The Cassini/Huygens Mission

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A brief description is given of the Cassini/Huygens project involving a Saturn Orbiter and a Titan Atmosphere Probe. This mission, with NASA providing the Cassini Orbiter and ESA the Huygens Atmospheric Probe, will address a wide range of fundamental issues in the origin of the solar system and planetary atmospheres.

1. Introduction

With the close encounter of the Voyager 2 spacecraft with the Neptunian system on August 24, 1989, the era of fast reconnaissance of the outer planets (except for the Pluto-Charon system) via flyby observations will reach an end. The next phase of outer solar system exploration, characterized by long-term orbiter observations, would await the launch in October, 1989, of the Galileo spacecraft towards the Jovian system. The Galileo mission, which is a joint NASA-BMFT project, consists of a two-year orbiter mission plus the delivery of an atmospheric probe to Jupiter. The date of Jupiter Orbit Insertion (JOI) is targeted to be in December 1995. The return of the scientific data from the Jupiter probe and the Galileo Orbiter are expected to increase dramatically our understanding of the atmospheric structure and composition of this giant planet, its magnetospheric system dominated by the SO_2 gas emitted from Io, and the Galilean satellite system.

As a second step to this major effort in the scientific investigation of the origin of the solar system and the origin of the life, the National Administration of Space and Aeronoautics (NASA), the European Space Agency (ESA) and the Bundesministerium für Forschung und Technologie (BMFT) are currently engaged in a program of space missions to a comet and to Saturn and Titan. The first part of the program is the CRAF (Comet Rendezvous and Asteroid Flyby) mission to comet Kopff and asteroid Hamburga. In this joint venture of NASA and BMFT, the BMFT would provide the retropropulsion engine for the spacecraft. The other part of this ambitious program is the Cassini Saturn Orbiter/Huygens Probe mission to Saturn and Titan. In this joint effort between the U.S. and Europe, NASA would provide the Saturn Orbiter and ESA the Huygens atmospheric probe to Titan. Both the CRAF spacecraft and the Cassini Orbiter share common heritage of the Mariner Mark II spacecraft which are being designed at the Jet Propulsion Lab (JPL). After the selection of the Cassini/Huygens mission by the Space Program Committee (SPC) of ESA as the next new space project in Dec. 1988, the approval of the Mariner Mark II program by the US Congress is still pending. There is every reason to believe that a positive decision will be forthcoming.

The present arrangement between ESA and NASA is that the Announcements of Opportunity (AO) should come out in October, 1989. The experimental proposals

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for the Saturn Orbiter would be evaluated by NASA and those for the Huygens Titan Probe by ESA. In the selection process, there would be participation by ESA and NASA representatives on both panels. The final selection of instruments is expected to be made in October, 1990. In the following, the scientific objectives and mission designs for the Cassini/Huygens mission as reported in the Cassini Phase A Study Report (SCI(88)5) will be briefly summarized. This joint ESA-NASA study has been supported by a science team and the engineering staffs from ESTEC, ESOC and JPL over a period of five years.

2. Titan and Saturn

In Galileo's telescopic observations of solar system objects, Saturn appeared as the most perplexing planet because of its variable appearance. A lot of scientific debates had raged centering around Saturn's variable configuration at this starting point of planetary astronomy. It was Huygens in 1665 who found the solution to the problem by suggesting that Saturn was surrounded by a ring system. (His discovery of Titan is now honored by the naming of the Titan atmosphere probe as the Huygens Probe.) The Observations by the Voyager spacecraft showed that the Saturnian ring system actually consists of a myriad of narrow ringlets with widths ranging from a few km to a few tens km. Many of these fine structures, including the twisted F-rings and the narrow rings embedded in the Cassini division, are not yet understood. The ring system as a whole is subject to various dynamical effects such as the gravity waves excited by the neighbouring satellites, the bombardment of interplanetary meteoroids, and the electromagnetic coupling with the planetary magnetosphere. The corresponding time scales for the dispersion of the rings have been estimated to be as short as $10^7 - 10^8$ years. The detailed observations afforded by the Cassini mission should permit definite answers to many of these outstanding questions.

Other unique features of the Saturnian system include the axial symmetry of the planetary magnetosphere, the plasma interaction of the icy satellites and ring particles with the huge magnetosphere, the plasma interactions of Titan's atmosphere and the very complex geological structures of the icy satellites. For example, only when we return to Saturn with the arrival of the Cassini spacecraft would we be able to study the exact cause of the very different albedos on the leading and trailing sides of Iapetus. At the same time, the possibility of re-surfacing of liquid water on Enceladus would be thoroughly investigated by a collection of advanced instruments on the spacecraft with unprecedented spatial resolution.

The Voyager 1 encounter with Titan has produced a most intriguing picture of this gaseous satellite. Its thick atmosphere with a surface pressure of 1.5 bars is composed mainly of nitrogen and methane. The photolysis of the methane gas has led to the escape of dissociated hydrogen gas and the formation of complex organic hydrocarbon molecules and heavy polymers in the atmosphere. The orange colored aerosol particles so formed are distributed in an opaque layer obscuring the satellite surface from direct imaging. A continuous photolysis in this nitrogen-rich atmosphere could lead to the presence of a km-thick ocean made up of CH_4 and C_2H_6 liquids at Titan's surface. The radar instrument and the microwave spectrometer/radiometer experiment onboard the Cassini spacecraft will address the issue of global ocean. During close flybys of Titan, remote sensing instruments such as the far infrared experiment, the ultraviolet spectrometer, and the microwave spectrometer/radiometer experiment will study the atmospheric structure and composition in great detail. The heart of the Titan science, however, lies in the atmospheric descent observations of the Huygens Probe which is to be described below.

3. The Cassini Orbiter Mission Profile

According to trajectory studies, the optimal launch date is in April, 1996 after which a period of 6.8 years of interplanetary cruise and manuevers will follow before Saturn arrival in October 2002. A close flyby of an asteroid (66 Maja is the current favorite) sometimes in 1997 is planned. The Jupiter flyby in 2000 will allow the exploration of a magnetospheric region not accessible to Voyager and Galileo. In addition, the interplanetary cruise phase will provide ample opportunities for study of the heliosphere up to a distance of 10 AU.

Upon Saturn arrival, the spacecraft will make a burn at the first pericone to enable Saturn Orbit Insertion (SOI). During the first inbound trajectory, a close flyby of Titan (up to an altitude of about 1500 km) could be scheduled such that new and important data on the atmospheric structure of Titan can be obtained. A number of uncertainties remaining in our post-Voyager knowledge of Titan's atmosphere (i.e., temperature and wind speeds at high altitude)thus could be eliminated. In this manner, the descent profile of the Hygens Probe may be further optimized.

In the design of the mission, there would be a number of trade-offs to be investigated such that different scientific objectives can be optimized. For example, to be studied would be the opportunity of ring study during the SOI phase at which time the ring system may be observed with the highest resolutions; and the plasma environment in the vicinity of the rings could be surveyed by the particles-and-fields experiments. Also, the satellite and magnetosphere tours might be modified in the course of the mission as the atmospheric environment of Titan has become better known for the purpose of trajectory calculations. As Titan is the only satellite which can provide enough gravitational assistance for shaping the trajectory of the Cassini Orbiter, in the course of the mission there would be about 30 or more close encounters with Titan down to an altitude of about 1000 km. During the nominal mission of four years, the orbit of the spacecraft would be gradually pumped up such that at the end of the mission, the orbital inclination of the spacecraft would reach 80° or higher. These high-inclination orbits are required to investigate the auroral zone and cleft region of the polar ionosphere. These high-latitude regions are believed to be the sites of strong plasma outflows as well as plasma turbulence and wave generations unique to the Saturnian magnetosphere.

At SOI, the spacecraft will be inserted into a highly elongated orbit with a period of around 3 months. At its first inbound leg, the spacecraft will release the Huygens Probe twelve days before the Titan overfly. The Orbiter will be subsequently deflected and delayed in such a way that the spacecraft will reach the closest approach of Titan at around 1500 km and about 3 hours after the atmospheric entry of the Huygens Probe. The main function of the Cassini Orbiter in this phase is to act as a radio-relay station to transmit the data to Earth via NASA's Deep-Space Network (DSN).

4. The Huygens Probe Mission Profile

The initial entry speed of the Probe would be about 6 km/s. Its 3.1 m diameter aerodynamic decelerator will slow down the descent speed to subsonic value at an altitude of < 175 km. The deployment and staging of the parachute system would allow a total descent time of 2-3 hours facilitating scientific measurements by the Probe instruments. At surface impact, the terminal speed would be on the order of a few m s^{-1}. It is thus possible that certain post-impact measurements could still be made before the loss of radio contact with the Orbiter. The design of the Huygens Probe, however, would not guarantee its survival after impact at either solid or liquid surface.

During the atmospheric descent, the instruments on the Huygens Probe will be operating to gather important chemical and physical information pertinent to the structure and composition of Titan's atmosphere. For example, the gas chromatograph/neutral mass spectrometer (GC/MS) will measure the atmospheric composition as a function of altitude and in combination with the aerosol collector and pyrolyser (ACP), will provide chemical analysis of the aerosols. Composition measurements of selected gas species (i.e., $CH_4, CO, CO_2, C_2H_2, C_2N_2, C_3H_4, C_3H_8$, etc) with high precisions would be made by the probe infrared laser spectrometer (PIRLS). The descent imager/infrared spectral radiometer (DI/SR) would allow in-situ measurements of the atmospheric and cloud structure plus imaging of the surface features. Doppler radio tracking of the Probe from the Orbiter should provide ground-truths for zonal wind profile when compared with measurements from the microwave spectrometer/radiometer on the Orbiter. Last but not least, the accelerometers placed in the Huygens Probe would yield very interesting information on the surface properties at impact. In the event of landing on a liquid surface, the possible incorporation of a science package designed to sample physico-chemical nature of the liquid material would give us a first glimpse of the state of the Titan Ocean.

5. Summary

The Cassini/Huygens mission to Saturn and Titan is one of the most ambitious planetary missions ever planned. Its wide scope of scientific investigations covers almost all fields of planetary sciences and space physics. The international cooperation fostered by NASA, ESA and BMFT in the framework of the Mariner Mark II Program certainly will lay the foundation for future research in the areas of the origin of solar systems, the formation of planets and ring systems, the origin and evolution of planetary atmospheres, and pre-biotic chemistry in primordial atmospheres.