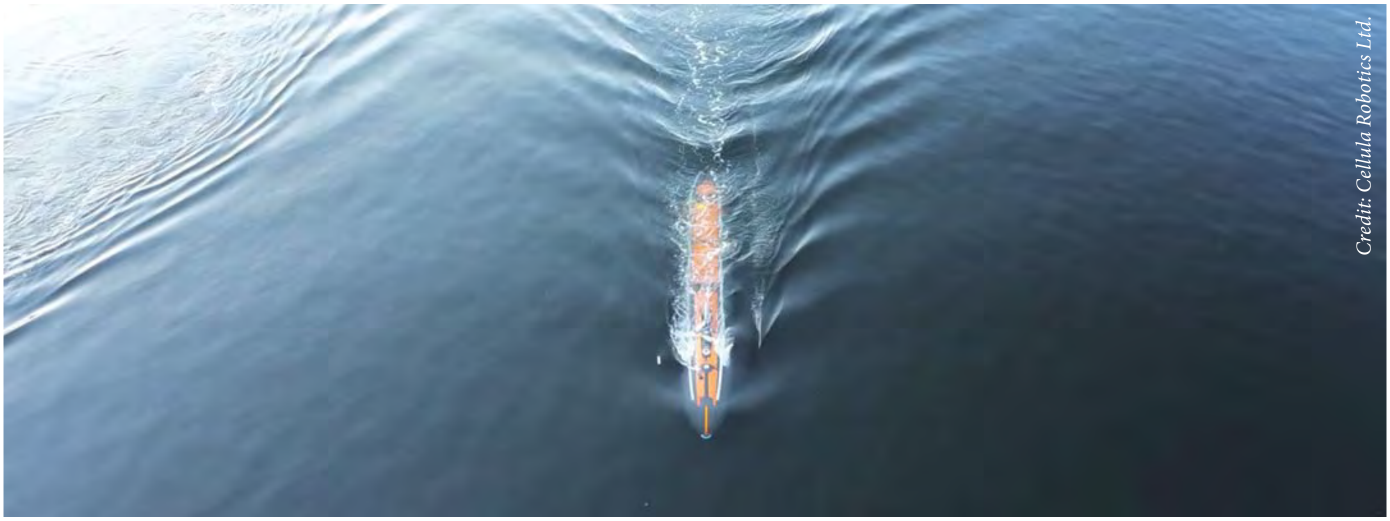
A Discussion with Richard Mills of Cellula Robotics



A Cellula Robotics Autonomous Underwater Vehicle operates just below the surface of unidentified waters.

In March, Ann Griffiths, Editor of *Canadian Naval Review*, exchanged emails with Richard Mills, Chief Commercial Officer of Cellula Robotics Canada. Because of scheduling, Mr. Mills was unable to sit down with *CNR* but answered questions that were posed via email. This is a summary of the discussion.

CNR: Technology is changing rapidly. Thus far, Uncrewed Surface Vessels (USVs) and Aerial Vessels (UAVs) have dominated the technology. How is the technology for Uncrewed Underwater Vessels (UUVs) coming along?

Richard Mills: UUVs and Autonomous Underwater Vessels (AUVs) have been around for longer than most people are probably aware of. The first recognisable UUV was built in 1957 by the University of Washington Applied Physics Lab as part of a US Navy funded project. It was called the Self Propelled Underwater Research Vehicle (SPURV). After that, there was a bit of a hiatus until 1980 when Ifremer, the French oceanographic research institute, launched Epaulard. International Submarine Engineering Ltd. then followed with Canada's first UUV, the Autonomous Remote Controlled Submarine (ARCS). Commercially, there are now about 12 companies globally which build vehicles in volume.

To date, there have been approximately 2,700-3,000 UUVs built. That includes everything from micro-UUVs right through to the Boeing Orca XLUUV. Some of the smallest vehicles are about 50 cm long, weighing in at just 7 kilograms. On the other end of the scale, the Orca is 26 metres long with the optional payload bay. The exact number of AUVs is difficult to accurately identify. The majority of these systems have been smaller, shallow-rated UUVs, but more exquisite, deep-water vehicles are also growing in prominence.

CNR: I understand that sub-surface vessels can be very useful to militaries. For what purposes can they be used?

RM: They are used for geophysical survey, scientific research and exploration, and of course, various defence applications. Most people associate military UUVs with mine countermeasures operations or route clearance, but they are also used for seabed warfare tasks, Intelligent Preparation of the Environment (IPoE) and Rapid Environmental Assessment (REA). The payload sensors and vehicle capabilities are very similar to those required for commercial survey operations. It has been commercial and scientific users that have largely driven the development path for cruising, survey-grade UUVs.

Until very recently, the majority of tasks have been focused on those survey-type missions and data collection. Now the user community is also investigating how AUVs may be able to deliver capability rather than just gather data. For example, a lot of work has been done to develop a surface intelligence, surveillance and reconnaissance (ISR) and electronic intelligence (ELINT) concept of operations using long-range UUVs that can enter an environment covertly, gather data using surface sensors, process and transmit information via secure communications links, and then egress safely.

The advent of larger platforms also allows users to deploy off-platform payload at very long ranges. This opens new opportunities to conduct offensive operations at reach. In essence, as capital programs become more and more expensive, and the risks associated with an ever-changing geopolitical situation, the desire to use uncrewed and autonomous assets means that more uses are being discussed all the time.

The threat to critical undersea infrastructure seen in Europe is also driving the development and adoption of UUV technology. Inspecting pipelines, cables, harbours, refineries and so on must be done regularly to achieve a reasonable confidence in detecting anomalies or threats. Again, the hardware is similar to that used in commercial survey, but linear features like cables require long-range capabilities such as the Canadian-developed Envoy AUV.

***CNR*:** There has been a long history of Canadian efforts in this field, much of which has been based in British Columbia. A number of vehicles have been produced and tested in the Arctic in support of the charting effort associated with the Arctic claims (amongst other things). Can UUV systems be operated regularly and effectively in the Arctic, have they been tested in ice edge or under-ice conditions?

RM: Canada has a long history of Arctic exploration using UUVs. In the 1990s, the joint US-Canadian Project Spinnaker was undertaken to lay a fibre-optic cable as a part of a now-declassified Arctic listening system. This spawned Theseus, the world's first XLUUV. Designed and built by International Submarine Engineering (ISE), it measured 10 metres long, 1.5 m diameter and it conducted a 220 kilometre mission to deploy the fibre cable under ice. The size was simply a design consideration due to the bend radius of the fibre cable and the amount of silver-zinc batteries required to achieve the mission.

In the late 2000s and early 2010s, ISE returned to the Arctic as part of Natural Resources Canada's submission under the UN Convention on the Law of the Sea (UNCLOS) Continental Shelf Extension Project. Two Arctic Explorer-class AUVs were built to map areas under ice as far as 88 degrees North.

Surveying, or exploring under ice is perhaps one of the most challenging environments for a UUV. Taking into account the high latitudes, as well as the inability to surface should something go wrong, then mission success is never quite guaranteed. As part of the UNCLOS work, specialists were brought in from Canada, France, New Zealand and the United Kingdom to assist with modeling success rates. To this day, those missions are exemplars of how to succeed. Many UUVs have been lost in the Arctic and Antarctic and remain in semi-permanent cold storage.

***CNR*:** To what extent are uncrewed sub-surface vessels affecting warfare? We've seen in the Black Sea that relatively cheap uncrewed surface vessels can be effective in countering traditional warships. What about UUVs?

RM: Ukraine is one example where rapid prototyping has changed how wars are fought. Asymmetric capability enables the implementation of different tactics, and UUVs are increasingly being used in offensive operations. Away from Ukraine, the Houthis in Yemen have used simple UUVs to target commercial shipping in the Red Sea in an attempt to close international waters and influence the situation in the Middle East.

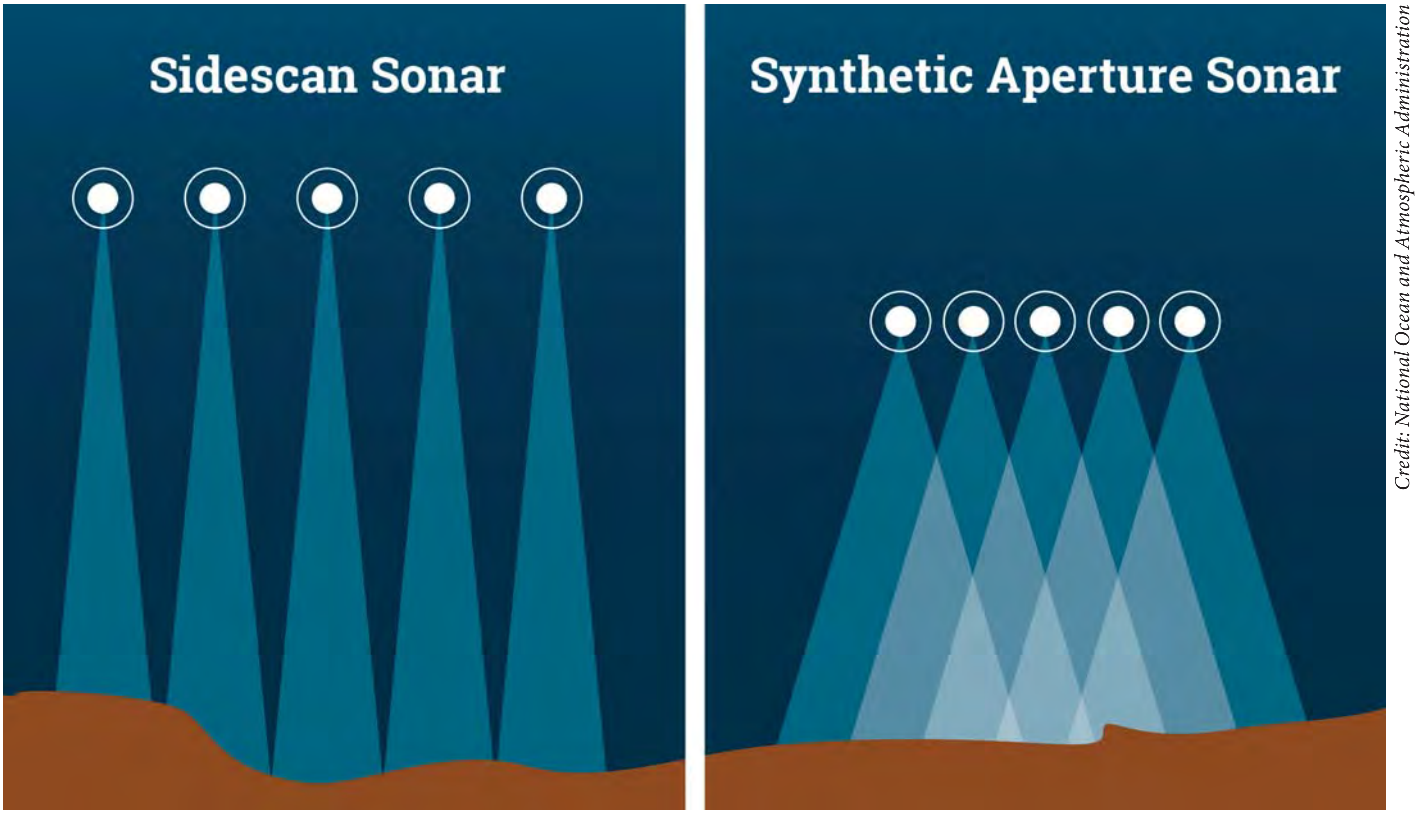
The acceptance of attrition – i.e., how acceptable the loss of vessels is – is key to being able either to deploy assets in a contested environment, or to deliver an effector at low financial risk. There are a few ways to achieve that. You can achieve it either through reduced complexity and thereby cost, or build in volume. We are not yet there with volume, and by limiting complexity, we also limit the possibility of positive mission outcomes.

***CNR*:** What is your vision of the place of uncrewed vessels, Artificial Intelligence (AI) and robotics in the maritime domain in the future? Are there any existing or emerging standards for their incorporation in naval operations?

RM: The acceptance of uncrewed systems is growing in all domains, from the wingman concept of UAVs, to large transport-style USVs and also UUVs. One of the driving factors of these systems is interoperability. That means

Credit: Bruce Butler, Wikimedia Commons

A photo of the AUV Theseus prior to leaving International Submarine Engineering on its first sea trials in August 1994.



A simple illustration of the difference between traditional side-scan sonars and modern synthetic aperture sonars which provide higher resolution images.

that standards are becoming essential. Whether those standards are focused on how UxVs[1] operate or how they are integrated with combat management systems, common architecture is here to stay.

The majority of autonomous systems have what is known as a condition-based decision matrix with hierarchical layers of safety applied to them. Basically, that means If This Then That (IfTTT). This is a common approach to navigational, or event-based autonomy and is quite predictable as a result. AI is applied to mission autonomy where adaptive capability requires large volumes of data handling and processing.

A good example of AI in UUVs is mine countermeasures (MCM). In this case, a UUV would carry a high-quality side-looking sonar, such as a Synthetic Aperture Sonar (SAS). Most SAS systems collect real aperture side-scan data in real-time. They then process the return many times, extending the length of the array through software to generate a very high-resolution image of the seabed. These data volumes are enormous, and manual processing takes a very long time.

In-mission SAS data can be analysed on-board the vehicle using Automatic Target Recognition (ATR) algorithms. Some ATR systems use machine learning heuristic algorithms to detect objects of interest and assign a measure of confidence to them. These objects can then be inserted into a revised mission plan on the fly, and the UUV can return to collect photographs of the targets. The result is in-mission detection, classification and identification of mines using AI processing.

CNR**:** Given Canada's geography – i.e., bordered by vast oceans – what would the navy do with UUVs in Canada's ocean territory. In other words, uncrewed systems have worked well in conflict in maritime areas that are limited in size like the Black Sea, but would they be useful to Canada in the open oceans off its coasts?

RM: Canada's coastline is not only very long, but part of it is also inaccessible for much of the year due to ice coverage. One only has to look at the limits of battery-powered UUVs or the XLUUV concept with a diesel-electric power plant that requires the vehicle to surface regularly to charge the on-board batteries. These can work for some applications, but the distances covered will be relatively small as a result of their limitations.

One thing that is being developed rapidly in Canada is the use of fuel cells to overcome some of the challenges posed by conventionally powered UUVs. Some of this has been driven by Defence Research and Development Canada (DRDC), but also by industry. Using a hydrogen-oxygen fuel cell, operational ranges can be as much as three times that of a battery vehicle for a given volume.

Small UUVs have been used inshore from the East and West Coasts predominantly for MCM and explosive ordnance disposal operations. Larger, ultra-long-range UUVs like Cellula Robotics' fuel-cell-powered Guardian XLAUV enable the Department of National Defence (DND) to consider alternative operations for missions requiring up to 5,000 km ranges, where previously they may have relied on a submarine to be deployed.

CNR: I think that communication with (and among) UUVs has been a challenge to overcome. How possible is it to transmit information from underwater systems, and how confident can we be that it is sufficiently secure for military operations?

RM: Acoustic communications is challenging due to the propagation of energy through sea water, the various layers and frequencies to achieve long distances. For example, sound can travel through multiple paths between a source and receiver, leading to interference patterns, or the attenuation of energy due to scatter particles in the water leading to a low signal-to-noise ratio, making receiving over long distances more challenging. There is no silver bullet or magic solution to solving these challenges, so we, as an industry, are working on what we can do on-vehicle to reduce the data volumes we need to transmit.

Data latency and security are key considerations for military operations, and encryption is only one part of the puzzle. For acoustic transmissions, where we may use low frequencies and very low bandwidths, it is not easy to encrypt such small data volumes. Another challenge is how do we cross the water/air barrier and access high-bandwidth, secure links in contested or congested environments.

One way is to come close to the surface and deploy a mast or buoy that has a limited surface expression. There are other challenges involved in this type of operation, not least ensuring position certainty when operating in blue water. The typical solution is binding the inherent drift of an Inertial Measurement Unit (IMU) with a Doppler Velocity Log (DVL) tracking the AUV's movement over the sea floor. This is known as 'bottom lock' and provides a reliable method for reducing position error uncertainty. There are emerging technologies that may assist with breaking the water/air barrier, and aid with data transmission. They may enable systems to remain submerged and transmit from depth.

Credit: Cellula Robotics Ltd.

Two AUVs operating in close proximity during Cellula Robotics' Technology Awareness Event in July 2024, West Vancouver.

CNR: A variety of commercial enterprises and states are working on using AI in their uncrewed systems. This would enable linking and networking and operating independently/autonomously. What degree of autonomous decision-making capability to enhance mission success does Cellula anticipate developing? Will the systems be able to network autonomous vehicles and their sensors both nationally and with allies?

RM: Interoperability across platforms, technologies and states is the ultimate goal for uncrewed systems. Vehicle-to-vehicle communication systems are being trialed for fleet and swarm operations. With increasing AI processing tools, the ability to hand off targets for further investigation by other UUVs is getting closer. This has been relatively common practice in the aviation world for many years. Previously discussed standards, interfaces and integration with combat management systems are key to succeeding, combined with wide-scale adoption of UxVs in multiple domains. One element on which there is still much to be done is data fusion: how do we get better quality, actionable information from multiple different sensors and platforms.

At Cellula, we are focused on adding capability to our platforms in the form of advanced and adaptive autonomy. Some of that work is in-house and some with partners. We have domestic and international partners for adaptive autonomy, signal processing and more. It is through these collaborations that we can bring such advanced capabilities to bear. It is also through these partnerships that we are exploring the international interoperability of UxVs.

CNR: I would imagine that you have been talking to the Canadian government about contracts. Are Cellula products, or can they be, deployable from existing RCN assets such as Arctic and Offshore Patrol Ships (AOPS)?

RM: Our systems are designed to operate from containerised solutions compatible with the payload bays on the AOPS and *River*-class destroyers. They can also be deployed from shore for the very large, long-range UUVs.

CNR: Could your products be mass produced if required?

RM: Yes.

CNR: Are there any government support programs for Canadian industries like yours? What would you like to see the government do to support this business?

Credit: Cellula Robotics Ltd.

The Cellula Robotics XLAUV development and trials team after successful sea trials, taken in West Vancouver, summer 2024.

RM: Long-range UUVs are a strategic capability and Canada currently leads the way. Whilst there are mechanisms to assist with research and development funding, we would like to see the government commit to increasing defence spending in line with NATO requirements. This would enable DND to procure UxVs in the volumes required to enhance capability.

***CNR*:** Will tense relations with the United States affect your business development or contracts? If so, how? Is there any reliance on US technology that might be an obstacle?

RM: Our supply chain includes domestic and international vendors. We are always working to achieve surety of supply regardless of origin.

Credit: Cellula Robotics Ltd.

A Cellula Robotics Envoy AUV (formerly SOLUS-LR) being retrieved from the water at an unspecified location and date.

***CNR*:** As I understand it, there are no regulations for the use of underwater vehicles, and we see some commercial enterprises using them for 'exploration.' Do you have any concerns about the lack of regulations? Should the International Maritime Organization (IMO) be looking at this?

RM: We are constantly reviewing the regulatory space for UxVs. Last year, our cruising UUVs were awarded Transport Canada Maritime Autonomous Surface Ship Compliance Certificates for safe operations. The sub-surface environment is largely unregulated at present. We anticipate the slow adoption of rules similar to those for uncrewed surface vessels to promote not only sound design, but also best practice in their usage.

***CNR*:** Let's look into the future. What are your priorities going forward? And what are the biggest challenges yet to be overcome?

RM: As a company, we are working to develop and deliver enhanced capabilities; to change the paradigm for autonomous underwater vehicles for all of our customers across survey, science and security. That means producing common technology platforms capable of adding value in each of those segments and applications. We are also striving to accomplish some very long duration missions with fuel-cell-powered UUVs in the near future to demonstrate safe and reliable operations with an alternative energy source.

***CNR*:** This has been very interesting. Thank you for taking the time to answer my questions.

Notes

1. The 'x' denotes the domain, in this example it indicates the class of robots not specifically air, water or ground.