Autonomous Underwater Vehicle Operations in the Arctic

James R. McFarlane, President

Linda Mackay, Manager, Marketing & Communications

International Submarine Engineering Ltd.

Port Coquitlam, BC Canada

Abstract

There is an increasing interest in Arctic and Antarctic studies, both from a scientific and from a commercial point of view. Due to the unpredictable climate conditions and the ice cover, as well as the difficulty conducting AUV operations with support ships due to the cost and scarcity of icebreakers and the presence of thick ice, AUVs are an ever-increasing option due to their ability to survey underneath the ice at long intervals.

With the increasing use of AUVs in unsupervised under-ice operations, users are becoming more receptive to the idea of these types of AUV missions, and the capability to do this is advancing. International Submarine Engineering Ltd is the only subsea AUV developer with the Arctic experience behind it, specifically in operational hours under the ice.

There is no doubt that the basis for ISE's successes lies in using a reliable, robust AUV and the underlying twenty years of work contributed to its development. For ISE, research deployments in the 1980's and 1990's and subsequent AUV deployments also provided background experience that was invaluable. From there, pulling off a successful under-ice deployment was essentially a matter of planning and testing.

An example of the capability of current AUVs to operate unsupervised is the high Arctic field work by two Arctic Explorer Autonomous Underwater Vehicles (AUVs) built by ISE for Natural Resources Canada (NRCan). They were deployed in 2010 and 2011 to conduct under-ice bathymetric surveys in support of Canada's sovereignty claim under the United Nations Convention on the Law of the Sea (UNCLOS). These were the first long range AUV missions to have been undertaken at high latitude, and the first in which seabed survey data was successfully gathered over long distances working from both ice camps and icebreakers.

As Autonomous Underwater Vehicles (AUVs) are now exploring more challenging terrain than ever, the need for an obstacle avoidance system has become apparent. Obstacle avoidance systems (OAS) in unmanned systems are far from new. However, adapting existing methodologies to AUVs presents a new set of challenges.

Last year, International Submarine Engineering Ltd (ISE) tackled the task of adding an OAS to its line of Explorer AUVs. ISE's experience with obstacle avoidance strategies started in 1985 when the technology was added to ARCS, ISE's first AUV. ISE is the only company in the world with proven under the ice capability using AUVs.

Some AUV History

ARCS

978-0-933957-43-5 ©2015 MTS

The first Canadian AUV developed was ARCS in 1982. Built by ISE as a progenitor for larger AUVS and as a technology test bed. ARCS has 18 years of productive service and more than 800 dives. Its operational depth is 1000 meters, and has a nominal payload capacity of 227 kg. ARCS was the first ever AUV to perform a seabed survey (with a single beam echo sounder) and performed the very first obstacle avoidance capability. ARCS paved the way for the next purposed built AUV, Theseus.

Some of the key development areas that were tested with ARCS were:

- Fuel cell testing and integration;
- Fiber optic cable deployment;
- Navigation systems;
- Mission controllers;
- Variable ballast systems; and
- Integration of a mass spectrometer.

ARCS was the first the world’s first AUV to operate in a truly autonomous manner. During its operational lifespan it was modified and used for a variety of developmental trials to validate new designs and test the integration of new sensors. These included navigation algorithms, mine countermeasures surveys, long range mission development and fuel cell trials. ARCS was also used to develop an iceberg mapping and profiling system, as well as to evaluate new AUV sensors – one significant integration being a mass spectrometer.

In 2002, ISE got together with Applied Microsystems Ltd., from Sidney, BC and successfully demonstrated the integration of AML’s underwater mass spectrometer using ARCS. Field tests were performed in Burrard Inlet, to map dimethyl sulphide plumes from a controlled release in the Inlet. The low power compact design of the spectrometer integrated very well with the AUV, and gave the user increased sampling speed and data density ideal for gradient mapping while eliminating sample contamination.

Theseus AUV – The Large Body

Starting in 1992, ISE and the Esquimalt Defence Research Detachment of Defence Research Establishment Atlantic (now DRDC) worked together to develop a large autonomous underwater vehicle for laying fiber-optic cables in ice-covered waters. The vehicle, named Theseus, was designed to lay up to 220 km of fiber-optic cable from a site near the shore of Ellesmere Island in the Canadian Arctic islands to a scientific acoustic array in the Arctic Ocean about 200 km from shore. The water depth along the cable route varies from 50 m at the launch site to about 600 m at the array site.

Both the environment and the complexity of the mission imposed severe constraints on the vehicle design. In the operating area the ocean is completely ice covered, mostly by multi-year ice 3.5 to 10 m thick, with ice keels that can extend to depths of 30 m within 10 km from the launch site, and 50 m further out; water currents vary from 0 to 25 cm/sec near the launch site and 0 to 10 cm/sec at the array site; air temperatures vary from -40 to -20 C; and water temperatures vary from -1 C in the shallow waters near the launch site to +4 C near the bottom at a depth of 600 m.

A vehicle endurance of 450 km was required to lay the cable, and return to the launch site. A navigational accuracy of 1% of distance traveled combined with an acoustic terminal homing system was needed to bring the vehicle through a 200 m wide cable recovery loop at the cable delivery site.

Transporting this equipment to the field was certainly a task that was highly reviewed and considered at great length. To permit air transport to the launch site, a modular construction was required with each section weighing less than 1400 kg. Since no currently available AUV could meet these specifications, ISE was awarded a contract in November 1992 to design and construct an AUV to meet the requirements.

Convenient to the development for this AUV and subsequent subsea developments is the sea trial testing that is done in local waters. For THESEUS, the testing was also done at the Canadian Forces Torpedo Firing Range at Winchelsea on Vancouver Island.
The first Arctic trials of Theseus were carried out in April 1995, in shallow ice-covered waters near Ellesmere Island. The objectives of the trials were to verify launch and recovery procedures, test all vehicle systems in an under-ice environment, and refine techniques for delivering the fiber-optic cable and bringing it up onto the ice.

Four under-ice dives were carried out. The longest individual dive covered a total distance of 5 km, and the cumulative distance for all dives was 13 km.

With testing out of the way, THESEUS carried out two main deployments in 1995 and 1996. It deployed single mode fibre optic cable covering distances of up to 200 km, with the longest mission totaling 174 km. The single strand fibre optic cable was dispensed through a pipe situated just out of the way of the propeller of the vehicle. It operated as a hybrid vehicle with full system control and monitoring (via the fibre) on the way out, then dropped the cable and returned autonomously to home base camp.

The power capability of this large AUV was immense. With its installed battery, THESEUS had a range of over 800 km. If the full space available for the batter was utilized, the range of the vehicle could have been up to 1400 km.

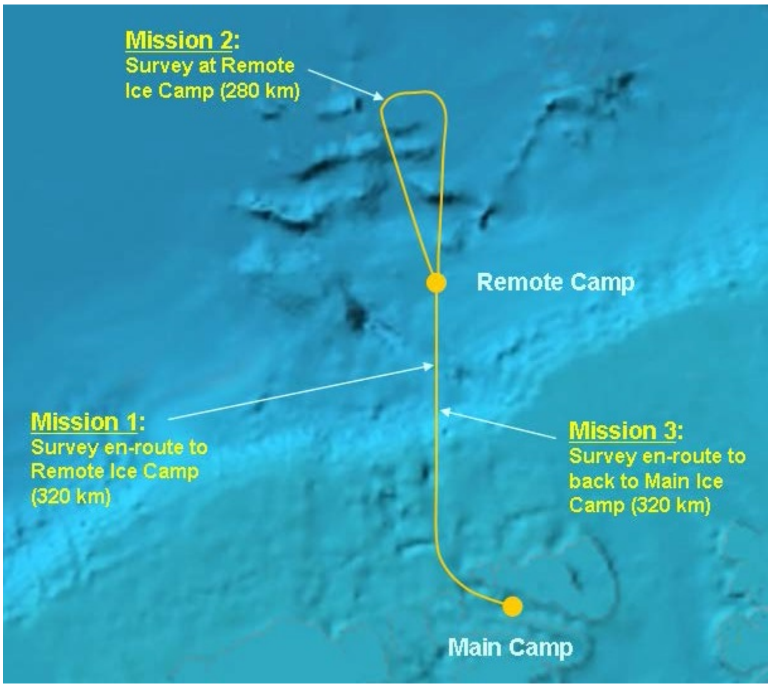
By laying the cable on the seabed, THESEUS was the first AUV to manage a variable payload. It remains as having the first unsupervised Arctic mission by an AUV, is still the largest AUV in the world, and holds the longest ever mission by a conventionally powered AUV.

ISE's AUV Family of Vehicles (Two Arctic Explorers, THESEUS, ARCs)

Explorer AUV - Arctic Endeavours

The Explorer class AUV is ISE's current baseline vehicle. Stemming from the successful developments of the vehicles described thus far, Explorer was first developed and tested in 2003. The first sale of Explorer was made to the French Oceanographic Agency, Ifremer in 2004.

Explorer AUV was a natural choice for upcoming Arctic missions with its distinct sections that allow it to accommodate additional batteries required, increasing its operational time as well as hold and easily swap out payload components. Dubbed the Arctic Explorer in this expanded configuration, ISE was ready to do work in the Arctic.



In 2010 and 2011, the ISE Arctic Explorer AUVs – two of them - built for Natural Resources Canada (NRCan), were deployed to Canada's high Arctic. The mission was to undertake under-ice bathymetric surveys supporting Canada's submission under the United Nations Convention on the Law of the Sea (UNCLOS). During these deployments several under-ice records were broken and several new technologies were demonstrated.

The Main Camp near Borden Island (78°N, 112°W) was the launch site for the AUV. It was launched from an 8 m by 3 m ice hole, cut through 2 – 3 m thick ice. To find the moving ice hole, the Arctic Explorer was equipped with a long range acoustic homing system developed by DRDC, manufactured by Omnitech Ltd., out of Nova Scotia.

The 2011 operations were conducted from the CCGS Louis St. Laurent, a Polar Class icebreaker working with the USCGS Healy. When surveying in ice, one icebreaker operates several kilometers ahead of the other as icebreaking is a very noisy operation. This allows the second ship to survey in relatively quiet waters that the 1st ship has cleared. As a rule of thumb, icebreakers can maintain a speed of 5 to 6 knots in this manner. This is faster than the AUV can operate for prolonged periods, and thus for these operations it was the primary method of survey.

After several test dives, the first mission was a transit to a Remote Camp, 320 km to the northwest. The AUV autonomously homed into the Remote Camp and was secured with the help of a small remotely operated vehicle (ROV). Without being removed from the water, it was charged and survey data was downloaded, all through a 1.3 m by 2 m ice hole. The AUV reached depths of 3160 m and transited at an average speed of 1.5 m/s at an altitude of 130 m above the seabed.

The Arctic Explorer AUVs completed 3 missions. The first was a survey and transit from the main ice camp to a remote location on a moving ice floe. The second mission was a survey around the remote camp location, and finally a return survey transit back to the main camp. During this operation, the AUV spent 10 days under ice before being successfully recovered. In total, 1000 km of under-ice survey was accomplished during the operation. This is the longest continuous operation of an AUV anywhere – under ice or under water. It is also the first arctic seabed survey conducted with an AUV.

The 2011 operations were conducted from the CCGS Louis St. Laurent, a Polar Class icebreaker working

NRCan Arctic Explorer AUV over the ice with the USCGS Healy. When surveying in ice, one icebreaker operates several kilometers ahead of the other as icebreaking is a very noisy operation. This allows the second ship to survey in relatively quiet waters that the 1st ship has cleared. As a rule of thumb, icebreakers can maintain a speed of 5 to 6 knots in this manner. This is faster than the AUV can operate for prolonged periods, and thus for these operations it was the primary method of survey.

Obstacle Avoidance

In the initial design phase using ARCS, various methods of acoustically detecting obstacles were investigated. Although some very sophisticated forward-imaging "fish-finding" sonars were available, potentially providing an equivalent to stereo vision, more research was needed to achieve the end result that was desired to identify a true objective form. Standard CFTM scanning sonars commonly used for collision avoidance in manned submersibles did not have the straight-forward computer interfaces. In order to simplify the computer interface and processing tasks, the concept of acoustic" whiskers was adopted. Essentially, eight forward-looking echo sounder transducers were mounted on the front, or within the nose of the vehicle.

For THESEUS' missions in the Arctic, it was determined at the time that an obstacle-avoidance sonar (OAS) system would be required to ensure that the vehicle would not hit uncharted bottom features or ice keels, which in the mission can extend to a depth of 50 m. Acoustic telemetry was also considered essential for communication with the vehicle. To achieve the navigational accuracy of the distance traveled, a ring laser gyro Inertial Navigation Unit (INU) was selected for heading reference, and a bottom-tracking Doppler sonar for ground speed. A provision was also included to allow the vehicle to update its position at acoustic beacons located along the route and also at the cable delivery site.

It makes sense to apply the OAS technology to the Explorer class of AUVs, of which ISE is working to expand upon with this proven line of vehicles.

In Summary

With the clear examples of AUV capabilities in the Arctic that have demonstrated the feasibility of surveying in ice covered conditions, as well as tackling the logistics of equipment transport, assembly and all other variables that come into the picture, it would be prudent to venture into other ice covered areas such as the Antarctic in order to exercise these capabilities quickly. Another favorable aspect to moving quickly in order to disseminate capability is that personnel are currently trained, and able to effectively transfer the technical and operational knowledge of working in the Arctic with AUVs.

BIOS (to follow)

James R. McFarlane, President

Linda Mackay, Manager, Marketing & Communications

International Submarine Engineering Ltd. – Corporate Profile (to follow)

Email: lmackay@ise.bc.ca