VALKYRIE: FIELD CAMPAIGN RESULTS FOR A LASER-POWERED CRYOBOT.

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Introduction: The NASA ASTEP VALKYRIE project has the objective of developing a field-deployable autonomous ice-penetrating cryobot of sufficient scale to deploy realistic astrobiology science payloads through ice caps of substantial thickness and to enable recovery of the vehicle and its in-situ-acquired samples at the conclusion of a mission. The project is testing novel life-sensing instruments and automated sampling systems and algorithms in the context of field deployment of the vehicle through ice caps. The novel technologies that enable multi-kilometer-thick ice cap penetration are a high power fiber laser; a vehicle-deployed optical wave guide; and integrated onboard thermal management systems. The laser source is fed to beam expansion optics at the front of the vehicle, which cause the beam to impinge on an infrared dispersion mirror which redirects the 1070 nm wavelength light onto a heat exchanger. Through the use of high temperature photovoltaics a portion of the optical power is converted to electricity used to drive the hot water jet pumps which emulate the operation of hot water drills. The vehicle can operate in several modes including active, passive, and recirculation states; the latter two can be used to allow for undisturbed bio-sensing and sampling of the fresh melt water at the nose of the vehicle. The vehicle also is designed to use forward-looking obstacle avoidance maps through the ice using a synthetic aperture radar. The astrobiology science payload consists of a laser-induced fluorescence-based flow cytometer which samples ice melt water as the vehicle descends and a series of water samples whose collection is autonomously triggered by onboard software based on analysis of the cytometer measurements that would suggest the presence of microbial life or particulate matter of interest.

Results: The expedition deployed to Alaska's Matanuska glacier in May 2014 and was on site for five weeks. Basecamp and an on-glacier laboratory were transported in by helicopter to a point 10 kilometers upglacier. On June 16, 2014 the vehicle achieved an extraordinary feat: it used the photons generated by a 5,000 watt laser, sent down a 25 micron pure silica fiber, to power an ice-penetrating robot. The vehicle descended to a depth of 30.52 meters in the glacier ice. The vehicle, measuring 25 cm in diameter by 2.5 m length, achieved average descent rates of 1 m/hour at the 5 kW power load rate, in agreement with theoretical calculations for the measured ice temperature. Water melted at the front of the vehicle was drawn into a series of pressurized hot water pump jets that were used to speed the descent. Lateral turning jets were included to permit the vehicle to steer away from a vertical line of descent to avoid obstacles. Despite the presence of glacial sediment in the ice, the hot water jetting technique allowed the vehicle to descend unimpeded.

Impact: The physics principles utilized in VALKYRIE's design enable operation of the vehicle to extraordinary distances, with penetrations into any of Antarctica's sub-glacial lakes now becoming feasible with pre-sterilized robotic systems capable of not only accessing such lakes, but of exploring them to great distances from the point of entry. Significant amounts of power can be transferred using VALKYRIE technology to robotic systems more than 40 kilometers from a point of entry, either within ice caps or undersea, with the potential of extension to as much as 100 kilometers. VALKYRIE's successful field tests represent the emergence of an enabling technology in which autonomous agents, now free of battery-life constraints, may perform persistent science at locations previously inaccessible.

Ongoing Research: The astrobiology objectives for the VALKYRIE project are to demonstrate the ability to integrate a protein fluorescence sensor into the vehicle and to use that sensor to detect and discriminate for microorganisms and dust depositions within the ice column as the vehicle descends and to selectively collect both water and filtered samples for comparison with parallel ice cores to validate decision-to-collect algorithms that will be applicable to autonomous life search systems for outer planet icy moon exploration. Results from the 2014 field campaign will be discussed, as will ongoing results from the 2015 field campaign which will be taking place during AbSciCon 2015.

Figure 1: Preparing VALKYRIE at Mission Control on the Matanuska Glacier, AK.