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Significant Science at Saturn from an Atmospheric Entry Probe Mission

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Abstract

A single planet cannot be understood in isolation. Comparative studies of the atmospheres of the gas and ice giant planets are needed to understand the origin and evolution of the solar system and the giant planets, the formation of giant planet atmospheres, and to provide a valuable link to emerging studies of extrasolar planets. Material from the epoch of solar system formation can be found in the giant planets' deep atmospheres and interiors. Some of these materials are expected to be unprocessed and thus would reflect the protosolar nebula's composition at the time and location of each planet's formation. Other materials will have been extensively processed, reflecting evolutionary processes in the planet.

Beginning in the 1970's with *Pioneer* and *Voyager* flybys, space flight missions began building the data sets needed for these comparisons. The *Galileo* orbiter and probe mission provided both remote sensing and *in situ* studies of Jupiter. A comparable understanding of Saturn and the ice giants Uranus and Neptune would provide an important comparative planetology context for the *Galileo* Jupiter results. The *Cassini* orbiter continues to yield a wealth of discoveries about Saturn's atmosphere from its remote sensing measurements. A Saturn entry probe mission, to complement the *Galileo Probe* investigations at Jupiter, would complete a solid basis for improved understanding of both Jupiter and Saturn, and an important stepping stone to understanding the ice giant planets Uranus and Neptune and the formation and evolution of the solar system.

The recently released recommendations of the United States National Research Council's "2012 Planetary Science Decadal Survey" (PSDS) support the high priority of a Saturn entry probe mission, adding it to the list of recommended science objectives for NASA's New Frontiers Program. The PSDS Giant Planets Panel recognized two levels of science objectives: Tier 1, the highest-priority objectives, ones that any New Frontiers implementation must achieve; and Tier 2, objectives whose priorities are high but are somewhat lower than the Tier 1 objectives. Tier 1 objectives focus on Saturn's composition and thermal structure. Specified compositional measurements include the abundances of the noble gases He, Ne, Ar, Kr, Xe, and their isotopes, and measurement of key isotopic ratios of H, C, N, and O. Structure measurements are a vertical profile of temperature, pressure, and mass density at the probe entry location. The Panel specified several Tier 2 objectives that will be listed in the poster. Examples include determination of the vertical profile of zonal winds at the probe entry location, and detection and measurement of disequilibrium species such as CO, PH_3, AsH_3, and GeH_4 to provide evidence for deeper internal processes. Payload options for the Tier 1 objectives include composition-measuring instruments such as a neutral mass spectrometer and a tunable laser spectrometer, and an atmospheric structure package consisting of multiple thermometers, barometers, and accelerometers.

The Giant Planets Panel also specified that the probe should make Tier 1 measurements down to the 5-10 bar level. Carbon in the reduced form (CH_4) does not condense at Saturn and thus is expected to be well mixed throughout the atmosphere. Sulfur is expected to be sequestered in and below an ammonium hydrosulfide (NH_4SH) cloud at 3-5 bars. Most noble gases are expected to be well mixed in the troposphere, and the key isotopic ratios should be representative of bulk values below the NH_4SH cloud.

Therefore the abundances of the noble gases, isotopes, carbon, and possibly sulfur, as well as vertical gradients of the reduced forms of oxygen and nitrogen below the ammonium hydrosulfide cloud, should be measured by entry probes penetrating to pressures of 5-10 bars. Among the noble gases the exception is neon, which might be depleted by solution in an interior helium-neon rain.

Leveraging the *Cassini-Huygens* mission's highly successful international collaborations, Tier 2 science objectives offer opportunities for significant enhancement of a Saturn probe mission's science return, as well as opportunities for international collaboration. Mission resource requirements for instrumentation and data return of the various Tier 2 objectives vary considerably. To enhance the competitiveness of a NASA New Frontiers mission concept a prospective Principal Investigator could use Tier 2 objectives to customize the mission for the proper balance of science return, science team composition, resource needs, and procured or contributed instruments. Contributed instruments could be a significant factor in such a mission, since they can result a more capable payload and a larger science team with broader expertise, and thus significantly enhanced science return.

This paper will discuss the recommendations of the PSDS regarding a Saturn probe mission for the NASA New Frontiers program, and the planetary and solar system science to be achieved.