Surface and Subsurface Sampling Drills for Life Detection on Ocean Worlds. Fredrik Rehnmark[1], Tighe Costa[1], Joey Sparta[1], Jameil Bailey[1], Kris Zacny[1] and Ralph Lorenz[2], [1]Honeybee Robotics, Pasadena CA 91103, USA (FLRehnmark@honeybeerobotics.com), [2]Johns Hopkins Applied Physics Laboratory, Laurel, MD 20723, USA (Ralph.Lorenz@jhuapl.edu).

Introduction: The authors propose two very different drilling machines to search for life on ocean worlds. SLUSH Drill (Search for Life Using Submersible Heated Drill) is a drilling probe that could penetrate several kms through Europa ice to reach the warm ocean below. CryoSADS (Cryogenic Sample Acquisition and Delivery System) is a transportable surface drill that could penetrate a few cm deep into the Titan regolith at various landing sites.

Background: Because liquid water plays such a central role in biological processes on Earth, the search for life elsewhere begins with a search for oceans, either present or past. There is evidence that Europa and Titan both have plentiful liquid water buried deep underground and, therefore, insulated from the cold temperatures (~100K) at the surface. On Europa, these subsurface oceans could be accessed by drilling through kilometers of ice. Titan, on the other hand, also has surface oceans consisting of liquid methane, which has a much lower freezing point than water but participates in the Titan climate in ways analogous to water on Earth. If they exist, heretofore undiscovered lifeforms that depend on methane, rather than water, could be detectable at or near the Titan surface. Therefore, a sampling drill for Titan would only need to penetrate a few cm deep. For maximum flexibility, both drills will use a proven rotary percussive drilling approach [1] that traces heritage back to the Apollo Lunar Surface Drill (ALSD).

SLUSH Drill for Europa: Drilling tests were performed in cryogenic ice to compare power consumption with room temperature drilling trials conducted in similar strength (~100 MPa) rock (**Figure 1**). Although different drill bits were used and it is, therefore, dangerous to draw too many comparisons, the specific energy (Whr/cc) measured while drilling in ice (unheated bit) was at least two orders of magnitude lower than in rock. In warm (~240K) ice, however, internal heating was necessary to prevent the drill bit from getting stuck, even at a very modest depth of 20 cm [2]. This increased the specific energy of drilling in ice to roughly one order of magnitude lower than drilling in rock. Internal heating would also provide a related benefit of facilitating the transport of cuttings from the drill, past the probe body and up to the open hole behind the probe, allowing it to make forward progress.

Figure 1. Drilling in cryogenic ice (unheated bit).

CryoSADS Drill for Titan: One of the requirements of sampling on Titan is to preserve the composition and physical properties of surface material by limiting temperature rise to no more than 10K above ambient. This motivates the use of pneumatic sample transport using Titan air. The drill will be powered by electromagnetic motors that can operate at Titan ambient conditions to minimize heating of the drill bit. Extreme environment electromechanical actuators have been built and tested in both cold [3] and hot [4] environments.

Surface observations of Titan provided by the Huygens probe are consistent with damp sand [5], raising concerns that the surface material at the landing site could be difficult to transport. To reduce the risk of fouling the sample acquisition system, the CryoSADS drill will first probe the ground and relay imagery and sensor data to Earth for landing site evaluation before initiating the sampling sequence. Testing in a range of wet and dry simulants with a range of particle sizes is planned and will be correlated with soil property measurements in an effort to define high-confidence screening criteria.

Conclusions and Future Work: Penetrating the surface of ocean worlds such as Europa and Titan is feasible by enhancing existing planetary drilling technology. SLUSH and CryoSADS offer unique capabilities necessary to expand the search for life to these destinations.

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