MODEL PAYLOAD FOR ICE GIANT ENTRY PROBE MISSIONS.

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Introduction: The ice giants Uranus and Neptune are the least understood class of planets in our solar system. Since planets similar in size to Uranus and Neptune are frequent among exoplanets, it appears that ice giant-sized planets are a common outcome of planet formation processes. Uranus and Neptune are fundamentally different from the better-explored gas giants Jupiter and Saturn, comprising a dilute outer envelope of hydrogen and helium, a deep interior comprising ~70% heavier elements, and presumably a small rocky core. Our knowledge of ice giant composition, atmospheric processes, and interior and atmospheric structure is limited to the single Voyager 2 flybys in 1986 and 1989, respectively, and is complemented by remote sensing from Earth and Earth-based space telescopes. As a result, the physical and atmospheric properties of the ice giants remain poorly constrained and their roles in the evolution of the Solar System are not well understood. Exploration of ice giant systems is therefore a high-priority science objective as these systems, including magnetospheres, satellites, rings, atmosphere, and interiors, challenge our understanding of planetary formation and evolution.

To afford improved understanding of the composition, structure, and processes of ice giant atmospheres, an atmospheric entry probe targeting the 10-bar level, approximately 5 scale heights beneath the tropopause, would yield insight into the formation history of the ice giants and, in a broader extent, that of the Solar System, as well as the processes governing the structure and composition of and processes within planetary atmospheres.

Probes descending under parachutes make essential measurements of atmospheres beyond the reach of remote sensing. In particular, in situ measurements by descent probes can measure the composition of the atmosphere including abundances of noble gases and key isotopes, and the thermal profile and dynamical structure of the atmosphere beneath the cloud tops. Measurements are defined as Tier 1 representing Threshold Science required to justify the entry probe mission, and Tier 2 representing measurements that significantly complement and enhance the Threshold measurements but are not of themselves enough to justify an entry probe.

Tier 1 measurements include the abundances of noble gases and helium, the ratio relative to solar of key isotopic ratios including D/H, $^{3}He/^{4}He$, $^{14}N/^{15}N$, $^{12}C/^{13}C$, $^{16}O/^{18}O$, and the thermal structure of the atmosphere. To make Tier 1 measurements, instrumentation includes mass spectrometers and a helium abundance detector, and an atmospheric structure instrument to measure the altitude profile of pressure and temperature. An acoustic properties instrument to measure the speed of sound in the atmosphere can provide the ratio of the ortho- and para- forms of hydrogen.

Tier 2 science comprises lower priority atmospheric structure and processes such as the altitude profile of atmospheric dynamics including zonal winds and waves, the location, density, composition, and structure of clouds and size distribution of liquid and solid cloud aerosols, and the profile of net radiative transfer of upwelling thermal infrared and downwelling visible fluxes in the atmosphere. Abundance measurements of disequilibrium species such as PH_3, CO, AsH_3, GeH_4, and SiH_4 due to atmospheric upwelling would provide insight into atmospheric composition and chemistries at much deeper levels, possibly helping to constrain the bulk oxygen, nitrogen, and sulfur abundances. Potential Tier 2 instrumentation includes a Nephelometer, Net Flux Radiometer, Accelerometers (likely an element of the ASI) from which the upper atmospheric density profile can be retrieved, and an ultrastable oscillator as part of the telecommunications system to provide wind measurements using Doppler techniques.

This paper presents a summary and prioritization of key investigations and a model payload for achieving the key objectives for in situ ice giant science.

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