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Science at Saturn with an Atmospheric Entry Probe

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Saturn is a target of high priority for future entry probe exploration. A fundamental goal of solar system exploration is to understand the origin of the solar system, the initial stages, conditions, and processes by which the solar system formed, how the formation process was initiated, and the nature of the interstellar seed material from which the solar system was born. Key to understanding solar system formation and subsequent dynamical and chemical evolution is the origin and evolution of the giant planets and their atmospheres. Several theories have been put forward to explain the process of solar system formation, and the origin and evolution of the giant planets and their atmospheres, each with distinct and quantifiable predictions of the abundances of noble gases He, Ne, Ar, Kr, and Xe, and abundances of key isotopic ratios $^{4}He/^{3}He$, D/H, $^{15}N/^{14}N$, $^{18}O/^{16}O$, and $^{13}C/^{12}C$. Of particular importance is helium, needed to understand the formation history and thermal evolution of Saturn, and water since it is thought that the heavy elements were delivered to Saturn by water-bearing planetesimals. Detection of certain disequilibrium species, diagnostic of deeper internal processes and dynamics of the atmosphere, would also help discriminate between competing theories. Measurements of the abundance profiles of many of these key constituents into the deeper well-mixed atmosphere must be complemented by measurements of the profiles of atmospheric structure and dynamics at high vertical resolution and can only be achieved with *in situ* exploration.

In addition, the atmospheres of the giant planets serve as laboratories to better understand the atmospheric chemistries, dynamics, processes, and climates on all planets including Earth, and offer a context and ground truth for exoplanets and exoplanetary systems. Giant planets have long been thought to play a critical role in the development of potentially habitable planetary systems.

A Saturn entry probe and remote imaging mission would make measurements that address many key and currently unresolved questions through delivery of an atmospheric entry probe into Saturn's atmosphere with remote imaging from the carrier / telecomm relay spacecraft. An *in situ* probe probe would provide direct measurement of composition and atmospheric structure including pressure, temperature, and dynamics along the probe descent path, providing science that cannot be achieved by remote sensing measurements from a flyby or orbiting spacecraft, as well as providing ground truth for tropospheric measurements from carrier remote sensing.

In the context of giant planet science provided by the Galileo, Juno, and Cassini missions to Jupiter and Saturn, a relatively shallow Saturn probe capable of measuring abundances and isotopic ratios of key atmospheric constituents, and atmospheric structure including pressures, temperatures, dynamics, and cloud locations and properties not accessible by remote sensing would serve to test competing theories of solar system and giant planet origin, and chemical and dynamical evolution.

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