Experimental Results of Melt Probes in Cryogenic Ice for a Future Europa Lander

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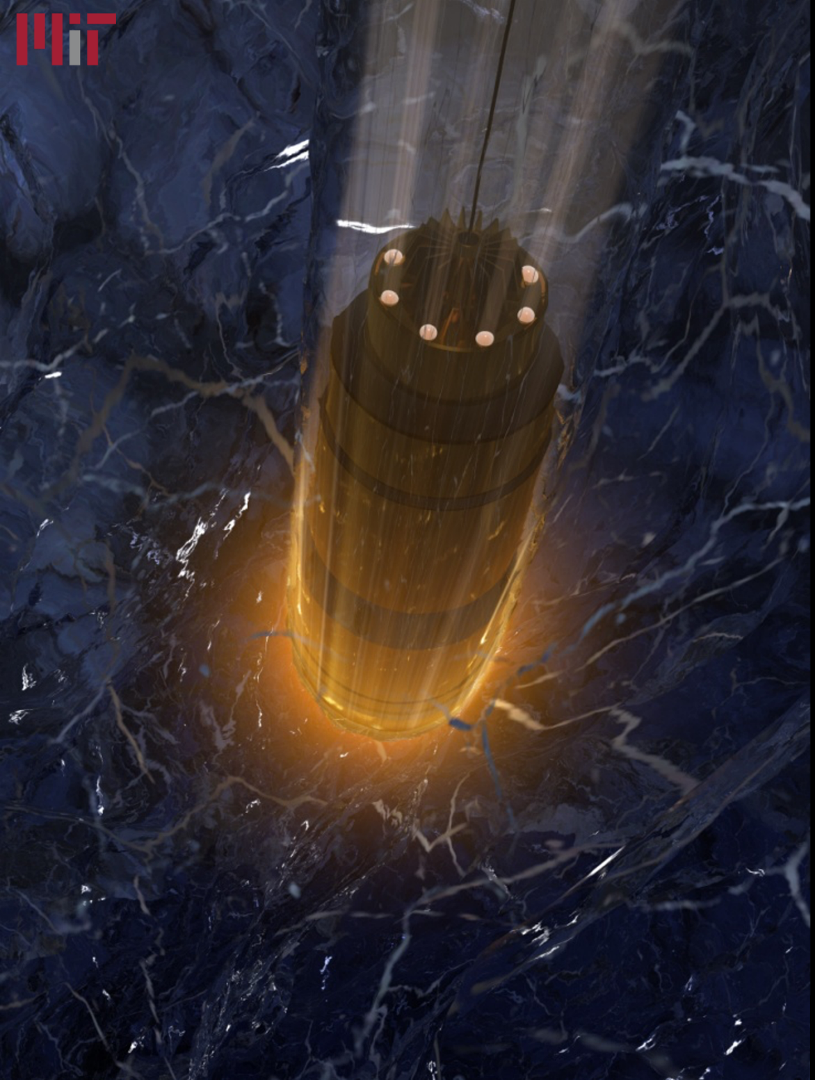
November 21, 2022

Abstract

Ocean Worlds are strong candidates for the first discovery of extraterrestrial life as they may provide liquid water, energy, and biologically essential elements. These bodies are characterized by large volumes of water under a layer of ice, often in contact with a rocky core and powered by tidal heating. Jupiter's moon Europa is believed to have at least twice as much water as Earth. A key remaining challenge is reaching the oceans of Europa: the thickness of the ice crust may range from 3 km to 30 km. Initial steps have been taken to develop analytical and numerical models of the thermal and physical dynamics of ice penetrators in cryogenic environments, but experimental validation of these models has been limited. We have built and experimentally tested the performance of a set of melt probes in the Europa Tower located at Stone Aerospace. The Europa Tower is a cryogenic vacuum chamber with an internal diameter of 0.75 m and an ice column height of 2 m, capable of maintaining ice at approximately 90 K and surface pressure at near-vacuum (10^{-3} torr), allowing for the testing of probes designed for the surface of Europa. The Model Validation Probes (MVPs) used are designed to test the fundamental thermal and kinetic properties of melt probes in cryogenic ice. They include monitoring of power, temperature, and penetration depth, with wires stored and released via spools internal to the probe, allowing continued connection after hole closure. MVP1 was tested in January 2020, was powered by a 500 W cartridge heater, and reached a total depth of approximately 1.1 m after about 10 h of test, resulting in an average steady state penetration velocity of roughly 12 cm/h, which is within 10% of theoretical model predictions. This test also confirmed two important aspects of hole initialization: the capability of the probe to start in cryogenic, vacuum conditions where the lack of liquid water limits heat transfer (the "starting problem"), and the rapid melt hole closure following penetration, which allows the probe to continue penetration in a pressurized bubble that contains liquid water. We will also present results of tests with other MVPs, which validate the modeled dependency between the average steady state velocity and the heater power input level. Future work will investigate the effects of ice density and impurities on penetrator performance.



Experimental Results and Initial Model Validation of Melt Probes in Europa Conditions

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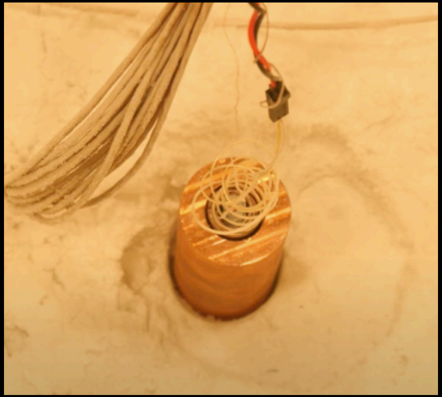
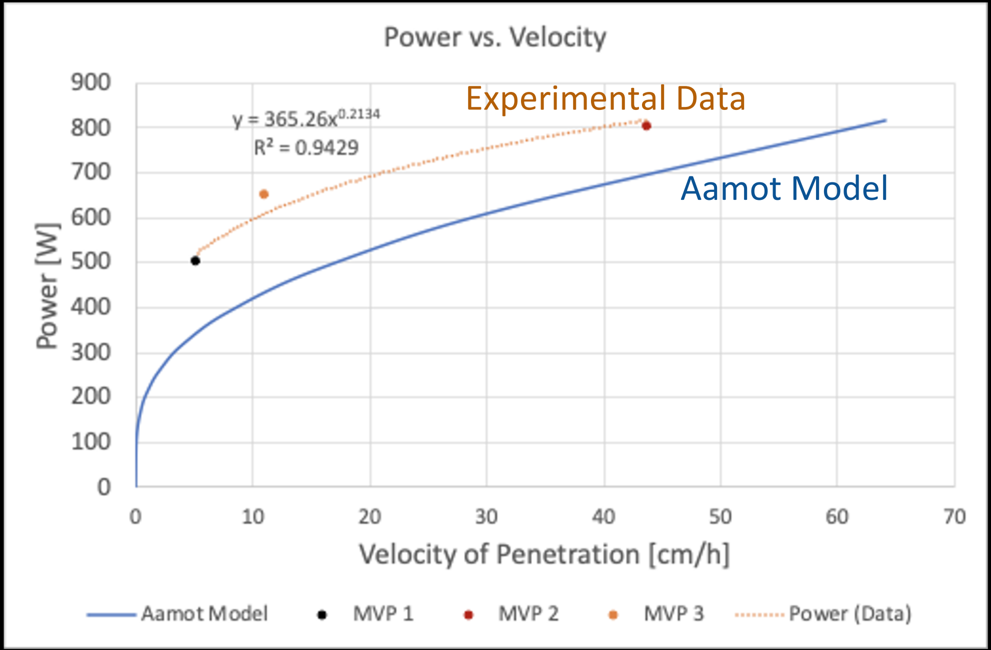
2020/12/11

Key Results

Experimental confirmation of hole closure, velocity measurement, Aamot power trend.





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Broader Impact

Model validation to answer unanswered questions, feeding into a future Europa probe.