TESTING OF SLUSH ICE PENETRATING PROBE IN EUROPA, ENCELADUS AND MARS ENVIRONMENTS
Leo Stolov1, Kris Zacny1, Caleb Lang1, Bolek Mellerowicz2, Joey Palmowski2, Carter Fortuin2, Lilly Ware1, Kathryn Bywaters1, Kevin Hand2, Christophe Sotin2, Sam Howell2, Tom Cwik2, Juergen Mueller2, Bethany Ehlmann3, Seiichi Nagihara4, Fred Bonn2, Stef Liller2 Honeybee Robotics (lastolov@honeyberobotics.com) 2Jet Propulsion Laboratory, 3California Institute of Technology, 4Texas Tech University, 5Integrity Communications Solutions

Introduction: The ocean worlds of Europa and Enceladus, and the subsurface of Mars are primary targets in the search for past and present life. Current research indicates that these three celestial bodies possess large bodies of liquid water—a key building block of life—beneath a layer of ice. The icy outer shells of Europa and Enceladus that sit above their global oceans are estimated to be a few kilometers to tens of kilometers thick [1]. On Mars, recent investigations suggest large bodies of water exist beneath one kilometer of ice [2]. The Search for Life Using Submersible Heated (SLUSH) probe is a hybrid, thermo-mechanical probe capable of penetrating the icy formation to reach the subsurface liquid water. To improve efficiency and drilling speed, SLUSH combines the two existing methods for traveling through ice: thermal (melting) and mechanical (cutting) [3]. “Slushing” uses drilling to break the ice and heat to partially melt the ice chips to form slush to enable the efficient transport of ice chips behind the probe.

SLUSH design: SLUSH has a heated drill bit with a rotary percussive mechanism in the front and an antitorque system on the side. It uses a Kilopower nuclear reactor for both thermal and electrical needs [4]. The fission reactor can be turned on/off and is self-moderating, simplifying thermal management. Sterling engines convert the thermal power to electrical. SLUSH baselines a tethered approach for communication with a lander on the surface. The system uses two conductive microfilaments and an optical fiber. The tethered approach provides high bandwidth and the accurate depth of the probe (using a rotary encoder). If the tether breaks, for example, from diurnal tidal stresses expected on Europa, the broken microfilaments can be used as an antenna for a so called “Tunable Tether” approach. The tether is wound inside several spool bays pucks that are left behind in the ice once the spool is depleted. The pucks act as transceivers/receivers to enable radio frequency (RF) communication through the microfilaments and decrease the probe length as they are released, making penetration more efficient.

Prototype probe: A stand-alone prototype probe has been developed to demonstrate the technology in a compact design. The probe will be tested in ice at temperatures found on Europa (250 K - 100 K) to at least 2x its length. It has all the critical functionality to demonstrate thermo-mechanical drilling, generation of slush, and refreezing above the probe. Once validated, the probe can be scaled to a larger design capable of carrying science payloads to study terrestrial glaciers in preparation for a future deep drilling mission.

The drilling subsystem has been used to compare the three drilling methods (thermal, mechanical, and thermo-mechanical or slushing). Testing has been conducted in relevant ambient and vacuum environments using “warm” (260 K) and “cold” (130 K)
ice. Slushing is shown to be the fastest and most efficient penetration method in the tested environments.

The tether and spooler section is also being developed in parallel to allow the probe to drill to longer lengths. Simulations and initial testing have been conducted to demonstrate RF communication through a broken tether.

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