

Spectroscopy on a Primordial World – Titan

Barry E. DiGregorio

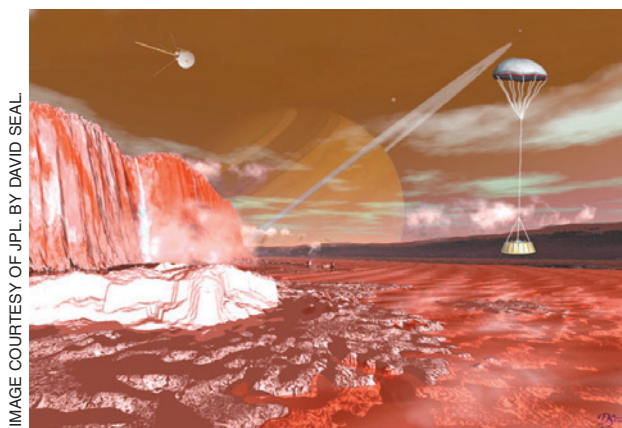


IMAGE COURTESY OF JPL. BY DAVID SEAL

Artist's rendering shows Titan's surface with Saturn in the background. The Cassini spacecraft flies over the surface with its high-gain antenna pointed at the Huygens probe as it reaches the surface.

Gas chromatography–mass spectrometry will help to characterize the atmosphere and surface of Titan, Saturn's largest moon.

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Ever since Dutch astronomer Christiaan Huygens discovered Titan, Saturn's largest moon, in 1655, astronomers have sought to understand the mysterious nature of this world that is just smaller than the size of Mars but larger than the planet Mercury. Easily visible with a small, backyard, 3-in. telescope as a mere star-like point of light, Titan would not be viewed at close range until NASA's Voyager 1 spacecraft flew past the Saturnian system in 1980. From a distance of 2.3 million km, Voyager's cameras revealed a hazy orange world cloaked in a cold (94 K), thick atmosphere composed of nitrogen and methane that is 1.5 times the density of Earth's, and which prevented any details on the surface from being seen.

Post-Voyager scientific results indicate that photochemical reactions in Titan's atmosphere might drive climate change and produce an abundance of complex organic molecules that rain down on the surface. Based on photochemical models of the reactions that might occur when Titan's dense atmosphere is bombarded by solar ultraviolet,

cosmic rays, and energetic electrons from Saturn's magnetosphere, planetary scientists have speculated that ethane clouds form and then condense and precipitate onto the surface, possibly forming large seas of liquid ethane. This strange planetary environment is what some scientists think the prebiotic Earth was like 4.3 billion years ago. Only three other objects in the solar system are thought to hold evi-

dence of such complex organic chemical reactions that may have continued up to the threshold of life — Mars, Jupiter's moon Europa, and Titan.

In a bold attempt to characterize the atmosphere and surface of Titan, the European Space Agency (ESA) has placed its Huygens probe (built by an industrial consortium led by Aerospatiale [Cannes, France]) aboard NASA's Cassini orbiter. Launched in October 1997, Cassini will carry the attached Huygens probe until it arrives in 2004 at Saturn. There, the probe will be released into Titan's atmosphere to conduct a scientific survey all the way down to the surface in a dramatic descent that will last more than two hours. Instruments onboard the 1.3-m diameter, 318-kg Huygens probe include a descent imager, spectral radiometer, Doppler wind experiment, atmospheric structure instrument, gas chromatography–mass spectrometry (GC-MS) system, and surface science package. The Cassini orbiter will collect data on Saturn's rings, 18 moons, and atmosphere, while also serving as a data link for the Huygens probe.

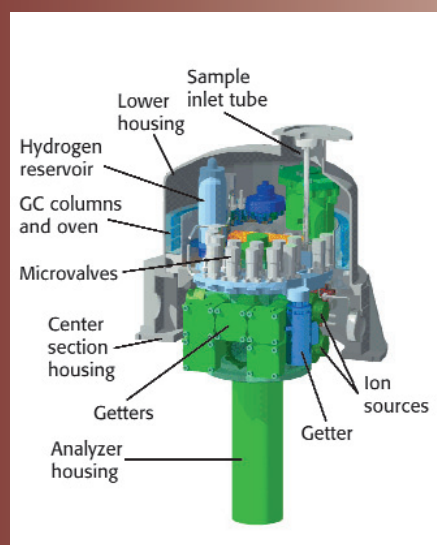
At the heart of Huygens' suite of scientific instruments is a specially designed 17.3-kg GC-MS system built by the Atmospheric Instrument Branch of NASA's Goddard Flight Center in Greenbelt, Maryland. Main elements include a mass spectrometer with five ion sources; a mass analyzer, an ion detector, and a gas sampling system consisting of three subsystems. Power consumption for the instrument is only 41 W with an onboard computer having a data transfer rate of 1700 bps.

With a dynamic range of 10^8 , the Huygens GC-MS system can identify atmospheric constituents over a range of

2–146 amu down to the 10–100 ppb level. The GC-MS system is connected to an interface with the probe's aerosol collector and pyrolyzer (ACP) built by Service d'Aeronomie du Centre National de la Recherche Scientifique (Verrieres-le-Buisson, France).

At an altitude of 170 km in Titan's atmosphere, the ACP will deploy a filter to collect aerosol samples that will be processed using three different methods — evaporation, pyrolysis, and gas product transfer — which are then sent to the mass spectrometer for analysis. A total of four samples will be taken. Both the gas chromatograph and ACP are self-contained units that share the mass spectrometer. Once on the surface of Titan, whether solid matter or an ocean of ethane, the GC-MS system will continue to operate and take measurements.

Another key instrument on Huygens is the surface science package (SSP) built by the Planetary and Space Sciences Research Institute at Open University (Milton Keynes, Buckinghamshire, UK). It will conduct a detailed analysis of the landing site environment. The SSP has a nine-instrument sensor subsystem designed to determine whether the surface of Titan is a liquid or solid by being placed in direct contact with it. A tube-like vent at the bottom of the probe leading to the sensors will



Three-dimensional cutaway view of the GC-MS system shows the complex flow system.

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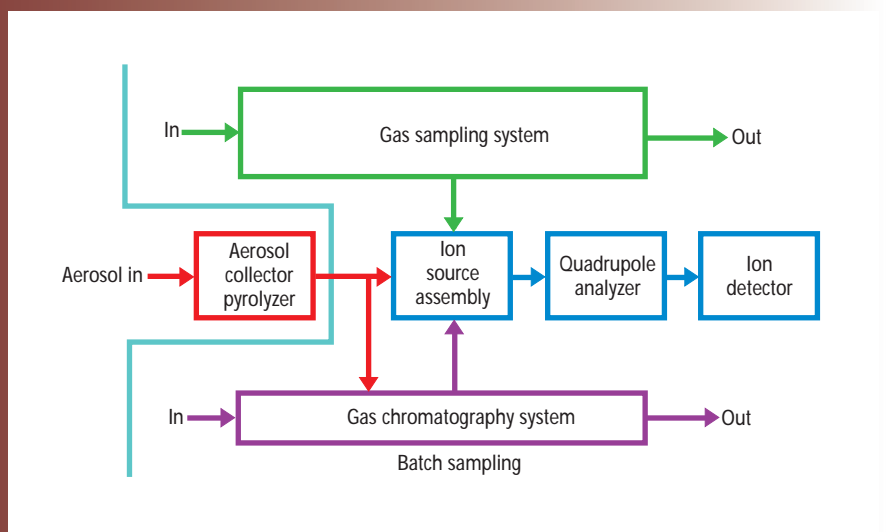
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The upper half of the GC-MS system seen in this picture includes the sampling system and the ion sources, and the lower half covers the electronics system. The gas inlet port is at the very top, at the dome of the housing.

make surface material available to the appropriate sensor. These sensors include a thermal properties sensor to measure the temperature of lower atmosphere and ocean that might exist; an acoustic properties sensor to measure the velocity of sound; a fluid permittivity sensor for detecting any polar molecules in a Titan ocean; a fluid density sensor that employs an Archimedes buoyancy detector for measuring the density of any Titan ocean; and a refractive index sensor for providing information about the illumination on Titan's surface.

Hailed as the last of the grand spacecraft missions, Cassini/Huygens — at a cost of more than \$1 billion — promises to be one of the most spectacular in the history of planetary science. ■

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A block diagram of the GC-MS sampling system.