Small Next-Generation Atmospheric Probe (SNAP) For Ice Giant Missions.

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Introduction: We present the Small Next-generation Atmospheric Probe (SNAP) concept for future Ice Giant missions. The primary scientific objectives of SNAP are to perform in-situ measurements of atmospheric composition, stratification, and dynamics as a function of altitude at the entry location. The 30-kg SNAP design could either enable a second probe that expores a separate location to determine atmospheric spatial variabilities, or serve as the only probe in a cost-constrained mission.

Concept Study Goals: A major objective of the SNAP design study is to examine the feasibility of a small 30-kg atmospheric probe that could be accommodated in a wide range of mission scenarios. A traditional design like the Galileo Probe weighs approximately 300 kg due to the need for a mass spectrometer that typically weighs at least 10 kg while a typical instrument mass fraction of a probe is 10%. A mass spectrometer is required to measure noble gas abundances and isotopic ratios, which are high-priority scientific objectives but these quantities are not expected to vary spatially. Thus, we present SNAP as a low-mass probe option to (A) enable a second probe to determine spatial variabilities in a mission that has a separate probe carrying a mass spectrometer; and (B) add a probe to a cost-constrained mission that otherwise cannot afford a probe.

Scientific Objectives: SNAP's scientific objectives are to determine: (1) Vertical distribution of cloud-forming molecules (CH_4, H_2S, and NH_3); (2) Thermal stratification; and (3) Wind speed as a function of depth. Through these objectives, SNAP will resolve a major controversy in the atmospheric vertical structure; while models of Uranus predict that CH_4 and H_2S ice clouds condense between 1 and 5 bars, remote-sensing retrievals do not agree on the vertical structure of the observed clouds. SNAP measurements will conclusively resolve this important open question.

In addition, SNAP will enable a major new objective to determine the spatial variabilities when combined with another probe that explores a separate location. Entry locations for multiple probes can be selected to examine different climatic zones, hemispheric seasonal differences, localized meteorological features, or temporally transient phenomena.

Uranus represents an especially interesting target to study seasonal variability because the planet's rotation axis is tilted ~98º to the orbital plane, imposing a strong summer-winter hemispheric dichotomy. If a Uranus mission launches around 2030, the spacecraft should arrive at Uranus around 2040; by then, the north pole will have been basking in continuous sunshine for over 30 years since the equinox of 2007, while the south pole will have been in winter darkness for the same period. Deploying an atmospheric probe into each of the hemispheres will reveal seasonal effects on the clouds, thermal stratification, and winds.

Instruments: The baseline instrument payload comprises an Atmospheric Structure Instrument (ASI) to measure entry and descent accelerations and the altitude profile of temperature and pressure, a carbon nanotube-based NanoChem atmospheric composition sensor, and UltraStable Oscillators (USO) on both the probe and the Carrier spacecraft to enable retrieval of atmospheric dynamics using Doppler Wind techniques. SNAP's atmospheric composition measurements are enabled by the adaptation of a low-mass, low-power atmospheric composition sensor, NanoChem. A major advantage of solid-state sensors like NanoChem is that they do not require a massive vacuum pump unlike a mass spectrometer. Ortho-Para Hydrogen Ratio could be measured with a relatively low-mass package while adding add significant scientific value, and should be considered for future designs.

Mission Architecture: Our point-design adds SNAP to a notional Uranus mission presented in the 2017 Ice Giant Flagship Science Definition Team study. In our design, the orbiter will deliver both the primary probe and SNAP to Uranus. The orbiter receives the data from the probes before relaying to Earth.

Mission Cost: Addition of SNAP to a carrier mission is expected to cost $80M including $18M reserve, or 4% of the $2.0B estimate for a Uranus mission.

Technology Needs: Two enabling technologies of a 30-kg SNAP design are (1) A solid-state atmospheric composition sensor such as NanoChem (under development at NASA Ames) that can operate under atmospheric pressure; (2) Low-density Thermal Protection System material such as the Heat-shield for Extreme Entry Environment (HEEET). Mission performance is enhanced by Li-CFx batteries' high energy density by lowering the battery mass without sacrificing capacity.

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