EELS (Exobiology Extant Life Surveyor): A Snake-like Robot for Enabling Enceladus Ocean Access

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Enceladus, despite its small size, is one of the most compelling destinations to explore in the solar system. Evidence from multiple instruments aboard the Cassini Mission indicates the presence of a global, subsurface aqueous ocean rich in salts and organics. Further evidence suggests that water-rock interactions may be occurring in hydrothermal systems at the seafloor [1,2]. Enceladus appears to meet most criteria for habitability [3], making it a high priority for future astrobiology missions in search of evidence of life. While meaningful science can be achieved at Enceladus via many architectures (flyby, orbiter, lander, etc.), future science investigations would substantially benefit from a robotic platform that is capable of descending down a vent to acquire fresh liquid samples and eventually reach the subsurface ocean.

EELS (Figure 1) is a snake-like robot designed to provide horizontal *and* vertical mobility on the ice [4]. It can travel on unconsolidated and highly undulating surfaces on Enceladus from a lander, such as Enceladus Orbilander, to the entrance of a vent; it can then descend into it while resisting the high-speed plume by pushing against the opposing walls to anchor itself. While there are substantial environmental uncertainties in the vent, our NIAC Phase 1 study [5] showed that such a mission is technically feasible except for an extreme case where the largest vent on Enceladus has a diameter of less than ~10 cm. Although further reconnaissance would be necessary to confirm, given the substantial mass flux [6] and observational evidence that there are >100 open vents, it would be highly likely that there are one or more vents that are suitable for robotic exploration. Furthermore, the system trade study in our ongoing NIAC Phase 2 study showed that the EELS mission is implementable as a subpayload of a Flagship-class lander mission, such as Orbilander [7].

Figure 1 EELS robot for a conceptual Enceladus vent exploration mission as a subpayload of Enceladus Orbilander. The full concept movie is viewable at: https://youtu.be/9E0USzPFEJ0

Under JPL's JNEXT program, we are currently prototyping the hardware and software of the EELS robot. Our primary field test site is the Athabasca Glacier in Canada, where there are vertical holes called *moulins* – a great analog of the Enceladus vent. Figure 2 shows EELS 1.0, our first working prototype, which successfully demonstrated surface mobility on an ice rink and vertical mobility in the lab. In September 2022, we conducted the first field test in Athabasca Glacier (Figure 3). We brought the sensor head and a screw actuator of EELS 1.0 and collected the 3D scans of moulins, and tested the SLAM (simultaneous localization and mapping) algorithms as well as the mechanical interaction with ice. In the next ~2 years, we will make multiple trips to Athabasca with the full EELS robot and test surface and vertical mobility. With successful field tests in the analog environment, we plan to advance EELS technology to TRL 6 by the end of the JNEXT program and make it ready for in-space demonstration.

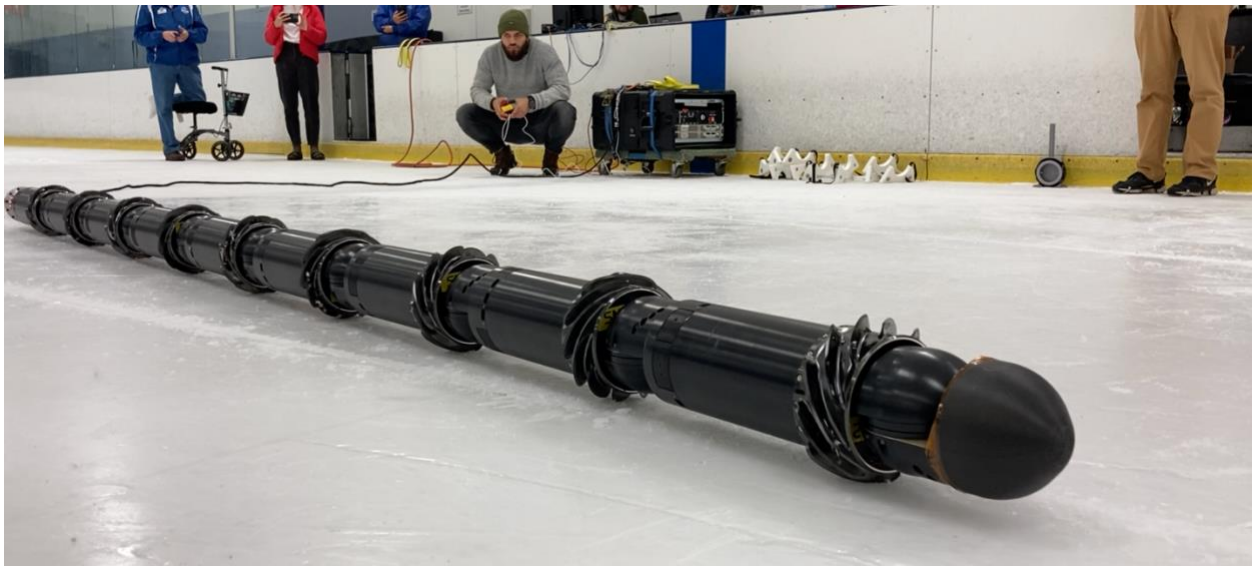

Figure 2: EELS 1.0 Robot tested on the Pasadena Ice Rink in July, 2022

Figure 3: First field test on the Athabasca Glacier in September, 2022, in which we tested the sensor head of EELS 1.0 in glacial vertical holes

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