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Cassini-Huygens

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The Cassini-Huygens mission to Saturn is the most ambitious effort in planetary space exploration ever mounted. A joint endeavour of the European Space Agency (ESA), NASA and the Italian space agency, Agenzia Spaziale Italiana (ASI), Cassini-Huygens is sending a sophisticated robotic spacecraft to orbit the ringed planet and study the Saturnian system in detail over a four-year period. On board Cassini is a scientific probe called Huygens that will be released from the main spacecraft to parachute through the atmosphere to the surface of Saturn's largest and most interesting moon, Titan.

Saturn is the second largest planet in the Solar System. Like the other gaseous outer planets – Jupiter, Uranus and Neptune – it has an atmosphere made up mostly of hydrogen and helium. Saturn's distinctive, bright rings are made up of ice and rock particles ranging in size from grains of sand to a freight container. More moons of greater variety orbit Saturn than any other planet. So far, observations from Earth and space have found Saturnian satellites ranging from small asteroid-size bodies to the aptly named Titan, which is the second largest moon of the Solar System (after Jupiter's Ganymede) and is larger than the planet Mercury.

Titan is a fascinating world because its thick nitrogen-atmosphere is very rich in organic compounds which are constantly reacting. If they were found on a planet with Earth-like conditions, their presence would be considered as a sign of life. If water exists on Titan, it cannot be in liquid form because its surface is far too cold (at minus 180°C). In fact very little is yet known about the surface and scientists speculate that Huygens may find lakes or even oceans of a mixture of liquid ethane, methane and nitrogen.

The Cassini-Huygens mission is named after two European astronomers from the 17th century. The Dutch astronomer Christiaan Huygens (1629-1695) discovered Saturn's rings and Titan. A few years later the French-Italian Astronomer Jean-Dominique Cassini (1625-1712) discovered Saturn's four other major moons – Iapetus, Rhea, Tethys and Dione. He also discovered that Saturn's rings are split largely into two parts by a narrow gap, known since as the 'Cassini Division'.

Objectives

The 12 scientific instruments on the Cassini orbiter will conduct in-depth studies of the planet, its moons, rings and magnetic environment. The six instruments on the Huygens probe, which will be dispatched from Cassini during its first orbit of Saturn, will provide our first direct sampling of Titan's atmospheric chemistry and the first photographs of its hidden surface. Huygens will make a detailed on-the-spot study of Titan's atmosphere. It will also characterise the surface along the descent ground track and near the landing site. Studying the complex organic chemistry at work on Titan may provide clues on how life began on Earth.

Some of the questions scientists would like to answer are:

- Mysteriously, Saturn emits 87 percent more energy than it absorbs from sunlight. Which is the source of heat inside Saturn to produce the excess energy?
- What is the origin of Saturn's rings?
- Where do the subtle colours in the rings come from?
- Are there any other moons to discover?
- Why has the moon Enceladus such an abnormally smooth surface? Has it recently melted to erase craters?
- What is the origin of the dark organic material covering one side of the moon Iapetus?
- Which chemical reactions are occurring in the Titan atmosphere?

- What is the source of the very abundant methane, an organic compound that on Earth is associated to biological activity?
- Are there any oceans on Titan?
- Do more complex organic compounds and pre-biotic molecules exist on Titan?

Cost

NASA's investment in Cassini represents a total of approximately 2100 million Euros. ESA's contribution for the Huygens probe is about 360 million Euros. An additional investment of about 100 million Euros by universities and research institutes funded the development of the instruments on board Huygens. ASI's contribution for the high-gain antenna, portions of three science instruments on board Cassini and one full instrument on board Huygens, is about 145 million Euros. All figures are adjusted to today's economic conditions.

Launch

15 October 1997 (Titan-IVB/Centaur from Cape Canaveral, United States).

Journey

On its seven-year journey to Saturn Cassini-Huygens performed four gravity-assist swing-by manoeuvres: Venus (April 1998), Venus (June 1999), Earth (August 1999), and Jupiter (December 2000). The gravity assists gave Cassini-Huygens the cumulative boost to reach Saturn. The spacecraft will arrive at Saturn on 1 July 2004, when it will enter orbit and begin its detailed scientific observations. On 25 December 2004, Huygens will be released on its 22-day cruise to Titan. Its entry into Titan's atmosphere is planned for 14 January 2005.

Planned mission lifetime

Cassini's four-year prime mission will last until 1 July 2008. Huygens will be fully activated for a few hours. Most of the data will be collected while descending through the atmosphere, which will take two to three hours. Upon a successful landing, Huygens will continue to send information back to Cassini up to two hours until its batteries run out. In any case, Cassini will listen to Huygens for four and a half hours, until it disappears below Titan's horizon.

Spacecraft

Design

The Cassini spacecraft, including the orbiter and the Huygens probe, is one of the largest, heaviest and most complex interplanetary spacecraft ever built. Of all interplanetary spacecraft, only the two Phobos spacecraft sent to Mars by the former Soviet Union were heavier.

The antenna subsystem consists of the high-gain antenna and two low-gain antennas. The primary function of the high-gain antenna is to support communication with Earth. It is also used for scientific experiments. To shield the harmful hot rays of the sun from the spacecraft's instruments during most of the early portion of the long journey to Saturn, the high-gain antenna was positioned toward the sun, functioning an umbrella. Cassini was the first planetary spacecraft to use solid-state recorders without moving parts instead of the older tape recorder.

Huygens is built like a shellfish: a hard shell to protect a delicate interior from extreme temperatures experienced during the descent through the atmosphere. It consists of two parts: the Entry Assembly Module and the Descent Module. The Entry Assembly Module carries the equipment to control Huygens after the separation from Cassini, and has a shield that will act as a brake and as thermal protection. The Descent Module has the scientific instruments. The probe will use three different parachutes in sequence during the descent.

Mass

The Cassini orbiter alone weighs 2125 kilograms. Total mass of the Huygens probe is 349 kilograms, including payload (49 kilograms) and Probe Support equipment on the orbiter (30 kilograms). The launch mass of Cassini-Huygens was 5.82 tonnes of which 3.1 tonnes were propellant.

Dimensions

The Cassini spacecraft stands more than 6.7 metres high and is more than 4 metres wide. The magnetometer instrument is mounted on an 11-metre boom that extends outward from the

spacecraft. The diameter of the Huygens probe is 2.7 metres.

International involvement

Hundreds of scientists and engineers from 16 European countries and the United States make up the team responsible for designing, building, flying and collecting data from the Cassini orbiter and Huygens probe.
The Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, manages the Cassini-Huygens mission for NASA's Science Mission Directorate, Washington D.C. JPL designed and assembled the Cassini orbiter. Development of the Huygens Titan probe was managed by ESA's European Space Technology and Research Centre (ESTEC), the Netherlands, whose prime contractor for the probe is Alcatel in France. ASI managed the realisation of the high-gain antenna and the other instruments of its participation. Equipment and instruments for the mission were supplied from many European countries and the United States.

What's on board?

Orbiter:

Imaging Science Subsystem - ISS
Takes pictures in visible, near-ultraviolet and near-infrared light.

Principal Investigator: Carolyn C. Porco, Space Science Institute, Boulder, CO, USA

Cassini radar - RADAR
Maps surface of Titan using radar imager to pierce veil of haze. Also used to measure heights of surface features.

Principal Investigator: Charles Elachi, Jet Propulsion Laboratory, Pasadena, CA, USA

Radio Science Subsystem - RSS
Searches for gravitational waves in the universe; studies the atmosphere, rings and gravity fields of Saturn and its moons by measuring telltale changes in radio waves sent from the spacecraft.

Principal Investigator: Arvydas J. Kliore, Jet Propulsion Laboratory, Pasadena, CA, USA

Ion and Neutral Mass Spectrometer -INMS
Examines neutral and charged particles near Titan, Saturn and the icy satellites to learn more about their extended atmospheres and ionospheres.

Principal Investigator: J. Hunter Waite, SPRL, University of Michigan, Ann Arbor, MI, USA

Visible and Infrared Mapping Spectrometer - VIMS
Identifies the chemical composition of the the surfaces, atmospheres and rings of Saturn and its moons by measuring colours of visible light and infrared energy given off by them.

Principal Investigator: Robert H. Brown, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ, USA

Composite Infrared Spectrometer - CIRS
Measures infrared energy from the surfaces, atmospheres and rings of Saturn and its moons to study their temperature and composition.

Principal Investigator: Michael Flasar, NASA/Goddard Space Flight Center, Greenbelt, MD, USA

Cosmic Dust Analyser - CDA
Studies ice and dust grains in and near the Saturn system.

Principal Investigator: Ralf Srama, Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Radio and Plasma Wave Spectrometer - RPWS
Investigates plasma waves (generated by ionised gases flowing out from the Sun or orbiting Saturn), natural emissions of radio energy and dust.

Principal Investigator: Donald A. Gurnett, University of Iowa, Iowa City, IA, USA

Cassini Plasma Spectrometer - CAPS
Explores plasma (highly ionised gas) within and near Saturn's magnetic field.

Principal Investigator: David T. Young, Southwest Research Institute, San Antonio, TX, USA

Ultraviolet Imaging Spectrograph - UVIS

Measures ultraviolet energy from atmospheres and rings to study their structure, chemistry and composition.

Principal Investigator: Larry Esposito, University of Colorado, Boulder, CO, USA

Magnetospheric Imaging Instrument - MIMI
Images Saturn's magnetosphere and measures interactions between the magnetosphere and the solar wind, a flow of ionised gases streaming out from the Sun.

Principal Investigator: Stamatios M. Krimigis, Johns Hopkins University, Laurel, MD, USA

Dual-technique Magnetometer - MAG
Studies Saturn's magnetic field and its interactions with the solar wind, the rings and the moons of Saturn.

Principal Investigator: David J. Southwood/ Michelle Dougherty (acting), Imperial College, University of London, United Kingdom

The interdisciplinary scientists (IDS) for Cassini are: Michel Blanc, OAMP, Toulouse, France (Plasma Circulation and Magnetosphere-Ionosphere Coupling) Tamas Gombosi, SPRL, Univ. Michigan, Ann-Arbor, MI, USA (The plasma environment in Saturn's magnetosphere) Jeffrey Cuzzi, NASA Ames, Moffet Field, CA, USA (Rings and Dust in the Saturn System) Darrel Strobel, JHU, Baltimore, MD, USA (Aeronomy / Magnetosphere & Solar Wind Interaction) Tobias Owen, Institute for Astronomy, Honolulu, Hawaii, USA (Atmospheres: Composition, Origin, and Evolution) Laurence A. Soderblom , United States Geological Survey, Flagstaff, AZ, USA (Satellites)

Probe:

Huygens Atmosphere Structure Instrument - HASI
HASI will measure physical and electrical properties of the atmosphere during the entry, descent and after landing.

Principal Investigator: Marcello Fulchignoni, Universite de Paris VII / Dept. de Recherche Spatiale, Observatoire de Paris-Meudon, France.

Gas Chromatograph and Mass Spectrometer - GCMS
GCMS will analyse the chemical composition of the gas in the atmosphere.

Principal Investigator: Hasso Niemann, NASA/GSFC, MD, USA

Aerosol Collector and Pyrolyser - ACP
ACP will collect aerosols for chemical-composition analysis.

Principal Investigator: Guy Israel, CNRS Service d'Aéronomie, Verrières-le-Buisson, France

Descent Imager/Spectral Radiometer - DISR
DISR will take images and make spectral measurements.

Principal Investigator: Marty Tomasko, University of Arizona, Tucson, AZ, USA

Doppler Wind Experiment - DWE
DWE will study the propagation of radio signals through the atmosphere to understand its properties.

Principal Investigator: Michael Bird, Universität Bonn, Germany

Surface Science Package - SSP
SSP will determine the physical properties of the surface at the impact site and provides unique information about its composition

Principal Investigator: John Zarnecki, Open University, Milton Keynes, United Kingdom

A group of interdisciplinary scientists has developed models to simulate the conditions the probe will face during the descent and is helping to coordinate the planning of Titan's observations by the orbiter. They are: Daniel Gautier, Observatoire de Paris-Meudon, France (Titan aeronomy) Jonathan Lunine, University of Arizona, Tucson, AZ, United States (surface-atmosphere interactions) Francois Raulin, Université-Paris 12, Creteil, France (organic chemistry and exobiology)

Operations

Saturn Orbit Insertion: Upon reaching Saturn on 1 July 2004 Cassini will fire its main engine for 96 minutes to brake the spacecraft's speed and allow it to be captured as a satellite of Saturn. Passing through the dusty, outermost ring (called E-ring), Cassini will swing in close to the planet –

to an altitude only one-sixth the diameter of Saturn itself – to begin the first of 75 orbits during the rest of its four-year mission. Huygens is dormant during the long journey to Saturn, but it is 'woken up' every six months by ESA's flight controllers for a complete check-up.

Descent to Titan: A system of alarm clocks will wake Huygens at a pre-programmed time a few hours before it reaches the outer fringe of Titan's atmosphere. During the first three minutes inside the atmosphere, Huygens will have to decelerate from 18000 to 1400 kilometres per hour. The heat developed by the friction on its shield may reach temperatures up to 1800°C. The robotic controls will then fire a pilot parachute to pull out the main parachute at a speed of about 1500 kilometres per hour. Within a minute, the speed will go down to less than 300 kilometres per hour. The shell of the Entry Assembly Module will then fall away and expose the scientific instruments to Titan's atmosphere, at a height of about 160 kilometres. The atmospheric temperature may then be about -120°C. At about 120 kilometres, the main parachute will be cut away and replaced by a smaller one. At an altitude of about 45 kilometres the probe will go through the coldest layer of the atmosphere (tropopause) where the temperature will be about –200°C. Within two and a half hours, the descent will be complete. The landing will take place at the relatively low speed of about 20 kilometres per hour.

Exploration of Saturnian system: During the course of the Cassini orbiter's mission, it will execute close fly-bys of particular bodies of interest – including more than 44 encounters of Titan and seven of selected icy moons of greatest interest. Many more distant fly-bys of other moons are also planned. Cassini's orbit will allow it to study Saturn's equatorial zone as well as its polar regions.

Ground control:

Cassini flight operations are conducted from JPL using stations of NASA's Deep Space Network in California, Spain and Australia. Huygens flight operations are conducted from the European Space Operations Centre (ESOC) in Darmstadt, Germany. All telecommands are prepared at ESOC and sent via NASA's Deep Space Network to Cassini which stores them on board for release to Huygens at a pre-determined time. Data are received back via the reverse path. Experiment data are distributed to the scientific teams by JPL and ESOC.

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NASA Mission Managers: Mark Dahl and Robert T. Mitchell
NASA Project Scientists: Jay Berstralh and Dennis Matson
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