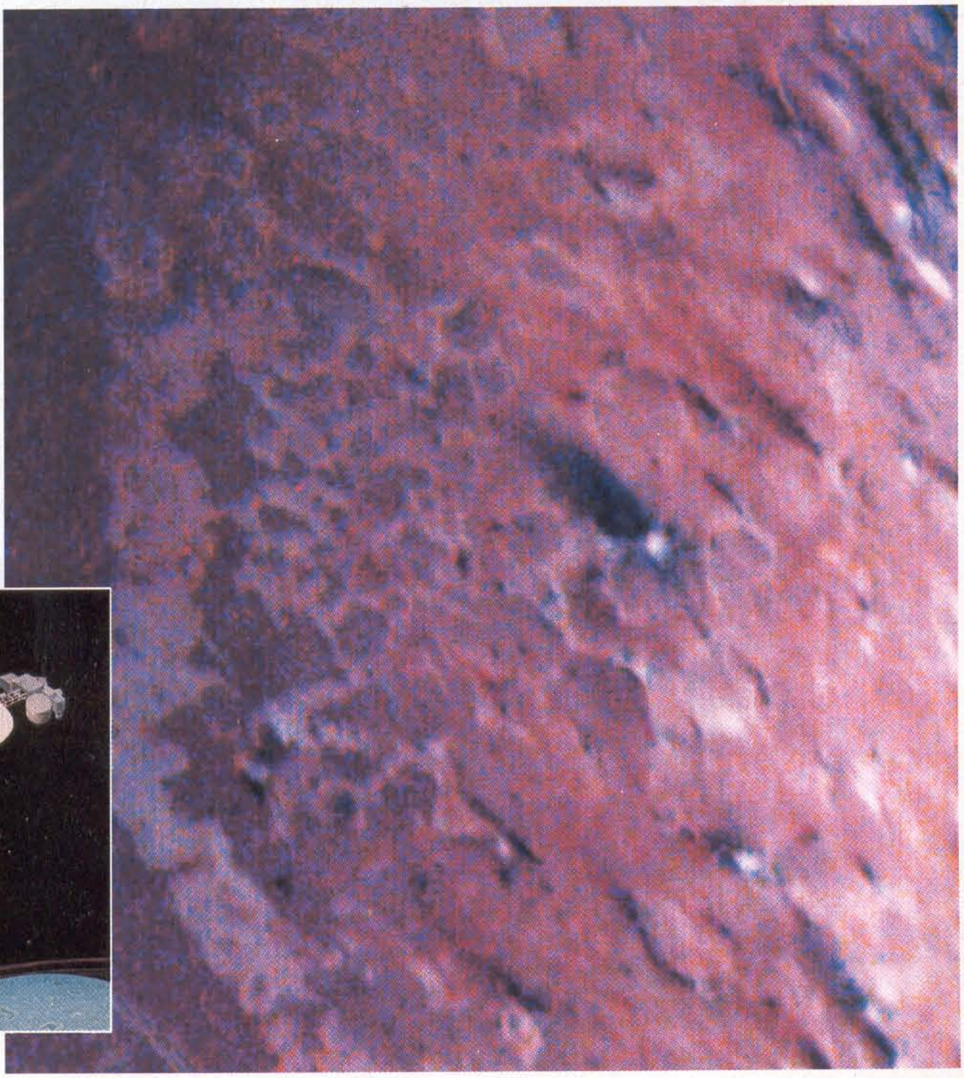
Because of its distance, scientists knew very little about Neptune and its moons prior to the Voyager 2 encounter in 1989. As the spacecraft approached the distant world the astronomers saw little in the way of detail: Neptune appeared as a blue disk with its largest moon, Triton, close by. Triton became the focus of interest because it was so large and also because it might, some scientists believed, have unusual or active surface features. Chief among these was the existence of an atmosphere. As the spacecraft drew nearer, however, accurate temperature measurements showed the moon's surface was only 40K above absolute zero. This made it the coldest body in the solar system. Scientists' hopes for surface activity plummeted with the temperature.

Once again, the immediate science at Triton left astronomers breathless. Those working on the Voyager imaging team were taken by surprise with the first closeup images. Cold or not, the moon's highly variegated surface told a tale of geologic activity. Among the features were mysterious streaks indicating that some types of exotic processes had occurred on Triton. What was even more unusual was that the streaks appeared to be in an area that would periodically be resurfaced due to the sublimation of polar ice on Triton. This meant that the streaks must have appeared recently, after the ice sublimated. Much to their surprise, scientists found themselves wondering, could active volcanic processes be occurring on the coldest body in the solar system?

"When we saw the streaks, it was an exciting possibility," says Laurence Soderblom, deputy director of the Voyager imaging team. "I strongly suspected something was going on, but the odds were pretty slim that we'd actually see active geysers." Yet the Voyager imaging team made second, third, and fourth looks through the data and

VOLCANIC OUTGASSING ON TRITON lurked in the Voyager data until scientists interpreted what they were seeing. NASA photos.





SAVING A NATIONAL TREASURE

During its 33-year history, NASA has launched over 260 successful scientific missions. From the early days of Mariner 2 in 1962, scientists have understood the importance of documenting travels into space. Currently, over one million data tapes containing the wealth of exploration are stored at dozens of sites across the country. It is an ever-growing collection of knowledge about the solar system we live in.

One Voyager image, made up of 5.12 million bits, is jammed with more information than all 21 pictures sent back from Mars by Mariner 4 in 1964. And both the Earth Observing Satellite (EOS) and the Hubble Space Telescope are designed to send back more data and images than all previous missions combined.

The United States has built an impressive planetary database, a national treasure. Some of it, however, is in danger because the storage technology that contains it is becoming obsolete. This matter came under fire from the General Accounting Office in 1990. Congress' watchdog agency charged that irreplaceable data were in danger of being damaged due to storage in "deplorable conditions." The GAO found some of the data stored in dusty hallways and previously flooded basements and other areas where protection from temperature extremes, humidity, fire, and water was lacking.

But even if the tapes are well cared for, few of them may last forever, according to Mike Martin, a technician with NASA's Planetary Data System (PDS) at the Jet Propulsion Laboratory. "We're still reading some magnetic tapes written in the late 1960s, so 20 years is a reasonable lifetime," Martin says. "On the other hand, we have had trouble reading tapes written during the 1989 Neptune encounter. We haven't lost any data, but tapes are hard to replicate and difficult to protect and store." This statement should make everyone with an interest in the future of astronomy scared to death.

The solution to the problem may be transferring everything to CD-ROM disks. The same technology that makes possible listening to symphonies on your CD player may be the perfect solution for NASA's databank. The PDS found that CD-ROM technology is not only cheap but also reliable for periods of up to 100 years. More importantly, one cheap, easily reproduced disk can store huge amounts of data. And because the disks are read by a laser beam they require minimal maintenance — they don't wear out.

The first major task for the PDS was converting Voyager's Jupiter and Saturn imaging data. Twelve disks represent about 25,000 Voyager images, mostly closeups of the planets and their satellites as well as Neptune and Uranus images. Currently the PDS is working on other projects to convert imaging data from other missions, such as Magellan, to CD-ROM. PDS plans to release 520 disks containing the imaging mosaics from Magellan's radar mapping of Venus. Scientists involved with Galileo and the Mars Observer projects are also considering CD-ROMs for data storage.

"That's what we've always wanted," Martin explains. "Rather than producing magnetic tapes that no one can afford to store, CD-ROMs are cheap, easy, and effective. They're the way of the future." Moreover, CD-ROM represents a shift toward directly distributed data, rather than data kept available on-line from a central clearinghouse. It's a powerful way to get the data into the hands of the astronomers, where it belongs.

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carefully analyzed frames, finding evidence of plumes on Triton. "After we saw the plumes were active, we then spent the next week trying to convince ourselves that it wasn't some artifact that could be fooling us," says Soderblom.

Indeed, the search through the data hasn't ended here. Two hypotheses have emerged to explain these phenomena: geysers — like Old Faithful on Earth — or dust devils. The dynamics of the eruption or atmospheric effects must be characterized, plotted, and documented, which might solve the debate. That means a thorough search through the 27,000 images collected at Neptune.

"No one anticipated the types of bizarre phenomena that we see occurring," Soderblom confesses. "Most scientific thinking was that the farther out you got, the greater the liklihood energy sources would go down. Eventually you would get into very lifeless, quiescent environments where nothing would happen for billions of years. But instead we found that the coldest object in the solar system is incredibly active."

Hide and Seek in the Rings

Perhaps the most ambitious use of data resulted from the work of two scientists searching through the mass of material returned by the Voyager spacecraft from Saturn. Due to the gravitational behavior of Saturn's moons and rings, Mark Showalter and Jeff Cuzzi of NASA's Ames Research Center believed that the planet had an undiscovered 18th moon. The two believed such a moon might be hiding in Encke's gap. Determined to find the moon, Showalter wrote a computer program to sift through the nearly 30,000 Voyager images of Saturn for the frames that might reveal the moon.

The immediate science at Saturn had been no less than spectacular. The Voyager spacecraft imaged six previously unknown moons and discovered that Saturn's rings were composed of innumerable ringlets locked in orbit, that there are dark, spokelike features in the B Ring, and that the moon Titan's atmosphere was predominantly nitrogen. Yet the question of another unknown moon nagged at Showalter and Cuzzi.

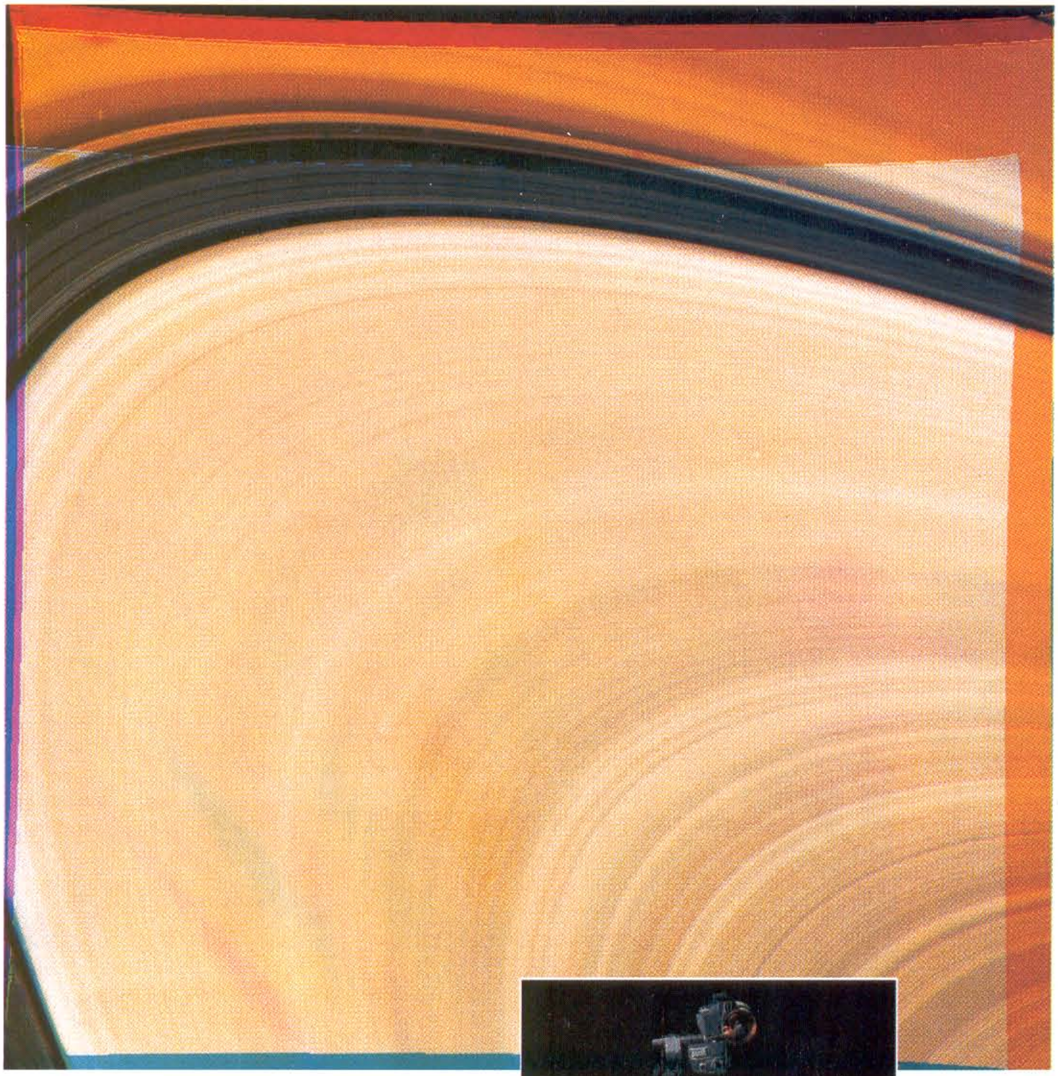
But not for long. Their computer search paid off handsomely. "Moon number 18 was in the first image I looked at, exactly where we expected it," Showalter says. "I remember being so excited I worked through the Fourth of July." Provisionally designated 1981S13 and later named Pan, the 18th moon was discovered on July 2, 1990. Pan is the smallest moon yet discovered around the giant ringed planet.

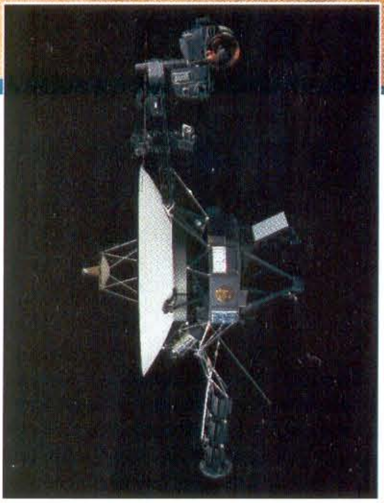
For Cuzzi, the Ames scientist who predicted the moon's location, the rings are *terra incognita*. "The data on the rings represent an unexplored wilderness that we're just now starting to poke our way through," he says. "Unquestionably many of the big discoveries at Saturn came right away, but we can't forget that storehouses of information subtly hide in the data, and it takes great effort to dig it out."

Before computers eased the task, however, searching for moons was time-consuming, miserable work. To get an idea, imagine staring at lots of grainy images with thousands of rings, enhancing one, and staring at it some more in search of a tiny bright spot. The moon Showalter found did not even occupy one complete pixel, one of the 640,000 tiny blocks that make up a single Voyager image. Pan is a mere 20 kilometers across, just under Voyager's resolution of 30 kilometers.

Showalter's task was simplified by recent advances in imaging and storage technology. Almost all of the U.S. space science information is stored on magnetic tape at NASA facilities and universities. Recently, CD-ROM technology has allowed easy, instant access to images for study and enhancement. A two-month process now requires a mere 30 minutes. The long and laborious process of getting data on m agnetic tapes has been replaced by an instant process thanks to CD-ROM-equipped computers.

Where will this newfound technology lead planetary astronomers? "I'm sure there will be a huge renaissance of looking at Voyager data when Galileo gets to Jupiter," predicts Candy Hansen. "The analysis will go on and on and on. We now have a historical record over the long term that will be compared to what the Galileo craft sees. The same thing will happen as spacecraft like CRAF-Cassini and the Hubble Space Telescope take more and more planetary data. We'll compare the old stuff with the new, and that will lead to more discoveries."





SATURN'S EIGHTEENTH MOON lay hidden in the planet's rings until a computer program separated the suspected speck from the tangle of Voyager data. NASA photos.

When we return to the planets with a second round of spacecraft, scientists will rush to review the old data — to chart changes in atmos-pheres, magnetic fields and satellite geology. Over time, armed with a growing historical database, scientists will begin to piece together an overall picture of the solar system in its historical, evolutionary context. They will compare changes over time — a necessary step in refining theories about the solar system's origin and the Sun's place in the Galaxy. □

John Williams is a freelance writer living in Kansas City, Missouri. His last article was "Built to Last" (December 1990).