German Aerospace Center

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A ten-year success story: The Cassini-Huygens mission to Saturn

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Saturn, its rings, and Earth backlit by the Sun

On 15 October 1997, one of the most exciting Solar System exploration projects began: from Cape Canaveral, a Titan 4B launch vehicle carrying a payload the size of a bus, almost seven metres high and weighing over five and a half tonnes, took off and disappeared into the night sky over Florida. A little later, a Centaur upper stage boosted the Cassini-Huygens spacecraft into its trajectory towards Saturn, the second largest planet in our Solar System and a miniature solar system in its own right, with its striking rings and numerous icy moons. The German Aerospace Center (DLR) is involved in many technical and scientific aspects of the Cassini-Huygens mission.

Launch of the Cassini-Huygens mission on 15 October 1997

Almost seven years later, the US-European spacecraft entered into orbit around Saturn on 1 July 2004. "The images and data which Cassini and Huygens have since returned to Earth are simply fantastic," says Professor Dr Ralf Jaumann of the DLR Institute for Planetary Research (DLR-Institut für Planetenforschung) in Berlin when asked to evaluate the mission's success. "The probe has simply revolutionised our view of the outer Solar System bodies in many different ways."

NASA wants to extend Cassini's mission until 2010

As early as the 1980s, following the two very successful Voyager Saturn flyby missions, the US space agency NASA started planning further missions. As the successor mission to Voyager, Cassini-Huygens is the most comprehensive endeavour to explore our Solar System so far. Because of its resounding success, NASA will soon announce that it will extend the mission beyond 2008. The preparations for many new close flybys of Saturn's icy moons, extending into the year 2010, are already in full swing. But plans to continue the mission even after that time already exist.

Several DLR scientists are working on this project, among other things on two spectrometer experiments. DLR has also made a decisive contribution to developing and building a measuring device for cosmic dust. Moreover, DLR is responsible for planning the taking of images during the close flybys of four of the icy moons. Furthermore, DLR's Space Agency in Bonn-Oberkassel supports researchers who are participating in the project at German universities and Max Planck Institutes.

Bizarre, strange worlds of ice, gas and dust

Saturn’s cloud cover with a shadow cast by the rings

The Cassini experiments on Saturn, with its distinctive rings and its 60 moons known to date, provided the researchers with deep insights into a bizarre world of gas, ice and dust, located at a distance of almost one and a half billion kilometres from the Sun. The scientists now have a considerably better understanding of the dynamics of Saturn's atmosphere and its cloud bands, which race around the planet at speeds of over 500 kilometres per hour. In Saturn's atmosphere, lightning storms discharge at energy levels thousands of times higher than those witnessed on Earth. As in the high northern and southern latitudes of Saturn, polar auroras also occur. Unlike their counterparts on Earth, however, they last for several days at a time rather than just a few minutes" added Jaumann.

Images of the rings, which consist of many segments and are interspersed with gaps created by a host of moonlets of only a few kilometres in size, could be recorded in all their detail and often astounding irregularities by high definition cameras and spectrometers. Billions of whirling ice and rock particles orbit the planet in its equatorial plane at high speeds inside the thin rings which are barely a hundred metres thick, forming waves, clumps, and other formations. Scientists still do not know how old the rings are, or how they came into being, but the Cassini mission at least provides some pieces of the puzzle.

The discovery of "icy volcanoes" - recorded on DLR maps

A tale of A Thousand and One Nights: Charting the icy volcano moon Enceladus

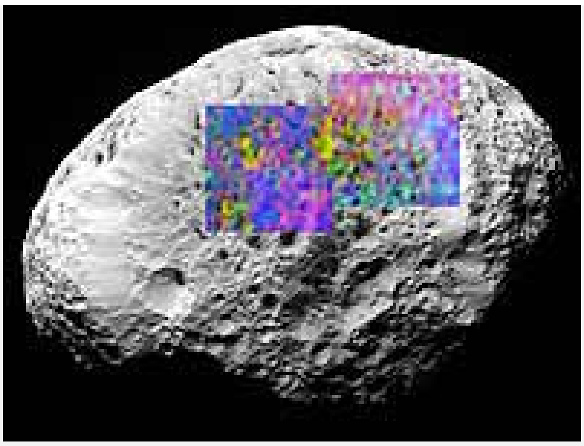
Thanks to specific observations of the icy moon Enceladus, we now know that this satellite, which is only 500 kilometres in size, is heated up by internal tidal friction. So-called "cryovolcanoes" are active in its south polar region, spewing vapour fountains hundreds of kilometres up into space, where the refrozen ice particles are finally trapped by Saturn's outer rings and from then on circle the planet.

This form of volcanic activity was long suspected to exist, but it was thanks to Cassini that its existence could be proven for the first time. "This was a magnificent result, which has been corroborated by several experiments. In general, using the various instruments we can now provide substantially more precise answers to questions about the planets of the outer Solar System," DLR researcher Jaumann summarises.

A team of cartographers and image data specialists around Dr Thomas Roatsch of the DLR Institute for Planetary Research in Berlin-Adlershof, in collaboration with SSI team member Profesor Dr Gerhard Neukum of the Freie Universität Berlin, use the high definition images of the Cassini SSI (Solid-State Imaging) camera system to create new and more precise sets of maps of the icy moons.

The most detailed result of this activity so far has been a global set of maps for the current 'star' among Saturn's moons: Enceladus. "However, next year we will already be able to improve the maps substantially in certain points. Since we will be flying the probe only 23 kilometres above Enceladus's ice fields, we will be able to obtain images with a resolution of just a few metres."" Dr Roatsch clarifies.

Enigmatic Iapetus: two 'faces' and a 20-kilometre high mountain ridge



Hyperion’s unusual surface, dotted with craters

The Saturnians satellites are very strange worlds:

- active volcanoes on Enceladus which renew this moon's surface
- on the same moon, ice surfaces billions of years of age
- on Thetys, a tectonic rift called "Ithaca Chasma", cracked open 100 kilometres wide by tectonic stress in the icy crust, several kilometres deep and 2000 kilometres long
- Dione has chasms of hundreds of metres deep, probably caused by repeated expansion and contraction of this celestial body, whereby separate layers probably slid over each other like pack ice
- a surprising geochemical and mineralogical diversity on the surface of the small moon Phoebe
- Hyperion's very unusually shaped crust, dotted with craters

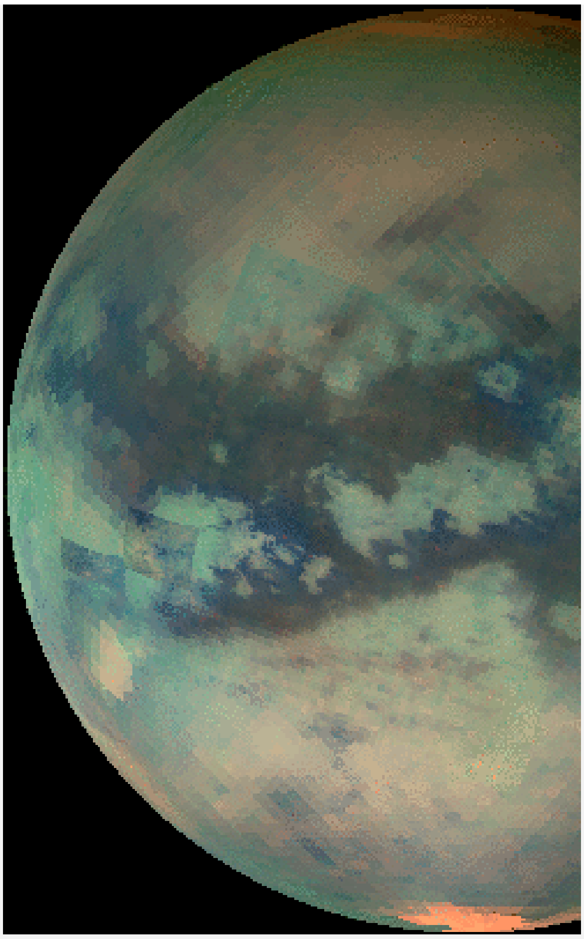
Cassini's close flybys of the icy moons brought to light many surprises, which still await more detailed scientific interpretation.

The bright and dark side of Iapetus

Iapetus, the third largest of Saturn's moons, has presented the scientists with two big riddles at the same time. Firstly, the two halves of this icy moon have developed in completely different ways. The "trailing side", the hemisphere facing the opposite direction of its orbit, as well as the polar areas consist of ice and are as white as snow; on the "leading side", the hemisphere facing the direction of orbit, however, carbon compounds cover the ice, making this side black as tar.

Ever since the Voyager mission it has been suspected that dark material from the neighbouring moon Phoebe has coloured Iapetus' leading side black. Analysis of the image data obtained in December 2004, only recently published by DLR researcher Dr Bernd Giese in the scientific journal Icarus, has shown that, in addition, sublimation processes - the transition from the solid to the gas phase - are also vital to understanding the light-dark structures on Iapetus' surface. The ongoing analysis of image data obtained during the close flyby of Iapetus in September of this year will show if this interpretation is correct. This flyby had been planned in great detail by staff members of the Freie Universität Berlin and DLR.

But there is more: along Iapetus' equator, a mountain ridge can be seen of up to 10 kilometres, and in some places probably up to 20 kilometres in height: a kind of "Super Himalayas" consisting of dust-covered ice. Dr Giese has been working for years already to precisely chart this phenomenon. "Right now, we can mark the shape of this unusual mountain ridge quite well, but we do not know exactly how far it stretches along the equator yet," according to the physicist. "We cannot yet say exactly how the mountain ridge came into being. In any case, it is a very old structure which possibly arose only a few million years after the birth of the moon." If the mountain ridge is just the result of a tectonic event, or if volcanic processes also played a role, is currently still under investigation.



VIMS-Spectrometer image of Titan. Credit: NASA/JPL/UoA.

The European contribution: the spectacular landing on Saturn's moon Titan

The Huygens atmospheric entry probe's solo flight through the nitrogen atmosphere of Titan, the largest of Saturn's moons, on 14 January 2005, and its subsequent landing on the icy surface of the satellite, at a temperature of 160 degrees Celsius below zero, is regarded as a milestone in the 50-year history of space exploration. Huygens was the European Space Agency's (ESA) contribution to this large research project. It was the first touchdown of a probe on the surface of a celestial body in the outer Solar System - and a soft landing at that.

During its descent through Titan's atmosphere, Huygens took photos of the valleys of a river network, and from its landing site it photographed a bizarre landscape of rounded blocks of ice on a frozen methane surface. The Max Planck Institute for Solar System Research (Max-Planck-Institut für Sonnensystemforschung) in Katlenburg-Lindau is prominently involved in this experiment. Saturn's largest satellite is of great interest to this research, most of all because of its dense atmosphere. Due to the low temperatures in the outer Solar System, chemical reactions on Titan proceed much slower than those in the inner Solar System, to which the Earth belongs.

Using Saturn's moon Titan to study the development of the young Earth

Based on the measurements carried out by the Huygens probe during its descent through Titan's atmosphere, the researchers were expecting to find clues on events and changes in Earth's early atmosphere, which originally consisted of carbon dioxide. It was only because of the appearance and development of life on our planet, three or four billion years ago, that Earth's original atmosphere was gradually transformed into a nitrogen-oxygen atmosphere. Many details about this time on Earth, billions of years ago, lie hidden in the past. Studying Titan may be able to shed some light on the darkness of Earth's early history.

"There are now also some clear signs that, at least from time to time, rain falls from Titan's clouds. However, this precipitation does not consist of drops of water, but of methane and ethane," says Professor Jaumann, while explaining the results of numerous observations by the infrared spectrometer VIMS (Visible and Infrared Mapping Spectrometer), a project which he is involved in himself. "On the moon's surface, we see traces of branched valleys through which the liquids flowed down the gradient towards the lowland."


64 Scenes from the Saturnian system – a tribute to Sir Paul McCartney

DLR also participates in the Ultraviolet Imaging Spectrograph (UVIS), which plays an important role in the research into Titan's atmosphere. For the UVIS experiment, hydrogen-deuterium absorption cells were designed and built in close cooperation between DLR, the former Max Planck Institute for Aeronomics (Max-Planck-Institut für Aeronomie) in Katlenburg-Lindau, and the Laboratory of Atmospheric and Space Physics (LASP) in Boulder, Colorado, USA . "We want to use it to study the local interstellar medium in the Saturnian system. Moreover, we also want to determine the deuterium/ hydrogen ratio in the planetary exosphere of Saturn and Titan."

"Made in Germany": The cosmic 'vacuum cleaner' onboard Cassini

Intensive study of Titan would also be the main priority for a second extension of the mission beyond 2010. Over 250 researchers from 17 countries and their teams are involved in the Cassini and Huygens projects. For one thing, Germany participates in the mission through its membership of ESA. Huygens, ESA's main contribution, accounts for about a quarter of the total mission cost of something over two billion dollars. The Italian space agency ASI contributed the antenna. Also, DLR's Space Agency supports the German scientific involvement in the project.


A cosmic vacuum cleaner “made in Germany”

The main German contribution to the experiments on the Cassini orbiter is to provide the Cosmic Dust Analyzer (CDA). The CDA's task is to simultaneously study the electric charge, speed, flight direction, mass and chemical composition of dust particles in the interplanetary space, especially near Jupiter and Saturn. The CDA was developed and prepared for use in the mission at the Max Planck Institute for Nuclear Physics (Max-Planck-Institut für Kernphysik) in Heidelberg under the scientific leadership of Dr Eberhard Grün; the current Principal Investigator is Dr Ralf Srama, also of the same institute.

The mechanical components of this instrument, which include a turntable allowing the device to be aimed at expected concentrations of dust, independently of the spacecraft itself, were developed and produced at the DLR in Berlin-Adlershof under the direction of Dr Franz Lura.

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