TESTING THE RETRIEVABLE MELTING PROBE TRIPLE-ICECRAFT IN A TERRESTRIAL ANALOG IN THE EKSTRÖM ICE SHELF IN ANTARCTICA

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Introduction: The exploration of subglacial worlds is one of the greatest technological challenges for both space science and terrestrial glaciology. Of particular interest is the exploration of the oceans hidden under the ice shells of some moons in the outer Solar System, for example the Jovian moon Europa and Saturn's moon Enceladus. It is of outstanding scientific importance whether and how life may have developed in these oceans [1].

For exploring these ocean worlds, suitable ice drilling and exploration technology must be developed and brought to a higher technology readiness level. This is one of the main goals of the TRIPLE projects.

The TRIPLE Projects: The acronym TRIPLE stands for **T**echnologies for **R**apid **I**ce **P**enetration and subglacial **L**ake **E**xploration, representing technology development for three required main components to explore the subglacial ocean of the Jovian moon Europa [2].

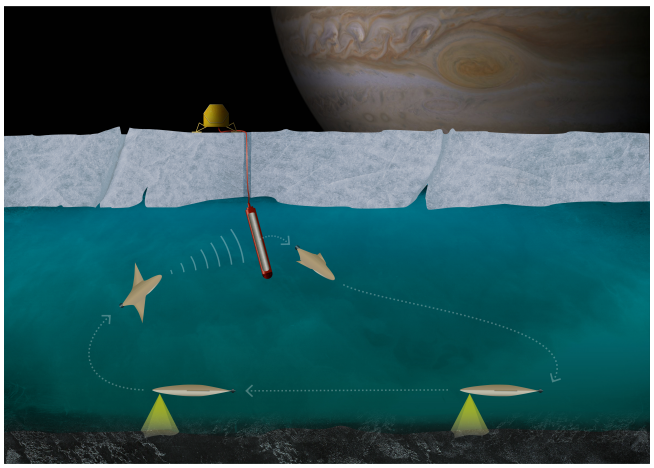

Figure 1. The TRIPLE mission concept. (Image courtesy MARUM, Bremen)

The first component is a melting probe which penetrates the ice shield and navigates to the ocean below [3]. It anchors itself at the ice-water boundary and releases the second component into the water - a small autonomous underwater vehicle (AUV), called the TRIPLE-nanoAUV. The untethered nanoAUV will explore the ocean in vicinity of the melting probe (exploration area diameter of about 100 m), identify points of interests and take samples. These samples will be delivered to the melting probe and analyzed by a miniaturized and highly automated astrobiological laboratory, the AstroBioLab as third component.

As a first step towards a potential future mission to Europa, the demonstration of the melting probe in a terrestrial analog is crucial. Especially for the goal of reaching and exploring a deep subglacial lake, Antarctica is an ideal test environment for such a probe. One possible location to conduct such a test is the Dome-C region. This test site requires a deep field camp, a high logistical effort and very high requirements on the TRIPLE system. At this location, the system needs to penetrate 3 to 4 km of ice and sustain the pressure under the ice cover. The terrestrial analog demonstration is aimed to be conducted during one Antarctic season, which requires a rapid melting probe with a velocity of about 10 m/h.

A melting probe, suitable for this demonstration, is not yet available. As a first step the TRIPLE-IceCraft development aims for an intermediate goal: A drill depth of several hundred meters and a drilling velocity of 3 – 5 m/h.

TRIPLE-IceCraft: The goal of the TRIPLE-IceCraft project is the development of a melting probe for the transport of standardized scientific payloads through an ice sheet. For this purpose, a modular carrier system has been developed.

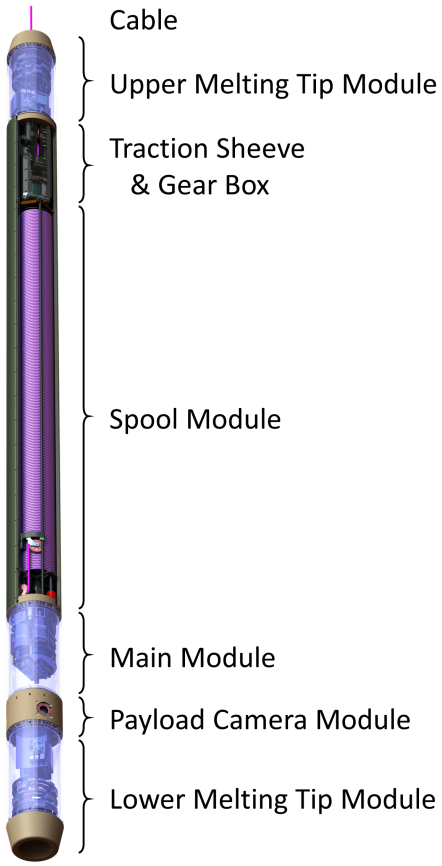

Figure 2. Scheme of the TRIPLE-IceCraft and its modules.

The system (see figure 2) consists of two efficient melting heads [4], one at the front and one at the back for retrieval and a payload segment with well defined mechanical and electrical interfaces. The carrier system was designed and built to penetrate several hundred meters of ice. At the same time, tehe development also focuses on the transferability to much thicker ice layers. This applies in particular to those systems that have a major impact on the scalability of melting probes, such as cable management, power supply and communication.

The TRIPLE-IceCraft has a diameter of 20 cm and a length of around 4 m. It consists of several watertight pressure vessels, the winch module, and the melting heads. Each melting head is equipped with electro-thermal heating cartridges with a total power of about 20 kW. The cable is included in a separate compartment and bears the weight of the probe and is used for communication and power. The cable is coiled inside the probe on an electric-motor-powered coil. This allows the refreezing of the melt hole including the cable, so it can be operated even in cold glacial ice.

The probe and the payload can be controlled and monitored via a data link from the surface. All telemetry data is stored there for later analysis. The surface equipment includes a computer interface, a power supply and a launch pad for the probe.

The payload module hosts the scientific payloads. To ensure that failures of the scientific payload will not affect the TRIPLE-IceCraft itself, the module is sealed by watertight bulkheads, and the communication and power interfaces can be controlled and decoupled individually. Standardized interfaces for voltage supply and communication are provided by the payload supply module. For the first demonstration in Antarctica, the TRIPLE-IceCraft is equipped with a payload camera module. The module contains three cameras and lights, to capture pictures of the icy sidewalls of the melted hole and from within the subglacial water reservoir as well. For the future, it is foreseen to integrate the TRIPLE-nanoAUV, its docking mechanism and other scientific payload.

Test in Antarctic Ice: The first Antarctic test of the TRIPLE-IceCraft was conducted close to the German research station Neumayer Station III [5] located on the Ekström Ice Shelf. The station provides all needed infrastructure. Due to the transportation of the TRIPLE-IceCraft and the support equipment via the research vessel Polarstern, the time window for the operation was February 2023. To handle and operate the melting probe, four scientists and engineers traveled to the site at the end of January.

The thickness of the ice shelf at Neumayer Station III is approximately 250 m. North of the station the ice thickness reduces down to approximately 80 m at the ice shelf edge next to the ocean. The ice temperature is between -25°C near the surface and -2°C at the ice-water interface.

Next to the station, all (sub-)systems were tested and a first drill was conducted. About 1 km next to the ice shelf edge we drilled down to approximately 25 m. We achieved a melting speed of up to 3,5 m/h. The speed was mainly limited due to power transfer restrictions to not overheat the melting probes main cable during drilling, since the melt water was draining out of the boreholes. In larger depth the water will stay within the hole, cooling the cable and allowing higher power transfer to the probe. A second test campaign is scheduled for the Antarctic season in 2023/2024 to reach the ocean below the ice shelf.

In this contribution we present the overall system design of the TRIPLE-IceCraft melting probe and first results from the February 2023 demonstration test in Antarctica.

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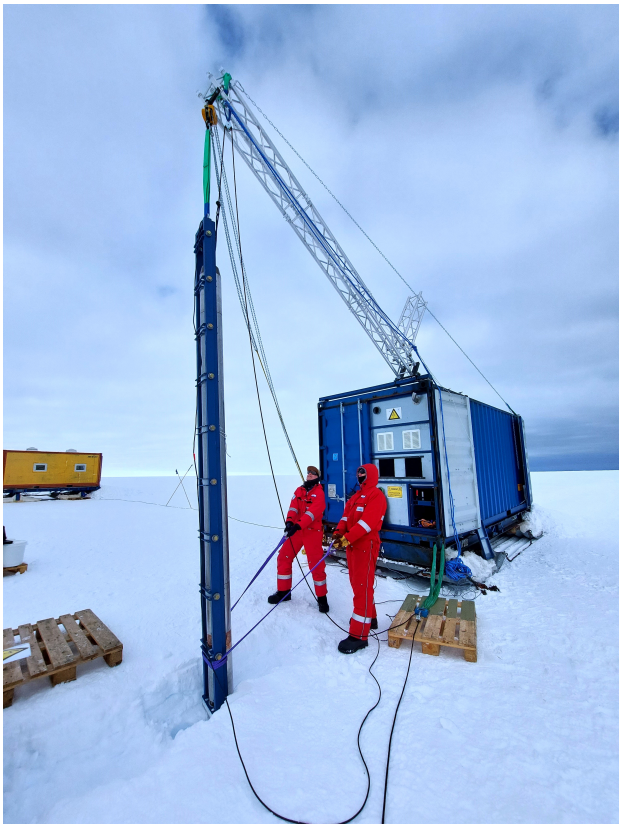

Figure 3. Deployment of the TRIPLE-IceCraft during the test at the Ekström Ice Shelf.

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