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The Saturn PRobe Interior and aTmosphere Explorer (SPRITE) Mission Concept

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The proposed NASA New Frontiers Saturn PRobe Interior and aTmosphere Explorer (SPRITE) mission would measure the abundance of helium and the other noble gases, elemental and isotopic abundances, the clouds, dynamics, and processes within Saturn's troposphere. In situ measurements of Saturn's atmosphere by SPRITE would provide a significantly improved context for understanding the results from the Galileo Jupiter probe, and the formation and evolution of the gas giant planets, resulting in a paradigm shift in our understanding of the formation, evolution, and ultimately the present day structure of the solar system.

The proposed SPRITE concept carries an instrument payload to measure Saturn's atmospheric structure, dynamics, composition, chemistry, and clouds to at least 10 bars. A Quadrupole Mass Spectrometer measures noble gases and noble gas isotopes to accuracies that exceed the Galileo probe measurements at Jupiter and allows for discrimination between competing theories of giant planet formation, evolution, and possible migration. Of particular importance are measurements of helium, key to understanding Saturn's thermal evolution. A Tunable Laser Spectrometer measures molecular abundances and isotope ratios to determine the chemical structure of Saturn's atmosphere, and disequilibrium species such as PH3 and CO which can be used to predict Saturn's deep water abundance. An Atmospheric Structure Instrument provides the pressure/temperature profile of Saturn's atmosphere to determine the altitude profile of static stability, and when combined with cloud measurements from the SPRITE Nephelometer, would elucidate processes that determine the location and structure of Saturn's multiple cloud layers. Coupled with the measurement of atmospheric vertical velocities from the Atmospheric Structure Instrument, a Doppler Wind Experiment provides a measure of the 3-dimensional dynamics of the Saturn atmosphere, including the profile of zonal winds with depth and vertical motions from atmospheric waves.

The proposed Science Objectives of the SPRITE mission are to:
1. Constrain competing models of habitable system formation and extent of migration in the early solar system by obtaining a chemical inventory of Saturn's troposphere,
2. Determine if Saturn's in situ atmosphere chemistry agrees with condensation models and remotely observed composition,
3. Constrain Saturn's helium depletion to reconcile observed temperatures with thermal evolution models.
4. Perform in situ characterization of Saturn's tropospheric cloud structure to provide the ground truth basis for cloud retrieval models, and
5. Determine Saturn's in situ 3-dimensional atmospheric dynamics along the probe descent path to inform global circulation and analytical models of the time-variable cloud top motions.

To develop an improved understanding of the formation, evolution, and structure of the solar system, it is essential that the role played by the giant planets be well understood, and this cannot be accomplished without in situ measurements of the composition, structure, dynamics, and processes of Saturn's atmosphere. The proposed SPRITE mission would carry a suite of instruments specifically tailored to achieve the science objectives, to provide fundamental ground truth measurements for improved understanding of remote sensing measurements including from Cassini, and to understand the formation, evolution, and structure of the solar system as well as represent key ground truth for understanding exoplanets.