Updates on the Sending Signals Through the Ice (STI) Project for an Ice-Ocean Probe at Europa and Ocean Worlds

K. L. Craft[1], C. R. German[2], M. V. Jakuba[2], R. R. Lien[1], R. D. Lorenz[1], C. McCarthy[3], G. W. Patterson[1], A. R. Rhoden[4], M. Silvia[2], V. Singh[3], M. Walker[5], N. Farr[2], L. Freitag[2], C. McRaven[2], J. Partan[2], R. Coker[1], E. Asenath-Smith[6], and J. Lever[6]

[1]JHU Applied Physics Laboratory (Laurel, MD, Kate.Craft@jhuapl.edu), [2]Woods Hole Oceanographic Institution (Woods Hole, MA), [3]Lamont-Doherty Earth Observatory (Palisades, NY), [4]Southwest Research Institute (Boulder, CO), [5]Planetary Science Institute, [6]US Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory (Hanover, NH)

Introduction: Future missions to icy ocean worlds will not be satisfied by remote, plume, or shallow surface analyses. In order to follow up on detections of habitable environments and potential life signals obtained by previous missions (e.g. Europa Clipper, Europa Lander, Enceladus mission concepts), deep subsurface exploration, or reaching the moons' oceans or perched water pockets (e.g. [1]), will reveal and/or confirm, as well as characterize in detail, any life that may exist there. However, in order to sample an ocean world's ocean, significant technical challenges would need to be overcome.

Europa and Enceladus' elliptical orbits around their parent planets, cause their ice shell to flex and distort, triggering surface cracks and shear motion [e.g. 2 & Lien poster this meeting]. A successful mission to the ocean will require penetrating the ice shell with instrumentation robust to these forces, down to possibly 10s of kms depth, while maintaining communication with the surface. The Signals Through the Ice (STI) project is working to develop a robust communication architecture for transmitting data collected by the descending ice probe up to the surface lander for transmission back to Earth. Progress to date is shared here and future '21- '24 COLDTech efforts are outlined.

Methods: The STI project is working to bring one (or more) communication optical tether designs to TRL 4/5 (through validation in a laboratory setting that simulates a relevant environment) and is evaluating the performance of multiple free-space communication techniques (RF and optical) that could be coupled with, or alternatives for, tethers to a subsurface probe. Fiber optic micro-tethers currently exist that have lengths sufficient to traverse Europa's ice shell and have sufficiently low mass to allow delivery as part of a planetary mission. We are testing two specific tether types, Linden's Strong Tether Fiber Optic Cable (STFOC) and High Strength (HS) STFOC, under the potential shear hazards for faults at Europa. Shear testing is performed by freezing a section of tether into ice and applying forcing loads to simulate shear (see procedure described in [3], Figure 1) while measuring data transmission performance.

Additionally, we are numerically modeling the tidally induced stress that Europa's ice shell likely undergoes [4], that can drive fault motion [2 & Lien poster this meeting]. Optical free space experiments will be getting underway at Lamont Doherty's laboratory this fall to assess the ability for optical transmission through the ice. RF module design has been evaluated for modeled Europa ice shell conditions.

Progress: Shear tests at ~ 100K on the STFOC and on the HS STFOC tethers at 120K damaged the outer jackets (Figure 1) but transmission capability survived with data transmission loss at only 0.1 dB at 100K for the STFOC ([3]). Further tests will be performed to complete the shear testing at ~100K for the HS STFOC, as well as long tether soaks in mixed chemistry ice (e.g. +salts) for data transmission evaluations.

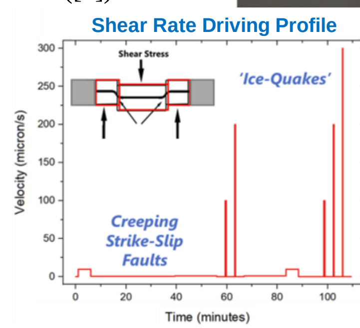

Figure 1. Shear testing

Fault motion due to tidal stress at specific locations on Europa (subjovian and Thera Macula at 50°S, 180°E) show deformation and motion that could challenge a tether's robustness crossing such a fault [2 & see Lien poster this meeting].

Future COLDTech efforts: Plans to complete more thorough environmental evaluations on tethers and RF modules will be completed over the next 3 years. Tethers will be designed specifically for Europa and Enceladus conditions and evaluated for shear, tension, and adhesion robustness. RF transmission modules will be designed, built, and tested for thermal and mechanical survival.

Summary: The STI communication techniques will enable the search for extraterrestrial life and deep subsurface exploration of ocean worlds.

References: [1] Oleson et al., 2019, NASA/TP–2019-220054; [2] Lien et al., 2021, *LPSC*, Abs. 1005; [3] Singh et al., 2021, *LPSC*, Abs. 2403. [4] Walker et al., 2020, *LPSC*, Abs. 2448.