TETHER COMMUNICATION FOR ACCESSING OCEAN WORLDS USING SLUSH.

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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 [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 the icy formation to reach the subsurface liquid water. 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. 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 (using a rotary encoder). 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 (**Figure 1**).

Prototype Probes: To develop the tether communication technology for ocean worlds, Honeybee Robotics is designing several iterations of melt probes for testing in Earth analog environments. The first iteration, called the Salmon Probe, carries a passively-unspooling, hybrid tether that uses the 2 conductors to power the probe and a plastic fiber optic to transmit data. In summer of 2022, the probe was taken to Devon Island in the Canadian high arctic and successfully tested on top of the glacier to a depth of about 1.8 meters (**Figure 2**). The Devon Island glacier is 100's of meters thick, allowing for testing at depths not attainable in the lab [5]. The team measured glacier conditions, grabbed a core sample for analysis, and evaluated logistics for return deployments in 2023 and 2024.

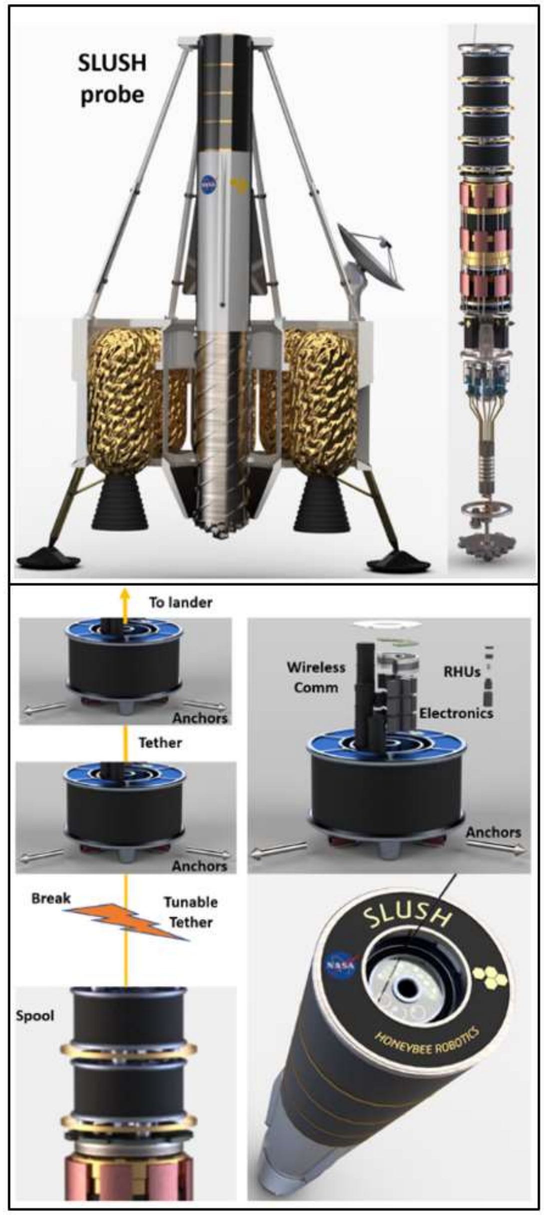

Figure 1. Conceptual design of SLUSH. Top Right: SLUSH probe inside the lander. Top Left: SLUSH concept with internals visible. Bottom: Spool bay pucks house the tether. The pucks are left in the ice as the probe descends, remaining connected by the tether to provide communication with the surface. If the tether breaks, communication continues through the Tunable Tether approach.

Figure 2. Left: Honeybee Robotics' Salmon Probe set up on top of the Devon Island glacier before deployment into the ice. Right: Drone shote of the team on top of the glacier during testing.

The next iteration probe, called the Dolphin Probe, is currently under development to test a higher fidelity spooler and tether design. The team will return to the Devon Island glacier in 2023 to deploy the Dolphin Probe with a target depth of 10+ meters. The following year will further develop the technology by targeting 100+ meters and include a deployable spool bay puck to test the SLUSH concept.

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