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Science from Shallow Saturn Entry Probes

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Abstract

Data from atmospheric entry probe missions at the giant planets could uniquely discriminate between competing theories of solar system formation and the origin and evolution of the giant planets and their atmospheres, providing for valuable comparative studies of giant planets as well as providing a laboratory for studying the atmospheric chemistries, dynamics, and interiors of all the planets including Earth. The giant planets also represent a valuable link to extrasolar planetary systems. For these reasons, a Saturn Probe mission with a shallow probe is ranked by the recent U.S. Planetary Science Decadal Survey as a high priority for a New Frontiers class mission. Atmospheric constituents needed to constrain theories of solar system formation and the origin and evolution of the giant planets could be accessed and sampled by shallow entry probes. Many important constituents are either spectrally inactive or are beneath an atmospheric overburden that is optically thick at useful wavelengths and are therefore not remotely accessible by flyby or orbiting spacecraft. A small, scientifically focused shallow entry probe mission could make critical abundance measurements of key constituents, and could measure profiles of atmospheric structure and dynamics at a vertical resolution that is significantly higher than could be achieved by remote sensing techniques.

The Galileo mission began the detailed study of the solar system's two gas giants by dropping an entry probe into the atmosphere of Jupiter and deploying an orbiter around Jupiter. In 2016-2017 the Juno mission will make measurements of Jupiter's deep oxygen abundance, and gravitational and magnetic fields. In the same epoch, the Cassini orbiter is planned to pursue a set of Juno-like orbits to make comparable gravitational and magnetic field measurements of Saturn. A Saturn atmospheric entry probe would complete the quartet of missions needed for a comparative study of the two gas giants, leading to improved models of solar system formation. A highly focused entry probe mission at Saturn carrying a minimal science payload could address unique and critical science while fitting within existing program budget caps. Fundamental measurements include abundances of the noble gases He, Ne, Ar, Kr, and Xe and, abundances of key isotopic ratios 4He/3He, D/H, 15N/14N, 18O/16O, and 13C/12C. Detection of disequilibrium species CO, PH3, AsH3, and GeH4 is diagnostic of deeper internal processes and dynamics of the atmosphere along the probe descent. Abundances of these key constituents, as well as carbon which does not condense at Saturn, sulfur which is expected to be well-mixed below the 4 to 5-bar ammonium hydrosulfide (NH4SH) cloud, and gradients of nitrogen below the NH4SH cloud and oxygen in the upper layers of the H2O and H2O-NH4 solution cloud, could be measured by an entry probe descending through 10 bars.

In concert with the results from Galileo, Cassini, and Juno, a shallow Saturn probe capable of measuring abundances of key constituents not accessible by a remote sensing mission would provide critical measurements enabling a comparison of composition and dynamical processes on the giant planets while also providing an improved context for understanding exoplanets.

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