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THE VIEWS FROM SATURN

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED EIGHTH CONGRESS

SECOND SESSION

JULY 22, 2004

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THE VIEWS FROM SATURN

THURSDAY, JULY 22, 2004

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 2:35 p.m., in room SR–253, Russell Senate Office Building, Hon. Sam Brownback, Chairman of the Subcommittee, presiding.

STATEMENT OF HON. SAM BROWNBACK, U.S. SENATOR FROM KANSAS

Senator BROWNBACK. The hearing will come to order. Thank you all for joining us today. We've got another exciting space hearing. For a guy who grew up on a farm to be able to talk about Saturn, this is fun, and to be able to do that.

I want to welcome you, Mr. Orlando Figueroa, NASA Solar System Exploration Director, today, delighted to have you here with your colleagues to discuss the spectacular discoveries of the Cassini Huygens mission to Saturn. I'm awestruck at the pictures, the images I see coming back, and the exploration that has occurred. As I travel around my home state of Kansas, so too are the American people.

A few months ago, we watched just two small emissaries from Earth. The Mars Rover found evidence for a complicated and interesting past history on the planet Mars, including the probable presence of significant water on its surface at some time in the distant past. Now we watch as NASA's mission to the giant planet Saturn unfolds. Already we are discovering truths about our own planet's past. Saturn represents a miniature solar system, and by studying it, we can learn more about how Earth came to be as it is in the larger solar system.

I have several thoughts I'd like to share with you in which I'd like your response to. First, both the Saturn mission and the Mars mission represents considerable international cooperation. In both cases, the United States worked closely with our international partners, particularly those in Europe, to achieve a mission which is more than the sum of its international parts. I think the key in establishing relationships is where partners assume a significant portion of the overall mission and are not just subcontractors on a U.S. mission. This, of course, means they assume responsibility for funding their portion of the program.

In the cases of both Mars and Saturn, they have done just that. I believe this is an essential template as we embark on even more impressive exploration in support of the President's expanded vision of space exploration, culminating in human and robotic exploration of the moon, Mars, and beyond.

My second observation concerns opportunities in the private sector. I note that both Cassini and the Mars Rover were built by the most private sector of the NASA centers, the privately managed jet propulsion laboratory. The recent Aldridge Commission recommended that all the NASA centers move toward this private sector management approach. This is an essential step, and I intend to work hard to make it a reality.

However, I do not think merely managing government centers by a private concern is sufficient. If we are to achieve the true promise the solar system offers our children, we must energize the full talents of the real private sector, men and women willing to spend their own hard-earned resources in space in order to achieve the benefits of the new opportunities there. I think this must start as it did with our own expansion across the continent two centuries ago. As the government leads pathfinding exploration of the moon and Mars, it should purchase its tools and information from that private sector, just as the government explorers purchased their provisions from private settlers and outfitters in the 19th century, beginning with Lewis and Clark.

I must tell you I'm in that way somewhat challenging to NASA's approach to the first new robotic mission in support of the President's vision, the lunar reconnaissance observer to be launched in 2008. This seems to me to be another government-developed, built, and operated system, not really different from the past. And I would hope NASA would look at that and we can have some discussion on that today of why it's not turning more to the private sector on that issue.

So as we ponder the wonder and opportunity in the solar system, I'd like to focus our attention on the future. These magnificent pathfinding missions are only a taste of what's to come in science, discovery, and most important of all, opportunity. I believe a new paradigm in our relationships with international partners is beginning. I also hear the words of the Aldridge Commission and others calling for a renewed commitment to private opportunity, and let's make that one real too.

Mr. Figueroa, thank you very much for coming here today. I want to congratulate you and NASA on a spectacular Saturn mission thus far. It really has been mind-opening and another great success, so I'm delighted to hear that, delighted to see that, wanted to have you here today to be able to present that, and then I hope along the way you can answer the two issues that I raised at some point as well.

STATEMENT OF ORLANDO FIGUEROA, DIRECTOR, SOLAR SYSTEM EXPLORATION DIVISION AND MARS PROGRAM OFFICE, OFFICE OF SPACE SCIENCE, NATIONAL NATIONAL AERONAUTICS AND SPACE ADMINISTRATION; ACCOMPANIED BY MARK DAHL, CASSINI PROGRAM EXECUTIVE AND DENIS BOGAN, CASSINI PROGRAM SCIENTIST

Mr. FIGUEROA. Yes, indeed. Good afternoon and thank you very much, Mr. Chairman. I am very pleased to be here this afternoon to discuss the latest success in NASA's space science program, Cassini's arrival at the lord of the rings, the planet Saturn.

I want to thank you for holding this hearing and for your continued support for our programs. I have written and submitted my written statement and also have left a copy of this package for you where exquisite details about the mission is provided.

Senator BROWNBACK. Your full statement will be put in the record.

Mr. FIGUEROA. Thank you. If I may, I want to take a moment to introduce my colleagues, Dr. Denis Bogan to my left, the program scientist for the Cassini mission, and Mr. Mark Dahl, the program executive from the mission, both from the NASA headquarters.

Senator BROWNBACK. Welcome, gentlemen.

Mr. FIGUEROA. They will certainly help me answer engineering and science questions that you and others may have.

Today I'm providing summary remarks of my testimony and beg ahead of time for your indulgence for such an exciting topic, as it is the arrival at Saturn, and will probably take a few extra minutes, not many but just a couple.

Senator BROWNBACK. Please take the time you need.

Mr. FIGUEROA. Now, almost 7 years ago, on October 15, 1997, to be exact, an anxious and excited group of NASA employees, the European Space Agency, the Italian Space Agency, 14 other contributing countries, and thousands of spectators watched as a massive Titan IV rocket lifted off Pad 41 at Cape Canaveral Air Force Station and sent the Cassini spacecraft and its Huygens probe on its long journey to unlock the secrets of Saturn and its largest moon, Titan.

After having traveled more than 2 billion miles on a journey that included two gravitational assist flybys of Venus, one of Earth, and one of Jupiter, I am delighted to say that the 2,000 pound, nuclear energy-enabled Cassini spacecraft started its maneuver to enter Saturn's orbit at 7:26 p.m. Pacific time on June 30.

After what seemed like an eternity, we got confirmation that the 96-minute engine burn necessary to reduce Cassini's speed was a success and Cassini was safely in its proper orbit. This opened a whole new chapter of space exploration. Cassini's four-year mission of discovery and science promises to surprise scientists and all the public around the world. Seventy-six Saturn orbits with 44 Titan flybys should make for an exciting campaign of exploration around the gas giant, and this is indeed a giant planet.

Unlike the two Voyager missions that flew by Saturn in the early 1980s and obtained just days' worth of close-in science, Cassini Huygens will be for Saturn what the Galileo mission was for Jupiter, a long-term science observatory. Cassini's Saturn approach science campaign began in January of this year, and the majestic image of Saturn presented on my opening is a product of such a campaign. Upon its arrival, Cassini awed us with fantastic early images and data. After only 3 weeks in orbit, we have already discovered a number of new things, some of which I would like to share with you today.

We have learned that Saturn's moon, Phoebe, has a surface covered with craters of varying size, probably from meteorite impacts.

The images and data have led scientists to believe that the tiny object may contain ice-rich material overlain within a thin layer of darker material perhaps ejected by the impacts themselves.

Early mapping with spectrometers illustrate what we know today about Phoebe's composition. This has led some to suspect that Phoebe may have originated in the outer solar system, perhaps in the Kuiper Belt, and have been captured by Saturn's gravity, a longstanding theory. Just 2 days after the Cassini spacecraft entered Saturn's orbit, preliminary science results are already beginning to show a far more complex and fascinating new world, as illustrated by the next two images, where the structure and dynamics of the rings is evident.

The first image illustrates a complex structure that resembles braiding in the outer two rings. Although such braiding seems to have been stable for a long time, we do not know what could cause such structure.

The second image illustrates the rippling that suggests an unknown dynamic process shaping the edge of the ring, perhaps due to an unseen moonlet. We observed hints of these ripples with Voyager, but now we can see them with much greater resolution.

While Saturn's rings are almost exclusively composed of water ice, new findings show that they contain relatively more dirt than ice in some regions. Further, the particles between the rings seem remarkably similar to the dark material that scientists now see on Phoebe. These dark particles refuel the theory that the rings may be the remnants of the moon.

The day after orbit insertion, Cassini revealed surface details of Saturn's moon, Titan. Titan's atmosphere is opaque at most wavelengths, but the spacecraft captured some surface details, including possible evidence of a geologically active surface through infrared wavelengths in which the atmosphere is clear. The light blue around the edge of the disk is the atmosphere. The white spot, now known as the south polar cloud, is believed to be methane and seems to be persistent.

A number of long held ideas are being challenged by the early Titan results. Surface areas of high reflectants seem to be composed of mixtures of water ice and complex hydrocarbons, while dark areas are just water ice. These observations are exactly backward from our expectations. Once again, Saturn didn't read our books.

No evidence has been 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 prebiotic chemistry of Earth. We cannot wait for the future flybys of Titan at a much closer distance. The first flyby occurred at roughly 300,000 kilometers from the moon.

We are delighted with the surprises thus far and what they have revealed in the Cassini mission in these early stages, surprises at the very heart of science. If there were no surprises, it wouldn't be science, but we have only begun to scratch the surface. We are in the very early stage of this fascinating mission. There will be much more science ahead. We eagerly await December 24 when the Huygens probe, built by the European partners, begins its descent toward the murky and mysterious moon, Titan.

At this moment, Cassini is on a long path toward it before it will turn around again and come inward toward Saturn on its way to the next Titan encounter. Let us catch our breath and prepare for more astonishing discoveries in the days to come.

[The prepared statement of Mr. Figueroa follows:]

PREPARED STATEMENT OF ORLANDO FIGUEROA, SOLAR SYSTEM EXPLORATION DIRECTOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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 percent 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.

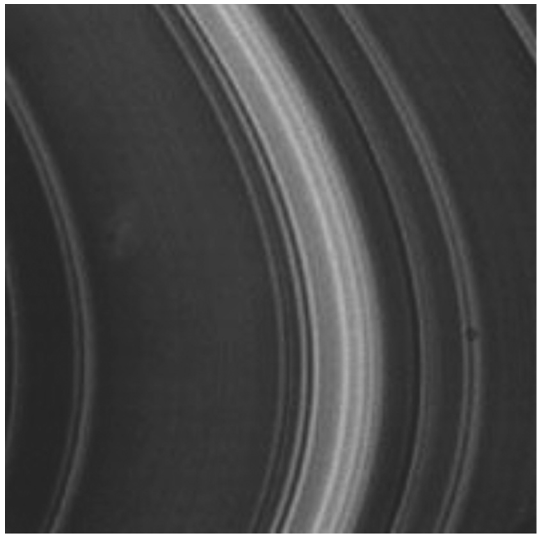
Bull's-eye

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 prebiotic 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 2½ 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.

Senator BROWNBACK. So how long will you spend this first time going around Saturn then with Cassini? What's the length of time you'll go around?

Mr. FIGUEROA. The present orbit is approximately 120 days.

Senator BROWNBACK. You'll stay there before you'll do a burn to go out to Titan, or how will you do that?

Mr. FIGUEROA. No, we keep making adjustments around in the present orbit outside of the rings and coming in closer to the Titan moon as one of the flybys. Mark, you may want to add more information.

Mr. DAHL. We have a maneuver. Because the Saturn orbit insertion was so close to the planet, we have a maneuver coming up in about 4 weeks that will raise the low end of the orbit. The first orbit is about, as Orlando said, about 120 days, and then the next time around we stay at the low end of the orbit is approximately the orbit of Titan. So about every time we come around we swing by Titan.

Senator BROWNBACK. So you're staying in the same orbit, just you will encounter at different times because you're in the same orbital height or orbital distance from Saturn?

Mr. DAHL. No, sir. We actually use Titan to change the orbit, so every orbit of Saturn will be unique. Some of the orbits will have different angles with relation to Saturn so that we'll get better looks at the rings. Some orbits will be further out on the back side of Saturn so that we can study the magneto tail. Some of the orbits will get as short as 7 days close to the end of the 4-year tour. So we'll be quite busy and every orbit will be unique. We use Titan itself as a gravity pump to save fuel and change our orbit.

Senator BROWNBACK. Now, you will go around Saturn and be doing this discovery for a period of about 4 years, and then what's the plan at that point in time?

Mr. FIGUEROA. Typically, our missions such as this one, to the extent that they're healthy, the limiting factor in this case will be the fuel, how much fuel we have left. We intend to keep them alive for as long as we possibly can. It's a valuable, incredibly capable observatory, and we will squeeze as much science out of it as we possibly can.

Senator BROWNBACK. It looks like it's worked great now, and I think of something that launched 7 years ago and the burn goes well after 7 years—that's impressive to be able to keep that going.

Go into more detail of what you're learning thus far on Titan in particular. The pictures you've got up here, they look very—you've got an atmosphere layer and then kind of a green and yellow and now it's different colors up here. I don't know the actual colors of what they are. But go into a little more detail if you would of what we're learning all on Titan.

Dr. BOGAN. The colors are——

Senator BROWNBACK. Get the microphone up close to you.

Dr. BOGAN. The colors indicate the different infrared wavelengths that were used. The longest wavelength penetrates to the greatest depth through the clouds and the haze. And so what you do experimentally is you look at longer and longer wavelength images, and when they begin to show the same shapes over and over again, you know that you've reached the surface. If those further change, you would know that you were looking at a cloud and at the longer wavelength you'd penetrated deeper.

So in those composites you see evidence of a crater. At the top center there is a large crater which you can faintly make out with a peak in the middle of it with an impact at some time in the moon's history, and extending diagonally below that, you see evidence of a ridge or a rift in the surface. And the scientists working on this believe that may be evidence of geologic activity.

The variations between the green and the yellow indicate the composition, whether it's relatively more water ice, or whether it's relatively more hydrocarbon. We have not yet seen evidence of pools of liquid hydrocarbon, but there is definitely hydrocarbon there on the surface, most likely in the form of frost or saturated soil.

We're going to get 300 times closer to Titan on the next pass and we're very excited about that because we're going to get data, given successful operation of the instruments, which we have every reason to expect the data will be far beyond anything we've seen so far.

Senator BROWNBACK. And then you put the probe down in December?

Dr. BOGAN. That's right.

Senator BROWNBACK. Tell me about how that will operate and what you will be doing with that probe.

Dr. BOGAN. That probe will be released on the third pass by Titan. It will coast for about 3 weeks and then enter the upper atmosphere. The atmosphere of Titan is very extended and it's denser than that of Earth, about 50 percent more dense than Earth, and extends to a very high altitude because of the relatively weaker gravity of a smaller body.

Senator BROWNBACK. So how high up is this atmosphere?

Dr. BOGAN. There may be traces of it at several hundred kilometers, 500 to 700 kilometers. The closest passes will be about 950 kilometers, and that number was chosen so as to avoid aerodynamic drag from the upper atmosphere upon the spacecraft. And once that probe is in the atmosphere, it will deploy a parachute, the parachute will slow its descent. The descent will take 2½ hours and data will be sent back continuously to the Cassini spacecraft, which will then relay the data to Earth. The batteries are designed for a 5 hour lifetime, and so if there is a successful landing, a landing that survives and the instruments continue to operate, we'll get a couple of hours of data from the surface itself.

Senator BROWNBACK. And what type of data will it send back if all things work?

Dr. BOGAN. There's an aerosol pyrolyzer, there is a gas chromatograph mass spectrometer, which will determine chemical compositions. There are inertial sensing instruments such that we can determine the structure of the atmosphere, the winds that will buffet the probes as it drops through the atmosphere. There will be cameras and all of this information will be sent back to Cassini, the orbiter, and it can be relayed to Earth at leisure.

Mr. FIGUEROA. It should be a very exciting part of the mission as well and I must remind all of us that the probe is not designed to be a lander, so we may get lucky and survive wherever we land on the surface and get a few more minutes, perhaps if we're lucky an hour, of additional data from the surface itself.

Senator BROWNBACK. What the probe is going to be doing is when it's coming down through the atmosphere, that's your main data collection time?

Mr. FIGUEROA. Taking data throughout the whole entry period and for as long as half an hour after it gets to the surface if it survives.

Senator BROWNBACK. Can you back up to the rings on the picture that you had earlier up there, is that possible? Go through that again. You were saying that there are ripples in this that you had seen before but now they've come through much clearer, and what does that indicate?

Mr. FIGUEROA. This is known as the Encke gap, and I will let Dr. Bogan explain what the significance of those ripples are.

Dr. BOGAN. We talk about shepherding moons when we talk about the rings and the moons moving through this material sweep clean a space near their path, and we have seen in many instances a kind of a scalloping of the edge of the ring where the moon passes by. Particles that get too close to the orbiting moon will either get attracted to it and stick, or they will get ejected from that region in space. So there is very complex dynamics going on, and even within the rings, the particles within those rings, which may be as large as a house at the largest and baseballs, marbles, beebees, and very small dust, and there are dynamics and motion and collisions going on among these.

So it's hard to imagine, given a scenario like that, how you could see regular geometric features that presumably persist for long periods of time, and the ring experts are working very hard right now. They were amazed at the detail of the ring pictures. They saw literally thousands of ringlets as opposed to the dozen or so identified rings that we have named based on our observations from Earth-based telescopes.

Senator BROWNBACK. Why thousands? I mean, what do you speculate?

Dr. BOGAN. Very good question. But there are alternating light and dark bands, and you can count them, and there are literally thousands of them.

Senator BROWNBACK. And we don't know what makes the different rings and the different colors?

Dr. BOGAN. Well, we do—there is a nice infrared map showing the water content of the rings. Water ice makes up about 99 percent or 98 percent of the rings as a whole, but there are dirtier regions, and the people looking at this have so far settled on the name dirt because they haven't obtained a good spectral identification. They are working hard on that. But there are definitely variations between water ice and this foreign material or dirt material, whatever you want to call it, as we go from the innermost rings to the outermost.

Senator BROWNBACK. Why is it flat like that? What do you speculate? I mean, it appears flat.

Dr. BOGAN. It does appear flat, it's very thin, the ring plane is very thin and most of it's——

Senator BROWNBACK. How fixed are you guesstimating, or do you have a measure on that?

Dr. BOGAN. —a few hundred meters to a few kilometers. And it's probably an angular momentum effect where that ring sits right above the equator of the planet, and that's where it has a stable dynamic situation where it can persist.

Mr. FIGUEROA. In celestial scales, several hundred meters or kilometers is a rather thin——

Dr. BOGAN. Yes, very thing.

Mr. FIGUEROA. Mother Nature seems to achieve states where it's minimum energy, and so you would see these rings closes to the equator of a planet and remaining a flat form, just like when our solar system formed where the planets tend to be in that plane in order around the sun.

Senator BROWNBACK. Do we know—do you have theories on where the material came from that's in the rings?

Dr. BOGAN. The theory of solar system formation, for which we think this is an analog, is that material is left over after a planet formation. In the case of Saturn, there's material left over after a satellite formation. Or perhaps some of the smaller satellites get broken up by collisions with one another and the fragments wind up in rings. Other planets have rings, Jupiter, Uranus, and Neptune have identified rings. Those are other giant planets, but none of them has rings to the extent of these very dramatic and bright rings around Saturn, so we have much to learn.

Senator BROWNBACK. And you don't have a working theory as to why these rings are so——

Dr. BOGAN. There are theories, and in fact, we see even in distant galaxies we see disks around stars that we believe are the early stages of planetary system formation. And these situations, Saturn and its rings may very well be a laboratory where we can better understand the dynamics of what's happening in distant galaxies when these planetary systems form.

Senator BROWNBACK. Mr. Figueroa, how's the international cooperation been on this project? How would you scale that?

Mr. FIGUEROA. I think it has been exemplary. From the very beginning, the partnership with ESA, the European Space Agency, the Italian Space Agency, and the other 14 countries have been excellent at all levels, at the programmatic levels, scientific, engineering-wise, and we continue to collaborate very closely of course to ensure the safe arrival of the Huygens probe to Titan, and the continued support in providing and exchanging data and knowledge with our colleagues. It has been simply excellent.

Senator BROWNBACK. And what's the funding mix on this mission?

Mr. FIGUEROA. The total mission cost is approximately $3.3 billion, .7 of which is contributed largely by ESA, about $550- to $600 million, and the balance the Italian Space Agency. Other countries have smaller components, but nevertheless very important to the mission.

Senator BROWNBACK. What has been the public response thus far in the mission? You got dramatic response on the Mars Rover. What about on this one?

Mr. FIGUEROA. Actually we're pumping the images as soon as we receive them, as soon as possible after receipt we were putting them on the Web and the traffic on the Web also increased significantly, matching in some cases the kind of response we got to the Rovers when they arrived on Mars.

Now, a few days later after we entered the Saturn orbit, the spacecraft hid behind the sun and it was hard to see it, so there was a period, a quiet period, and we will start picking up again in the next few days and we will get to see equally, if not more exciting, images coming back. The calls and the interest, judging by the traffic on the website and the questions we have received and the press requests, have been very high.

Senator BROWNBACK. What's your Web traffic for this particular, do you know?

Mr. FIGUEROA. I do not recall the exact number. Do you know?

Mr. DAHL. I believe that the first 5 days the NASA website experienced over one billion hits.

Senator BROWNBACK. Just for this or that's the broad——

Mr. DAHL. Just for Cassini.

Senator BROWNBACK. They're dramatic pictures. It seems that the conditions on Saturn's moon, Titan, are pretty harsh. Even so, do any scientists believe life may exist there in some different or strange form?

Mr. FIGUEROA. I think, and Dr. Bogan can expand a little, but we know the primordial materials may be present and perhaps giving us clues as to what the early conditions may have been when life started emerging on Earth during the early days of our planet.

Dr. BOGAN. Yes, when we say primordial material, we mean material that's never been close to the sun and therefore never been warmed up and altered by chemistry and various physical processes. So the Earth's atmosphere is very different than the early Earth and we call Earth's atmosphere an evolved atmosphere. Titan's is primitive. And we're looking for the chemical building blocks of life, the organic materials, the hydrocarbons, and the temperatures are however low enough that nobody believes at the present time that life exists there now or that it could exist at those temperatures.

There is some hope of finding a liquid water ammonia mixture below the surface in the interior, in the sense that we have found water in the interior of some of the Galilean satellites of Jupiter. That material would have to be warmed by something, and the theory is that there is enough radiologic heat from radioactive elements within the core of Titan that it is possible there could be liquid water ammonia solutions. But no one is expecting life there.

Senator BROWNBACK. What's the temperature on Titan roughly?

Dr. BOGAN. It's less than 100 degrees Kelvin, which is 350 degrees or so Fahrenheit below zero.

Senator BROWNBACK. Well, congratulations. I think it has been exciting to see and to take place. Mr. Figueroa, anything else on this Saturn mission or the Titan probe that you'd like to put into the record?

Mr. FIGUEROA. Well, when we speak of space exploration, and even though the Cassini mission began before the new vision for space exploration, it certainly is a key component of it and illustrates the power of knowledge, the power of ingenuity, and the power of collaboration to help us expand beyond our own orbit. We began with pieces of Mars, now the moon, and of course the outer planets remain incredibly important to the understanding of the solar system we live in.

Senator BROWNBACK. Do you have other missions going to other places in the solar system right now?

Mr. FIGUEROA. In 2000—not at the present time. We have in 2006 the launch of the New Horizons mission to Pluto.

Senator BROWNBACK. And that will take how many years to get there?

Mr. FIGUEROA. It is approximately 12 years.

Dr. BOGAN. Ten to twelve. And it will depend on the exact launch window date that eventually is selected.

Senator BROWNBACK. And you've got a lunar reconnaissance orbiter you're doing in 2008?

Mr. FIGUEROA. In 2008.

Senator BROWNBACK. I noted that the Chinese are sending an orbiter to the moon sooner than that period of time, I believe. Is that accurate?

Mr. FIGUEROA. I'm not aware of a Chinese mission. I'm aware, of course, of a European mission, Smart I, the Celine, and Lunar A, both Japanese missions that are planned.

Senator BROWNBACK. When are they planned for?

Mr. FIGUEROA. Celine at the moment, due to budgetary problems, are sort of in limbo, and the Celine mission is presently scheduled for launch in 2007. Also, budgetary challenges may alter that. We have begun discussions with them. We have an ongoing partnership on Lunar A and would like to establish a similar one for Celine. There is a great deal of data and information that will be valuable to the long-term vision of space exploration, beginning with the moon.

Senator BROWNBACK. I noted to you in the opening statement that—wondered why we didn't follow—or are not following in the design of the lunar reconnaissance orbiter for 2008 more of the Aldridge Commission reports or suggestions to involve much more of the private sector in the data purchases. In other words, you'd contract it with the private sector and say we're going to purchase data from you.

Thoughts? I'm sure you must have considered that in NASA putting together this lunar probe.

Mr. FIGUEROA. In our view, data for that mission may not be realistic. We have chosen an approach that we believe was the best balance of risk and programmatic and technical risk and delivering the key measurements that we need to get the first steps in the lunar exploration program going.

Now, I am aware of concerns that exist such as the one that you mentioned and are looking at other alternatives.

Senator BROWNBACK. Have you reviewed already the possibility of going more private sector and just purchasing data back from them? Have you reviewed that idea?

Mr. FIGUEROA. We will be over the next few months looking at that idea. We took a look at greater private sector contributions to the mission, different components on the mission, even though I think it's fairly significant at the present time. Going as far as data buy, we made an assessment based on what we have learned in the past, missions such as Sea Waves and LANDSAT, where the returns that were expecting never really materialized and ended up being incredibly expensive and ineffective.

Senator BROWNBACK. Go into that in more detail. The returns you expected didn't materialize?

Mr. FIGUEROA. Well, it ended up being significantly more expensive to the government and never achieving the full potential that was expected. This is in a full data-buy mode. Now, whether there are other approaches that we can look at the mission, we will be looking at that over the next couple of months.

Senator BROWNBACK. I just want to make sure that you are looking at that, because that's something that was outlined and we've been talking about, others have been too, that if we can trail blaze and then leave some infrastructure behind. Now, if it doesn't work, if it's too expensive for us, obviously we don't want to go those routes. But if there are ways that we can do that, that can be useful to do.

Gentlemen, thank you very much. I wanted to do this after I saw these pictures and images and stories coming out in the press. I wanted to bring you up here to be able to see it, but also to congratulate you and give you a chance to show off what all you've been getting, and that's a remarkable achievement, I think, when you launch something 7 years ago and it still works, it does what you planned on it to do. I don't think my minivan will get that done after using it for 7 years. I think we've put a little more into this than that one costs, but still that's an impressive scientific achievement, and it is opening our eyes and yearning us on forward into the solar system. So another milestone achieved. Congratulations.

Mr. FIGUEROA. Thank you very much, Mr. Chairman, for the opportunity. It's a pleasure to be here.

Senator BROWNBACK. We will keep the record open if others have questions to submit to you or if you have other things you want to submit for the record. Otherwise, the hearing is adjourned.

[Whereupon, at 3:15 p.m., the hearing was adjourned.]

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