Huygens probe lands on Titan: a scientific leap for mankind

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"If I have seen further, it is by standing on the shoulders of giants"—Sir Isaac Newton

On January 14, 2005, the Huygens probe, a joint space mission between NASA, the European Space Agency (ESA) and the Italian Space Agency, landed on the surface of Titan, the largest moon of the planet Saturn. Huygens separated from the Cassini orbiter "mothership" on December 25, 2004, and landed successfully near the flat Xanadu region of Titan in an area described as resembling "shoreline" and almost earthlike (albeit with methane instead of water). One scientist observed that it landed on a surface with the texture of "creme brulee" that may once have been flooded.

Cassini-Huygens was initially launched on October 15, 1997, from Cape Canaveral in the United States. It was named after two seventeenth century European astronomers. Jean-Dominique Cassini (1625-1712), who was born in Italy and worked most of his life in France, studied Saturn's rings, discovered their gaps and first proposed that the rings were composed of tiny particles. Christiaan Huygens (1629-1695), the great Dutch physicist, discovered Titan and collaborated with Cassini on many astronomical projects.

The mission, involving more than 22 years of preparation, had a number of scientific objectives centred on the exploration of the Saturn system, its distinctive rings and flybys of some of its dozens of moons. The landing on Titan was an integral part of the project. It was the first time a man-made object had landed on the moon's surface, and is the most distant controlled-descent mission ever undertaken.

On January 21, Huygens's initial data and its findings were outlined in a press conference at ESA head office in Paris. Aware of the magnitude of the landing, Professor David Southwood, ESA's director of science, read from the poem "On First Looking Into Chapman's Homer" by John Keats to sum up the exhilaration of uncovering a new world.

Cassini-Huygens is a product of international collaboration in space exploration, a cooperative enterprise that stands in stark contrast to the increasing tension in international relations in other spheres. ESA is responsible for managing the Huygens probe from its control centre in Darmstadt, Germany, while NASA's Jet Propulsion Laboratory in Pasadena, California, designed, developed and assembled the Cassini orbiter. NASA's Deep Space Network, also managed by JPL, provides communications support via the Cassini orbiter and then relays this information to the ESA's control centre. The high-gain antenna on the Cassini orbiter was built by the Italian Space Agency, which also devised some of the radio system and parts of several of Cassini's onboard instruments. The Huygens payload itself was a joint operation by teams of European scientists from various institutions and NASA.

The success of Cassini-Huygens can be measured not simply in terms of landing the probe upright on Titan but on the functioning of virtually all the scientific devices aboard the craft and the subsequent sending of their data back to Earth.

The Titan landing captured the public's imagination. News regarding the fate of the Huygens probe was eagerly awaited by millions of people internationally. On January 15 alone, the ESA web site portal recorded 919,000 external visitors and 6.8 million page views. Between January 14 and January 21, visitors to the site downloaded a total of 6 terabytes of data. At its peak, the site was recording 3,000 separate hits per second. As a reflection of the spirit of international cooperation that launched and maintains the Cassini-Huygens project, the ESA also welcomed the many e-mails sent by the public.

The Cassini spacecraft will continue to orbit Saturn for the next four years, returning invaluable information about the Saturnian system back to earth at regular intervals.

On July 22, 2004, NASA released the first stunning images of Saturn rings taken by Cassini. The last single "eyeful" image of Saturn and its rings achievable with the narrow-angle camera on Cassini as it moved towards the rings of the planet images can be viewed at here.

Further images are available on NASA's website.

On it way to Saturn, Cassini-Huygens also passed by Jupiter, the largest planet in the solar system, garnering much new scientific data and capturing the most detailed global colour photo of the planet ever produced.

The Huygens probe had a special role within the mission. Equipped with six scientific multifunction instruments, it was designed to land on the surface of Titan and relay information gathered about the satellite back to Earth. Due to limited battery life, scientists expected a maximum of 90 minutes of data if the lander lasted that long on the surface of Titan. In the event, the probe performed flawlessly, relaying data to Cassini throughout its final 700-mile descent through the atmosphere, which lasted two hours, 27 minutes, and then another 60 minutes worth of data after it landed.

Titan was chosen over any of the other 30 moons in the Saturn system because it is the only moon in the solar system with its own significant atmosphere. Titan's atmosphere is 94 percent nitrogen and is the only dense nitrogen-rich atmosphere in the solar system apart from the Earth. The remainder of the atmosphere includes a fusion of hydrocarbons such as methane, ethane, diacetylene, methylacetylene, cyanoacetylene, acetylene, propane, and carbon dioxide, carbon monoxide, cyanogen, hydrogen cyanide, and helium.

Many of the chemical compounds previously discovered on Titan are similar to those present on the early life of our own planet 4.6 billion years ago. It is in some ways a deep-frozen version of the Earth in formation. The initial findings of the mission and the ongoing analysis of the latter will allow scientists access to important insights into how celestial bodies are formed, what chemical and molecular compounds produce the basis for life, how life may evolve and the evolution of solar systems.

Titan has fascinated astronomers since its discovery. In his pioneering work, *Cosmos*, US astronomer Carl Sagan, wrote more than two decades ago, "With abundant organic molecules on its surface and in its atmosphere, Titan is a remarkable and unique denizen of the solar system." He added that "There is no strong evidence either for or against life on Titan. It is merely possible. We are unlikely to determine the answer to this question without landing instrumented space vehicles on the Titanian surface" (*Cosmos*, Book Club Associates, 1981, p.162).

The mission's findings

The majority of the data returned by the probe will be sifted over by scientists for the next weeks, months and years, but the images taken by its onboard camera and already released were of a quality even beyond that imagined by its designers. The findings regarding the topography and geography of Titan were also very significant in helping to understand this world some 2.2 billion miles away.

The Descent Imager-Spectral Radiometer (DISR) imaging system onboard the probe produced a remarkable series of 350 high-resolution photos of a surface bearing an uncanny resemblance to the geology and meteorology of the Earth.

The first images available to the public reveal a tight-knit network of narrow drainage channels that are located between brighter coloured highlands and "lowland" areas that are darker in tone. From the images, it appears that these converge into "river"-type systems before flowing into lakebed regions. Within these can be seen what can be described as offshore "islands" and "shoals." Although these areas appear to be dry, data from the Gas Chromatograph and Mass Spectrometer (GCMS) and Surface Science Package (SSP) points strongly to the possibility that liquid methane flows on Titan's sub-170°C-temperature surface. The SSP information reveals that beneath the crust of the surface, the "under soil" appears to be a sort of loose-sand type of material. This would be consistent with liquid methane falling on the surface for eons.

It appears that the dark material seen in the DISR on Titan's surface firstly settles out of the deeply layered atmosphere. According to a theory arising from the Huygens images, the dark matter is then washed off high elevations by methane rain and coalesces in concentrated areas at the bottom of the drainage channels and riverbeds, contributing to the dark areas seen in the photos.

Dr. Martin Tomasko, the principal investigator for the DISR, said of the images that "We now have the key to understanding what shapes Titan's landscape. Geological evidence for precipitation, erosion, mechanical abrasion and other fluvial activity says that the physical processes shaping Titan are much the same as those shaping Earth. Like dry riverbeds where I come from, those drainage channels may fill up again and again as methane rains down from the atmosphere and fills the seas along the shorelines".

Scientists believe that Titan's thick atmosphere is a result of hydrocarbons forming in Titan's upper atmosphere as a result of the breakup of methane by the Sun's ultraviolet light. This dense atmosphere blocks virtually all sunlight from reaching the surface of Titan, and the Huygens probe was therefore unable to detect the direction of the sun as it approached the moon's surface. Its images were taken with three radar and infrared camera lenses at different altitudes that produced a spiral-type patterned image.

Data and images taken by Huygens indicate that liquid methane and other organic compounds periodically rain onto its surface. Scientists speculate that sections of Titan's surface could be covered with a mushy layer of organic precipitate called tholin. Huygens also located the presence of argon 40 in the atmosphere. This is likely evidence of cryovolcanism—volcanic activity producing a mixture of water ice and ammonia—as opposed to molten lava produced by volcanoes on Earth. Triton—the largest moon of Neptune—is another satellite known to have cryovolcanism properties.

Torrence Johnson, of NASA's Jet Propulsion Laboratory, said of the findings that "We now have a laboratory up there, where nature has set up a world where you don't have rocks; you have ice...you don't have water; you have liquid methane. And it looks like the Mojave Desert."

Other instruments analysed wind speeds of up to 150 mph, and microphones picked up sounds of storms rumblings and squealing sounds. Results from the data released on February 10 show that the maximum wind speed of roughly 120 m/s (430 km/h) was measured at an altitude of about 120 km. The winds are weakest near the surface and increase slowly with altitude up to around 60 km.

Further images from the Cassini-Huygens mission can be viewed at the ESA web site.

Life without water?

One of the most intriguing theories relating to Titan and other bodies in the solar system is the question: Does the existence of life depend on the presence of liquid water? There are several scientific opinions and hypotheses regarding this. François Raulin, one of the scientists on the Huygens mission, said, "We cannot say there is absolutely no chance for life. There is no chance for life on the surface because it is too cold and there is no liquid water.

"However, models of Titan's interior show there should be an ocean about 100 km deep at around 300 km below the surface. We have liquid water, organics not so far away; we have everything on Titan to make life."

In article published in Nature magazine, January 31, writer Philip Ball argued that this presumption may not be so clear-cut. "Even on Earth, many of the chemical reactions of life take place without water, catalysed by enzymes with water-repellent pockets. And many enzymes work perfectly well in the oily, water-free environment inside cell walls."

Ball cites the research of Steven Benner and his colleagues at the Department of Chemistry, University of Florida, who hypothesised in the Current Opinion in Chemical Biology magazine that water-free environments on other worlds might fulfill the basic prerequisite conditions for the formation of life.

Scientists are still attempting to understand why the elementary original biological life forms on Earth were not destroyed by contact with water. As a reactive substance, water can interfere with delicate chemical processes. Benner argues that the development of organic life in non-aqueous hydrocarbon liquids (such as the liquid methane thought to flow on Titan) would not face such an obstacle.

He stated that "If life is an intrinsic property of chemical reactivity then life should exist on Titan. We need to go back, with a lander that can survive for weeks, not minutes."

Another issue fixating Titan observers is that of uncovering the source of the methane detectable in its atmosphere. Methane is constantly destroyed by UV light, so an important aspect of the research into Titan is to establish what replenishes it in the atmosphere. Methane disappears after 300 years, so whatever is replenishing it is still expected to be present locally on Titan.

One of the instruments onboard Huygens, the GCMS, was devised to provide data to help assist in resolving this quandary.

The significance of Christiaan Huygens

The landing of the Huygens probe more than 300 years after Titan's discovery by Christiaan Huygens is a significant milestone in the development of astronomy and science as a whole. The mission has once again brought the towering name of Huygens into the public vocabulary.

Huygens is a pivotal figure in the history of astronomy and made a number of other groundbreaking scientific discoveries and contributions. In this respect, he was cast in a similar mould to Leonardo da Vinci.

Born in Den Haag, Huygens lived and worked within a climate of intellectual and cultural freedom in Holland. As Sagan explained, "The connection between Holland as an exploratory power and Holland as an intellectual and cultural centre was very strong. The improvements of sailing ships encouraged technology of all kinds. People enjoyed working with their hands. Inventions were prized. Technological advance required the freest possible pursuit of knowledge, so Holland became the leading publisher and bookseller in Europe, translating works written in other languages and permitting the publication of works proscribed elsewhere.

"Growing up in this environment, the young Christiaan Huygens became simultaneously adept in languages, drawing, law, science, engineering, mathematics and music. His interests and allegiances were broad. 'The world is my country,' he said, 'science my religion' "(*Cosmos*, p.142).

A product of the scientific renaissance, Descartes said of Huygens, "I could not believe that a single mind could occupy itself with so many things and equip itself so well in all of them."

Huygens extended the work of Galileo in the field of telescopic science, constructing his own 5-metre-long version. He contributed to the theory of refraction, and as a result of his theory of the wave form of light he was able to calculate the refraction within the lenses and make refractors with lesser chromatic and spherical aberration.

Huygens was the first person to measure the size of another planet and the first to draw part of the Martian surface based on his observations of the planet. He carried out the first systematic survey of Saturn (published in his work Systema Saturnium in 1659) and recognised that it was surrounded by rings that did not touch the planet. (Galileo had already discovered the rings of Saturn but had thought they were physically attached to it.) He also cited the difference of the polar and equatorial diameter of Jupiter and studied the inner brighter regions of the Orion nebula, including mapping its stars. That part of the nebula became known as the Huygens Region. A man of prodigious talent, Huygens made most of these discoveries while still in his twenties.

He also made breakthroughs in the science of marine navigation, whilst his invention of the "gunpowder engine" would later influence the invention of the steam engine. Following his study of the game of dice, he became known as the founder of the theory of probabilistics.

To paraphrase Sir Isaac Newton, a contemporary and admirer of Huygens, the achievement of the Cassini-Huygens mission both "stands on the shoulders of giants" and is itself a wonderful testament to scientific progress based on the international collaboration of mankind.