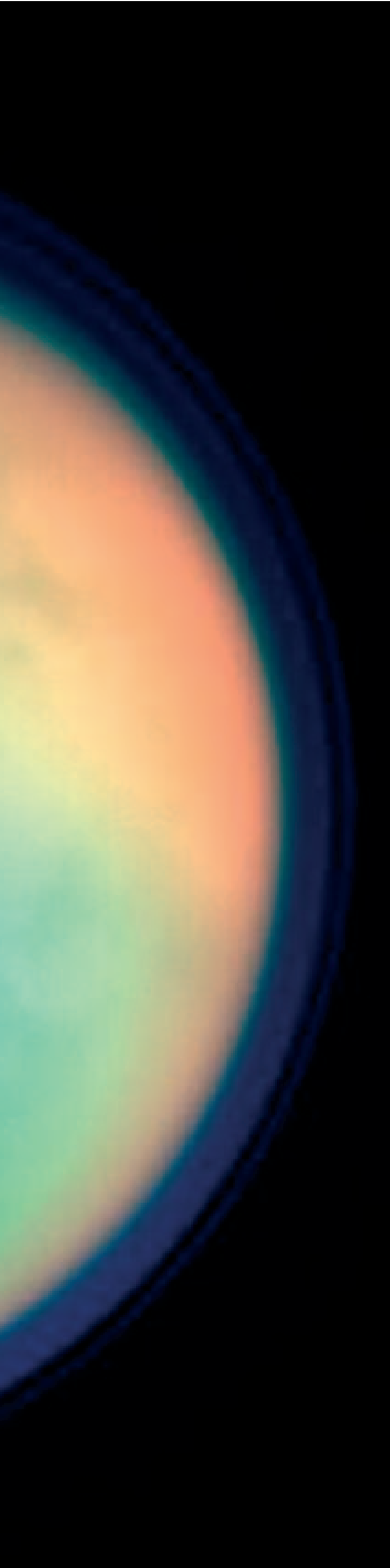
High Ambitions for an Outstanding Planetary Mission: Cassini-Huygens

Composite image of Titan in ultraviolet and infrared wavelengths taken by Cassini's imaging science subsystem on 26 October. Red and green colours show areas where atmospheric methane absorbs light and reveal a brighter (redder) northern hemisphere. Blue colours show the high atmosphere and detached hazes (Courtesy of JPL /Univ. of Arizona)



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Cassini-Huygens, named after the two celebrated scientists, is the joint NASA/ESA/ASI mission to Saturn and its giant moon Titan. It is designed to shed light on many of the unsolved mysteries arising from previous observations and to pursue the detailed exploration of the gas giants after Galileo's successful mission at Jupiter. The exploration of the Saturnian planetary system, the most complex in our Solar System, will help us to make significant progress in our understanding of planetary system formation and evolution, which is also a key step in our search for extra-solar planets.

Questions to be Answered by Cassini-Huygens

- What is the source of heat inside Saturn that produces almost twice the amount of energy that the planet absorbs from sunlight?
- What is the origin of Saturn's rings?
- Where do the subtle colours in the rings come from?
- How many more moons are there?
- Why does the moon Enceladus have such an abnormally smooth surface? (Has recent melting erased craters?)
- What is the origin of the dark organic material covering one side of the moon Iapetus?
- Which chemical reactions are occurring in Titan's atmosphere?
- What is the source of the methane, a compound associated with biological activity on Earth, which is so abundant in Titan's atmosphere?
- Are there any hydrocarbon oceans on Titan?
- Do more complex organic compounds and 'pre-biotic' molecules exist on Titan?

Introduction

In many respects, a journey to Saturn is a journey back to the origins of the Solar System. Saturn's rings and moons are a model of the archetypal Solar System, when fragments of rock and ice collided with each other and melted on a grand scale. Titan, Saturn's most interesting moon, is thought to bear similarities to the primaeval Earth in its frozen state. A complex organic chemistry is at work in Titan's atmosphere and on its surface. Perhaps the building blocks of life have been preserved there, but did not evolve in Titan's cold and hostile environment? This environment is certainly an intriguing place, where time appears to have stood still for billions of years.

Cassini-Huygens is the most ambitious effort in planetary space exploration ever mounted. The mission calls for a sophisticated robotic spacecraft to orbit the ringed planet over a four-year period and a scientific Probe called 'Huygens' to be released from the main spacecraft, parachuting through Titan's atmosphere and eventually touching down on its surface.

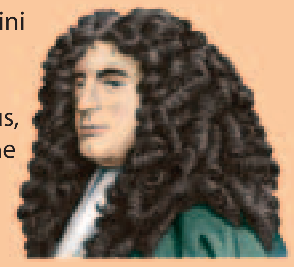
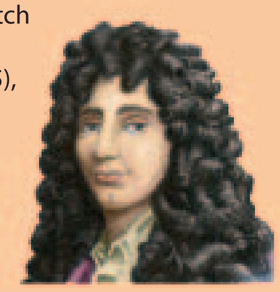
Cassini-Huygens is a masterpiece of collaboration that, from the initial vision in the early 1980s to the completion of the nominal mission in July 2008, will span nearly 30 years. It is a joint endeavour by the US National Aeronautics and Space Administration (NASA), providing the Cassini Orbiter, the European Space Agency (ESA), providing the Huygens Probe, and the Agenzia Spazio Italiana (ASI) which, through a bilateral agreement with NASA, is providing hardware systems, such as the High-Gain Antenna, for the Cassini Orbiter and instruments.

The twelve scientific instruments on the Orbiter will conduct in-depth studies of the planet, its rings, atmosphere, magnetic environment and a large number of its moons. The six instruments on the Probe will provide our first direct and detailed sampling of Titan's atmospheric chemistry and the first detailed photographs of its hidden surface.

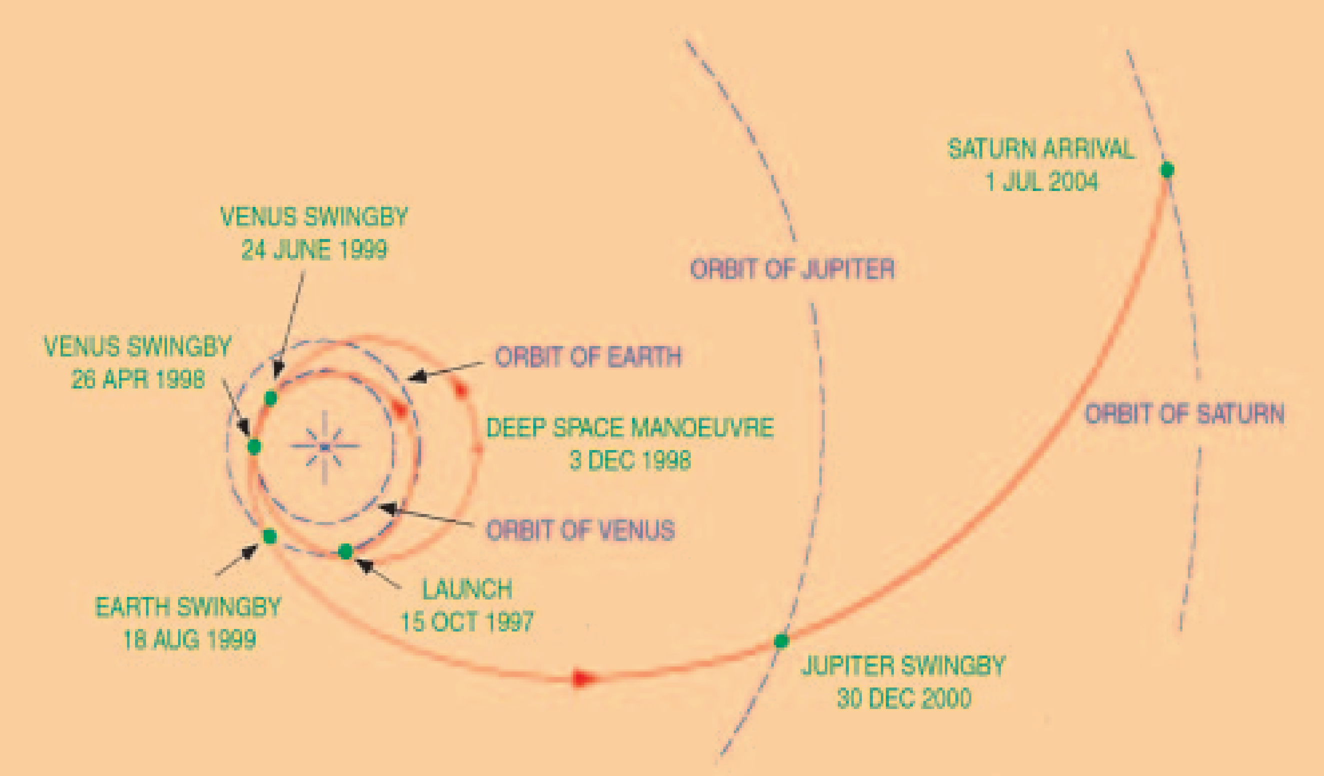
The Scenic Route to Saturn via Venus (twice), Earth and Jupiter

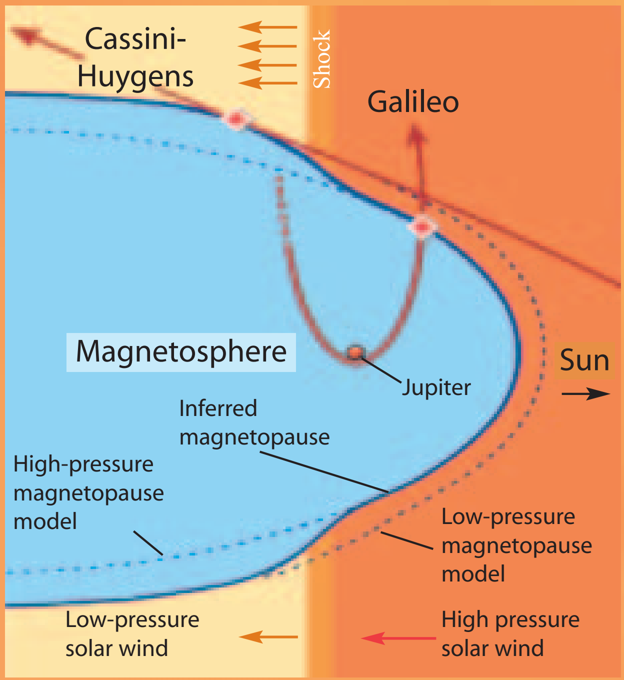
Cassini-Huygens has flown-by three planets – Venus, Earth and Jupiter – to acquire sufficient energy to reach Saturn. In addition to boosting the spacecraft's velocity, those planetary flybys have provided a wealth of unique observations thanks to the Cassini Orbiter's highly sophisticated instrument payload with its outstanding capabilities. In tandem with Galileo, Cassini performed

The Mission at a Glance

	Cassini Orbiter	Huygens Probe
Mission name	Named after the French-Italian astronomer Jean-Dominique Cassini (1625-1712), who discovered the four major moons – Iapetus, Rhea, Tethys and Dione – and the 'Cassini Division' 	Named after the Dutch scientist Christiaan Huygens (1629-1695), who discovered Saturn's rings and Titan 
Destination	Saturn and its moons	Titan
Objectives	In-depth studies of Saturn, its atmosphere, rings, magnetic environment and moons, especially Titan	First direct sampling of Titan's atmospheric chemistry and first photographs of the surface
Experiments	12 instruments, led by the USA, Germany and United Kingdom	6 instruments, led by France, Italy, Germany, the United Kingdom and the USA
Launch date	15 October 1997, from Cape Canaveral (USA)	
Launcher	Titan-IVB/Centaur	
Expected operational lifetime	Four years, from 1 July 2004 (Saturn Orbit Insertion) to 1 July 2008	22 days, including up to 2.5 hours of descent through Titan's atmosphere and a few hours on its surface
Ground operations	NASA/JPL, using stations of NASA's Deep Space Network in California, Spain and Australia.	ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany

The Cassini-Huygens mission's interplanetary trajectory





Cassini-Huygens explored the dynamics of the Jovian magnetosphere, which was 'caught in the act of compression.'

what NASA calls a 'discovery-class mission' at Jupiter. The planetary flyby opportunities were also used by the Science Teams to 'calibrate' the instruments and to 'train' for the arrival at Saturn.

Getting Closer to Saturn: Phoebe

The encounter with Phoebe, Saturn's distant moon, was the first and only targeted flyby of a Saturnian object planned for Cassini-Huygens before Saturn Orbit Insertion (SOI). Phoebe was discovered by William Henry Pickering in 1898 and has a rotation period of about 9.4 hours, an orbital period of 550 days, and a diameter of about 220 km. Its inclined, retrograde and chaotic orbit is strong evidence that the moon is a captured object. The Phoebe encounter occurred 19 days prior to the SOI burn. The trajectory to and arrival date at Saturn were specifically selected to accommodate this flyby as it was the only opportunity during the mission to study Phoebe at close quarters. Phoebe's orbit is simply too far from Saturn – at almost 13 million kilometres, nearly four times as far as the planet's next closest major satellite Iapetus – to make a later encounter feasible. At closest approach, Cassini passed within a mere 2000 km of Phoebe's surface, allowing imaging with a resolution of up to 15 metres per pixel. At this distance, it also allowed gravity measurements to be made through precise spacecraft tracking.

The Phoebe flyby provided far more information about the moon than the distant observations made by Voyager, whose images were only a few pixels across. Cassini returned truly spectacular images and composition colour maps of what is most likely a captured Kuiper Belt object. The Phoebe data will help to determine the moon's surface properties, geological history, surface age, body shape, local topography, and the distribution of its surface materials. These latest spectacular observations have demonstrated the ability of the many instruments in the payload to work together efficiently to study targets in the best possible manner. They also brilliantly demonstrated that the spacecraft and the mission teams were ready for the task at Saturn.

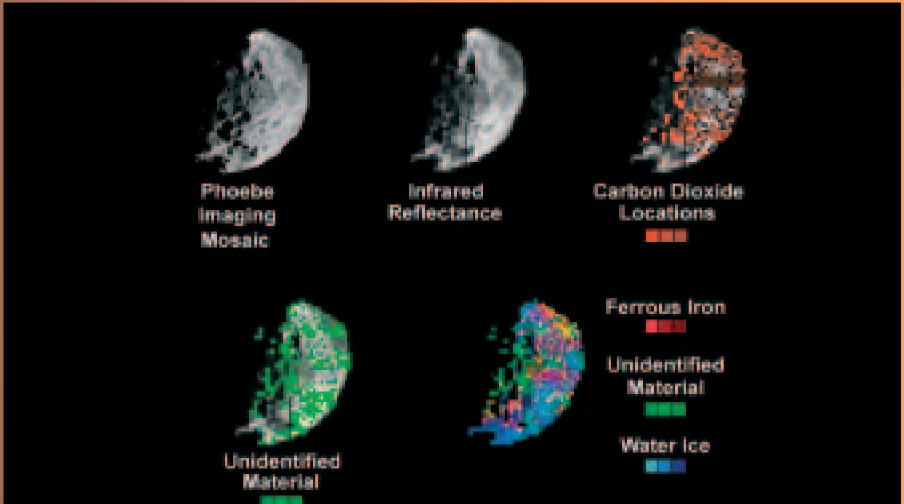
Saturn Orbit Insertion

Saturn Orbit Insertion for Cassini-Huygens took place on 1 July 2004. The SOI sequence included science observations, as the insertion geometry offered a unique opportunity to probe Saturn's higher magnetic field moments and its nearby environment, and to observe its rings. The spacecraft passed twice through the planet's rings, the first time prior to the 96-minute main-engine burn, and again later after the burn had been completed, allowing some unique scientific observations.

One hour and 25 minutes before the burn, the spacecraft turned to orient its high-gain antenna (HGA) in the direction of the incoming dust. Cassini-Huygens crossed through Saturn's ring plane at a radius of 158 500 km – between the F and G rings (both before and after the burn). This location was considered safe, but to protect the spacecraft as much as possible it was felt prudent to use the HGA as an 'umbrella' to shield it from any dust that might be present. The main engine's cover was opened before the ascending ring-plane crossing. After the crossing, the spacecraft was turned to the burn attitude, and the orbit-insertion burn initiated.

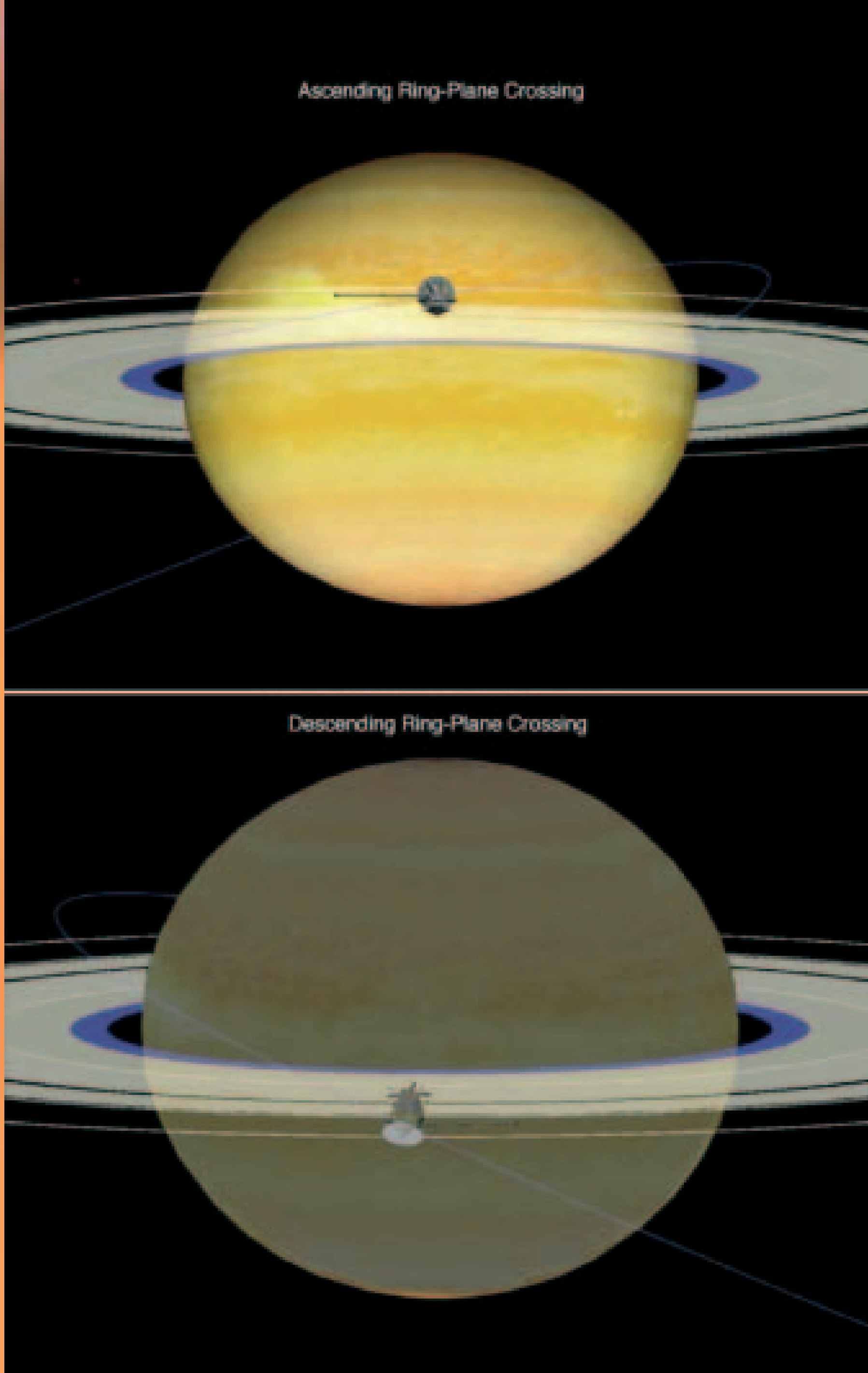
The SOI manoeuvre consisted of a 96.4-minute main-engine burn, delivering a total velocity increment (ΔV) of 626 m/s. Cassini was captured into an orbit around

High-resolution image of Phoebe taken by Cassini's camera near closest approach (Courtesy of NASA/JPL/Space Science Institute)



Composition map of Phoebe (Courtesy of NASA/JPL/Univ. of Arizona)

Trajectory of Cassini-Huygens for the two ring crossings



Saturn after 78 minutes of main-engine firing, and the remaining time was used to reduce the period of the initial orbit, which had a periapsis radius of 1.3 R_s, an apoapsis radius of 150.5 R_s (where R_s is the radius of Saturn), a period of 117 days, and an inclination of 16.8 degrees.

After the burn was completed, the spacecraft reconfigured itself for normal operations. It turned back towards the Earth, gave a call home, and then went on with the planned post-burn science observations. After about an hour of such observations, the spacecraft again oriented the HGA towards the incoming dust direction for the descending ring-plane crossing. About 45 minutes of further science was collected, and then the spacecraft turned back to Earth again to play back both the engineering data collected during the SOI period and the science data, which had been recorded onboard.

Breathtaking images of the rings were sent back. Some showed ‘textbook’ features within the rings (density waves across the rings, scallop-shaped edges, etc). Besides the camera, the spectrometers also obtained data that were converted into ‘false-colour’ images showing the subtle compositional variations across the rings in unprecedented detail (see accom-panying images).

The field and particle instruments also acquired their fair share of excellent data, starting with an earlier-than-anticipated crossing of the bow shock, the region in which the solar wind piles up against the planet’s magnetic field that the magnetosphere. The bow-shock crossing occurred about 3 million kilometres in front of Saturn, about 50% further away from the planet than was expected based on the Pioneer-11 and Voyager-1 and -2 observations made in 1979, 1980 and 1981.

In fact, the bow shock varied significantly during Cassini’s approach, in response to large variations in the solar wind, which allowed the spacecraft to cross the shock several times (more correctly, the bow shock swept in and out of Cassini’s path during its approach to the planet).

Thanks to a new kind of camera, which allows one to observe source regions of energetic neutral atoms which can be ‘imaged’, Cassini discovered a new inner radiation belt inside the innermost ring of Saturn.

Mysterious Titan

Titan, Saturn’s largest moon, is a truly fascinating world. It is freezing cold, with temperatures reaching minus 180°C, and has a very thick atmosphere whose origin is still unknown, consisting mainly of nitrogen, just like Earth’s, but also very rich in organic compounds, which are

Science experiments on Huygens

Instrument	Purpose
Gas Chromatograph and Mass-Spectrometer – GCMS (USA, A, F, D)	Measures the chemical composition of gas in the atmosphere
Aerosol Collector and Pyrolyser – ACP (F, A, USA)	Measures the chemical composition of aerosols (dust)
Descent Imager (panoramic camera) and Spectral Radiometer – DISR (USA, D, F, CH)	Takes images to study the distribution of aerosols (dust) and cloud droplets and to determine the nature of the surface. Makes spectral measurements to record the thermal properties of the atmosphere and measure its composition
Huygens Atmosphere Structure Instrument – HASI (F, I, A, D, E, N, FIN, USA, UK, ESA, IS, P)	Measures the temperature, density and electrical properties of the atmosphere during the entry, descent and after landing. Research into lightning on Titan
Doppler Wind Experiment – DWE (D, I, USA)	Measures the vertical wind profile and the horizontal winds via the propagation of radio signals through the atmosphere
Surface Science Package – SSP (UK, F, PL, USA, ESA)	Studies the state (physical properties and composition) of the surface at the impact site

Image of Saturn's rings taken by the Cassini camera (Courtesy of CICLOPS/Space Science Institute)

constantly reacting. In particular, a few percent of methane is continuously re-supplied in Titan's atmosphere by a mechanism that is still a complete mystery.

Orange-coloured clouds and mists due to the organic haze are so opaque that the surface can only be seen when looking through infrared 'atmospheric windows'. The haze is created by sunlight and cosmic rays breaking down the methane in the moon's atmosphere, and producing a range of complicated organic compounds that float down to the surface and accumulate over time.

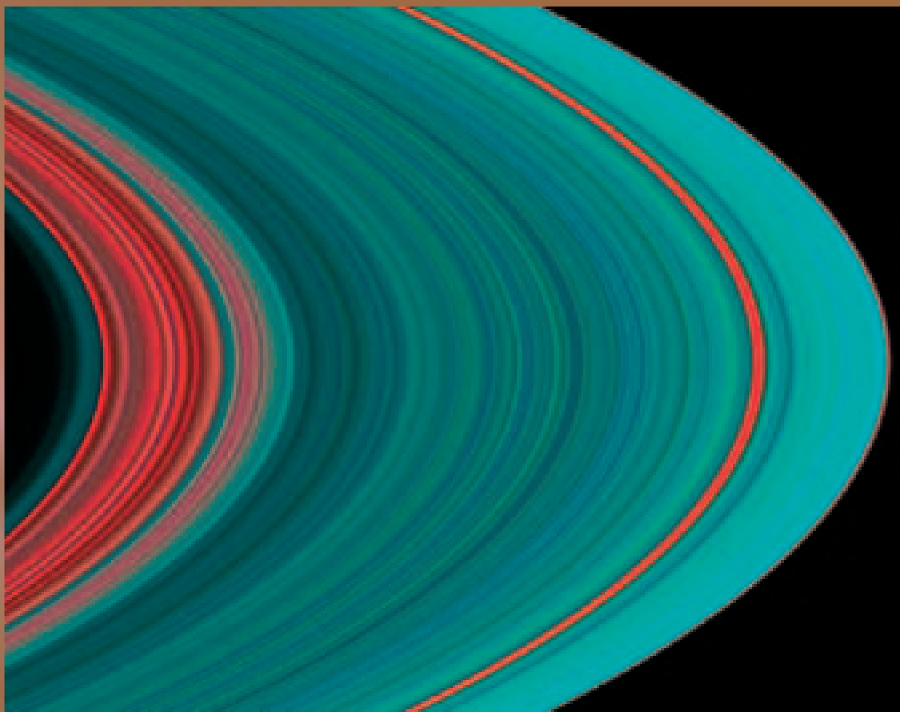
Titan also has a 'greenhouse-warmed' climate, like the Earth, but sustained by different gases. Volcanoes and impacts shape the surface and maybe provide energy to make even more complex organic molecules. Water cannot exist in liquid form because the surface is far too cold, unless it exists for relatively short periods because of the heat generated by volcanism or asteroid impacts. Very little is known about the moon's surface and scientists speculate that Huygens may find lakes or even oceans composed of a mixture of liquid ethane, methane and nitrogen, and possibly underground reservoirs. The pressure and temperature on Titan's surface are sufficient to liquify these natural gases.

The Main Characteristics of Titan

Distance from centre of Saturn	1 221 870 km (= 20.3 Saturn radii)
Orbital period (Titanic day)	About 16 Earth days
Diameter	5150 km (larger than Mercury - 4878 km, and slightly smaller than Jupiter's Ganymede – 5262 km; Earth's Moon is only 3476 km in diameter)
Atmospheric thickness	More than 1000 km
Mass	1/45 of Earth's mass (more massive than Pluto)
Expected surface temperature	About -180°C
Surface pressure	About 1.5 times higher than on Earth
Average density	About 1.9 times the density of water

Science Experiments on the Orbiter

Instrument	**Purpose**
Imaging Science Subsystem – ISS (USA, F, D, UK)	Takes pictures in visible, near-ultraviolet and near-infrared light
Cassini radar – RADAR (USA, F, I, UK)	Maps surface of Titan using radar imager to pierce veil of haze. Also used to measure heights of surface features
Radio Science Subsystem – RSS (USA, I)	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
Ion and Neutral Mass-Spectrometer –INMS (USA, D)	Examines neutral and charged particles near Titan, Saturn and its other moons to learn more about their extended atmospheres and ionospheres
Visible and Infrared Mapping Spectrometer – VIMS (USA, F, D, I)	Identifies the chemical compositions of the surfaces, atmospheres and rings of Saturn and its moons by measuring colours of visible light and infrared energy emitted or reflected
Composite Infrared Spectrometer – CIRS (USA, F, D, I, UK)	Measures infrared energy from the surfaces, atmospheres and rings of Saturn and its moons to study their temperature and compositions
Cosmic Dust Analyser – CDA (D, CZ, F, UK, USA, ESA)	Studies ice and dust grains in and near the Saturnian system
Radio and Plasma-Wave Spectrometer – RPWS (USA, A, F, S, UK, N)	Investigates plasma waves (generated by ionised gases flowing out from the Sun or orbiting Saturn), natural emissions of radio energy and dust
Cassini Plasma Spectrometer – CAPS (USA, F, FIN, HU, N, UK)	Explores plasma (highly ionised gas) within and near Saturn's magnetic field
Ultraviolet Imaging Spectrograph – UVIS (USA, F, D)	Measures ultraviolet energy from atmospheres and rings to study their structure, chemistry and composition
Magnetospheric Imaging Instrument – MIMI (USA, F, D)	Images Saturn's magnetosphere and measures interactions between the magnetosphere and the solar wind, a flow of ionised gases streaming out from the Sun
Dual-technique Magnetometer – MAG (UK, D, USA, HU)	Studies Saturn's magnetic field and its interactions with the solar wind, the rings and the moons



False-colour image of Saturn's rings obtained using Cassini's UV Imaging Spectrograph (Courtesy of Univ. of Colorado)

Both Cassini and Huygens will look at Titan, and their combined data will greatly improve our understanding of this mysterious moon. They will study its atmospheric chemistry and investigate the energy source that makes it so active. They will also look into Titan's 'weather', measuring winds and temperatures, monitoring cloud physics and circulation, lightning and seasonal changes, as well as possible climate changes.

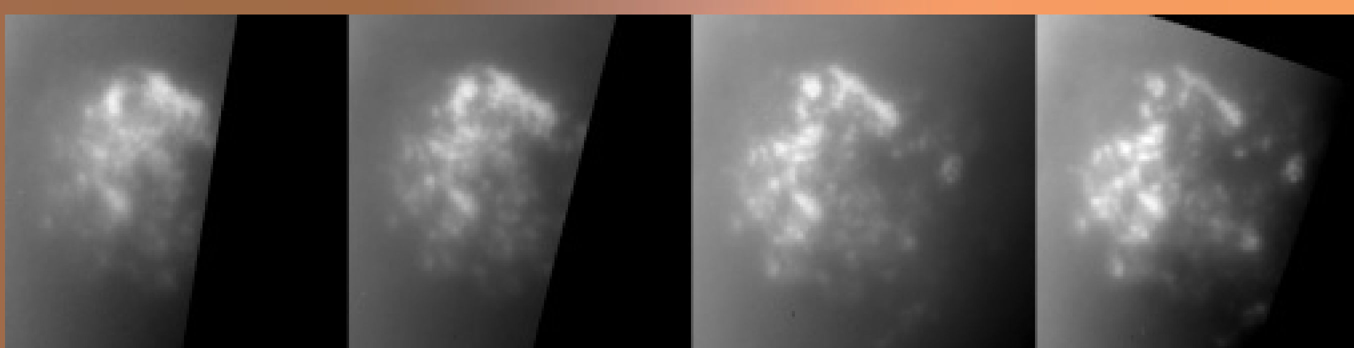
The physics, topography and composition of the surface will all be investigated. A radar will map the surface of Titan. Both Cassini and Huygens will provide clues about the moon's inner structure. Cassini will also see how Titan's upper atmosphere interacts with the magnetosphere of Saturn and if it has a significant magnetic field of its own. The combined observations of Cassini and Huygens will help constrain the possible scientific scenarios for the formation and evolution of Titan and its unique atmosphere.

Cassini's First Look at Titan

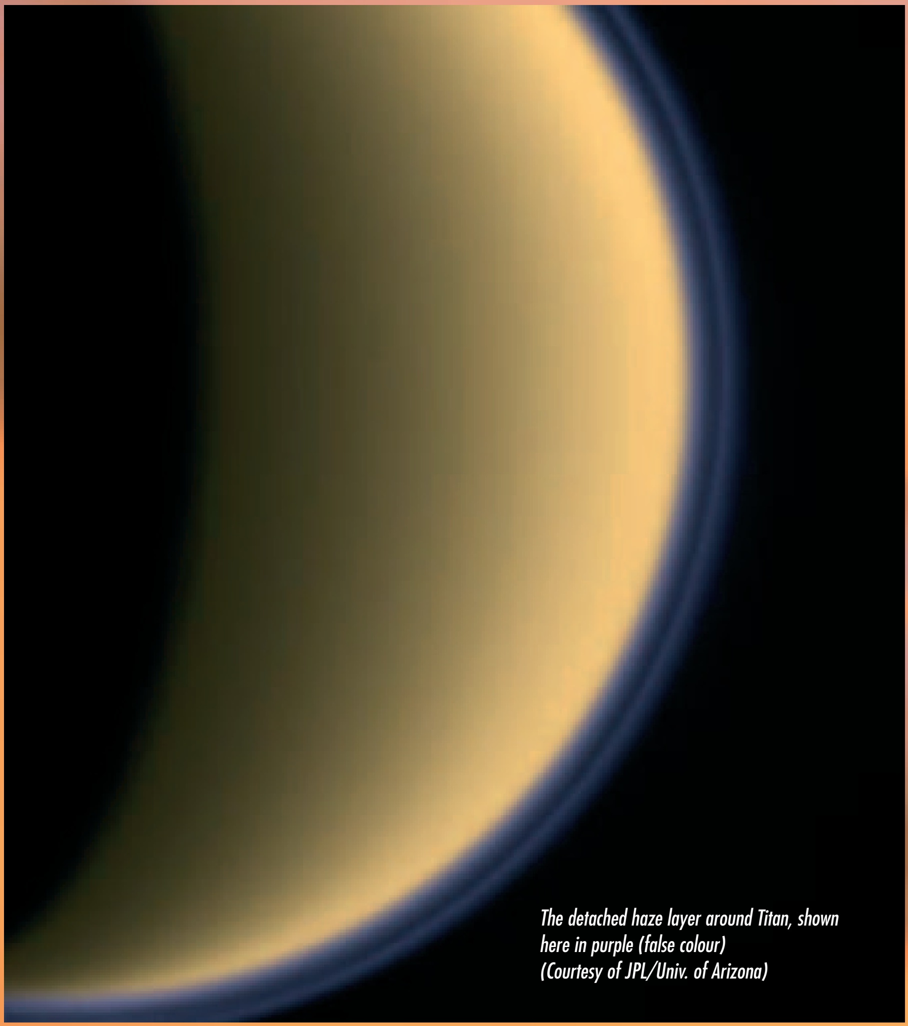
The Cassini camera has already observed Titan over a period of several months while approaching Saturn. It obtained a composite image of its surface that confirmed the main features seen in the Hubble Space Telescope observations in 1994 and later in ground-based adaptive-optics infrared images.

An early opportunity to observe Titan occurred on the day after SOI. In addition to the Phoebe flyby, the 1 July arrival date also provided an opportunity for a non-targeted flyby of Titan about 31 hours after SOI at a distance of less than 340 000 km. This so-called 'Titan-0 opportunity' (revolution 0 is defined as the orbit segment from SOI until the initial apoapsis) was exploited to acquire a unique data set for Titan using the four optical remote-sensing instruments aboard Cassini, namely ISS, VIMS, CIRS and UVIS. Highlights included some observations of the methane polar cloud, which seemed to vary over a matter of just a few hours, and a composite map of Titan's surface with approximately 150 km resolution by VIMS.

One of the main goals of the Titan-0 observations was to obtain a data set that would allow validation of the model of Titan's atmosphere that has been used to design the Huygens Probe's entry and descent, especially in the stratosphere, in the altitude range between 150 and 400 km, where the Probe first brakes and then its parachutes are deployed. The data set, which was of excellent quality, was analysed in combination with recent ground-based observations. It confirmed that the state of the atmosphere at the time of the Titan-0 flyby was well within the envelope of the model used for Huygens (Yelle model), and in fact only slightly warmer and denser than the recommended profile.



Four views of the Titan south polar cloud taken by Cassini-Huygens over a period of almost five hours (Courtesy of NASA/JPL/Space Science Institute)



The detached haze layer around Titan, shown here in purple (false colour) (Courtesy of JPL/Univ. of Arizona)

Two low-altitude flybys of Titan at a height of 1200 km take place, on 26 October and on 13 December, before Huygens's descent begins on 14 January 2005. They will provide additional data that will be used to further validate the moon's atmospheric model for Huygens and to validate the estimated density at 950 km altitude, which Cassini is intended to reach during the 5th Titan flyby.

A Drop into the Unknown

The whole of the Huygens scientific mission is to be carried out during just 2.5 hours of exciting descent through Titan's atmosphere and possibly up to a few hours on its surface. Despite such a short mission duration, however, scientists will be able to gather such a huge amount of data that it will make their enormous efforts over many years worthwhile. The Probe is not designed to survive long after the touchdown and so even if it does not survive the impact, the mission will still be considered a tremendous success.

Is there a primaeval Earth around the corner?

One of the main reasons for sending Huygens to Titan is because in some ways it is the closest analogue to Earth before life began. Its atmosphere and surface may contain many chemicals of the kind that existed on the young Earth, and stocked the primaeval soup in which the first living organisms appeared. It is known that complicated carbon molecules are present in cosmic space, but ultraviolet light from the Sun, cosmic rays and lightning strokes could also manufacture carbon compounds on planets like Earth.

Huygens will investigate this 'home cooking' on Titan. It will identify the complex molecules by their masses, and by their speeds of transit through various filters. It will collect particles from the atmosphere and use an oven to vaporise them for identification. Even today, we still do not know how the self-sustaining assemblies of nucleic acids, proteins and fats at the basis of life came into existence. By identifying the likely chemical precursors that filled the primaeval soup, Huygens will give a fresh impetus to the theories regarding the origin of life on the Earth.

Weather and chemistry in the haze

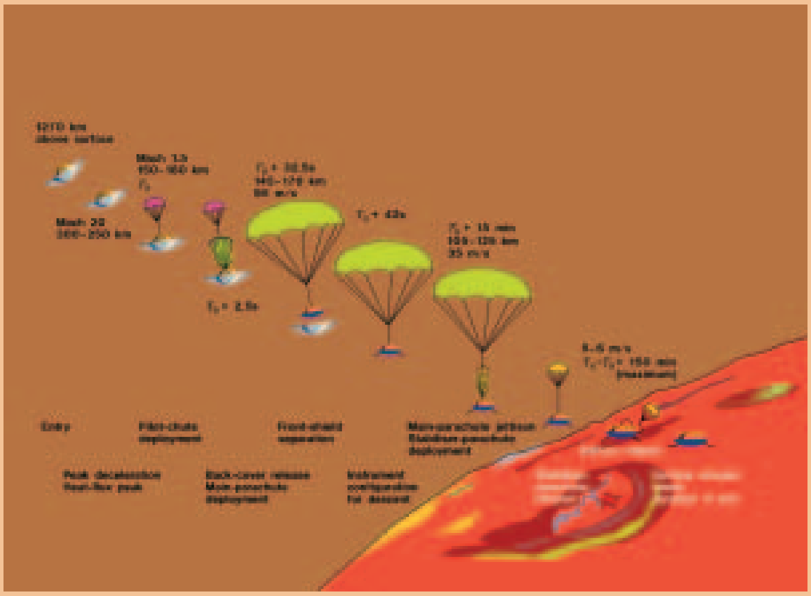
Meteorologists will be fascinated by the parallels and contrasts with the weather on Earth, in a world where clouds and raindrops are made of methane and nitrogen. Winds of 500 km/h, which are expected to diminish during the descent, will propel Huygens sideways when the main parachute opens. The Probe will be able to deduce the prevailing wind speeds and provide detailed weather information, such as temperature and pressure. It will also be able to measure the electrical properties of the atmosphere and register radio pulses from lightning strokes, if they occur. A microphone will listen for any noise from Titan.

The Huygens Probe's Arrival

Huygens is attached to the Cassini Orbiter by a separation mechanism, which will push it off towards Titan at the right moment. The mechanism will also start the Probe rotating, to make sure that it is stabilised and enters the moon's atmosphere front-shield-first. Huygens is built like a shellfish, with a hard shell (carbon-fibre honeycomb covered by silica-fibre tiles) to protect its delicate interior from extreme temperatures (as high as 8000°C in the heated gas in front of the Probe) during the entry into Titan's atmosphere. The Probe itself consists of two parts: the Entry Assembly Module and the Descent Module. The Entry Assembly Module carries the equipment to control Huygens after its separation from Cassini, and has a front shield that will act both as a brake and as thermal protection. The

Huygens Descent Profile

Huygens' entry into Titan's atmosphere is currently planned for 14 January 2005 at 9:07 UTC.



With Huygens' instruments awoken and the radio link activated, the Orbiter can listen to the Probe for 4.5 hours (after that Cassini will disappear behind Titan's horizon).

During the first three minutes inside Titan's atmosphere, Huygens will decelerate from 18 000 to 1400 km/h. The temperature of the gas heated by friction with the Probe's heat shield may reach 8000°C.

When Mach 1.5 (400 m/s) is reached, a pilot parachute is automatically deployed to pull out the main parachute at a speed of about 1500 km/h. The Probe's speed is then reduced to less than 300 km/h within a minute.

The shell of the descent module falls away and exposes the scientific instruments to Titan's atmosphere at a height of about 160 km. The atmospheric temperature may then be about -120°C.

15 minutes later at about 120 km altitude, the main parachute will be cut away and replaced by a smaller one, designed to allow a steady descent at about 20 km/h to touch-down.

At about 45 km altitude, the Probe will go through the coldest layer of the atmosphere, with about –200°C at the tropopause.

A radar altimeter will measure the Probe's altitude during the last 30 km. During its descent, the Probe's camera will capture images of Titan's cloud deck and surface. Data from Huygens will be relayed to Cassini as it passes overhead for later playback to Earth.

Descent Module contains the six scientific instruments. The Probe will use three different parachutes in sequence during its descent.

Huygens remains dormant until just before its separation from Cassini. Contacts with Huygens during the cruise phase were only possible via an umbilical link with Cassini. This link has been used to subject the Probe to periodic checkouts during the long journey for health-monitoring and instrument-calibration purposes. The setting of the timers that will wake up Huygens about four hours before it reaches Titan's atmosphere will be the last commands sent to the Probe from the ground. After its separation, Huygens will have to work autonomously.

Huygens will rotate as it drops, and its cameras will scan the surrounding scene over a full 360 degrees, imaging the cloud layers. The view will be very fuzzy, with the Sun plainly visible, but its halo will allow the Probe to measure the size and abundance of the haze particles, while the spectrometers will measure the heat flows inwards from the Sun and outwards from Titan into space. These instruments will tell us about the kinds and numbers of molecules in the atmosphere, and will analyse aerosol (dust) particles distributed in two layers of Titan's atmosphere (between 150 and 40 km altitude, and at around 20 km altitude).

As the Probe breaks through the haze layers, its camera will take up to 1100 pictures of the panorama and observe surface properties. Perhaps 50 km above the surface, the haze may clear and give Huygens its first glimpse of the surface between fluffy cloud-tops. A radar altimeter, whose main function is to measure the Probe's altitude, will also help to determine Titan's surface characteristics by listening for echoes.

A special lamp, turned on for the final stage of the descent, will allow accurate measurement of the colours of the surface to help the Probe's spectrographs analyse its composition.

Will Huygens splash down in an ocean of methane and ethane, with coloured organic icebergs, or will it touch down on a solid surface with geysers spouting methane from underground reservoirs? Will it see volcanoes erupting with ammonia and water? If the Probe survives the touch-down, the Surface Science Package will come into its own for the last phase of the mission with a sonar and an array of 'simple' sensors for measuring the physical properties of the surface material. It will be able to tell whether the surface is in a liquid, and if so the chemical composition of that liquid. It may even detect waves and measure the depth. It will be able to deduce the ratio of methane to ethane in the liquid, which will give an indication of how long Titan has spent converting the one into the other. Scientists should then be able to judge whether the ocean is as old as Titan, or a later addition. On a dry surface, Huygens will be able to measure its hardness and whether the surface is level.

Cassini's Exploration of Saturn Continues

After the Huygens portion of the mission, Cassini will continue to focus on making measurements with the Orbiter's 12 instruments and returning the information to Earth. It will study Saturn's polar regions in addition to the planet's equatorial zone. Observations of seven selected icy moons will be made, plus at least two dozen more-distant fly-bys of other moons, and there will be more than 44 encounters with Titan (also used for gravity-assist orbit changes that shape the Cassini orbital tour):

- 15 February 2005: 4th Titan low-altitude fly-by.
- 17 February 2005: 1st Enceladus fly-by at about 2900 km altitude. This smooth moon is ten times as bright and reflective as the Earth's moon. Its orbit is embedded in the thickest part of Saturn's E-ring.
- 9 March 2005: 2nd Enceladus fly-by at about 750 km altitude.
- 2005-2008: Cassini continues Saturn observations and Titan fly-bys.
- 1 July 2008: Nominal end of the Cassini Huygens mission.

An International Endeavour

Hundreds of scientists and engineers from 18 nations, including 17 European countries and the USA, make up the team responsible for designing, building, flying the Cassini-Huygens spacecraft and collecting their scientific data. Of these 18 countries, 17 have been active participants since the mission started.

The mission is managed by NASA/JPL, where the Orbiter was designed and assembled. Development of the Huygens Probe was managed by ESA. The Prime Contractor for the Probe is Alcatel (F). Equipment and instruments for the mission have been supplied from many European countries and the USA.

Cassini flight operations are being conducted from NASA/JPL in Pasadena, California, using Deep Space Network (DSN) stations in California, Spain and Australia. The Huygens flight operations are being conducted from ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany. All of the Probe's commands are prepared at ESOC and sent to JPL for merging into the strings of commands sent via the DSN to Cassini, which stores them onboard for release to Huygens at a pre-determined time. Huygens data are received back via the reverse path, and distributed to the Scientific Teams by ESOC.

Acknowledgements

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