THE INDUSTRY'S RECOGNIZED AUTHORITY FOR DESIGN, ENGINEERING AND APPLICATION OF EQUIPMENT AND SERVICES IN THE GLOBAL OCEAN COMMUNITY

MAY 2013

SINGLE ISSUE PRICE $4.50

SEA TECHNOLOGY

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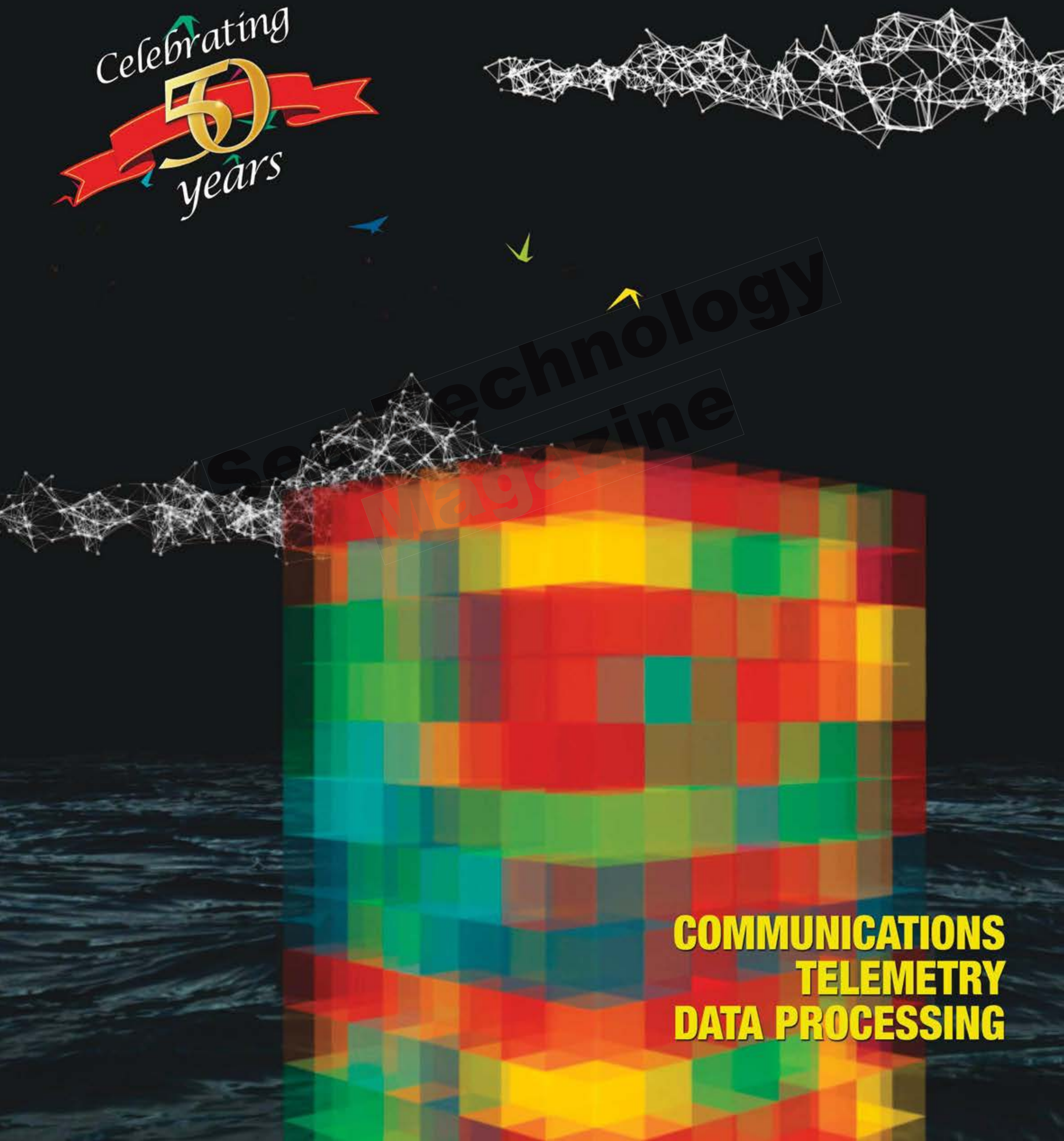

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AUVs Survey The Canadian Arctic

ISE's Arctic AUVs Evolve to Conduct Under-Ice Missions

By Dr. James McFarlane • Raymond F. Murphy

As a Canadian manufacturer involved in the development of subsea technology, the ice-covered Canadian Arctic became a natural priority for Port Coquitlam, Canada-based International Submarine Engineering Ltd. (ISE) and its AUV program. ISE has carried out numerous Arctic operations since the program began.

ARCS

ISE's first AUV was built in 1983 and was named ARCS. It was originally intended to be used for a survey of the approaches to Bridport Inlet in Viscount Melville Sound as part of a Canadian government plan to establish an LNG port in the area. When this project was abandoned, ARCS was used as a test bed for technology that would be used in future under-ice missions.

Between 1985 and 1991, extensive testing of various batteries, control systems, acoustic modems, obstacle-avoidance strategies and payload modules was undertaken to support the design of future AUVs.

Later, ARCS was also used to develop the fiber-optic cable laying strategy that would be used on a larger AUV.

Theseus

ISE's first large-diameter AUV, Theseus, was the first AUV to lay fiber-optic cable on the seabed. This was the first instance of cable laying with an AUV anywhere—in open water or under ice.

The AUV was named after the mythical founder-king of Athens, son of Aegeus and Poseidon (god of the sea). Theseus laid thread in the labyrinth built by Daedalus, enabling him to escape with Ariadne, the daughter of Minos, king of Crete, after slaying the Minotaur.

The Theseus program began at ISE in 1985 as part of a Canada-U.S. program to lay cable under Arctic ice. ISE and the Defence Research Establishment Pacific (DREP) of Canada's Department of National Defence worked together to develop a large AUV for laying cable from a site near the shore of Ellesmere Island in the Canadian Arctic to a scientific acoustic array in the Arctic Ocean about 200 kilometers from shore. Two under-ice cable-laying missions were con-

Explorer AUVs on ISE's RV Researcher *in Nanoose Bay during sea trials, just prior to the 2010 missions in the Arctic. (Photo Credit: ISE Ltd.)*

ducted from Ellesmere Island in 1996 in water depths that varied from 50 meters at the launch site to about 600 meters at the array site.

Theseus is 10.8 meters long, has a diameter of 1.28 meters and a depth rating of 2,000 meters. Its large size is driven by the volume and buoyancy requirements of the fiber-optic cable payload. With the full payload of 220 kilometers of cable, the weight of the vehicle is 8,600 kilograms. Theseus is powered by silver-zinc batteries and can reach speeds of 7 knots. At its designed cruising speed of 3.7 knots, the range is 920 kilometers.

An endurance of at least 450 kilometers was required to lay the cable, allowing a return to the launch site and providing some reasonable margin for contingencies. A navigational accuracy of 1 percent of distance traveled, combined with a terminal homing range of 3 kilometers was needed to navigate the vehicle as it laid a 200-meter-long cable.

On the Arctic deployment, Theseus completed two long under-ice missions, one of which was 460 kilometers in length—a record that still holds today. Navigational accuracy of the vehicle on average was 0.4 percent of the distance traveled.

The Arctic operating environment is harsh. In 1996, the area of the ocean in which Theseus operated was completely ice covered, mostly by multiyear ice 3.5 to 10 meters thick, with ice keels extended to depths of 50 meters, water currents up to 25 centimeters per second and air temperatures of -40° C. Water temperature varied from -1° C at the launch site to 4° C near the bottom at the terminus.

Theseus was transported to the Arctic in modular sections, which were delivered by helicopter to the final assembly point on the ice. It was reassembled in a large hut on the ice pack and then lowered through 3-meter-thick ice. Programmed to lay fiber-optic cable along a preplanned route, Theseus proceeded with its mission, following the sea bottom at an altitude of 20 to 50 meters.

While a full duplex communications link existed through the cable on the outbound leg, the vehicle was autonomous on the return leg. The total mission times were 63 and 52 hours, during which a total of 398 kilometers of cable was laid.

Explorer

Following market research and further study in the late 1990s, ISE determined that there was a need for smaller AUVs in the range of 4 to 6 meters long. Production was begun on the Explorer-class AUVs in 2003. The first of these vehicles was delivered to France's ocean research institute, Ifremer, followed with a similar vehicle for Memorial University of Newfoundland, and another for the University of Southern Mississippi for scientific research in the Gulf of Mexico. The experience with these AUVs provided confidence to build deeper-diving, longer-range AUVs.

In 2008, ISE began production of the Arctic Explorer-class of AUVs. These vehicles were used in 2010 and 2011 for missions in the Canadian Arctic. Their specific task was to obtain data that supported Canada's submission to the In-

(Top) An Explorer under-ice AUV at work in the Arctic in 2010. (Photo Credit: Defence Research and Development Canada)

Explorer AUVs at ISE headquarters in Canada. (Photo Credit: ISE Ltd.)

"In 1996, the area of the ocean in which Theseus operated was completely ice covered."

ternational Seabed Authority under the provisions of the United Nations Convention on the Law of the Sea Article 76. They were tested in local waters in greater Vancouver, Canada, and on the torpedo firing range at Nanoose in British Columbia.

Two missions were conducted, both under the direction and management of Natural Resources Canada. The first mission in 2010 consisted of transporting an Explorer vehicle in modular sections to the ice camp south of Borden Island in the Arctic. After reassembly and testing at the site, the vehicle was programmed and sent on missions that would terminate at an advance base camp approximately 375 kilometers further north. The advance base was located on drifting ice, which moved an average of 4.0 kilometers a day.

Using a long-range homing system, the vehicle listened for a beacon and homed in on it. Below the advance-base ice hole, the vehicle mated with a capture device. This device, designed by Memorial University, Defence Research and Development Canada, and ISE, was used to recharge the vehicle and simultaneously upload the data that had been collected. Then, with a new mission loaded to the vehicle's onboard computer, it proceeded to the next leg. A total of three legs were completed before weather terminated the operation. At this point, the AUV had traveled more than 1,100 kilometers in a 10-day period under the ice.

A second mission commenced in 2011 that involved operating vehicles from Canada's icebreaker CCGS *Louis S. St-Laurent*, which was accompanied by the U.S. icebreaker USCG *Healy* (*Sea Technology*, October 2012). Successful operations were conducted in two areas—one less than 100 nautical miles from the North Pole to depths of 3,600 meters and the other in the vicinity of the 2010 missions. These missions were shorter than those conducted in 2010, but they were conducted in conditions that were more challenging. The operations near the pole are particularly noteworthy as they provided the team with experience in operating inertial navigation systems at very high latitudes.

Conclusion

The 1996 and 2010-2011 Arctic AUV deployments clearly demonstrated the feasibility of surveying ice-covered polar regions with unmanned and autonomous vehicles. Government and industry operators worked together to develop plans and procedures, modify equipment and train the personnel needed for the job.

At the end of each deployment, a competent under-ice survey capability existed. The danger lies in not continuing to exercise this, which would result in capability lapse. Personnel would move on to other work, the equipment would rust and ultimately become obsolete, and the Arctic surveying experience would be lost.

Given that the grant of seabed under the United Nations Convention on the Law of the Sea Article 76 comes with the responsibility to manage and regulate the use of the seabed, it makes sense to continue with survey operations that would ultimately provide the seabed database upon which a management plan could be based. ■

Dr. James McFarlane is the president of ISE Ltd. He founded the company in 1974 to build ROVs. He has been a part of engineering teams that have built more than 400 robotic manipulators and more than 240 vehicles. He is an Officer of the Order of Canada and a member of the Canadian Academy of Engineering, Sigma Xi, Marine Technology Society, Institute of Electrical and Electronics Engineers, and the Mine Warfare Association.

Raymond F. Murphy is the marketing and business development manager of ISE Ltd. He spent nearly 30 years with the U.S. Navy as a specialist in antisubmarine warfare, and submerged vehicle performance and evaluation. He joined ISE in 2002 and has the task of connecting ISE to various navies for the purpose of enhancing their underwater equipment.