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SPRITE (Saturn PRobe Interior and aTmosphere Explorer): A Saturn Entry Probe Mission Concept

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Abstract

To improve models of Solar System origin, formation, and evolution, and to provide an improved context for exoplanet systems, measurements of the composition, structure, and processes within giant planet atmospheres are needed. In particular, measurements that cannot be made in any other way than direct sampling are particularly important, including the abundances of noble gases and noble gas isotopes. Other measurements of high value for in situ measurement include isotope ratios of hydrogen, carbon, oxygen, and nitrogen, as well as the atmospheric dynamics, thermal profile and processes, and cloud structure are necessary. To improve understanding of Saturn's interior structure and composition, and (by proxy) those of extrasolar giant planets, the Saturn PRobe Interior and aTmosphere Explorer (SPRITE) entry probe mission concept would address these science priorities as well as provide ground truth for remote sensing.

The SPRITE Mission concept comprises a solar powered Carrier Relay Spacecraft (CRSC) and an entry probe descending through ten bars in about 90 minutes. The primary scientific instrument payload of SPRITE would comprise two spectrometers – a a Tunable Laser Spectrometer and a Quadrupole Mass Spectrometer, and an Atmosphere Structure Instrument that includes a simple nephelometer and a Doppler Wind Experiment for characterizing Saturn's tropospheric thermal, cloud, and dynamical structure. The Atmospheric Structure Instrument also includes accelerometers to measure entry accelerations from which the probe entry trajectory and descent location would be reconstructed and from which the thermal structure of the upper atmosphere would be determined. The Carrier Relay Spacecraft carries a Multi-Channel Imager to provide local and global context imaging for the probe measurements and for pre-entry imaging of the probe entry location.

SPRITE would reach Saturn in ten years following an Earth-Venus-Earth-Earth gravity assist trajectory. The SPRITE probe would enter Saturn at an atmosphere-relative velocity of ~27 km/s resulting in a peak deceleration up to 45 g's and a peak heat flux near 3000 W/cm^2. The aeroshell would be released above the tropopause, initiating the descent science sequence and allowing up to 2 hours for the probe to reach 10 bars. The descent probe design is fully-redundant to ensure low risk data return, with a dual-channel telecommunication system powered by primary batteries. After the probe science data is collected by the Carrier Relay Spacecraft, the probe data and carrier imaging data would be downlinked to Earth multiple times through the Deep Space Network.

In the context of giant planet science provided by the Galileo, Juno, and Cassini missions to Jupiter and Saturn, a small, relatively shallow Saturn probe to make measurements not possible from remote sensing including the abundances and isotopic ratios of noble gases, as well as the vertical profile of other key atmospheric constituents, the atmospheric structure and processes including the profiles of pressure, temperature, dynamic, and the location and properties of the clouds would serve to test competing theories of solar system and giant planet origin, and chemical and dynamical evolution.

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