SLUSH: AN ICE DRILLING PROBE TO ACCESS OCEAN WORLDS

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**Introduction:** Ice shelves more than a kilometer deep conceal large bodies of water beneath the surfaces of Europa, Enceladus, and Mars \cite{1,2}. These bodies of water are primary targets in the search for past or present life in the solar system. The Search for Life Using Submersible Heated (SLUSH) probe is a hybrid, thermo-mechanical probe capable of penetrating kilometers of ice to deliver science instruments to the subsurface liquid water (Figure 1). To improve efficiency and drilling speed over traditional melt probes, SLUSH combines the two existing methods: thermal (melting) and mechanical (cutting) \cite{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. Once SLUSH reaches the subsurface water, integrated science instruments send data to the surface lander for transmission back to Earth. SLUSH baselines a tethered approach to communicate through kilometers of ice. The tether system uses two conductive microfilaments and an optical fiber. The fiber provides high bandwidth and the accurate depth of the probe. If the tether breaks, for example, from the 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 bay pucks that are left behind in the ice once the spool is depleted. The pucks act as transceiver and receivers to enable radio frequency (RF) communication through the microfilaments and decrease the probe length as they are released.

**Prototype Probes:** Honeybee Robotics has developed prototype probes to advance the drilling technology and communication technology for a future ocean world probe. A stand-alone SLUSH prototype probe has been developed to demonstrate the slushing approach in a compact design and was tested in an ice tower inside Honeybee’s walk in freezer. Rate of penetration and specific power was measured to compare speed and efficiency metrics.

![Figure 1. Conceptual design of SLUSH.](image-url)
Honeybee is now developing the Narwhal Probe and adding a modular science bay and a deployable tether puck. Instrumentation includes a side-looking camera and electrical conductivity sensor. The deployable puck is a flight-forward design replicating those that may be used for communicating through thick ocean world ice shells (up to tens of km, e.g., Europa or Enceladus) [5]. The Narwhal Probe is designed to profile the Devon Ice Cap to a depth of 100 m.

Acknowledgments: This work is funded by NASA PICASSO, SESAME and COLDTech Programs. Field work was supported by CSA FAST grant and Polar Continental Shelf Program.