Development and Testing of a Subsurface Probe for Detection of Life in Deep Ice

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We present the novel concept of a combined drilling and melting probe for subsurface ice research. This probe, named "IceMole", is currently developed, built, and tested at the FH Aachen University of Applied Sciences' Astronautical Laboratory. Here, we describe its first prototype design and report the results of its field tests on the Swiss Morteratsch glacier (see Fig. 1). Although the IceMole design is currently adapted to terrestrial glaciers and ice shields, it may later be modified for the subsurface in-situ investigation of extraterrestrial ice, e.g., on Mars, Europa, and Enceladus. If life exists on those bodies, it may be present in the ice (as life can also be found in the deep ice of Earth).

The current terrestrial method to study deep ice primarily uses the traditional drilling and ice-core-sample-return method, which is not well suited for (robotic) planetary exploration missions. A probe with all scientific instruments on board would be better suited for in-situ ice analysis. In this case, only the data has to be sent back to Earth. Melting probes, however, being developed since the 1960s, have also drawbacks for extraterrestrial deep ice research: they penetrate only vertically down and cannot change direction, and they cannot penetrate dust/dirt layers. To remedy these drawbacks, the IceMole concept uses a hollow ice screw (as it is used in mountaineering). The first IceMole prototype was build in 2009/10 and was tested on the Swiss Morteratsch glacier in September 2010. It has the shape of a rectangular tube (15cm x 15cm cross section) with a ~3kW melting head at the tip. The required electric power is generated by a surface aggregate and transmitted via a cable that is uncoiled from the probe. Communications and data transfer to the surface is also via the power cable. The ice screw, being located at the tip of the melting head, generates a driving force that presses the melting head against the ice, thus leading to a good conductive heat transfer. The thermally isolated ice screw transfers ice into the probe, where it can be analyzed in situ. The IceMole can change direction by differential heating of the melting head (in the next prototype, also side heaters will be implemented), which generates a torque that forces the IceMole into a curve. At FH Aachen University of Applied Science's Institute of Bioengineering, a method is currently developed that prevents biological contamination of the ice. A prototype sensor to detect life in ice is also under development.

On the glacier, three penetration tests have been successfully performed: 1) melting 45° upwards for ~1.5m, against gravity; 2) melting horizontally for ~5m; 3) melting 45° downwards for ~3m, thereby penetrating three obstructing mud and sand layers and driving a curve with a radius of ~10m. The penetration velocity was ~0.3m/h (but will be increased to ~1m/h for the next prototype). Although the decontamination method and the life detection sensor have not yet been tested on the glacier, the IceMole concept seems to be a viable approach to detect life in deep ice.

Figure 1. Testing of the IceMole prototype on the Morteratsch glacier.