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Introduction: Enceladus, a ~500 km diameter moon of Saturn, hosts a subsurface ocean beneath its icy crust. Unlike other ocean worlds, this subsurface ocean is readily accessible via the plume of vapor and ice particles that emanate from fractures at the south pole. The Cassini mission interrogated Enceladus and its plume, finding that the subsurface ocean seems to meet our criteria for habitability: an aqueous environment with biologically-relevant elements and energy sources. Thus, Cassini's legacy motivates a return to Enceladus to (1) ascertain whether the subsurface ocean is inhabited and (2) why or why not.

In preparation for the 2023-2032 Decadal Survey, we investigated four different architectures for returning to Enceladus to address these two goals. We found the best balance of resources and scientific return to be Orbilander, a single spacecraft that first orbits Enceladus and then lands on the surface.

Mission Overview: The preliminary design represented in the report to the National Academy would launch in October 2038 on a direct trajectory. Saturn orbit insertion in Sept 2045 begins a 4.5 year moon tour to pump down into Enceladus orbit. Science operations begin with at least 1.5 years in orbit conducting life detection and remote sensing science, as well as collecting the data necessary to identify a safe landing site. Landing takes place as early as September 2051 but can be delayed if more time is needed in orbit. Descent and landing are enabled by terrain relative navigation and hazard avoidance. Landed operations include characterizing the landing site for suitable sample excavation areas, life detection analyses, and seismic monitoring and would continue for 2 years. The spacecraft is powered by 2 Next-Generation RTGs and uses chemical propulsion to enter Enceladus orbit as well as to conduct deorbit and landing maneuvers. Ka-band downlink over the course of the science mission translates to a data return capability of 1.1 Tbits of data.

Science Objectives and Payload: Orbilander's primary goal is to search for life. A convincing life detection will require multiple lines of evidence. We therefore defined five objectives that map to five biosignatures: 1. Amino acid characterization, 2. Lipid Characterization, 3. Pathway Complexity Index, 4. Genetic biopolymer, 5. Cell characterization. The instrument types needed to meet these objectives are largely at high Technology Readiness Level thanks to NASA programs like MaTISSE, PICASSO, and ColdTech. Instrument types include high resolution mass spectrometer, a separation capable mass spectrometer, an electrochemical sensor array, microcapillary electrophoresis and laser-induced fluorescence, microscope, and a solid state nanopore sequencer. This data collected by this payload would allow a complementary and orthogonal approach to life detection.

The secondary science goals are to determine ejection mechanics and assess ocean habitability. A combination of in situ and remote sensing instrument types meet these goals both in orbit and on the surface: narrow and wide angle cameras, a radar sounder, a thermal emission spectrometer, a laser altimeter, a context imager, and a seismometer.

Sampling Strategies: In orbit, Orbilander acquires plume samples passively through a gas inlet (vapor) and a funnel (particles). With maximum orbital velocities of ~ 200m/s, Orbilander collects sample at about the particle's velocity, minimizing sample modification from impacts. On the surface, Orbilander uses the same funnel to acquire sample passively and also excavates surface material with an active sampling mechanism.

Resilience to Biomass Uncertainty: Between ample schedule margin and access to multiple reservoirs within the plume, the Orbilander mission concept has access to sufficient sample volumes to be resilient to the inherent uncertainty of how much biomass is available within the plume. These volumes are driven by the specific implementation of the life detection suite. Geochemical and geophysical measurements provide further insight by collapsing some of the uncertainty in how much biomass the Enceladus environment might provide.

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