Icefin: A New AUV/ROV for Sub-Ice Exploration on Earth and Europa

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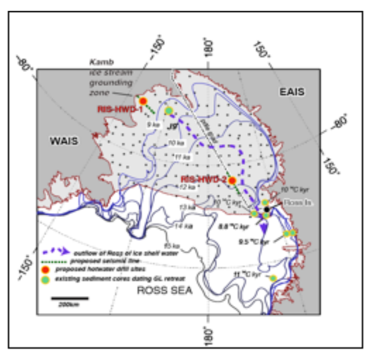

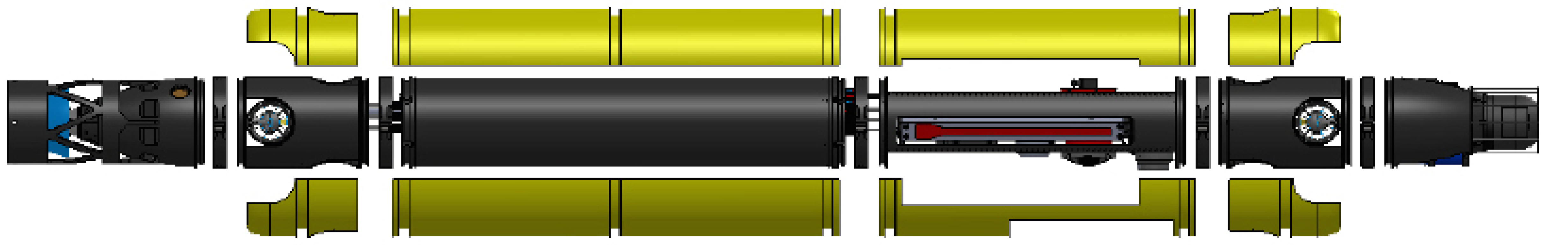

Fig. 1 - Exploded assembly view of Icefin with oceanographic survey package

Introduction

Icefin is a modular, field-portable remotely operated vehicle (ROV) designed as a long-range, and deep water under-ice robotic oceanographer that can survey cavity geometry, ice properties and ocean conditions beneath floating ice that are not resolvable in remotely-sensed observations or using localized mooring data. It was designed and built at Georgia Tech, under Dr. B. E. Schmidt's startup funds with effort contributed from the Georgia Tech Research Institute (GTRI). Icefin's unique design provides greater capability and improved operational simplicity relative to large vehicles. Icefin is optimized by modularity: the vehicle consists of detachable sections containing the thrusters, power and electronics, and multiple sensor bays, with a main sensing module that can be oriented up or down depending upon the mission. Here, vehicle control and data systems can be stably developed and power modules added or subtracted for mission flexibility, while multiple sensor bays can be developed and/or installed to serve multiple science objectives. As opposed to larger vehicles which require much greater logistical infrastructure with much larger costs, the relatively small, modular Icefin can be deployed through small holes drilled in the ice.

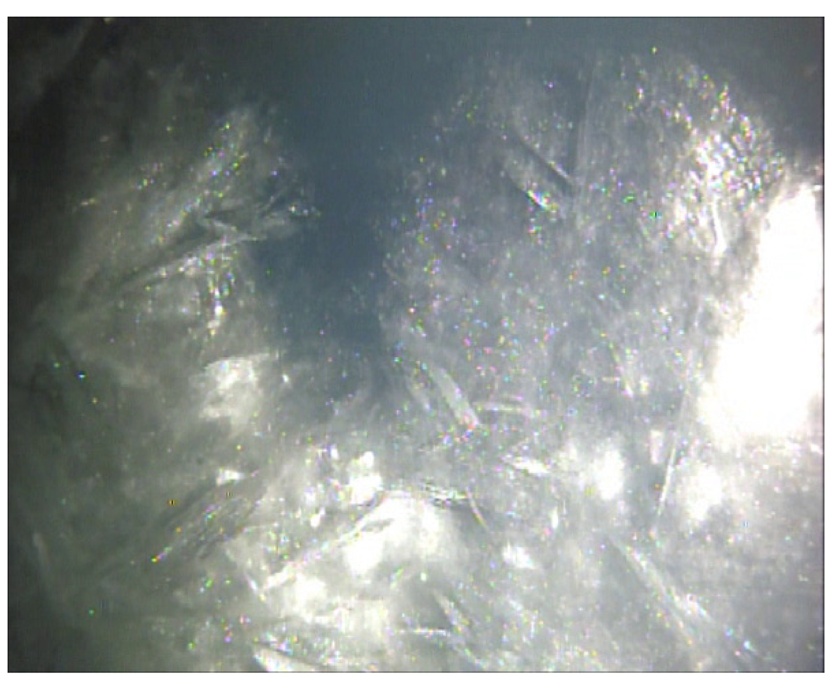

Fig. 2 - Basal surface of the McMurdo Ice Shelf taken by Icefin showing accreting frazil ice crystals

Methods & Materials

The design of Icefin began with specifications for desired scientific metrics necessary to characterize the under-ice environment. Along with the scientific drivers, the main mechanical drivers of Icefin were to be easily portable to and from drill site and capable of diving up to 1500 m through a 35 cm hole drilled in the ice.

The engineering team then designed a vehicle that met these requirements while maximizing portability and customization necessary to accommodate different payloads. Commercial off the shelf parts (COTS) were integrated into a custom-designed module to achieve the science goals.

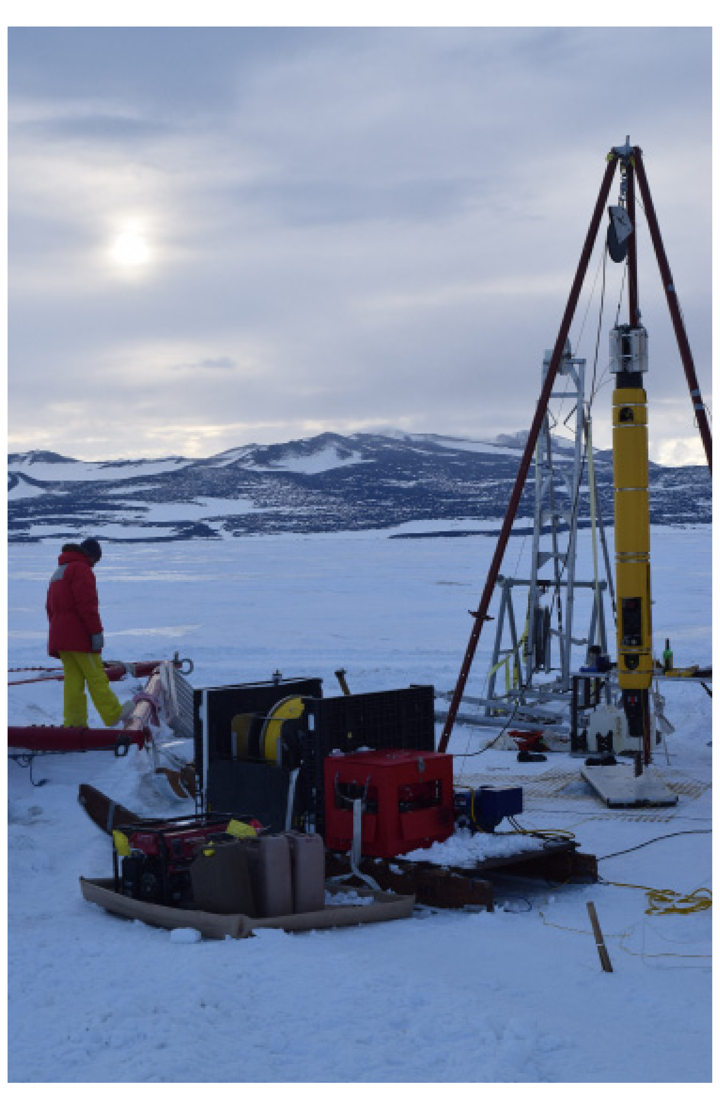

Fig. 3 - View of Icefin above the Ross Ice Shelf prior to deployment

Results

Using these constraints, a modular low profile torpedo shape design was selected for the vehicle. The modular design allows for each section to be broken down for transport to the field as well as rapid integration of different science modules. The fully assembled Icefin is 26 cm in diameter, 3 m in length and weights 109 kg. As shown in Figure 1 above, the current modules include a front nose cone, two vertical/horizontal thruster modules, survey module, sealed electronics module and rear propulsion module all encased in a layer of syntactic foam. This modular design is robust to failures and allows for rapid integration of science modules.

Propulsion - Five thrusters (two vertical, two horizontal and one rear) are used to control the vehicle in five degrees of freedom as well as hovering capability. An inertial measuring unit (IMU) allows position, orientation and velocity estimation.

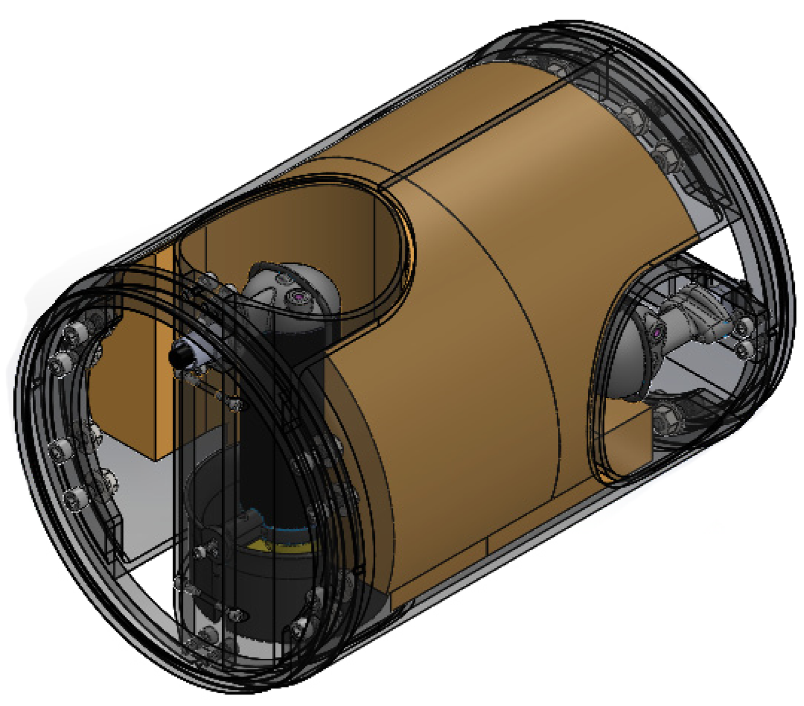

Fig. 4 - Thruster module with syntactic foam

Sensor Suite - Icefin is currently fitted with sensors for scientific analysis of the ice-ocean system including, a sensor bay with Side Scan Sonar (SSS), Dopplar Velocity Log (DVL) with current profiler, altimeter, and imaging sonar. This sensor bay may be pointed in the down position for ocean bottom mapping or in the upward position for topographical ice mapping. The forward module includes a forward looking blazed array sonar, a CTD sensor and obstacle avoidance camera.

Control & Communications - The current guidance navigation and control of the Icefin will allow for efficient collection of scientific data through the fusion of a fiber optic gyro (FOG) IMU, compass, DVL, altimeter and pressure sensor for low-level motion control and high-level localization through a XMOS communications board and Kontron. The vehicle is attached to a 3.5 km Kevlar-reinforced single optical fiber cable rated to 600 lb for communication, data retrieval, and emergency vehicle recovery.

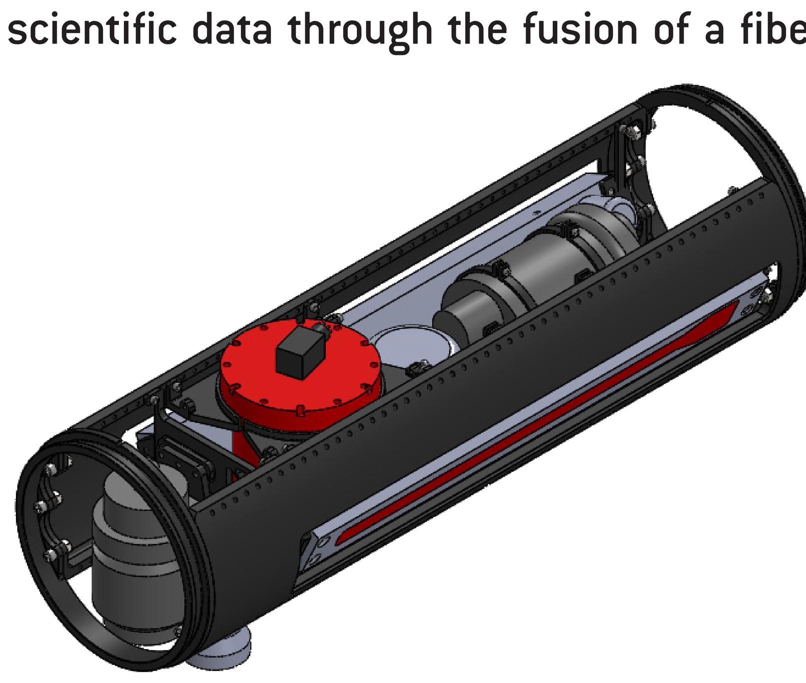

Fig. 5 - View of oceanographic instrument module

Conclusions

The first Icefin prototype has been developed and successfully operated under the McMurdo Ice Shelf near Black Island in Antarctica in Austral summer 2014. Icefin was deployed through a small hole in the Ross Ice Shelf and successfully collected sonar, imaging, video and water column data at depths up to 500 m. At the time of deployment, Icefin was the first vehicle to capture video and sonar images of the ocean floor under the Ross Ice Shelf.

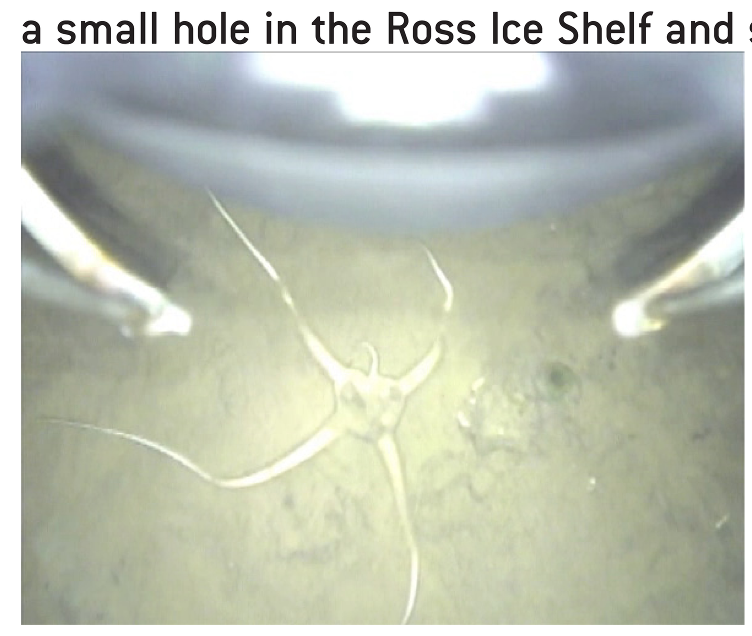

Fig. 6 - Image captured by Icefin 500 m under the Ross Ice Shelf

Future Work

To further characterize the under-ice environment multiple science modules will be built to compliment the the current oceanography focused sensor suite. A biology-focused module, shown in Figure 7, will be developed to map the horizontal and vertical distribution of dissolved gas and chemical species as well as mapping the available organic material and sediment in the water column.

In order to effectively map large areas under the ice, the endurance life of the vehicle will need to be improved. A docking station, as shown in Figure 8, is currently under developement to allow the vehicle to perform longer missions when mapping a desired area. The docking station will be lowered into the drilled hole with the vehicle attached and will release Icefin once it passes through the ice. An inductive charging system will be integrated into the docking station and will charge the vehicle without the need to resurface between missions. This will allow for more missions to be completed in less time as well as eliminating the risk of the vehicle getting stuck under the ice during retreival.

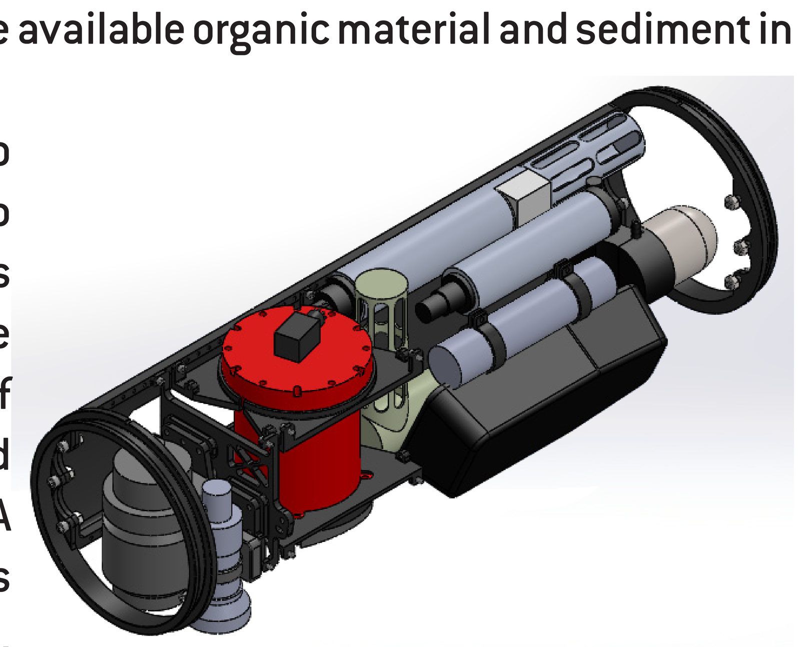

Fig. 7 - View of new biology module

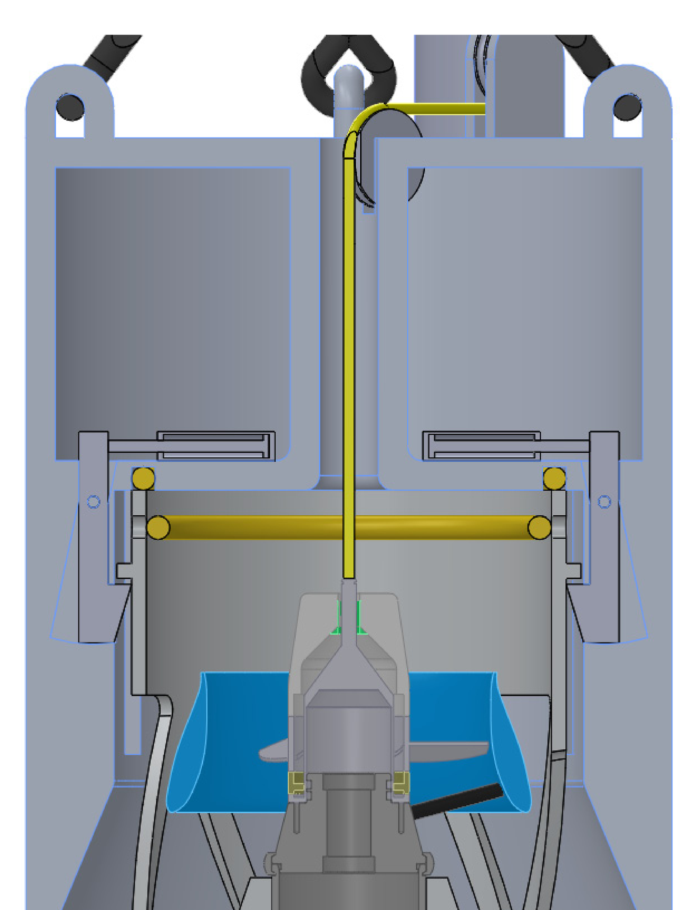

Fig. 8 - Cross-section of Icefin attached to the docking station

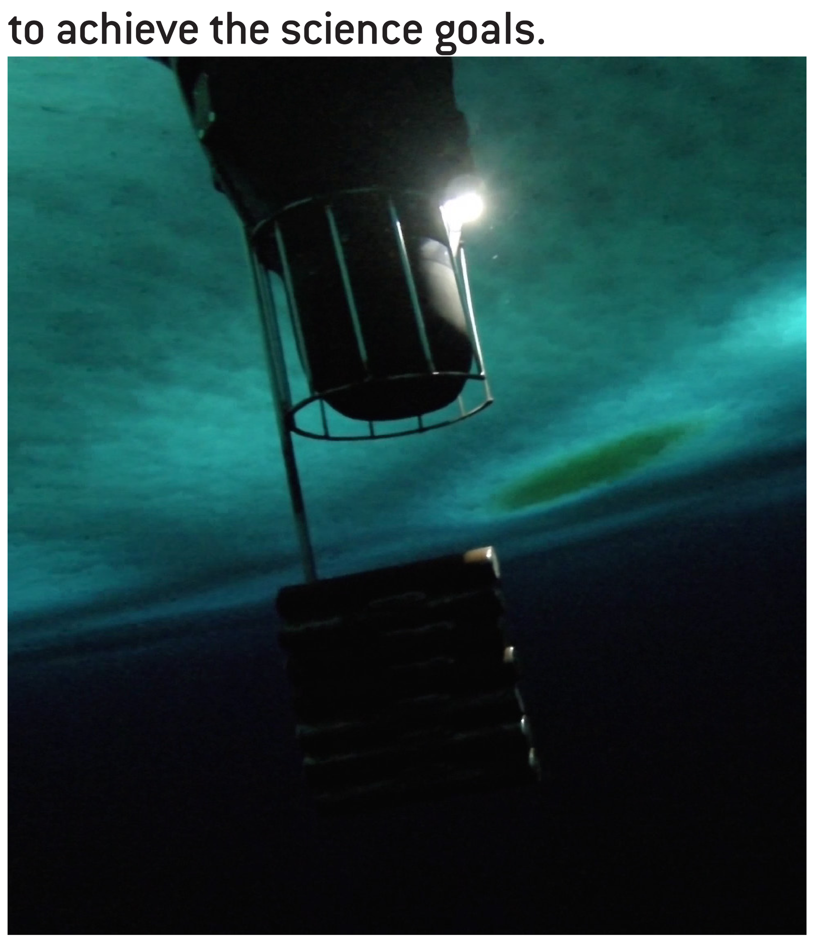

Fig. 9 - Close-up view of weight release system under the sea ice off McMurdo Station

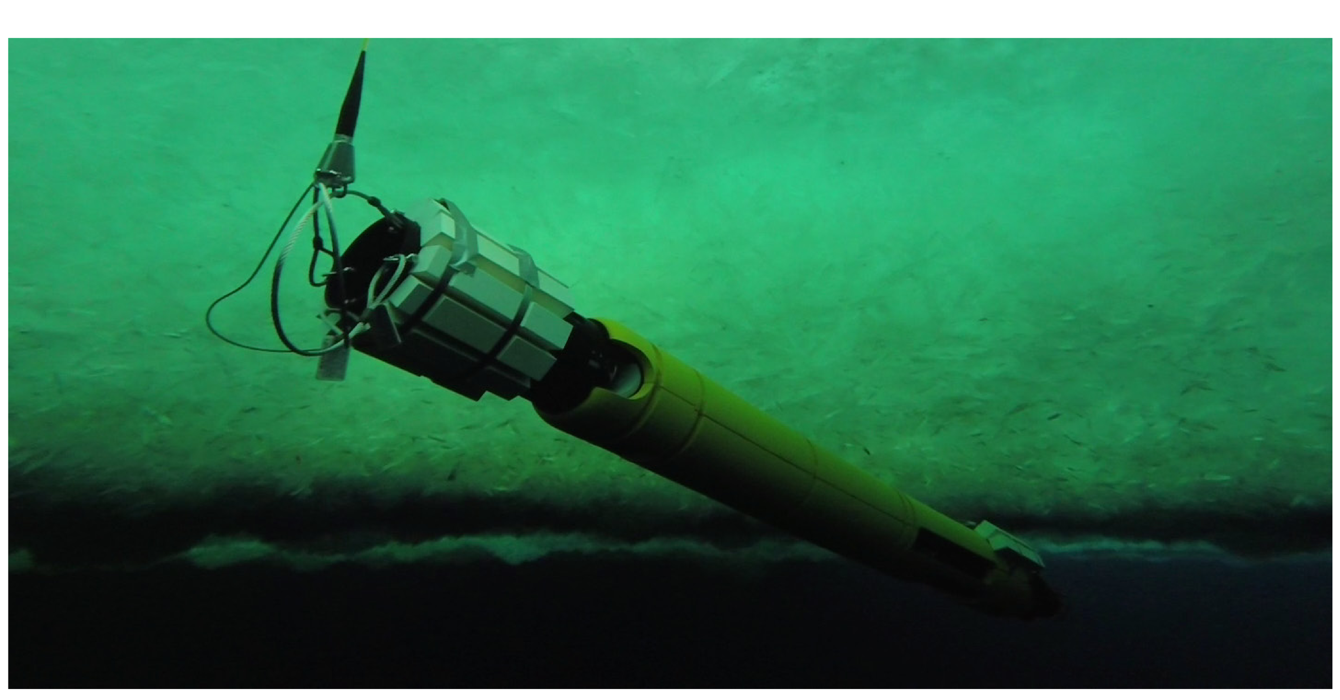

Fig. 10 - First open water systems test of Icefin under sea ice just off McMurdo Station.

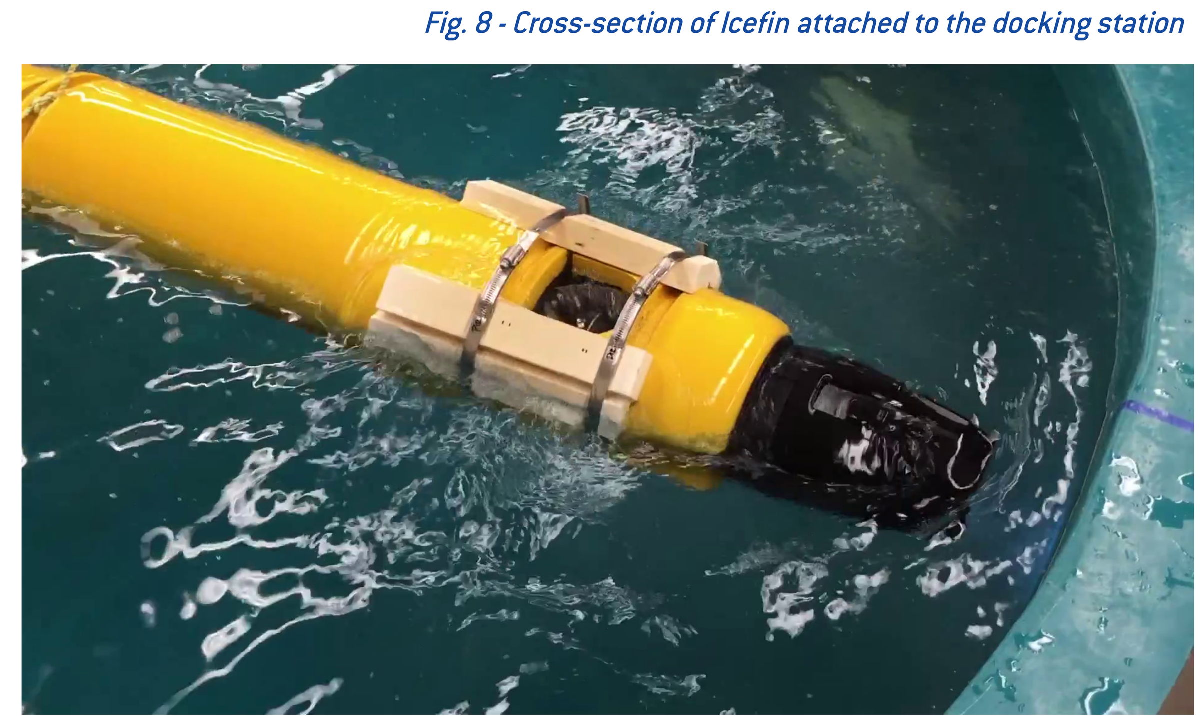

Fig. 11 - Testing of vertical thruster in test tank in the Crary Science Center

Fig. 12 - Assembled Icefin without syntactic foam.