Small Next-generation Atmospheric Probe (SNAP) for In-Situ Atmospheric Exploration of Ice Giant Planets

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Abstract

We present a concept for a small atmospheric probe that could be flexibly added to future missions to a giant planet, which we call the Small Next-generation Atmospheric Probe (SNAP). SNAP's main scientific objectives are to determine the vertical distribution of clouds and cloud-forming chemical species, thermal stratification, and wind speed as a function of depth. As a case study, we present the advantages, cost and risk of adding SNAP to the future Uranus Orbiter and Probe flagship mission; in combination with the mission's main probe, SNAP would perform atmospheric in-situ measurements at a second location, and thus enable and enhance the scientific objectives recommended by the 2013 Planetary Science Decadal Survey and the 2014 NASA Science Plan to determine atmospheric spatial variabilities.
Our study demonstrates that the science objectives can be achieved with a 30-kg entry probe _˜0.5m in diameter (less than half the size of the Galileo probe) that reaches 5-bar pressure-altitude and returns data to Earth via the carrier spacecraft. As the baseline instruments, the probe will carry a carbon nanotube-based NanoChem atmospheric composition sensor, an Atmospheric Structure Instrument (ASI) that measures the temperature, pressure and acceleration, and an Ultra-Stable Oscillator (USO) to conduct a Doppler Wind Experiment (DWE). We also catalog promising technologies currently under development that will strengthen small atmospheric entry probe missions in the future.

By offering a small atmospheric probe as an option for future missions, SNAP will enable multiple mission architectures for giant planet missions such as:

- Adding SNAP as a second probe to a flagship mission with probe to Uranus or Neptune.
- Adding SNAP as a second probe to the Saturn Probe New Frontiers mission.

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- Deploying SNAP at Saturn during a gravity-assist flyby en route to Uranus or Neptune.

In particular, we emphasize that SNAP will enable future multi-probe missions to Uranus, Neptune and Saturn. Planetary Science Decadal Surveys have expressed desires for multi-probe missions; the 2003 survey advocated for a Jupiter Multi-Probe mission; and the 2013 survey emphasized that a second probe that takes measurement at a separate location can significantly enhance the scientific value of the mission by providing data on atmospheric variability. In addition, multi-probe missions enhance the scientific value of remote-sensing observation as well as mitigates the risk of sampling an unrepresentative site. In 1996, the Galileo probe measured an unexpectedly low concentration of cloud particles as well as cloud-forming molecules. Due to orbital dynamics constraints, the probe was directed at a latitude that was known to harbor transient patches of cloud-free regions called the 5-micron hotspots; remote-sensing observation revealed that the probe indeed entered one of the hotspots. As a result, the volatile (especially water) abundances at Jupiter remain uncertain to date. The Galileo Probe highlighted the importance of measuring spatial variation, and influenced the 2003 Planetary Decadal Survey to recommend a Jupiter Multi-Probe mission to mitigate such risks.

The SNAP concept study proves that a dual-probe mission as part of a future flagship mission to Uranus or Neptune is highly desirable and feasible. Multi-probe missions have not been considered because their costs are perceived to be prohibitive. We advocate the SNAP concept as a path toward giant-planet multi-probe missions. A dual-probe mission to Uranus is especially desirable because of its extreme seasonal effect caused by the rotation axis tilted by 98 degrees with respect to its orbital plane. In-situ measurements of any north-south interhemispheric seasonal differences will reveal seasonal variations in the thermal stratification, and leads to an improved understanding of the planet's energy balance, which is of especial interest for Uranus.