A MISSION CONCEPT INVESTIGATING THE HABITABILITY OF ENCELADUS: S.I.L.E.N.U.S.

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Summary: 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 (Fig. 1). Building on the legacy of Cassini, SILENUS significantly advances our understanding of the interrelations 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 and radio science is used to map the gravity field to high accuracy. A seismic network with context cameras is deployed to characterize the structure of the ice shell and deep interior of Enceladus thereby determining exchange pathways between ocean, ice shell, and core which are critical for habitability.

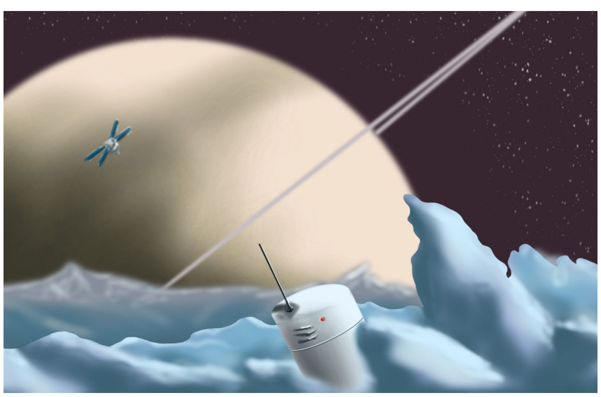

Fig. 1 Artistic concept of a seismometer-equipped penetrator operating on the surface of Enceladus as the orbiter makes key measurements to achieve our science goals.

Introduction: Enceladus is one of the most promising and accessible targets for astrobiology research in the solar system [1]. Cassini discovered water plumes emanating from the South Polar Terrain (SPT), demonstrating that Enceladus is geologically active [2]. These plumes originate from a global subsurface ocean, which is in contact with a rocky core [3, 4]. Moreover, detected silica grains hint at hydrothermal activity on the ocean floor [5]. Additionally, Cassini's Cosmic Dust Analyzer (CDA) detected organic compounds in the plumes [6]. These measurements suggest that Enceladus is a promising place to look for modern habitable environments beyond Earth. However, Cassini was not fully-equipped to assess habitability [1]. SILENUS is a New Frontiers class mission that will assess habitability, establishing the groundwork for life detection missions to follow.

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. From our overarching science question, “Is or was there a habitable environment on Enceladus?”, we identify three high-level scientific objectives:

A. Characterize the organic chemistry of the plume ejecta.
B. Characterize the inorganic chemistry of the plume ejecta.
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. These instruments were chosen after exploring key science trades in communication with mission architecture and engineering trades. Additional synergistic secondary 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. 2).

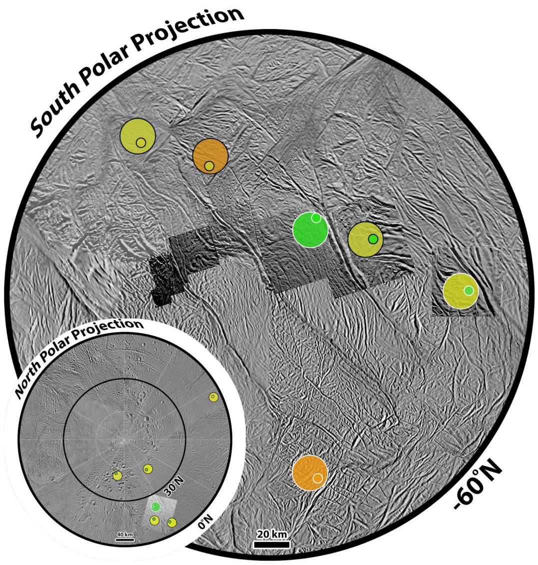

Fig. 2 Ellipses represent selected landing sites and backups in northern hemisphere and SPT categorized broadly by hazard levels. Selected high resolution imagery is overlaid.

Mission Architecture: Different mission architectures were evaluated based on science return, cost, and risk. Several important constraints on our design include: arriving at Enceladus when the SPT would be in darkness, lack of stable polar orbits, hazardous and unknown terrain at landing sites, and extreme environmental conditions at the surface. After exploring trade space, we decide on a mission architecture that consists of a single orbiter and four penetrators deployed from orbit (Fig. 3). 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. 2). This geometry allows us 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 and core. A key element of our design is that it prioritizes maximum science return on our science objectives even if higher risk mission components, the penetrators, experience technical difficulties.

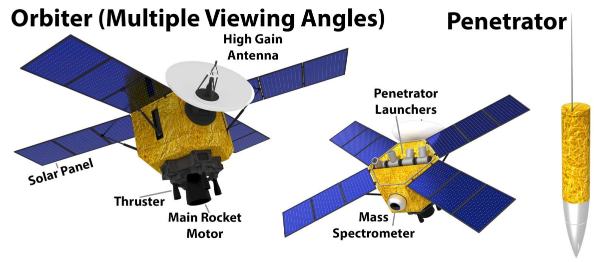

Fig. 3. CAD models of orbiter and penetrator.

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. 2). After a time lapse of eight days on this orbit, SILENUS settles into a stable orbit with an inclination of 60° and an altitude of 250 km [8]. SILENUS deploys the remaining seismometer at Samarkand Sulci (Fig. 2). 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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