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Science investigation options with a NASA New Frontiers Program Saturn entry probe mission

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1. Introduction

In 2011 the Space Studies Board of the US National Research Council released its report, "Vision and Voyages for Planetary Science in the Decade 2013-2022" [1] (PSDS). This document is intended to be the guiding document for NASA's planetary science and space flight mission priorities for that decade. The PSDS treats three classes of flight missions: small, medium, and large. Small missions are ones that could be flown within the resource constraints of NASA's Discovery Program, a program of PI-led, competed missions, including a US $500 million (FY 2015) recommended cost cap, excluding the launch vehicle. The PSDS makes no specific recommendations for science objectives or destinations for small missions. Medium missions could be flown under NASA's New Frontiers Program, also a program of PI-led, competed missions, with a recommended cost cap of US $1 billion excluding the launch vehicle. Both of these competed mission programs have been highly successful, with multiple spacecraft currently in flight and more either under development or in the final steps of competition. Large missions, generally called flagship missions, would have total mission costs exceeding US $1 billion and would be directed by NASA, not PI-led.

Unlike Small class missions, the PSDS recommends specific science objectives for Medium class missions. Four Medium class mission concepts and their science objectives carry over from the previous PSDS [2]:

- Comet Surface Sample Return
- Lunar South-Pole Aitken Basin Sample Return
- Trojan Tour and Rendezvous
- Venus In Situ Explorer

The current PSDS adds a fifth mission concept to the list for the next New Frontiers Program AO ("NF-4"), currently anticipated in 2016: a Saturn probe mission. This mission would deliver an atmospheric entry probe into Saturn's atmosphere to make composition and atmospheric structure measurements critical to understanding the materials, processes, and time scales of Saturn's formation, and by comparison to Jupiter and the ice giants, understanding these for the outer solar system as a whole.

2. Saturn probe science objectives

The PSDS Giant Planets chapter lists two "Higher-Priority" and five "Lower-Priority" science objectives. Higher-priority objectives (HPOs) are:

- Determine the noble gas abundances and isotopic ratios of hydrogen, carbon, nitrogen, and oxygen in Saturn's atmosphere
- Determine the atmospheric structure at the probe descent location acceleration [Note: the authors believe the word "acceleration" is a typographical error and should have been deleted]

"Atmospheric structure" is the vertical profile of atmospheric temperature, pressure and density. Lower-priority objectives (LPOs) are:

- Determine the vertical profile of zonal winds as a function of depth at the probe descent location(s)
- Determine the location, density, and composition of clouds as a function of depth in the atmosphere
- Determine the variability of atmospheric structure and presence of clouds in two locations
- Determine the vertical water abundance profile at the probe descent location(s)

- Determine precision isotope measurements for light elements such as S, N, and O found in simple atmospheric constituents

3. Potential investigations

The first HPO involves *in situ* measurements of elemental or molecular abundances. Such measurements could exploit differences in the constituents' atomic or molecular masses, or their molecular spectra, with instruments such as mass spectrometers or tunable laser spectrometers. Each type of instrument has strong and weak points. It would be the prospective PI's task to decide upon the instrument (or combination) that provides the best science at an affordable cost. The second HPO involves time series measurements of temperature, pressure, and accelerations. These can be accomplished with a fairly straightforward package of sensors, though proper placement is important. The paper will discuss the LPOs also.

4. Combinations of investigations

A prospective PI of Saturn probe missions will need to choose and balance carefully the objectives the mission concept will address. Studies performed as a part of the PSDS indicate that mission cost constraints will severely limit the probe's payload, so the PI would not be able to add instruments (or entire probes) to cover all the HPOs and LPOs. In some cases, instruments selected for the HPOs could also address one or more of the LPOs. Instrumentation for some LPOs is low in mass, cost, and power consumption, and would not seriously impact the probe as a whole. The paper will discuss various options available with current instrumentation.

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References

[1] US National Research Council, Space Studies Board: Vision and voyages for planetary science in the decade 2013-2022, National Academies Press, 2011.

[2] US National Research Council, Space Studies Board: New frontiers in the solar system: an integrated exploration strategy, National Academies Press, 2003.