CASSINI UNDER CONSTRUCTION TO EXPLORE SATURN

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The last of the United States' large, many-instrument, interplanetary spacecraft is being built this year at NASA's and Caltech's Jet Propulsion Laboratory (JPL) in La Canada Flintridge. Assembly began late last year on JPL's *Cassini* Saturn-orbiting spacecraft, which will carry the *Huygens* probe to study the atmosphere and surface of Saturn's largest moon, Titan. The very complex, six-ton *Cassini/Huygens* spacecraft has an ambitious mission of studying Saturn's rings, atmosphere, and magnetosphere; its moons from the close proximity of the planet; and the atmosphere and surface of Titan. Together, the orbiter and probe carry 27 scientific investigations built by over 3000 people in 33 states plus another 1300 people in 17 foreign countries. The European Space Agency and Italy are the major foreign participants. Like *Galileo,* which sent its probe into Jupiter's atmosphere last December and is now conducting a two-year orbiting mission of Jupiter, *Cassini/Huygens is* large, complex, ambitious, expensive, and has taken many years to design and build. To reduce costs and permit more diverse missions, future NASA missions will be shorter, will use smaller and less expensive spacecraft, and will carry one or only a few science investigations.

Cassini/Huygens is being assembled and tested for an October 1997 launch to Saturn aboard the United States' most powerful launch vehicle: a Lockheed-Martin Titan IV rocket carrying a centaur upper stage. The large rocket is necessary because of the large mass of the spacecraft--5510 pounds of dry mass plus661 S pounds of fuel--and because of the. large amount of energy it takes to get from Earth to a planet circling the sun at a distance of almost a billion miles. Even this large launch rocket, however, cannel provide enough energy to go directly to Saturn, so the spacecraft must twice get help from the gravitational field of Venus in April 1998 and June 1999, from an Earth flyby in August 1999 and from Jupiter in December 2000. The spacecraft will finally arrive at Saturn in June 2004, and will send the *Huygens* probe into Titan's atmosphere five months later while the *Cassini* Orbiter Continues on its four-year mission to study the planet and moons until the summer of 2008. The orbiting mission will comprise 60 orbits of Saturn, including 30 close encounters with Titan.

Saturn, one of the five planets visible to the unaided eye, and known since ancient times as a star whose position wandered among the background of fixed stars, has been studied with ground-based telescopes since the seventeenth century, and has been visited by the *Pioneers 10 and J 1* spacecraft and by two *Voyager* spacecraft in 1981. The Remans named it after their very important god of agriculture, whose annual festival of revelry and gift giving at the winter solstice, the Saturnalia, influenced the establishment of our modern Christmas and New Year celebrations. Along with Jupiter, Uranus and Neptune, Saturn is one of the four gas giants containing most of the solar system's planetary mass. Although it is almost the size of Jupiter, it contains only one third of Jupiter's mass, so it would float in

water because its density is so low. Saturn is 766 times as large as our own planet Earth, but is only 9S times as heavy. Saturn's density is low because it is composed almost entirely of light elements and gases: 91% hydrogen, 6% helium and small amounts of methane, ammonia and other gases. Saturn has no solid surface since hydrogen changes from a gas to a liquid and remains liquid for tens of thousands of miles into Saturn's interior where temperatures arc thousands of degrees Farenheit and pressures arc more than a million times the pressure at the Earth's surface. Because it is fluid, Saturn's period of rotation varies with latitude, but is about ten hours. Saturn radiates 1.8 limes as much energy as it receives from the sun, and the Source Of this energy is unknown, so *Cassini* contains instruments that will study this phenomenon. Onc proposal suggests that the excess is generated by the kinetic energy of falling helium drops, since *Voyager* found lcss helium in Saturn's upper at mosphere than it found at the top of Jupiter's atmosphere. *Voyager* also found that Saturn's spectacular rings arc some 40,000 miles wide, but only 30 to 100 feet thick and arc composed of dirty icc particles from the size of dust grains to about 20 feet across. The best guess is that the rings arc the remnants of broken icy moons.

JPL's Saturn orbiter is named for Gian Domenico Cassini, a seventeenth century astronomer who discovered a major gap in Saturn's rings, discovered four of Saturn's moons, and correctly guessed that the rings were debris from moons. In addition, hc measured Mars' and Jupiter's periods of rotation using the shadows of their moons, and mapped Earth's moon. Cassini accepted the then-controversial sun-centered solar system proposed by Copernicus in the previous century (1543), but he incorrectly rejected Kepler's newer (1609) idea that the planets' orbits were ellipses with the sun at onc focus. Nevertheless, his scientific stature was enough for France's sun king, Louis XIV, to invite him to Paris to become director of the Paris Observatory.

The *Cassini* orbiter can extend the *Voyagers', Pioneers'* and ground-bawd discoveries about Saturn to much greater detail. It carries instruments to make images in visible light, shoricr-wavelength and higher-energy ultraviolet light, and lower-energy, longer-wavelength infrared heat. Its antenna for communicating to Earth (at up to 140,000 bits pcr second from a billion miles away) can do double duty as a radar antenna to map Titan's hay.c-obscured surface the same way *Magellan's* radar saw through the clouds of Venus to make a map of over 90% of that planet in the early 1990s. By just listening, to the radio signal from *Cassini*, astronomers can infer the structure of the planet's atmosphere, and of its rings in many locations when the signal passes through the rings. The radio signal can also map Saturn's gravitational field and, with other spacecraft then flying, search for gravitational waves passing through the solar system. Three spectrometers (instruments which sense how much energy they receive in each of the frequencies or energies over a broad range of the ultraviolet, visible light, and infrared [heat] spectrum) can be used to infer the structure and chemical composition of the surfaces of the planet, its moons, and its rings. Several instruments study particles near the planet and its moons and rings, from atoms and ions through molecular sizes, and up to the size of dust and icc grains. A final group of instruments will study Saturn's own radio emissions and analyze the interaction of elementary particles

and atomic nuclei streaming from the sun (the "solar wind") with Saturn's magnetic field, its rings and ils moons. Onc of these instruments can even get images of Saturn's magnetic field's interactions with the solar wind. All of this sophisticated instrumentation mans that *Cassini/Huygens* must pack a lot of capability into as small and as reliable a spacecraft as technology permits. To that cad, the spacecraft uscs much more modern electronics on integrated semiconductor (such as silicon) chips, it uscs both solid slate switches and a solid state memory of four billion bits volume, instead of mechanical switches and a mechanical tape recorder, which require moving parts and should bc less reliable. Its power source dots not rely on (IIC sun, since the sun is too faint at Saturn's distance to provide the 650 Watts which Cassini needs to carry out its operations; it therefore relics on a thermocouple healed by radioactive plutonium as its primary energy source. Some of this electrical energy is used to keep the spacecraft electronics at temperatures between 50 and 104 degrees Farenheit; more Earlh-like than the cold environment at Saturn's distance from the sun. To keep *Cassini* less complex and more reliable, it has no mechanism to point instruments in all desired directions, so the entire spacecraft must turn toward the appropriate point on the planet or moon. But, using the sun, stars, and its own internal gyroscopes for pointing references, it can accomplish this pointing to an accuracy of better than a tenth of a degree, and it won't drift away from a specified direction faster than a tenth of a degree every two minutes. Wi(h the spacecraft guidance system and the ground navigators, *Cassini/Huygens* ca n bc navigated to a 20-mile target at Sat urn after having travelled for four years and several billion miles in orbit around the sun.

Titan is Saturn's and the solar system's largest moon, and the only moon with a visible atmosphere containing clouds. In Greek mythology, the Titans were the twelve children of Uranus (heaven) and Gaca (Earth, and mother and wife of Uranus), and their names and those of their children have been given to many of Saturn's moons. *Voyager* found that Titan has an atmosphere composed of nit rogen, and it also detected compounds of hydrogen, carbon, and oxygen such as methane, ethane, ammonia, and water. It may even have a solid surface of methane, ammonia and water ice, with lakes of methane or ethane. The hazy and opaque atmosphere is thought to bc caused by the sun's ultraviolet rays' interaction with methane and nitrogen, producing photochemical smog. Most of the ingredients for life arc found on Titan, but it is far too cold to permit the mobility that would bc required for life to evolve.

Titan was discovered in 165S by Christiaan Huygens, so his name has been given to the probe that will bc targeted to its atmosphere and surface. Huygens, who lived from 1629 to 169S during the height of the seventeenth century flowering of modern science, was a member of a wealthy, influential, diplomatic family, and was able to work with the leading natural philosophers of his day throughout Europe: Decartes, Pascal, Leibnitz and Newton. His father Constantijn was a patron of the Delft artist Johanncs Vermeer, many of whose magnificent canvases were shown at the National Gallery earlier this year. Resides using his improved telescope to discover the correct shape of Saturn's rings and find its largest moon, hc made major discoveries in analyzing pendulum motion, in the mathematics of curvatures and rotating bodies, and in the reflection and bending of light.

Huygens' namesake probe is almost nine feet in diameter, and will hit Titan's atmosphere at 13,000 miles per hour on November 27, 2004, producing temperatures on its protective aeroshell above 3000 degrees Farenheit. A 28-foot diameter parachute will deploy at about 105 miles above Titan's surface, and the probe will then take about two hours to descend through the atmosphere. It strikes the surface of Titan at 11 miles per hour, so there is a chance it could survive a landing if its batteries last until the *Cassini* orbiter flies over to receive the data to be relayed to Earth. *Huygens* can take 1100 images as it descends through Titan's atmosphere, plus it carries many instruments to determine the structure and chemical composition of the at mosphere, the clouds and the haze. Other experiments measure winds, the tilt of the probe if it lands in a liquid, and the characteristics and depth of such a liquid.

Cassini/Huygens is about half-way through its assembly and test program in preparation for a launch in sixteen months. Early next year it will be moved from JPL to NASA's Kennedy Space Center launch site on Cape Canaveral. If we have the patience to wait another seven years after the spacecraft launch, we hope to receive history's first information from the atmosphere and surface of another planet's moon; and after eleven years we expect to have made radar maps of much of the surface of that moon and to have conducted a complete 60-orbit reconnaissance of the Saturnian system.