EIR Science & Technology

Unlocking the Secrets Of Mysterious Saturn

When the Voyager spacecraft flew by Saturn in the early 1980s, they revealed a complex of rings and moons that scientists could not explain. Marsha Freeman reports on the Cassini mission now observing the ringed planet.

The long wait is over. After almost seven years of travel, the *Cassini* spacecraft, carrying along with it the Huygens probe for the Saturnian moon Titan, fired its onboard engine, slowed down from its interplanetary trek, and was captured by the gravity of Saturn.

At 10:36 p.m. Eastern Daylight Time on June 30, the spacecraft executed a 96-minute burn to reduce its speed, bringing it to its closest approach to Saturn throughout its upcoming four-year mission. (The times are Earth-received time. It takes an hour and 24 minutes for the signals from the spacecraft to reach the Earth.) NASA engineers have taken measures to increase the likelihood of success of the mission, by providing a second, redundant engine for this critical maneuver. During its orbit insertion, *Cassini* will sail a mere 12,000 miles above the planet's cloud tops.

Cassini will pass through the plane of Saturn's rings from below during insertion into its orbit of the planet, traveling between the outer tenuous F and G rings, through a gap of about 18,600 miles. It will fly above the plane of the rings, and then cross, descending between the same two rings on the other side of Saturn. To protect itself from any dust or debris, the spacecraft's high-gain antenna will be turned to face forward into the direction of travel and away from the Earth, so it functions as a protective shield.

After the engine firing, the antenna was pointed toward the Earth for a quick, one-minute transmission to report its status to mission control, and then for 75 minutes the spacecraft turned back toward Saturn, in order to observe the majestic rings below. "We want to look at the rings; we'll never be that close again," said Dr. Charles Elachi, director of NASA's Jet Propulsion Laboratory, before the maneuver.

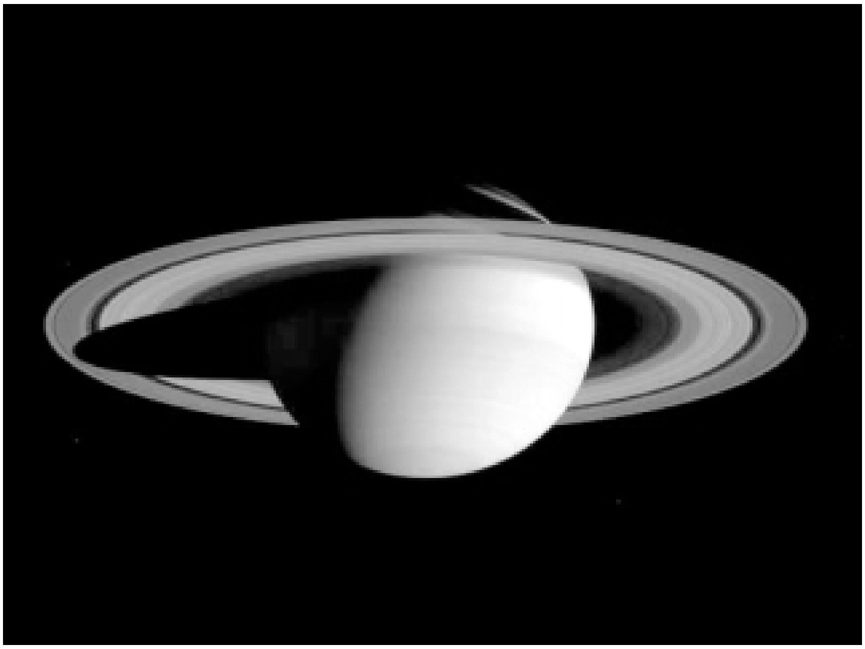
Two days later, *Cassini* will encounter the planet-sized and cloud-shrouded moon Titan, for a flyby at an altitude of 210,000 miles; first of 45 planned Titan encounters. On July 4, the spacecraft enters Solar Conjunction, where *Cassini* is behind the Sun, as seen from Earth. For the following eight days, its communication with Earth will be limited. But it should have safely begun its mission of discovery through Saturn's miniature "solar system," and its magnificent rings.

The last time astronomers had a close-up look at this gas giant was when the two *Voyager* spacecraft briefly flew by in 1980 and 1981. The small ice worlds that accompany Saturn on its journey around the Sun were seen up close for the first time. Structures in the rings became apparent, and preliminary data was collected about Titan.

The *Voyager* encounters produced more questions than they answered, so in 1982, scientists began to plan a mission that would not just fly by Saturn, but go into orbit and follow the changes in the planet's atmosphere, magnetic field, moons, and rings, over time.

Cassini was launched on Oct. 15, 1997 on a roundabout route. The launch vehicle could not send *Cassini* on a direct trajectory to Saturn, so over the past seven years—and more than 2 billion miles—the spacecraft has picked up gravity assists from two flybys of Venus and one past Earth. It also made an energy-boosting swing by Jupiter in December 2000.

This Christmas Eve, the European-built Huygens probe will be released from the *Cassini* spacecraft, glide toward the



On May 7, at a distance of 17.6 million miles, the Cassini spacecraft took two pictures of Saturn, which were combined to produce this image. Some of Saturn's 31 moons are just barely visible.

moon Titan for two weeks, and then descend on parachutes slowly through its dense atmosphere. This will be the first *in situ* study of a planetary moon (other than the Earth's), and attempted landing. Scientists expect that during its more than two-hour journey down to the surface of Titan, Huygens will lay bare the data to help explain why this Saturnian moon has an atmosphere, where it came from, how it developed, and if there are any analogues to the early Earth.

Throughout *Cassini*'s four-year intensive study of the Saturnian system, it will travel another 3 million miles. It will make 45 encounters with Titan from orbit, and pass seven other of Saturn's icy moons. It will measure and characterize Saturn's turbulent atmosphere and lopsided magnetosphere.

The scientists can only expect the unexpected.

New Questions To Answer

Even before *Cassini* reached its orbit of Saturn, the information it was sending back was puzzling planetary scientists. When it was still three months and millions of miles from Saturn, cameras aboard the spacecraft sent back photographs of developing storm systems in the atmosphere. Two storms were in the process of merging into one larger one. On Earth, storms last for a week or so and usually fade away, explained Dr. Andy Ingersoll from the *Cassini* imaging team, "but many storms on the giant planets end their lives by merging. How they form, however, is still uncertain."

The storms were traveling at different speeds in the southern hemisphere, and spun around each other in a counterclockwise direction as they approached each other, which is the opposite of how hurricanes spin in the southern hemisphere on Earth. Storms at Saturn's equator move east at speeds up to 1,000 miles per hour, which is 10 times the Earth's jet streams, and three times greater than the equatorial winds at Jupiter. "Saturn is the windiest planet in the Solar System," Ingersoll said. But no one knows why.

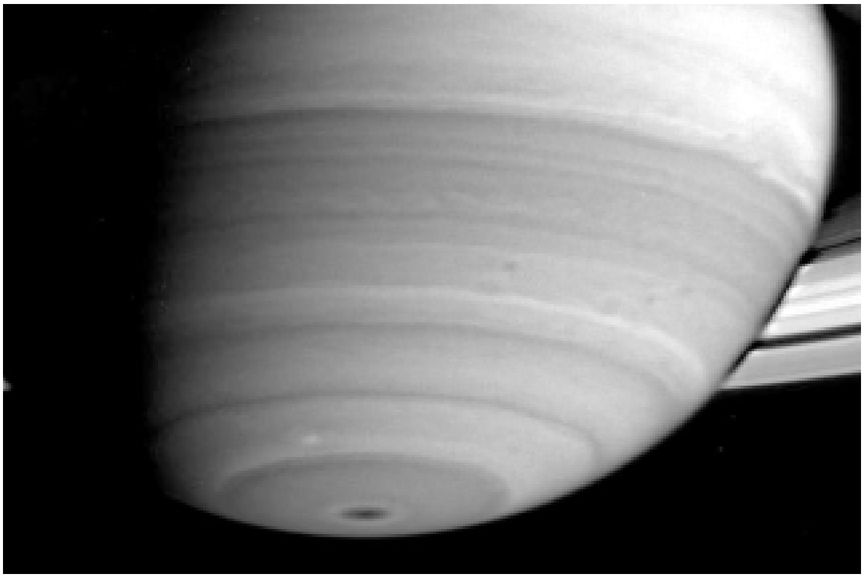
Compared to the Earth, Saturn is 9.5 times farther away from the Sun. Any area on Earth receives 90 times more sunlight than an equivalent area on Saturn. This means that the same light-driven chemical processes in Saturn's atmosphere take 90 times longer than they would on Earth. Unlike the Earth's near-circular orbit around the Sun, Saturn's is slightly elliptical, which means that the amount of sunlight reaching the gaseous planet varies throughout its year, equal to 29.46 Earth years. This may affect the upper atmospheric composition of the planet.

On April 16, from a distance of more than 23 million miles, *Cassini*'s narrow-angle camera took a remarkable photograph of Saturn, revealing another atmospheric feature—a dark spot at the South Pole, which is quite small, and centered. Space scientists believe it is possible that this spot is affected by Saturn's magnetic field.

Scientists have been faced with a conundrum concerning the length of Saturn's day, or its period of rotation on its axis. Studies of Saturn's atmosphere show that the period of rotation can depend upon how it is measured. Using the visible features of the planet, scientists know that the cloud tops show a rotation period of 10 hours, 15 minutes at the equator, but it is 23 minutes longer at higher latitudes. The high rotation rate (the Earth's is 24 hours), creates a strong centrifugal force that causes a bulge at the equator, and flattens Saturn's North and South Poles, undoubtedly affecting its climate and weather.

As the gas giants have no solid core, and are covered with clouds that move at variable speeds, the movement of surface features cannot be used to accurately measure their rate of rotation. The same is true for the Sun. Therefore, scientists are attempting to obtain a more precise measure for the length of Saturn's day by studying the rhythm of radio signals emitted from the planet, that were collected by *Cassini* between April 29, 2003 and June 10, 2004. The radio signals are produced by the action of the planet's magnetic field, created deep in its interior, on surrounding charged particles.

Cassini's measurments of the radio pulse lead to a computation of the rotational period of the planet on its axis of 10 hours, 45 minutes, and some seconds. However, that is about



Looking more like Jupiter than Saturn, this image shows the delicate banded nature of Saturn's atmosphere. Note the dark spot at the South Pole, and the white clouds just north of the pole.

six minutes—or 1%—longer than the radio rotational period measured by the two *Voyager* spacecraft, more than 20 years ago. Is Saturn slowing down? Scientists do not think so.

There is most likely some variability in how the rotation deep inside Saturn drives the radio pulse. One explanation, proposed by Dr. Don Gurnett, may be tied to the fact that Saturn's rotational axis is nearly identical to its magnetic axis. This is not true of the other planets with notable magnetic fields—Mercury, Earth, Jupiter, Uranus, and Neptune—which have more of a difference between the two, and show no comparable irregularities in their radio rotation periods.

Scientists do not understand this alignment of Saturn's strong magnetic field and its rotational axis. They believe the planet's core to be a molten rocky material, covered with a thick layer of very hot metallic liquid hydrogen; and that turbulence or convective motion in this layer of Saturn's interior may create its magnetic field.

This finding of a change in Saturn's radio rotation period "is very significant," says Dr. Alex Dessler, a research scientist at the University of Arizona. "It demonstrates that the idea of a rigidly rotating magnetic field is wrong." He suggests that analyzing the gas giant planets is akin to studying the Sun, whose magnetic field also does not rotate uniformly.

Intensive studies will be done, over the course of the mission, of Saturn's magnetic field, through studies of its interaction with the solar wind. That interaction creates its magnetosphere, and inside the bubble of the magnetosphere reside charged particles separated from the solar wind by Saturn's magnetic field. The magnetosphere acts as an intermediary between the solar wind and Saturn's atmosphere, and gives rise to aurora.

At a briefing just before orbit insertion, on June 29, navigation team member Dr. Jeremy Jones explained that there will be a seven-month study of Saturn's magnetotail, (the side of the magnetosphere facing away from the Sun), followed by a study of the magnetic structures on the Sun-facing side.

Over the period of its four-year primary Saturn mission, *Cassini* will have the opportunity to monitor long-term variations in the radio period, and use other techniques to investigate Saturn's rotational period.

A Captured Comet?

Two weeks before orbit insertion, on its way in toward Saturn, *Cassini* made a close approach to one of Saturn's outermost moons, Phoebe, a small body not visible from Earth. *Cassini* mission planner Dave Seal reported on June 10 that the arrival date and trajectory to Saturn "were specifically selected to accommodate this flyby, which will be the only opportunity during the mission to study Phoebe at close range." He explained that "Phoebe's orbit is simply too far from Saturn, at about 8 million miles, nearly four times as far as the next closest major satellite, Iapetus, [so] a late encounter is not feasible."

In 1982, cameras aboard *Voyager 2* photographed Phoebe from 1.4 million miles. At that distance, all that was visible was a fuzzy image of black and white dots. Scientists were able to discern that Phoebe has a diameter of about 136 miles, rotating on its axis every nine hours, while completing an orbit around Saturn in about 18 months.

Phoebe's irregular elliptical orbit is inclined about 30° relative to Saturn's equator, and is also retrograde, going around Saturn in the opposite direction of most of the other moons. Unlike Saturn's icy moons, Phoebe is very dark, reflecting only about 6% of the sunlight it receives. All of these characteristics suggested that Phoebe is a body that was gravitationally captured by the giant planet, and is not a moon that was created along with most of the others. Scientists believe that the majority of Saturn's moons were created from a disc of pre-planetary material in Saturn's neighborhood, which formed into moons through a similar process as the formation of the planets from the rotating disc of material around the young Sun.

On June 11, the *Cassini* spacecraft passed within 1,285 miles of the dark moon, as astronomers debated whether this body was a captured comet, asteroid, or Kuiper Belt object—which would mean it resided, initially, outside the orbit of Pluto. If it were an asteroid, it would be a piece of a larger body, mainly made of rocks and metals, such as an exploded planet, that once orbited the Sun between Mars and Jupiter.

If Phoebe spent most of its existence in the Kuiper Belt, it probably is fairly pristine, has suffered few collisions, and is largely made of ice.

The first images revealed Phoebe to be a scarred, heavily cratered body with a very old surface, and variations in brightness. It appears that Phoebe is an ice-rich body, covered with a layer of darker material, perhaps up to 1,600 feet thick. The camera captured craters containing layers of alternating bright and dark regions.

As *Cassini*'s data about Phoebe was transmitted back to Earth, more was learned from its ultraviolet and infrared measurements, radar data, and Phoebe's gravitational effect on the spacecraft itself.

Having reviewed all of the data, scientists reported on June 23 that they had concluded Phoebe is a primordial mixture of ice, rock, and carbon-containing compounds, water-bearing minerals, possibly containing clays and primitive organic chemicals. These are similar to the material seen in Pluto and Neptune's moon, Triton, which are also believed to have resided originally in the Kuiper Belt.

NASA titles this image, "Phoebe's Surprise." The small moon is shown to be a pockmarked body with layers of bright and dark material, and is believed to have been captured when it wandered near Saturn from the outer reaches of the Solar System.

During the formation of the giant planets, many of these ice *planetesimals,* or small bodies, were incorporated into Jupiter, Saturn, Uranus, and Neptune. Some of the material was ejected to distant orbits, joining other, similar bodies, forming the Kuiper Belt. "Phoebe apparently stayed behind, trapped in orbit about the young Saturn, waiting for eons for its secrets to be revealed," said Dr. Torrence Johnson, *Cassini* imaging team member.

Dr. Roger Clark, from the U.S. Geological Survey in Denver, reported that the scientists also "see spectral signatures of materials we have not yet identified." Using precise tracking data of the spacecraft and optical navigation, combined with accurate estimates from images, the scientists have determined that Phoebe's density is about 100 pounds per cubic foot, much lighter than most rocks, but heavier than pure ice, suggesting a combination of both. There are chemical similarities between the materials on Phoebe and those seen on comets, as well. *Cassini*'s Composite Infrared Spectrometer transmitted measurements that show this very cold moon to be only about 100° above absolute zero, or –261° Fahrenheit.

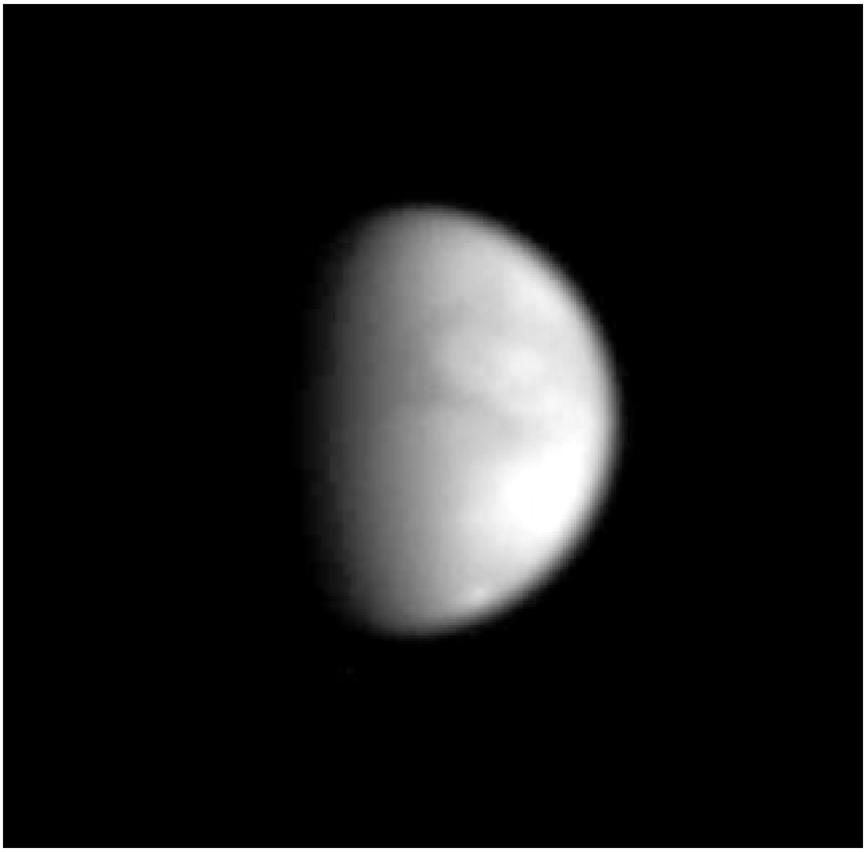
"In two short weeks, we have added more to what we know about Phoebe than we had learned about it since it was discovered 100 years ago," commented Dr. Dennis Matson, project scientist.

Unveiling Titan

Saturn and Jupiter are often described as miniature solar systems, due to their families of moons. During *Cassini*'s seven-year journey, 13 new moons of the planet were discovered using ground-based telescopes, bringing the total to 31 known moons. Most of the larger companions of Saturn are icy worlds, each with interesting features, and some will be studied up close during this mission.

Saturn's moon Titan is the second largest moon in the Solar System after Jupiter's Ganymede. Titan is about the size of Mercury, and the only moon besides Neptune's Triton to have an atmosphere. Christian Huygens (1629-1695), a Dutch astronomer who pioneered the development of improved lenses for telescopes, made extensive studies of Saturn, and solved a puzzle that had vexed astronomers before him. What looked from Earth like handles of a cup, protruding on either side of the planet, were actually rings, Huygens proposed.

In 1659, he stated that the planet "is surrounded by a thin, flat ring, which nowhere touches the body." His observations were later confirmed by Italian-French astronomer Jean Dominique Cassini who, in 1675, discovered that the rings were split in two by a narrow gap, which now bears his name.



Shrouded Titan shows variations of light and dark features in this Cassini image, taken during in early June. Cassini's Huygens probe will plunge through Titan's thick atmosphere, providing an in situ *study of the planet-sized moon.*

During his extensive study of the ringed planet, Huygens also discovered Saturn's moon Titan in 1655.

Astronomers discovered an atmosphere around Titan in 1943, using ground-based telescopes. In 1980, *Voyager 1* discovered that nitrogen is the most abundant gas in its dense atmosphere, and that the second-most abundant is methane. It also took atmospheric temperature and pressure measurements, finding that Titan's atmosphere is about one and a half the pressure of the Earth's.

On Titan, *Cassini* mission scientist Jonathan Lunine explained, methane plays the same meteorological role that water does on Earth. It is too cold for water to be present on Titan, but methane could exist in liquid form there. Dr. Lunine explained that the breakup of methane molecules by ultraviolet radiation from the Sun could produce organic chemicals (not meaning living, but containing carbon), which may rain down on the surface of the moon in liquid form. These include ethane, propane, acetylene, and other others.

It is also possible that heat from the moon's interior, or from intermittent comet impacts, alters the chemistry of its atmosphere and its surface. But if the methane is constantly being depleted through photochemical reactions, how is it replenished? Where did the nitrogen and methane come from to begin with, and why is this moon unique in the Solar System?

Titan's orbit around Saturn takes it both inside and outside the magnetosphere of the planet. When outside Saturn's magnetic protection, Titan is exposed to the solar wind. Interactions with the solar wind may account for some of the unique features found on the large moon. Titan also interacts with Saturn's magnetosphere, providing a way for charged particles trapped within the magnetosphere to enter Titan's atmosphere, and for atmospheric particles to escape from Titan.

Based on what they know so far, scientists expect they might find a rich soil on the surface of Titan, filled with frozen carbon-based molecules, resembling a tar-like permafrost. Ground-based studies do not indicate a global liquid ocean on Titan, but there could be lakes and seas.

Photographs of Titan taken by the Hubble Space Telescope indicate areas of brightness, which may be partly due to differences in chemical composition and/or roughness of material. Although there are weak spectral indications that there is water ice on Titan's surface, scientists conclude that other material is masking the ice.

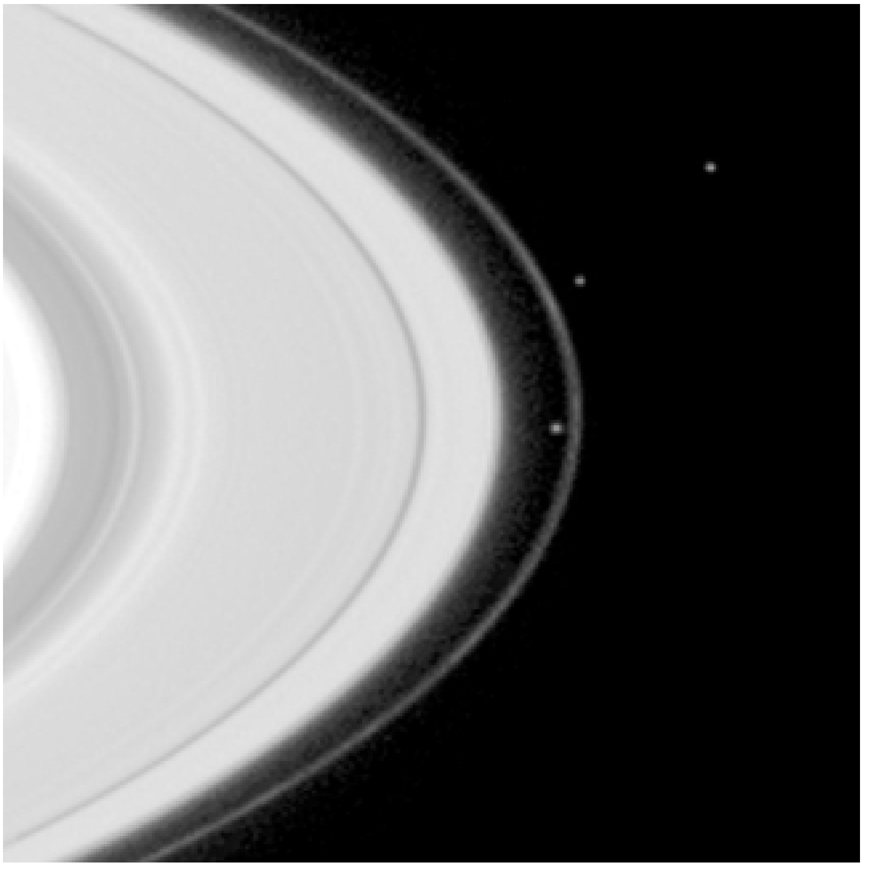
Out of *Cassini*'s total of 77 orbits of Saturn, 44 will include passes by Titan. But the real opportunity to unmask the hazy moon will come at the beginning of next year.

On the evening of Dec. 25 (Eastern Time), the 770-pound Huygens probe will be released from the *Cassini* mother craft. It will coast toward Titan for three weeks, and on Jan. 14, enter the moon's atmosphere. On the way down, the composition of the atmosphere will be analyzed by its Gas Chromotograph. Solid particles will be collected and vaporized into gaseous form and analyzed.

Huygens' Descent Imager and Spectral Radiometer will take photographs of the methane clouds, allowing scientists to determine their size and shape. When Huygens is about 30 miles above the surface, it will start to take panoramic views of the landscape, with a resolution of about three feet. Nearer to landing, a lamp will illuminate the surface, which Dr. Lunine explains is a muddy red color, because the nitrogen/methane atmosphere absorbs the blue frequencies of light.

The Descent Imager is to carry out a spectral analysis of the composition of the surface, which scientists believe could be in a liquid or solid state. During the final stages of descent, the probe will emit sound waves and use its radar to describe the roughness of the moon's surface.

It is possible that Huygens will be able to collect up to half an hour's data from the probe if it survives its landing. After that, the *Cassini* mother spacecraft orbiting overhead disappears over Titan's horizon, preventing the relay of any further data to *Cassini,* and then to Earth.



When the Voyager spacecraft found two moons, Pandora and Prometheus, seen in this Cassini image, scientists believed they were "shepherding" Saturn's outer F ring. It is more likely that the rings are the product of collective electromagnetic effects in the Saturnian system.

Mystery of the Rings

Certainly the most distinctive feature of Saturn is its intricate complex of rings, the expanse of which would fit in the space between the Earth and the Moon. Jean Domenic Cassini, after whom this mission was named, was born on June 8, 1625. He studied the planet Saturn and its system of rings and moons until becoming blind in 1710, dying two years later. Cassini discovered four of Saturn's moons—Iapetus, Rhea, Tethys, and Dione—and the separation between the two largest rings of Saturn, subsequently called the A and B Rings. (The rings have been named alphabetically in the order in which they were discovered, not in the order of their distance from the planet or their size.) That space between the rings is called the Cassini Division.

The *Voyager* spacecraft found ring particles ranging in size from the nearly invisible, to icebergs the size of a house. They also confirmed a finding from the ground, that the rings contain water ice, which may cover rocky particles.

During its flyby in 1979, the *Pioneer 11* spacecraft detected Saturn's faint outermost F ring. When the *Voyager* spacecraft arrived there soon after, the F ring was shown to be braided in places, to have clumps or knots of material, and variations in brightness. From a distance of less than half a million miles above the rings, the *Voyagers* sent back data that indicated the F ring is about 50 miles in diameter. Some of the particles in the Saturnian ring system carry an electrical charge, it was also discovered.

Small moons on either sides of the F ring, found by the *Voyagers,* were described by planetary scientists as "shepherding moons" which, they proposed, kept the particles within the structure of the ring. But no matter how many times Newtonian mathematics was applied to the problem, treating the ring particles as billiard balls, it was never possible to explain how tiny moons could account for the stunning complexity of the ring system.

Since then, scientists have proposed that the vast magnetic field of Saturn, and the complex of moons, interact with the charged ring particles, producing collective electromagnetic effects that result in the system that is observed. This is a more fruitful line of inquiry into the history and development of the Saturnian rings.

Voyager also photographed dark or opaque patches, appearing as radial spokes, in Saturn's B ring. Scientists have concluded that they are apparently the result of the electromagnetic levitation of dust particles above the ring plane. The Saturnian system includes many narrow ringlets with slightly eccentric shapes and orbits, generally lying in gaps in the mass of the more circular, major set of the planet's rings.

During its traverse to enter its orbit of Saturn, and over its four-year mission, *Cassini* is getting the closest-ever look at the rings, moons, atmosphere, and magnetic field of Saturn. The 12 scientific instruments on the orbiter, and six on the Huygens Titan probe, will present the 250 scientists from the United States and 17 European nations, who are anxiously awaiting the data, an unprecedented picture of Saturn.