Statement of

Mr. Orlando Figueroa

Solar System Exploration Director

National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology and Space

Committee on Commerce, Science, and Transportation

United States Senate

July 22, 2004

Mr. Chairman and Members of the Subcommittee, I appreciate the opportunity to appear here today to discuss NASA's Cassini-Huygens mission. This has been an amazing year for NASA's Space Science Program. In January, we landed the twin rovers Spirit and Opportunity on the surface of Mars, and they have been sending back incredible scientific data and images since then. Then, just a few short weeks ago, the world watched again in awe as we navigated the Cassini spacecraft into orbit around the "Lord of the Rings" – the planet Saturn.

Mission Overview

The Cassini mission is an international cooperative effort of NASA, the European Space Agency (ESA), and the Italian Space Agency (ASI) to explore the planet Saturn. Eighteen highly sophisticated science instruments (twelve in the Cassini orbiter, and six in the Huygens probe) will study Saturn's rings, icy satellites, magnetosphere and Titan, the planet's largest moon. In December of this year the Cassini spacecraft will release the Titan atmospheric probe (Huygens) for its descent through the murky atmosphere of Titan. The probe will collect data on the composition of Titan's atmosphere and haze layers, and may also create an image of Titan's surface. Understanding the chemistry of Titan's atmosphere may be key to understanding the evolution of early life on Earth. After delivering *Huygens*, the Cassini spacecraft will perform several flybys of Saturn's icy satellites, acquire data on Saturn's rings from various angles, perform radar mapping of Titan's surface, and take measurements of Saturn's atmosphere, magnetic field, and charged-particle environment. Cassini's primary science mission tour is scheduled for 4 years of observations.

Why Saturn?

Saturn offers a rich scientific environment to explore. While the other giant planets, Jupiter, Uranus, and Neptune, have rings, the rings of Saturn are unique in the solar system in their extent and brightness. They are the signature feature by which Saturn is known. The planet and the ring system serve as a physical model for the disc of gas and dust that surrounded the early Sun and from which the planets formed. The success of searches for other planetary systems elsewhere in our galaxy partly depends upon how well we understand the early stages of the formation of planets.

Detailed knowledge of the history and processes now occurring on Saturn's elaborately different moons may provide valuable data to help understand how our Solar System’s planets evolved to their present states. Represented among Saturn's collection of moons are a huge variety of chemical, geologic and atmospheric processes. Physics and chemistry are the same everywhere, and the knowledge gained about Saturn's magnetosphere or Titan's atmosphere will have applications here on Earth.

Chief among Cassini’s goals within Saturn's system is the unmasking of Titan. Titan is the only moon in the Solar System that possesses a dense atmosphere (1.5 times denser than Earth’s). The fact that this atmosphere is rich in organic material and that living organisms, as we know them, are composed of organic material is particularly intriguing. ("Organic" means only that the material is carbon-based, and does not necessarily imply any connection to living organisms.) Forty-four of Cassini’s 76 orbits through the Saturnian system will include Titan flybys, and the Huygens probe is dedicated to the study of Titan’s atmosphere.

After decades of speculation and experiment in the modern age, scientists still seek fundamental clues to the question of how life began on Earth. Most experts suspect that life arose by chance combinations of complex carbon compounds in a primeval soup. But all studies of life's origin are hampered by ignorance about the chemical circumstances on the young Earth. By understanding what starting material was present at the beginning of life on Earth, we will better understand our early beginnings. Cassini-Huygens' study of Titan may go far toward providing the answer to these and many other questions.

In our Solar System, only Earth and Titan have atmospheres rich in nitrogen. Earth's siblings in the inner solar system, Venus and Mars, possess carbon-dioxide atmospheres, while Jupiter and Saturn resemble the Sun in their high content of hydrogen and helium. Hydrocarbons like the methane present on Titan may have been abundant on the young Earth.

The importance of Titan in this connection is that it may preserve, in deep-freeze, many of the chemical compounds that preceded life on Earth. Some scientists believe we will find that Titan more closely resembles the early Earth than Earth itself does today.

The results from Cassini's instruments and the Huygens probe, along with the results of our continuing explorations of Mars, Europa and the variety of life-bearing environments on Earth, will significantly enhance scientific efforts to solve the mystery of our origins.

Saturn's Allure

Saturn is easily visible to the naked eye, and was known to ancient peoples around the world. It was not until the invention of the telescope, however, that Saturn's characteristic rings began to come into focus.

The Italian astronomer Galileo was the first to look at Saturn through a telescope in 1609-10. Viewed through Galileo's crude instrument, Saturn was a puzzling sight. Unable to make out the rings, Galileo thought he saw two sizable companions close to the planet. Having recently discovered the major moons of Jupiter, he supposed that Saturn could have large moons, too. Galileo was even more astonished when, two years later, he again looked at Saturn through his telescope only to find that the companion bodies had apparently disappeared. The rings were simply "invisible" because he was now viewing them edge-on. Two years later, they again reappeared, larger than ever. He concluded that what he saw were some sort of "arms" that grew and disappeared for unknown reasons. He died never knowing that he had been the first to observe Saturn's rings.

Nearly half a century later, the Dutch scientist Christiaan Huygens solved the puzzle that vexed Galileo. Thanks to better optics, Huygens was able to pronounce in 1659 that the companions or arms decorating Saturn were not appendages, but rather the planet "is surrounded by a thin, flat ring, which nowhere touches the body." His theory was received with some opposition, but was confirmed by the observations of Robert Hooke and Italian-French astronomer Jean Dominique Cassini.

While observing Saturn, Huygens also discovered the moon Titan. A few years later, Cassini discovered Saturn's four other major moons — Lapetus, Rhea, Tethys and Dione. In 1675, Cassini discovered that Saturn's rings are split largely into two parts by a narrow gap — known since as the "Cassini Division."

NASA's Pioneer 11 spacecraft in 1979, and a few years later the NASA Voyager 1 and Voyager 2, furthered our knowledge of the ringed planet by detecting a magnetic field and revealing more details about Saturn's complex moons and rings. The Voyagers found ring particles ranging in size from nearly invisible dust to icebergs the size of a house.

The Ringed Planet

Saturn is the sixth planet from the Sun and is 9.5 times farther away from the Sun than Earth. From Saturn, the Sun is about 1/10th the size of the Sun we see from Earth. Sunlight spreads as it travels through space; because of this fact, the same light-driven chemical processes in Saturn's atmosphere take 90 times longer than they would at Earth. The farther away from the Sun, the slower a planet travels in its orbit. Saturn's year is equal to 29.46 Earth years.

Saturn has the lowest density of all the planets and has a vast, distended, hydrogen-rich outer layer. Like the other giant planets, Saturn contains a core of heavy elements including iron and rock of about the same volume as Earth, but having three or more times the mass of Earth.

Scientists believe that the core of molten rocky material is covered with a thick layer of metallic liquid hydrogen and, beyond that, a layer of molecular liquid hydrogen. This conductive liquid metallic hydrogen layer, which is also spinning with the rest of the planet, is believed to be the source of Saturn's magnetic field.

Temperature variations in Saturn's atmosphere are the driving force for the winds and thus cloud motion. The lower atmosphere is hotter than the upper atmosphere, causing gases to move vertically. Temperature variations, combined with the planet's rapid rotation rate (a Saturn day is only 11 hours), are responsible for the high wind speeds in the atmosphere.

Titan

Saturn’s moon Titan presents an environment that appears to be unique in the Solar System, with a thick hazy atmosphere containing organic compounds, a possible organic ocean or lakes and a rich soil filled with frozen molecules, similar to what scientists believe led to the origin of life on Earth. In the three centuries since the discovery of Titan, we have come to see it as a world strangely similar to our own, yet located almost 900 million miles from the Sun. With a thick, nitrogen-rich atmosphere, possible seas and a tar-like permafrost, Titan is thought to harbor organic compounds that may be important in the chain of chemistry that led to life on Earth.

Titan has been described as having an environment similar to that of Earth before biological activity forever altered the composition of Earth's atmosphere. The major difference on Titan, however, is the absence of liquid water and Titan’s very low temperature. Thus there is no opportunity for aqueous chemistry at Earth-like temperatures — considered crucial for the origin of life as we know it. Scientists believe that the surface temperatures on Titan are cold enough to preclude any biological activity whatsoever at Titan.

The opacity of Titan's atmosphere is caused by naturally produced photochemical smog. With Titan's smoggy sky and distance from the Sun, a person standing on Titan's surface in the daytime would experience a level of daylight equivalent to about 1/1,000th the daylight at Earth's surface.

The surface of Titan was not visible to Voyager at the wavelengths available to Voyager's cameras. What knowledge existed about the appearance of the surface of

Titan prior to July 1 of this year came from Earth-based radar measurements and more recent images acquired with the Hubble Space Telescope at wavelengths longer than those of Voyager’s cameras. Hubble images from 1994 and later reveal brightness variations suggesting that Titan has a large continent-sized region on its surface that is distinctly brighter than the rest of the surface at both visible and near-infrared wavelengths.

Titan's orbit takes it both inside and outside the magnetosphere of Saturn. When Titan is outside the magnetosphere and exposed to the solar wind, its interaction may be similar to that of other bodies in the Solar System such as Mars, Venus or comets (these bodies have substantial interaction with the solar wind, and, like Titan, have atmospheres but no strong internal magnetic fields).

The interaction of Titan with the magnetosphere provides a way for both the magnetospheric plasma to enter Titan's atmosphere and for atmospheric particles to escape Titan. Voyager results suggested that this interaction produces a torus of neutral particles encircling Saturn, making Titan a potentially important source of plasma to Saturn's magnetosphere. The characteristics of this torus are yet to be explored and will be studied by the Cassini orbiter. The interaction of ice particles and dust from Saturn's rings will play a special role as the dust moves out towards Titan's torus and becomes charged by collisions. When the dust is charged it behaves partially like a neutral particle orbiting Titan according to Kepler's laws (gravity driven), and partially like a charged particle moving with Saturn's magnetosphere. The interaction of dust with Saturn's magnetosphere will provide scientists with a detailed look at how dust and plasma interact.

Titan may have its own internally generated magnetic field. Recent results from the Galileo spacecraft at Jupiter indicate the possibility of an internally generated magnetic field associated with the moon Ganymede. For Titan there are two possibilities: A magnetic field could be induced from the interaction of Titan's substantial atmosphere with the flow of Saturn's magnetosphere (like Venus's interaction with the solar wind); or a magnetic field could be generated internally from dynamo action in a fluid core (like Earth's). (Under the dynamo theory, a magnetic field is created by the circling motion of electrically conductive fluid in the core.) In addition to being important to understanding the Titan interaction with Saturn's magnetosphere, a Titan magnetic field, if generated internally, would help scientists define the natural satellite's interior structure.

The Rings

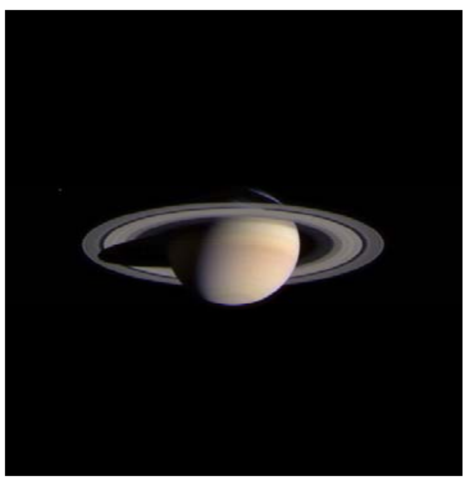
From a distance, the majestic rings of Saturn look like symmetrical hoops surrounding the planet. In the best, most recent pre-Cassini images, the rings appear to be a still splendid but somewhat unruly population of ice and rock particles jostling against each other or being pushed and pulled into uneven orbits by bigger particles and by Saturn's many moons.

The mass of all the ring particles measured together would comprise a moon about the size of Mimas, one of Saturn's medium-small moons. The rings may, in fact, be at least partly composed of the remnants of such a moon or moons, torn apart by gravitational forces.

Their precise origin is a mystery. It is not known if rings formed around Saturn out of the initial Solar System nebula, or after one or more moons were torn apart by Saturn's gravity. If the rings were the result of the numerous comets captured and destroyed by Saturn's gravity, why are Saturn's bright rings so different in nature from the dark rings of neighboring planets? Over the lifetime of the rings, comets and meteors must have bombarded them continually, and therefore they should have accumulated a great amount of carbon containing, rocky debris. However, spectra of the rings indicated a composition of about 98% water ice. Saturn's rings, as well as the rings of all the other large planets, may have formed and dissipated many times since the beginning of the Solar System. Studies of the main rings show that the ring system is not completely uniform in its makeup and that some sorting of materials within the rings exists. Why such a non-uniform composition exists is unknown.

The Very Recent Past

In recent months, as Cassini drew near to its destination it began returning images that exceeded the resolution of the best earth and space based telescopes. This color "postcard", sent in February 2004, offers one of the most stunning images ever of the mysterious ringed planet. Even though Saturn loomed larger than ever, Cassini was still more than 43 million miles away!



Two months later, the spacecraft was close enough to observe two storms in the act of merging into one storm. This is only the second time in history that this phenomenon has been observed on Saturn. While storms on Earth have a relatively short lifespan, storms in the giant planet atmospheres last much, much longer and often merge rather than just dissipate.

In June, Cassini did a flyby of Saturn's moon Phoebe, thus completing the first satellite flyby of its four-year prime mission. Up close and personal, Cassini revealed that Phoebe's surface is covered with craters of varying sizes, probably from meteorite impacts. The images led scientists to believe that the tiny object contains water ice, as was expected, overlain in many areas with one or more thin layers of darker material that may have been ejected from the depths of the craters by impact events. . The evidence thus far has strengthened the belief that Phoebe may have originated in the outer Solar System, perhaps in the Kuiper Belt, and been captured by Saturn's gravity.

The spacecraft navigators consider the tour to have begun with the trajectory correction maneuver that targeted Phoebe in May 2004. The rich science returned from the Phoebe encounter justifies this viewpoint.

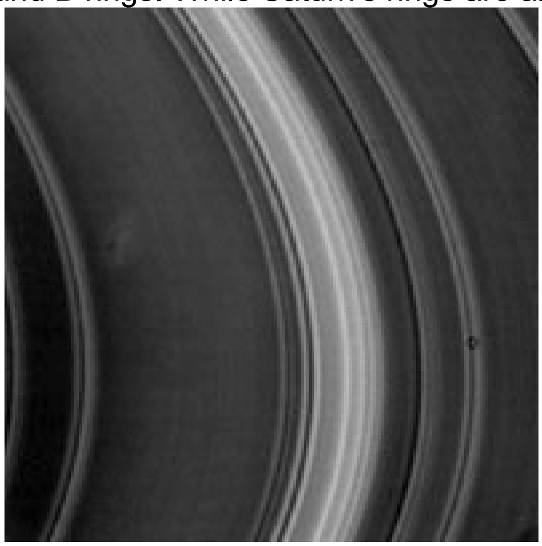
Bull's-eye

After almost seven long years and a journey of more than 2 billion miles, the 12,000-pound Cassini-Huygens spacecraft successfully entered orbit around Saturn at 7:26 PDT on June 30. The Saturn Orbit Insertion maneuvers were orchestrated and executed with flawless precision. After what seemed like an eternity, flight controllers received confirmation that Cassini had completed the 96-minute engine burn and been successfully captured into the correct orbit. And thus began a new chapter in space exploration: a four-year study of the giant planet, its majestic rings, and its 31 known moons.

Early Results

Just two days after the Cassini spacecraft entered Saturn's orbit, preliminary science results were already beginning to show surprises. The complexity of the rings exceeded our wildest imagination. While a large number of rings and much structure in the rings were expected, high-resolution pictures show thousands of alternating light and dark bands. Theories of ring formation, dynamics, and structure may have to be completely revised.

Another early result intriguing scientists concerns Saturn's Cassini Division, the large gap between the A and B rings. While Saturn's rings are almost exclusively composed



of water ice, new findings show the Cassini Division contains relatively more "dirt" than ice. Furthermore, the gaps between the rings seem to be populated by darker particles remarkably similar to the dark material that scientists saw on Saturn's moon, Phoebe. These dark particles refuel the theory that the rings might be the remnants of a moon. The F ring was also found to contain relatively more dirt. The term “dirt” has been used because the material has thus far defied precise spectral identification. It is almost certainly an amorphous, and spectrally very challenging, mixture.

The next day, Cassini revealed surface details of Saturn's moon, Titan. Titan's dense atmosphere is opaque at most wavelengths, but the spacecraft captured some surface details, including possible evidence for a geologically active surface, through infrared wavelengths in which the atmosphere is clear.

A number of long-held ideas were challenged by the early Titan results. Surface areas of high reflectance were found to be composed of mixtures of water ice and hydrocarbon tar. Dark areas were found to be just ice. These observations are exactly backwards from our expectations. No evidence was found for liquid hydrocarbons in pools or lakes. These results have raised questions about whether Titan possesses a primordial soup of hydrocarbons that could yield insights about the pre-biotic chemistry of earth. This Titan flyby, the first of the tour, was at a closest approach distance of 200,000 miles. The tour includes numerous Titan flybys; some, including an upcoming pass in Oct. 2004, will be as close as 700 miles. If all goes well we can expect far better data in the near future and it may be premature to draw any major conclusions about Titan as an early earth analogue.

Cassini's magnetospheric imaging instrument revealed a vast diffuse swarm of hydrogen molecules surrounding Titan, well beyond the top of Titan's atmosphere. This instrument, the first of its kind on any interplanetary mission, provided images of the huge cloud being dragged along with Titan in its orbit around Saturn. The cloud is so big that Saturn and its rings would fit within it.

What Next?

On Christmas Day in Europe and Christmas Eve in the US, Cassini will release the European-built Huygens probe which will coast for 3 weeks and then parachute down through Titan's atmosphere. The recent SOI was NASA's opportunity to shine and the Huygens probe mission will be Europe's opportunity. Huygens is equipped with six scientific instruments powered by batteries with a five-hour lifetime. The descent will take about 2 ½ hours. Huygens was designed to take data continuously during descent through the atmosphere and it is hoped that it will also survive the landing and return data from the surface. The Huygens mission will enhance the value of the Cassini mission, and vice versa. Both scientifically and operationally, Cassini/Huygens is a true international collaboration involving 260 scientists from 17 nations. The missions are thoroughly integrated; many Europeans are on Cassini science teams and many Americans are on Huygens science teams.

We are delighted with the surprises thus far revealed by the Cassini mission. Surprise is at the very heart of science. If there were no surprises, it wouldn't be science. At this moment Cassini is on a long path outward before it will turn around and again come inward toward Saturn on its way to the next Titan encounter. Let us catch our breath and prepare for more astonishing discoveries.