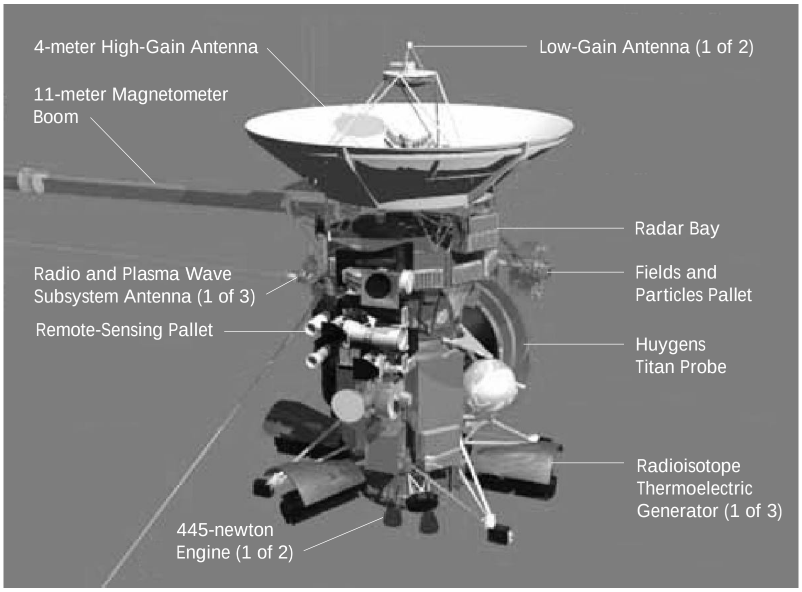
CASSINI SPACECRAFT AND HUYGENS PROBE

JET PROPULSION LABORATORY

The Cassini spacecraft is designed for a daunting task — to leave Earth on a seven-year interplanetary voyage to the giant gas planet Saturn. Once there, Cassini will spend four years exploring the planet, its rings, and its moons. It will also deploy a probe to the moon Titan — a world with an atmosphere sufficient to allow a parachute to land the probe on the surface. These are the challenges facing the Cassini mission, an international cooperative effort of the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and the Italian Space Agency (Agenzia Spaziale Italiana, ASI). The mission is managed for NASA by the Jet Propulsion Laboratory (JPL) of the California Institute of Technology.

The Cassini spacecraft is composed of the orbiter and the Huygens probe. It is the second-largest interplanetary spacecraft ever to be launched, owing to its cargo of multiple science instruments and an enormous quantity of propellant. (The former Soviet Union launched the largest interplanetary vehicles: the Phobos 1 and 2 Mars craft, each weighing 6,220 kilograms, or nearly 7 tons.) The Cassini probe and orbiter together weigh about 5,574 kilograms (6.1 tons), more than 50 percent of which is liquid propellant. The propellant mass alone is more than the mass of the Galileo and Voyager spacecraft combined. Cassini stands more than 6.7 meters (22 feet) high and is more than 4 meters (13.1 feet) wide (not including a deployed boom and antennas).



This illustration shows the main design features of the two-story-tall Cassini spacecraft.

The cone-shaped probe remains dormant during the cruise to Saturn. After arrival at Saturn, the probe will be activated and deployed into the atmosphere of Titan, sending data to the orbiter. The Cassini orbiter will relay the probe data to Earth, and then conduct its own scientific investigation of the Saturn system for nearly four years.

THE CASSINI ORBITER

The design of the orbiter is derived from the special demands of the Cassini mission. Communication, for example, is essential to allow commanding of the spacecraft from Earth and for the return of the scientific data from the orbiter and the probe. This is done by the use of radio systems operating on several different microwave frequencies. The orbiter communicates with controllers on Earth via three separate antennas — a high-gain antenna that is 4 meters (13.1 feet) in diameter, and two low-gain antennas. The rigid high-gain antenna was developed by ASI. Depending on mission phase, data transmission can vary from a low of 5 bits per second up to 249 kilobits per second. The data travel at the speed of light. When the spacecraft is at Saturn, Cassini will be 8.6 to 10.6 astronomical units (AU) from Earth — 1 AU is the mean distance from Earth to the Sun: about 150 million kilometers or 93 million miles. At that distance, it will take from 68 to 84 minutes for radio waves to travel from Earth to the spacecraft or from the spacecraft to Earth.

The orbiter receives electrical power from three radioisotope thermoelectric generators, or RTGs. These produce power by converting heat into electrical energy. Heat is provided by the natural radioactive decay of plutonium dioxide. RTGs have no moving parts and are a very reliable source of energy. Upon the spacecraft's arrival at Saturn, Cassini's three RTGs will provide more than 700 watts of power for engineering and scientific devices.

Propulsion for large changes to the orbiter's trajectory is provided by either of two identical main engines. These powerful engines use nitrogen tetroxide and monomethylhydrazine as the oxidizer and fuel, respectively. Sixteen smaller engines, called thrusters, use hydrazine to control orientation and to make small changes to the spacecraft's flight path.

Cassini was launched October 15, 1997, on a Titan IVB/ Centaur rocket.

Guidance and control for the spacecraft are governed by sensors that recognize reference stars and the Sun, and by onboard computers that determine the spacecraft's position. Using a new type of gyroscope that vibrates rather than spins, the spacecraft can perform turns, twists, and propulsion engine firings while retaining continuous knowledge of its own orientation. The orbiter is stabilized along all three axes and thus does not normally rotate during its long cruise to Saturn.

The Cassini trajectory takes the spacecraft past Venus twice and past Earth once on its trip to Saturn. This poses a challenge of temperature control, because the orbiter is close to the Sun for the first several years of the mission. The high-gain antenna is used as a sunshade to shield the rest of the orbiter and probe. Special paints are also used on the antenna to reflect and radiate much of the Sun's energy. Later in the mission, as the spacecraft approaches Saturn, the sunlight is approximately 1 percent of that received at Earth, and extreme cold becomes a concern. Heat is retained by using a highly efficient insulating blanket that wraps most of the orbiter. The blanket's outer layer is a three-ply membrane composed of a Kapton core with an aluminized inner surface and a metallic outer surface. The translucent Kapton has a yellow color and, when backed by a shiny aluminum layer, appears amber. Additional electrical heaters and 1-watt radioisotope heaters are applied in selected areas. The thermal blankets also provide protection from micrometeoroids that will impact the spacecraft at speeds of 5 to 40 kilometers per second (11,000 to 90,000 miles per hour).

The orbiter requires extensive onboard computing capability because most of the Cassini mission is performed while the orbiter is not in direct communication with ground controllers. Sequences — programs stored on the spacecraft that are detailed computer instructions — direct the activities of the spacecraft. A typical sequence may operate the spacecraft for four weeks without the need for ground controller intervention, but controllers do send at least one command each week to reset the command timer.

The computers must also be designed to withstand the radiation environment of deep space, particularly when the Sun is at peak activity. During solar flares, the effects of which can last for several days, the levels of radiation emitted by the Sun can be 1,000 times higher than normal.

Sophisticated fault-protection software resides in the spacecraft computers to continuously sample and sense the health of the onboard systems. The fault-protection system will automatically take corrective action if it determines that Cassini is at risk due to an onboard failure.

ORBITER SCIENCE EXPERIMENTS

The orbiter carries 12 science instruments. The Radio Science Investigation will search for gravitational waves in the universe and study the atmosphere, rings, and gravity fields of Saturn and its moons by measuring telltale variations in radio waves sent from the spacecraft. The Imaging Science Subsystem will take pictures in visible, near-ultraviolet, and near-infrared light. The Cassini Radar will map Titan's surface using radar and passive microwave imagery to pierce the veil of haze, and will measure heights of surface features. The Ion and Neutral Mass Spectrometer will examine neutral and charged particles near Titan, Saturn's rings, and the icy satellites to learn more about the extended atmospheres and ionospheres of these bodies.

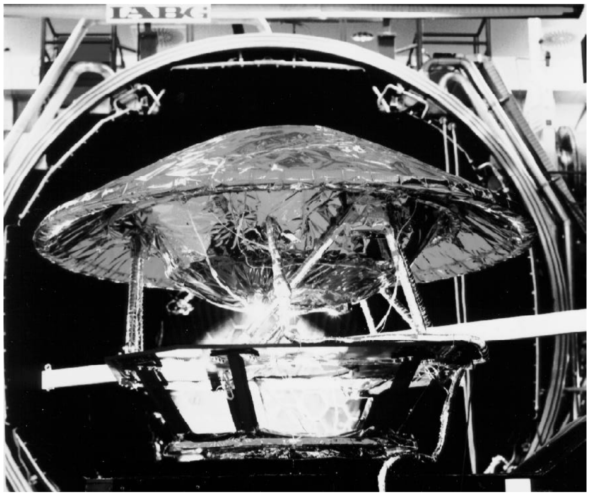
The Visible and Infrared Mapping Spectrometer will identify the chemical composition of the surfaces, the atmospheres, and rings of Saturn and its moons by measuring the colors of the visible light and the infrared energy they reflect. The Composite Infrared Spectrometer will measure infrared energy from the surfaces, atmospheres, and rings of Saturn and its moons to study their temperatures and compositions. The Cosmic Dust Analyzer will study ice and dust grains in and near the Saturn system. Radio and Plasma Wave Science will investigate plasma waves generated by ionized gases flowing out from the Sun or around Saturn, natural emissions of radio energy, and dust.

The Cassini Plasma Spectrometer will explore plasma — electrically charged (ionized) gas — within and near Saturn's magnetic field. The Ultraviolet Imaging Spectrograph will measure ultraviolet energy from atmospheres, satellite surfaces, and rings to study structure, chemistry, and composition. The Magnetospheric Imaging Instrument will image Saturn's magnetic environment and measure interactions between the magnetosphere and the solar wind, a flow of ionized gases from the Sun. The Dual Technique Magnetometer will study Saturn's magnetic field and its interactions with the solar wind, the rings, and the moons of Saturn.

THE HUYGENS TITAN PROBE

The probe is provided by ESA. Except for semiannual health checks, the probe will remain dormant throughout the 6.7-year interplanetary cruise. Prior to the probe's separation from the orbiter, a final health check will be performed, and the orbiter will position the probe on a trajectory to intercept Titan. Cassini will set Huygens' onboard clock to the precise time necessary to "wake up" the probe systems 15 minutes prior to encountering Titan's atmosphere. For 21 days, Huygens will simply coast to Titan with no systems active except for its wake-up clock.

Huygens' main mission phase will occur during its parachute descent through Titan's atmosphere. The batteries and all other resources are sized for a Huygens mission duration of three hours, which includes the possibility of up to half an hour or more on Titan's surface. The probe's radio link will be activated early in the descent phase and the data will be relayed to the orbiter for onboard storage and subsequent transmission to Earth. At the end of this three-hour-long communication window, the Cassini orbiter will fly out of radio contact with Huygens — and shortly thereafter its high-gain antenna will be turned away from Titan and toward Earth.


The 2.7-meter-diameter Huygens probe undergoing tests in Germany.

HUYGENS PROBE DESIGN FEATURES

The probe is ESA's first planetary atmospheric entry mission, and some of the technologies required are very different from those needed for more traditional missions. Special systems such as the thermal-protection system and high-speed parachutes have been developed specifically for entry into Titan's atmosphere.

The thermal protection system (TPS) is designed to protect the probe from the extreme heat generated by its rush into Titan's atmosphere at about 6 kilometers per second (13,400 miles per hour). At such a high speed, surface temperatures as hot as 1,700 degrees Celsius (3,000 degrees Fahrenheit) could be reached in less than a minute. The front of the heat shield is covered by tiles similar to those used to protect the space shuttle, made from a material known as AQ60 — a low-density "mat" of silica fibers. The tile thickness on the front shield is calculated to ensure that the structure will not exceed 150 degrees Celsius (302 degrees Fahrenheit), which is below the melting temperature of lead. The rear side of the probe will reach much lower temperatures during atmospheric entry; thus, a spray-on layer of "Prosial" (a silicon-based foam) was used. The total mass of the thermal-protection system is more than 100 kilograms (220 pounds) — almost one-third of the entire probe mass.

The Cassini
spacecraft
in the test
chamber
at JPL.

The parachute system on board Huygens is designed to work in concert with the TPS to ensure that the sensitive instrumentation on the central module will survive atmospheric entry. The main parachute is almost 9 meters (28 feet) in diameter, and will deploy at an altitude of 170 kilometers (105 miles). Thirty seconds after parachute deployment, the probe's heat shield system (including the supporting structure) will be jettisoned, significantly lightening the payload. Finally, a smaller drogue chute will take over for the remainder of Huygens' descent.

During the probe's descent, data acquired will be transmitted to the orbiter in real time via an S-band radio link. The data rate required will be 8 kilobits per second for each of two channels. On the orbiter, the data will be received via the high-gain antenna pointed toward the probe's position.

HUYGENS SCIENTIFIC PAYLOAD

Six scientific instruments comprise the Huygens payload. During the descent, these instruments will have both timing and radar attitude data available for their use in sequencing. The Gas Chromatograph and Mass Spectrometer is a versatile gas chemical analyzer designed to identify and quantify various atmospheric constituents. It is equipped with gas samplers that will be filled at high altitude for analysis later in the descent. The Aerosol Collector and Pyrolyser will collect aerosols for chemical composition analysis. After extension of the sampling device, a pump will draw the atmosphere through filters that capture aerosols. Each sampling device can collect about 30 micrograms of material, which will be vaporized and then passed along to the Gas Chromatograph and Mass Spectrometer for chemical analysis.

The Descent Imager and Spectral Radiometer can take images and make spectral measurements using sensors covering a wide spectral range. A few hundred meters before impact, the instrument will switch on its lamp in order to acquire spectra of surface material. The Huygens Atmospheric Structure Instrument consists of sensors for measuring the physical and electrical properties of the atmosphere.

The Doppler Wind Experiment uses radio signals to deduce wind speeds. Winds in Titan's atmosphere will cause the probe to drift, inducing a measurable Doppler shift in the carrier signal. The swinging motion of the probe beneath its parachute and other radio-signal-perturbing effects, such as atmospheric attenuation, may also be detectable from the signal.

The Surface Science Package is a suite of sensors to determine the physical properties of the surface at the landing site and to provide unique information about its composition. The package includes an accelerometer to measure the impact deceleration and other sensors to measure the index of refraction, temperature, thermal conductivity, heat capacity, speed of sound, and dielectric constant of the (possibly liquid) material at the landing site.

FOR MORE INFORMATION

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VISIT THE CASSINI WEB SITE

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