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SILENUS: A Mission Concept Investigating the Habitability of Enceladus

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Abstract

SILENUS (Spectrometer Investigating the Livability of Enceladus with a Network of Underground Seismometers) is a New Frontiers class mission concept to determine the habitability potential of Enceladus. The spacecraft system consists of an orbiter and a network of penetrators equipped with seismometers that will reach the surface. Building on the discoveries of Cassini, SILENUS significantly advances our understanding of the interplay between chemistry and geophysics at Enceladus and provides context for more advanced future missions. The spacecraft samples the south polar plumes of Enceladus, identifying specific life-critical gases, molecules, and ions. Simultaneously, the laser altimeter measures topography while radio science maps the gravity field to high accuracy. A seismic network with context cameras is strategically deployed to characterize the structure of the ice shell and deep interior of Enceladus to constrain exchange pathways between ocean, ice shell, and core critical for habitability.

1. Introduction

Enceladus is one of the most promising and accessible targets for astrobiology research in the solar system. Cassini discovered water plumes emanating from the South Polar Terrain (SPT), demonstrating that Enceladus is geologically active [1]. These plumes originate from a global subsurface ocean [2] in contact with a rocky core [3]. Detected silica grains hint at hydrothermal activity on the ocean floor [4]. Moreover, Cassini's Cosmic Dust Analyzer (CDA) detected organic compounds [5]. However, Cassini was not fully-equipped to assess habitability. SILENUS is a New Frontiers class mission that will assess habitability, establishing the groundwork for life detection missions to follow.

2. Science Objectives

Our science objectives follow the discoveries of Cassini and address the priorities identified in NASA's 2013-2022 Decadal Survey [7]. We focus primarily on testing whether the environmental conditions for life and physico-chemical energy sources are or were present on Enceladus. The three high-level scientific objectives are: (A) characterize the organic chemistry of the plume ejecta; (B) characterize the inorganic chemistry of the plume ejecta; and (C) constrain the age, structure, and exchange pathways of habitable environments

More detailed sub-questions have been identified for each of the aforementioned objectives to inform necessary measurements and instrument payload: a mass spectrometer, capillary electrophoresis, ion-selective electrodes, altimeter, context cameras, and a seismic network. Additional synergistic science objectives are also identified based on selected instruments. The science objectives and required measurements, together with detailed surface hazard assessment and mapping, inform surface site selection (Fig. 1).

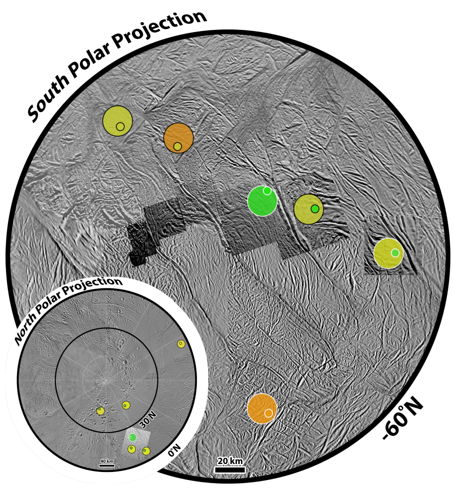

Figure 1: Ellipses represent selected landing sites and backups in northern hemisphere and SPT categorized broadly by hazard levels. Selected high resolution imagery is overlaid.

3. Mission Architecture

Different mission architectures were evaluated based on science return, cost, and risk. After exploring trade space, we decide on a mission architecture that consists of a single orbiter and four penetrators deployed from orbit. The orbiter is equipped with a set of instruments for chemical analysis to fulfill objectives A and B; an altimeter and a deep space transponder for radio science to accomplish objective C. The penetrators are used to deploy a seismic network. Three penetrators are deployed in a triangular geometry around Damascus and Baghdad fractures (Fig. 1). This geometry allows us to perform seismic tomography to study the ice shell structure in the SPT. Additionally, another seismometer is deployed 100°from the SPT (in Samarkand Sulci) to characterize Enceladus' deep interior.

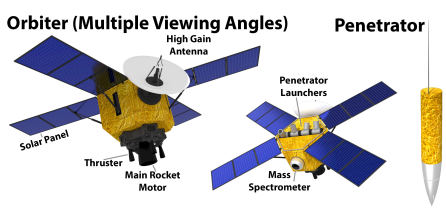

Figure 2: CAD models of orbiter and penetrator.

4. Concept of Operations

Launching in 2028, SILENUS takes 13 years to reach Enceladus. Once there, it enters a HALO polar orbit allowing it to fly 15 times through the plumes at an altitude of 30 km to collect samples and drop off three of the four penetrators in the SPT (Fig. 1). After a time lapse of 8 days on this orbit, SILENUS settles into a stable orbit with an inclination of 60° and an altitude of 250 km [6]. SILENUS deploys the remaining seismometer at Samarkand Sulci (Fig. 1). SILENUS remains in this orbit for one year to perform altimetry measurements and mapping of Enceladus' gravity field. Afterwards, the orbiter is deorbited and set on a collision course with Tethys for disposal, conforming to NASA planetary protection guidelines.

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