MARINE TECHNOLOGY REPORTER

September 2019

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ROBOTICS Edition

NATO
Flexes its MUSCLE

BP goes
Over the Horizon

IMR Moves
Robotic

NATO CMRE Interview
Catherine Warner

Advances in Subsea
CO_2 Storage

Volume 62 Number 7

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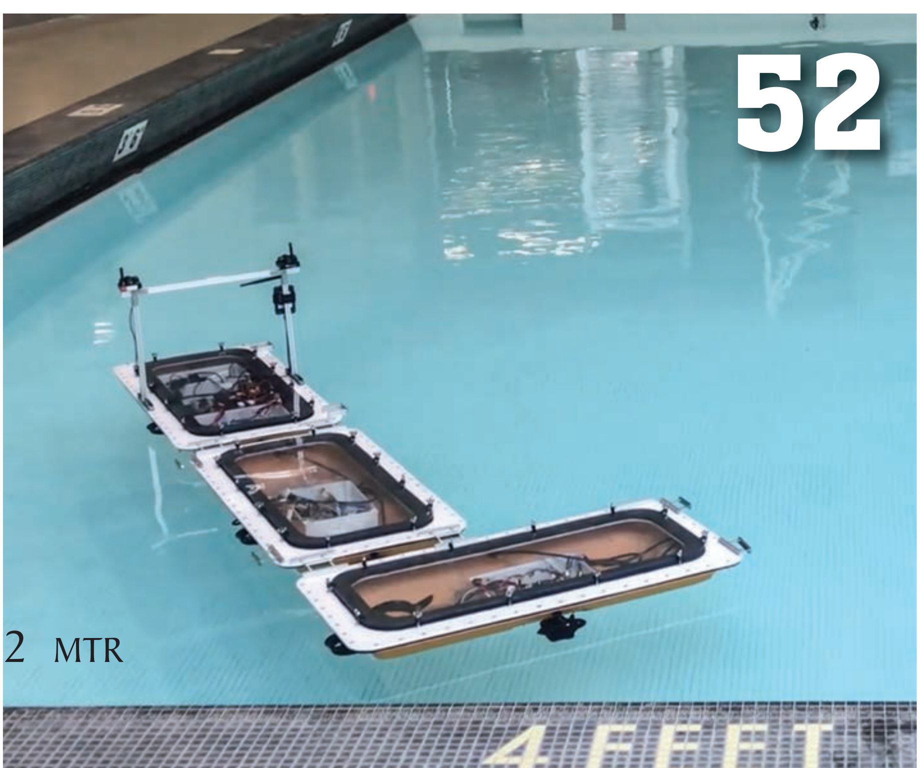

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Editor's Note

A Robotic Future

I write this in Aberdeen at the Offshore Europe 2019, the perfect juxtaposition for MTR's September 2019 "Robotics" edition. First, for those of you who did not make it to Aberdeen for OE '19, the new P&J Live venue – which literally opened for the first time with OE '19 – is spectacular, and the trade show floor was largely packed and busy for the four-day event, as the offshore energy business rebounds with cautious optimism.

While this is the "Robotics" edition, it could reasonably be argued that every edition of MTR could be the "Robotics" edition, as automated, efficient vessels and systems on and below the world's waters are helping to transform the way we work in the defense, offshore energy and scientific sectors.

Looking at robotics in defense is Edward Lundquist with a pair of stories in this edition. The first, starting on page 16, looks at the NATO CMRE in La Spezia, Italy, and the Minehunting UUV for Shallow Water Covert Littoral Expeditions (MUSCLE) experimental platform. This story is followed by a one-on-one interview with Dr. Catherin Warner, Director of the NATO Center for Maritime Research and Experimentation (CMRE), starting on page 40.

While the defense industry is a traditional leader (and funder) of work in this regard, the offshore energy sector, which has endured a five-year downturn and just now seems poised to regain its financial footing, has embraced automated solutions that help to drive down the costs of subsea energy exploration and production. To that end, starting on page 28 Justin Manley explores the growing use of robotics in inspection, repair & maintenance (IMR). On page 34 we invite you to 'Go over the Horizon' with Elaine Maslin, as she takes an insightful look at a project BP has been running, using USVs to help reduce emissions, costs and risks.

Gregory R. Trauthwein
Associate Publisher & Editor

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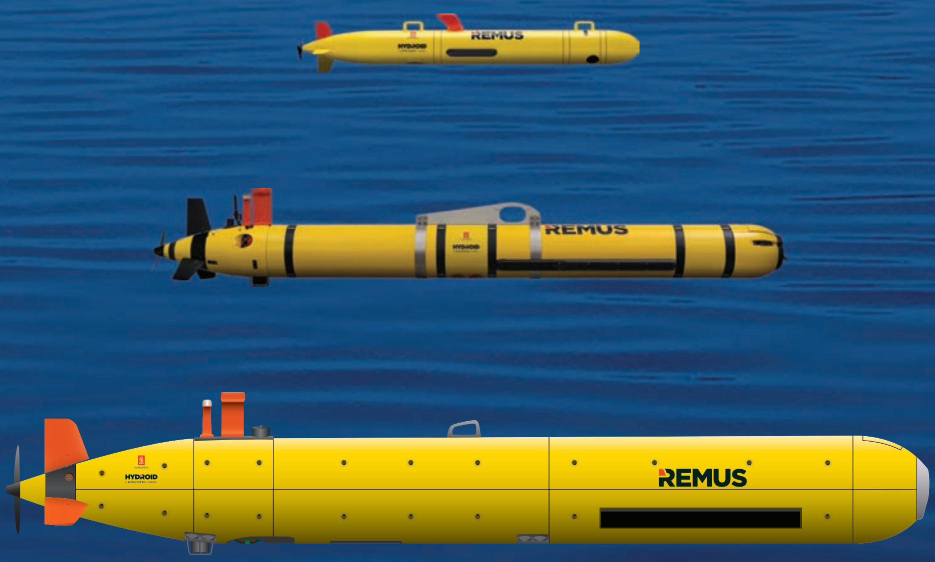
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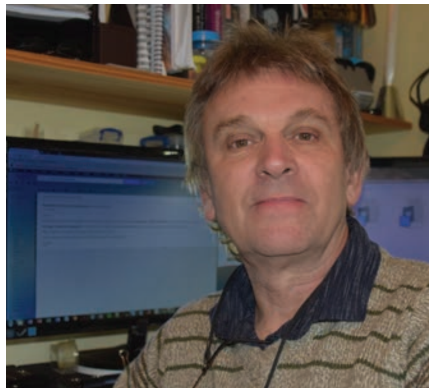

Lundquist

MacPherson

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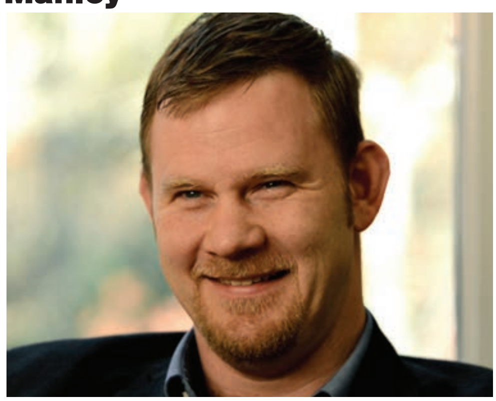

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Edward Lundquist is a retired U.S. Navy captain who write frequently for Marine Technology Reporter. He travelled to La Spezia, Italy to report this story.

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Donald MacPherson, a leading specialist in propulsion system simulation, is HydroComp's Technical Director, where he oversees all software development and engineering services. A graduate of Webb Institute, he is a Fellow of SNAME and member of its Propulsion Hydrodynamics Panel.

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Mulligan
Tom Mulligan graducated from Trinity College Dublin in 1979, with a BA Hons Degree in Natural Sciences (Chemistry). In 1986 he obtained a Masters Degree in Industrial Chemistry in 1988. Today he is Marine Technology Reporters science and technology writer based in Dublin.

RV Nanuq

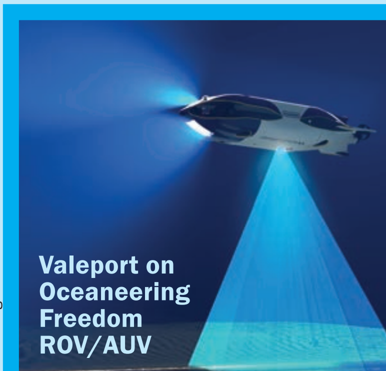
Armstrong Marine

R/V Nanuq Delivered

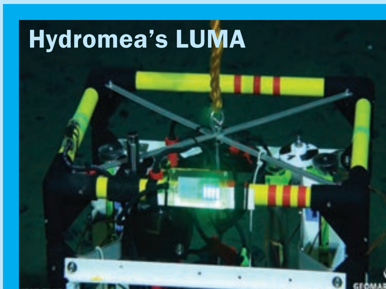
The College of Fisheries and Marine Science at the University of Alaska Fairbanks added a new Armstrong Marine-built research vessel to its fleet dubbed Nanuq. Armstrong Marine designed the 40-foot aluminum hulled boat and Pacific Power Group fit the vessel with a pair of Volvo Penta D6 engines that deliver 330hp each. The engines are paired with Aquamatic outdrives and Volvo hydraulic power steering. "Research vessels have very specific performance requirements and Volvo Penta propulsion systems have proven extremely capable of meeting those needs," said Doug Schwedland, PPG's vice president of the marine division. Along with the Volvo Penta engines, Nanuq is outfitted with side power electric bow thruster with joystick control to ensure precision maneuverability during research operations. The monohulled boat is capable of cruising at 32 knots and has a 400-gallon fuel capacity that allows the boat long-range travel capabilities in the remote waters of Alaska.

Valeport on Oceaneering Freedom ROV/AUV

Valeport sensor technology has been selected by Oceaneering International for integration into its subsea Freedom vehicles. Oceaneering's next generation hybrid ROV, Freedom, will be fitted with Valeport Bathypack, Altimeter and Hyperion Fluorometer sensors. The Valeport sensors in the Midas Bathypack were ethernet enabled to offer precision



Oceaneering



Hydromea

sound velocity, conductivity, temperature, depth and altimeter data, which is used to enhance the operational capability of the Freedom resident vehicle. The subsea vehicle is also equipped with Valeport's compact and robust environmental monitoring sensor, the Hyperion Fluorometer, for the high performance measurement of Chlorophyll A. Oceaneering's Freedom ROV is designed to offer a new level of flexibility and efficiency while performing common ROV tasks including survey, inspection, valve and torque tool operation, manipulator-related activities and underwater inspection in lieu of dry docking operations.

Hydromea's LUMA Wireless Nodes

During a recent science cruise, Germany's oceanographic research institutes used Hydromea's LUMA 250LP wireless node in depths down to over 4000m. The scientists of the Alfred Wegener Institute (AWI)/Max

VideoRay wins Navy Deal

VideoRay

Planck Institute for Marine Microbiology (MPI) on board the research vessel Sonne were examining the possible environmental impact of deep sea mining of polymetallic nodules in the Clarion Clipperton Fracture Zone (CCZ) in the Eastern Pacific (PDF of cruise report). By fitting their in situ modules as well as the ROV KIEL6000 (GEOMAR) with Hydromea's LUMA wireless nodes they were able to directly communicate with instruments at over 4000m depth to ensure that their delicate sensors on board are working properly and to reconfigure the measuring program if necessary.

VideoRay Wins US Navy Deal

VideoRay announced its second multimillion-dollar award with the U.S. Navy to develop, define, and deploy new technology for Explosive Ordnance Disposal (EOD) operations. This contract follows the completion of an earlier prototype facilitated by the Defense Innovation Unit in 2018. The platform for both contracts is the VideoRay Mission Specialist Series (MSS) Defender ROV, which has been delivered for military and commercial uses to customers worldwide. Defender is a powerful, portable unit with open architecture, featuring Greensea Integrated Control and Navigation. Greensea's EOD Workspace software for sophisticated supervised autonomy and precise maneuvering. Greensea supports the US Navy with a Cooperative Research and Development contract for software development on this project.

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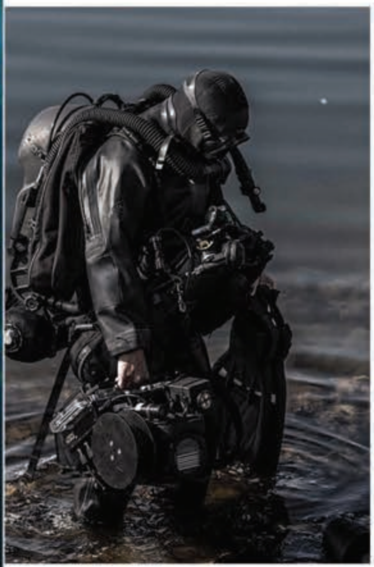

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New Autonomous Vehicle for Offshore Wind Surveys

A new autonomous sailing platform aims make the collection of offshore wind energy data easier, faster, cleaner and more cost efficient.

The 16-foot wind- and solar-powered Datamaran, launched recently by Norwegian energy company Equinor and US technology firm Autonomous Marine Systems Inc. (AMS), carries a LiDAR (Light Detection and Ranging, a well-established technology used to record wind characteristics hundreds of feet above the surface) to gather data on wind and weather conditions at offshore lease areas for the development of wind energy projects.

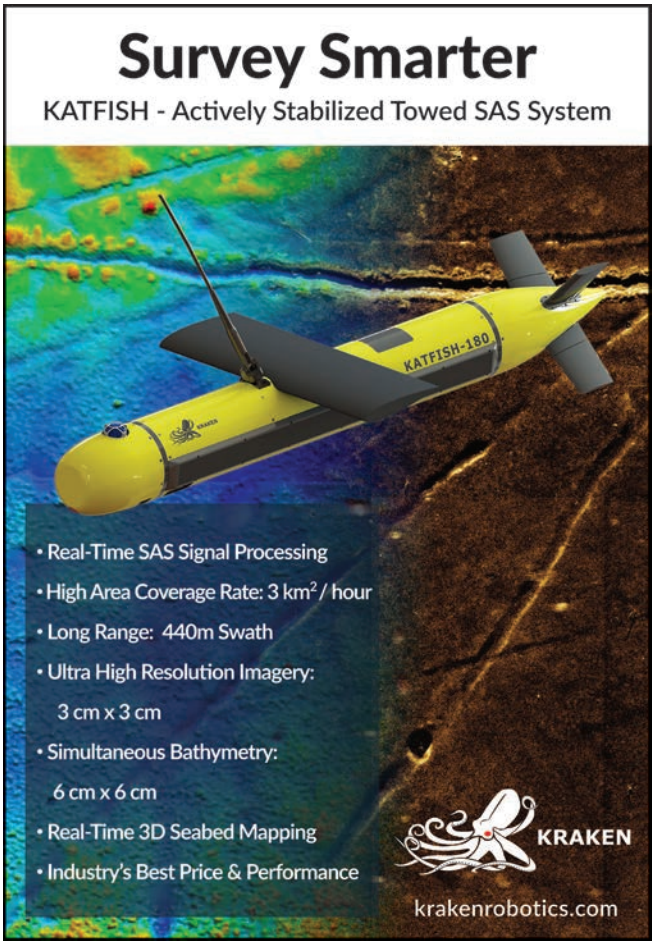
Typically, this data has been collected by a combination of a vessel traversing the offshore wind area and a LiDAR system mounted to an anchored, stationary buoy.

Using the rapidly-deployable Datamaran, offshore wind farm developers can collect this data completely autonomously without a manned support vessel. The vehicle is able to continuously transmit acquired data and vessel health status to onshore operations via fault-tolerant communication channels. The vessel is propelled by a rigid wing sail while the LiDAR, navigation, and communication systems are powered by deck and sail mounted solar panels and large batteries.

In addition, standard integration interfaces enable broad flexibility in sensor payload and survey types such as standard meteorological ocean, bathymetric and hydrographic, current and wave characteristics, avian and marine mammal detection, and alerting. Over the last 18 months, Equinor and AMS have conducted studies and built prototypes to test the system. These have shown dramatic improvements in lead time, cost and areal coverage versus today's options, and the Datamaran is now ready for commercial deployment.

"In keeping with our partnership with Equinor, we've named this latest class of vessels 'Njord.'" said Ravijit Paintal, CEO of AMS. "We launched it successfully last week, and now we're looking forward to deploying the technology worldwide to deliver order-of-magnitude benefits to offshore wind development."

Christer Af Geijerstam, President of Equinor Wind US, said, "Equinor's collaboration with Massachusetts startup AMS underscores our commitment to collaborate with, invest in and support local business. The emergence of the US offshore wind energy industry presents an exciting opportunity for local, nimble, innovative companies to partner with established wind-farm developers."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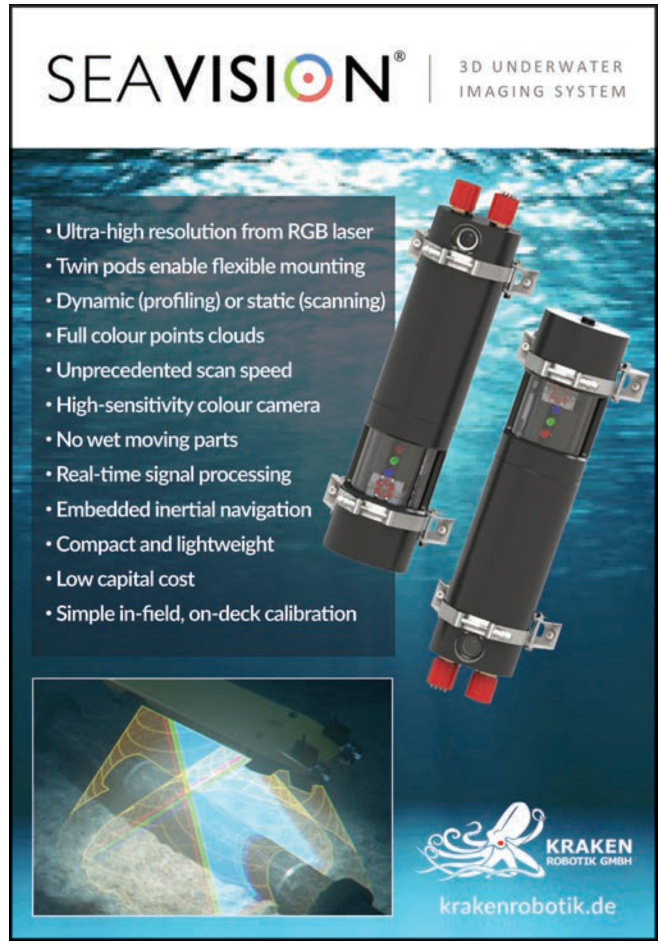
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Pioneering Ocean Energy

Innovation in New England

By Maggie Merrill

If one is wondering when and if and where the offshore wind business is going to become established, wonder no longer. Massachusetts is the epicenter of the offshore wind business and as such will translate nicely for ocean tide and wave energy development. Synergies in offshore engineering, resource assessment, permitting, construction, and maintenance of ocean wind, wave and tidal energy are obvious but not fully articulated.

Sharing lessons learned in "getting steel in the water" was the purpose of the May 23, 2019 2nd Annual Marine Renewable Energy conference. The one day conference was held at UMass Dartmouth's Center for Innovation and Entrepreneurship, a business incubator where many of marine renewable energy's leading lights started – Resolute Marine, ORPC, and Littoral Power. They gravitated to the CIE because of its prototyping capability, access to student interns and location at the heart of the marine technology and clean energy ecosystem in the South Coast of Massachusetts.

The CIE's new director, Phil Adams, a forward-thinking energy entrepreneur welcomed participants and remarked, "to me, it's pretty clear that our voracious appetite for energy has created the greenhouse gas effect. We reached 415 ppm of carbon a week or two ago, and on that day, it was 86 degrees in the Arctic". He pointed out several solutions to

Philip Adams, Director UMass Dartmouth's Center for Innovation and Entrepreneurship (CIE).

recent environment crises that are moving markets and society to action, including: credit trading to stem the acid rain problem; banning fluorocarbons to close the ozone hole and the public awareness campaign in Cape Town S. Africa around their plight of running out of water on "Day Zero", where the entire population was mobilized to conserve water and it worked!

Phil also talked about the nature of change, showed a news video of the Brayton Point towers being imploded in April, and encouraged folks to "see the change happening right before our eyes – the site of a coal fired plant being repurposed to be the onshore receiving point for the power from offshore wind."

Philippe Frangules, V.P. IHS Markit provided a sweeping overview of the energy markets from the 80s to present, and elucidated the reason for the sudden adoption of renewables. In the case of offshore wind, costs to manufacture, install and maintain commercial scale operations is directly in line with what the market will bear. Major utilities are banking on very competitive per/KW pricing; favorable financing schemes and grid ready power being generated within 3-5 years all along the east coast, close to the most energy intensive population centers of the US. In addition, he showed in one of his slides that offshore wind looks to be prominent with 450 GW of new capacity to be built between 2019and 2050 requiring over $US 1 trillion in investment.

Government agencies are working together to facilitate technology development to enable offshore wind to take hold as well as encourage innovation in tidal, wave and in-current devices. Steven DeWitt, from US Dept of Energy's Water Power Technology Office, provided an overview of his office's focus on helping industry tackle tough issues such as power take off technologies and


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creating systems that are appropriate for distributed power in remote sites such as islands and remote communities that otherwise rely upon diesel power for electricity. Justin Normand of the British Consulate General is bringing the lessons learned in the UK to secure a supply chain to support OSW to the US, and showed a compelling graphic of the potential future for the US with the myriad renewable energy facilities in the UK, and noted that there have been many days recently where the country generated no power from coal. Bruce Carlisle, of the Massachusetts Clean Energy Center enforced that this industry is moving into the region quickly, opening offices in Boston, Providence, New Bedford and beyond. "There will be many opportunities for suppliers to participate and jobs to fill".

Tray Taylor, founder of Verdant Energy inspired all entrepreneurs to follow their dream and instincts and do something amazing. His company has installed several generations of tidal turbines in the East River in NYC. Marcus Gay of Resolute Marine outlined their journey to harness wave power to pump water ashore for desalination, providing clean potable water - a valuable commodity globally. Lindsay Bennet, of the FORCE program in Canada, talked about their massive program, funded largely by the Canadian government to characterize the tidal resource in the Bay of Fundy and work with world experts to test turbines at commercial scale. Many, many lessons have been learned there, principally, that it takes a lot of collaboration to harness tidal power in the Bay of Fundy.

"When you are putting up a shed in your back yard, said Steve Barrett of Barret Energy LLC you have to ask your neighbors for permission. If you don't and you put up a surprising structure, they have the right to push back". Similarly, if you are going to put wind towers, tidal generators or wave devices in the waters that are used by many, all users of those waters need to be apprised of the project. Sr. stakeholder engagement officers, Stacey Tingley from Orsted Wind and Nate Mayo from Vineyard Wind, Audra Parker from the Alliance to Preserve Nantucket Sound, and Amber Hewitt from the National Wildlife Federation, participated in a lively discussion of dos and don'ts of stakeholder engagement. Chris Sauer, CEO of ORPC talked about their success at getting community support of their first tidal energy project in Cobscook Bay, Maine. He said they had a place they thought was going to work the best for their engineering and cost point of view, but fishermen protested because it was also a rich fishing area. After much discussion, the fishermen convinced ORPC to move the turbine to another area that had better current flow in an area where they did not fish. It was a win- win.

Photo courtesy Maggie Merrill

L-R: Barry Logue, Scottish Development International; Lindsay Bennet, FORCE; and Steve DeWitt, Water Power Technology Office DoE.

The last panel, moderated by MRECos Executive Director John Miller scanned some of the key R&D assets being directed toward offshore wind development. Anthony Kirincich of the Woods Hole Oceanographic Institution presented his work to integrate state of the art ocean technologies to be adapted to support offshore wind operations. Chris Niezrecki of UMass Lowell talked about a multiple university R & D collaborative, WINDSTAR which works on many facets of offshore wind engineering and operations. Ravi Paintal presented a rigid sail powered autonomous surface vehicle that can be used to gather data in and around wind, tidal turbines or other structures offshore. Finally, Stephen Conant of ANABARIC detailed their plans to "plug in" the major cable from Vineyard Wind to the Brayton Point power grid, on the site of the former Brayton Power Coal plant.

Offshore wind, wave and tidal energy are all considered key sectors of the Blue Economy. Hugh Dunn of UMass Dartmouth gave an overview of the project that Center for Policy Analysis at UMassD is working on to quantify the blue economy sectors, supply chain and workforce, a study to be released this summer.

Renewable energy systems are taking off. Solar, geothermal, traditional Hydro and natural gas led the way, and offshore wind is taking center stage here in the US. Marine technology suppliers and service providers have A LOT to offer; survey systems, meteorological systems, autonomous site characterization for monitoring and operations, making the South Coast of New England the hub for all this new activity.

NATO *employs* MUSCLE *memory to find mines*

By Edward Lundquist

The NATO Center for Maritime Research and Experimentation (CMRE) in La Spezia, Italy, is combining smarts and muscle to solve a complex warfighting challenge: finding and destroying mines in the murky waters of the littoral.

CMRE has developed experimental unmanned vehicles for experimentation. Now it is evolving those vehicles to communicate and cooperate with each other, and to solve problems on their own.

According to CMRE's director Dr. Catherine Warner (see related story on page 40), the center is trying to figure out where the unmanned systems best fit into operations, and doing the science to make them better, smarter, interoperable, autonomous, and more effective.

That's a tall order, but the short answer is that CMRE's scientists and engineers have adapted existing unmanned vehicles to work as a team.

CMRE developed JANUS, the NATO-standard protocol for communicating between underwater acoustic modems, and the Distributed and Decoupled (D2) Collaborative Autonomy Framework (D2CAF), so a network of unmanned underwater vehicles (UUVs) can talk to each other and work together. With D2CAF, the team of vehicles shares the processing among the different UUVs,

MUSCLE Autonomous Underwater Vehicle Deployment.

Photo courtesy of CMRE


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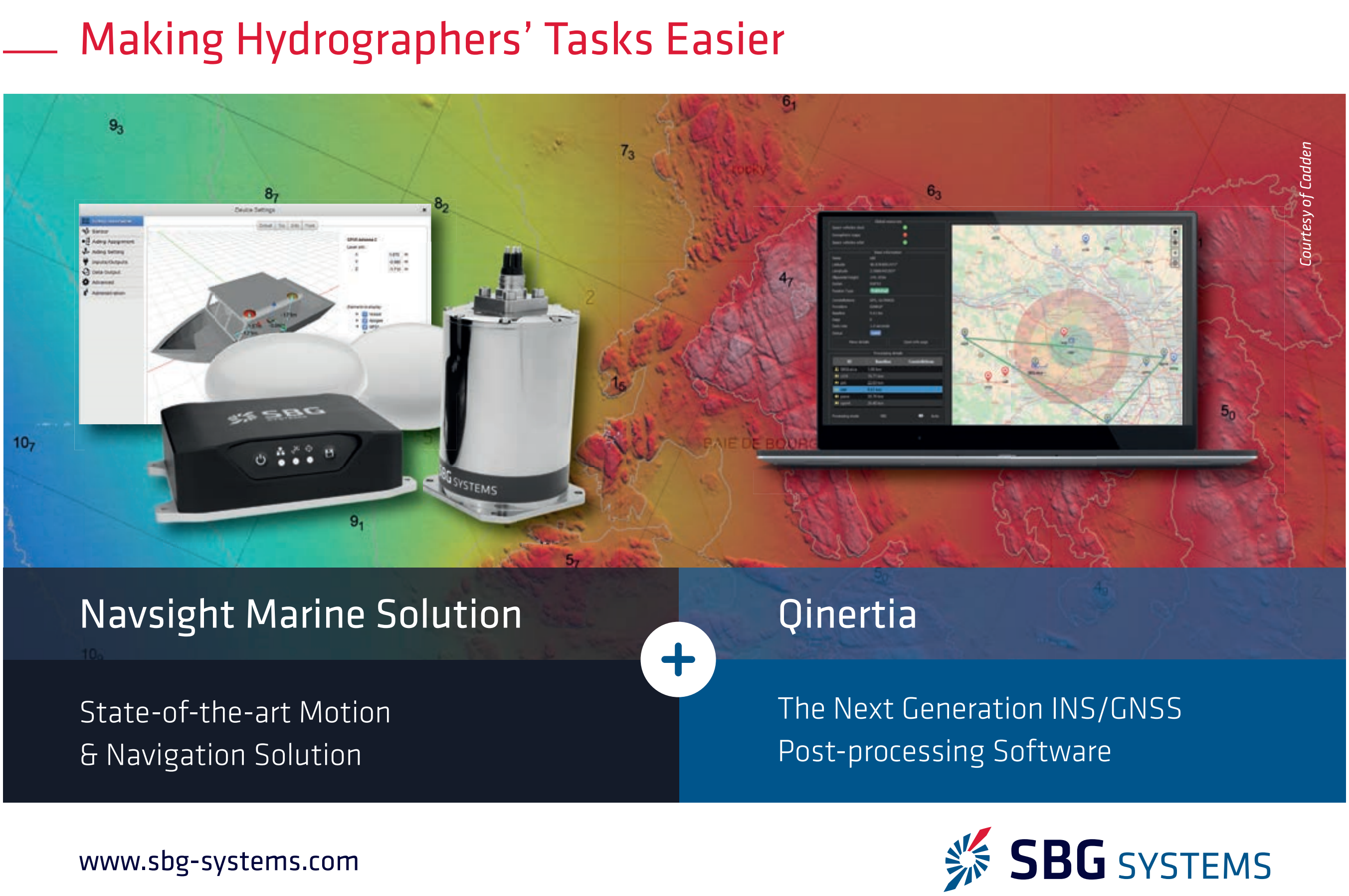
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> CMRE adapted another **Bluefin-21** as a collaborative autonomy test bed — named Black CAT — to demonstrate D2CAF by having **MUSCLE** and **Black CAT** work together. MUSCLE has an acoustic Doppler current profiler that detects current direction and velocity, and can reprogram its search patterns to account for currents. Black CAT, which hosts a version of D2CAF and is used for reacquisition, is equipped with a **Teledyne Blueview 900** forward-looking sonar (FLS), optical camera, Blueview 2.25MHz multi-beam 3D sonar, and **ARIS** camera. CMRE also has a pair of **Konsgberg Hydroid REMUS 100 vehicles** with sidescan sonar and multi-beam echosounder (MBES) for reacquisition, and an IQUA Robotics SPARUS UUV with ARIS for reacquisition and simulated neutralization.

The MUSCLE and BLACK CAT UUVs on board NRV Alliance prior to participation in GAMEX'17.

Photo: NATO CMRE

and accompanying "gateway" unmanned surface vehicle (USV) if present, all connected by JANUS.

At the center of the effort is CMRE's General Dynamics Mission Systems Bluefin-21 unmanned underwater vehicle (UUV), which it has adapted as the Minehunting UUV for Shallow Water Covert Littoral Expeditions (MUSCLE) experimentation platform.

CMRE took advantage of the open architecture and modularity of the Bluefin -21 to equip it with a Thales synthetic aperture sonar (SAS), so it can look at and cover large areas quickly with high resolution. MUSCLE has onboard memory with a digital library of objects to help it conduct automatic target recognition (ATR). It can recognize and categorize objects in real time, and considers factors such as the quality of data and complexity of the area to determine the threat and level of certainty. It can then plan its mission to reduce that uncertainty. And with D2CAF, it can carry out those missions as a team.

For its experimentation, CMRE needed a system that's robust, sturdy, and reliable.

"That's exactly what MUSCLE is," said Rob Been, deputy head of CMRE's engineering. Division. "We've had the Bluefin-21 for quite a long time. And over the years, with the collaboration of Bluefin, we have made it more modular."

Been said CMRE started off with a Bluefin with an integrated synthetic aperture sonar that had the ability to follow pre-programmed waypoints record data. "We would have to recover the vehicle and dump the data after each run. But with the collaboration between our scientists and engineers, you can see what it can do now. It has both CPUs and GPUs—central processing units and graphical processing units--so it can do a lot of parallel processing. We have enabled the Bluefin MUSCLE to see underwater in real-time, and thus by looking at the images, determine what to do next."

Been said MUSCLE can start off with a 'radiator' search pattern, and depending on the visibility and the performance of the senor, which is based on the environment at that time, it determines the spacing of the radiator pattern. "You don't want to have gaps, so you need to optimize that. The advantage of having that data available and the ability to process that on board is that you can make those decisions in stride, so you can make sure that you don't have gaps. When it sees something, it uses its underwater acoustic modem to send a message to the gateway buoy and the gateway buoy sends it back to the ship, and they can see the detections in real time. There's automated target recognition software on board the vehicle so it can determine that it is this type of target, with a degree of probability. If it detects sand ripples, it can optimize its position relative to sand ripple to get a better look. With collaborative autonomy, it can also task smaller vehicles to go and inspect a series of detections, collecting video feeds, which in turn, also, can be fed back to the ship."

Dr. Samatha Dugelay, program manager for autonomous naval mine countermeasures at CMRE said the center adapted another Bluefin-21 as a collaborative autonomy test bed—named Black CAT--to demonstrate D2CAF by having MUSCLE and Black CAT work together. MUSCLE has an acoustic Doppler current profiler that detects current direction and velocity, and can reprogram its search patterns to account for currents. Black CAT, which hosts a version of D2CAF and is used for reacquisition, is equipped with a Teledyne Blueview 900 forward-looking sonar (FLS), optical camera, Blueview 2.25MHz multi-beam 3D sonar, and ARIS camera. CMRE also has a pair of Konsgberg Hydroid REMUS 100 vehicles with sidescan sonar and multi-beam echosounder (MBES) for reacquisition, and an IQUA Robotics SPARUS UUV with ARIS for reacquisition and simulated neutralization.

If MUSCLE cannot communicate directly with one of its collaborating vehicles, it can use the gateway buoy on a USV such as CMRE's LiquidRobotics WaveGlider, to relay messages from one submerged vehicle to another, or back to the host platform.

"They all can perform different tasks," Dugelay said. "For example, MUSCLE goes out, conducts the wide area survey, and finds the detections. BlackCAT has an optical camera and a forward-looking multi-beam echosounder to conduct reacquisition of the target. So they are two similar Bluefin vehicles that have been adapted to do different things

"The analysis of what it has seen, and the determination about what needs to be done next by the group of vehicles, is done in-stride onboard the MUSCLE, said Dugelay. "MUSCLE can determine the risk that there may still be something there that it hasn't found, and it can develop a compound risk map to either go back to further search an area, or deploy other vehicles, like the Black CAT, to look closer and reduce that risk."

CMRE conducts in-water testing, and has integrated its systems into operational exercises like Greek ARIADNE Mine Countermeasure Experiment (GAMEX) and the Spanish and Italian Mine Countermeasures Exercises (MINEX).

The center can also leverage its extensive modelling and simulation capabilities to evaluate the collaborative autonomous systems and concepts of operation in various and complex operating environments.

Cruising to Increased Confidence in

CO_2 Storage

By Kelvin Boot

The bespoke drill rig being lowered over the side of the RRS James Cook. The rig is designed to push the curved steel pipe into the seabed sediment.

Image: Image: Copyright STEMM-CCS Project

If we are going to store large volumes of carbon dioxide (CO_2) in depleted oil and gas reservoirs beneath the seabed we need to be sure that, in the unlikely event of a leak, we can detect it. A research expedition, carrying a world-first experiment designed to develop methods for the detection and monitoring of leaks, has just returned from the North Sea; it has been declared a great success.

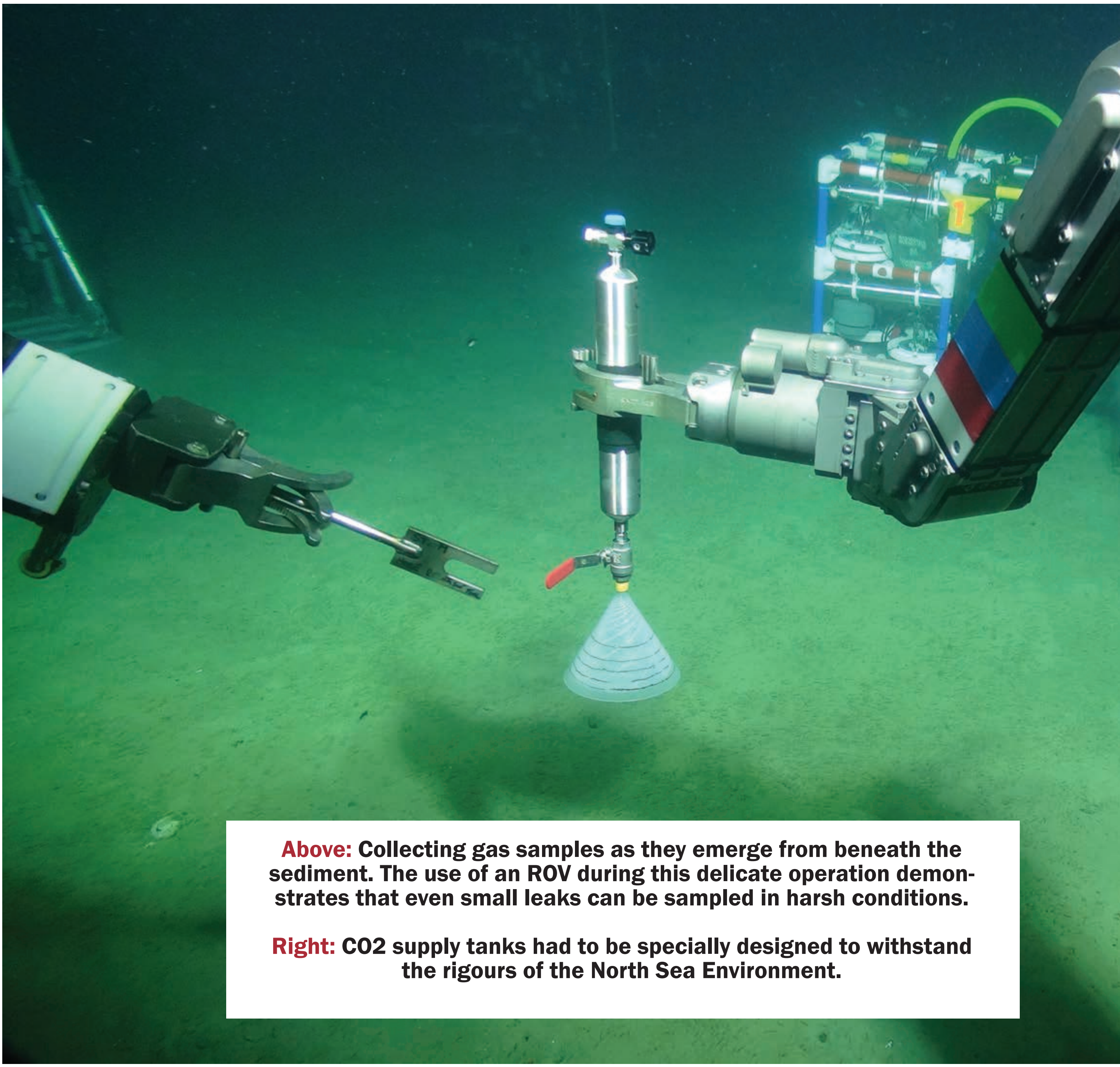
Climate change, driven by increasing CO_2 levels in the atmosphere, is now a well-established side-effect of human activities that is having profound effects on the Earth's natural systems. While efforts are being made to reduce future sources of human-related CO_2 production, such as from industry and transport, there is a parallel need to prevent the gas from existing activities entering the atmosphere. Carbon dioxide capture and storage (CCS), whereby CO_2 is contained at source, transported and ultimately stored away from the atmosphere, is one such strategy. Putting the CO_2 back from whence it came, deep beneath the seabed in depleted gas or oil reservoirs, seems a logical solution, but there are challenges. To generate confidence in this approach, a priority is to be able to deal quickly with any leak, should it occur: detect it, to measure its strength and duration, predict any effects it may have on the environment, and seal it if necessary.

Previous laboratory and mesocosm-based research on the effects of CO_2 on marine life has shown that it can change the pH of seawater and create localised 'ocean acidification' conditions, which appear to be detrimental to many types of benthic (seabed) life. A previous, shallow water experiment, the Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage (QICS) project, provided some clues as to the extent, duration and behaviour of a CO_2 plume from a simulated leak, while studies at natural seep sites have also provided crucial information. Now a larger experiment has been testing methods, equipment and sensors under real-life conditions in the rigorous environment of the UK's North Sea.

The Strategies for Environmental Monitoring of Marine Carbon Capture and Storage (STEMM-CCS) project is a European Union Horizon2020-funded research project. It brings together researchers from Germany, Norway, Austria and the UK, along with industry partner Shell, to develop the techniques and technology to detect traces of CO_2 leaks if they occur in the marine environment, to observe how the gas behaves in sediments and the water column above, and predict how far leaks may spread and what impacts they might have

- but this time in as near to 'real' conditions as possible. During May this year, a research expedition set sail from the UK's National Oceanography Centre in Southampton, aboard the RRS James Cook. Once on station, close to Shell's Goldeneye platform approximately 100km off the coast of Scotland and in 120m water depth, the experiment began. A pipe was robotically inserted into the seabed - the first time such an experiment has been attempted at depth in the open sea. The 1.5cm-diameter curved steel pipe was successfully positioned within the sediment to ensure its exit was three metres beneath the seabed surface. It sounds simple, but in order to achieve this, a bespoke 'drill' rig to push the pipe into the sediment was developed and built by Cellula Robotics in Canada. The pipe was then connected by a remotely operated vehicle (ROV) to a CO2 supply on the seabed, allowing gas to flow through the pipe into the sediments. Again, this sounds simple, but specially-designed gas cylinders housed in a second rig had to be built to withstand the tough salt-water environment of the North Sea.

Fortunately conditions remained calm during this operation and the science team on board breathed a sigh of relief as CO2 bubbles began to emerge from beneath the sediment. The idea

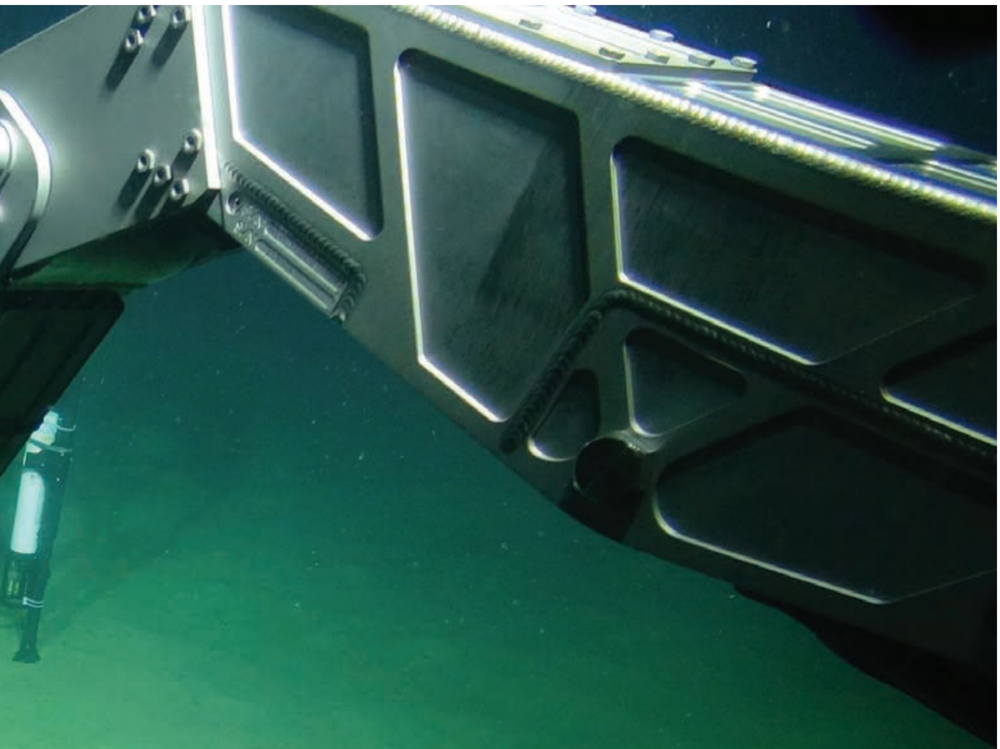


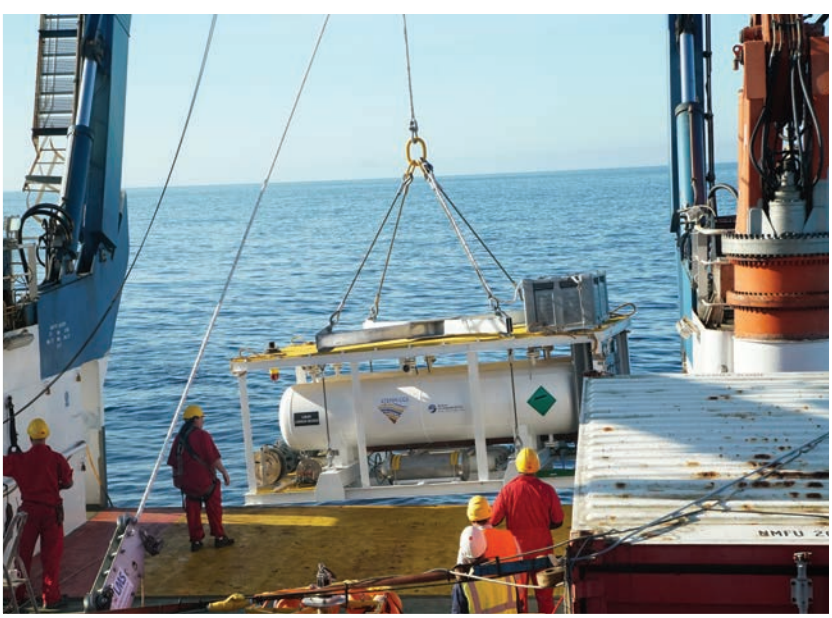
Above: Collecting gas samples as they emerge from beneath the sediment. The use of an ROV during this delicate operation demonstrates that even small leaks can be sampled in harsh conditions.

Right: CO2 supply tanks had to be specially designed to withstand the rigours of the North Sea Environment.

was then to test how well an array of sensors, developed and built for the experiment, might perform.

Acoustic and optical instruments were deployed to detect the sound made by streams of bubbles or spot them with cameras, while chemical sensors 'sniffed out' the CO_2 and the minute amounts of inert chemical tracers it contained, so allowing the scientists to differentiate this signal from any naturally occurring CO_2. ROVs and autonomous underwater vehicles (AUVs) bearing other sensors completed the arsenal of technology employed. The team aboard were extremely pleased and gratified that the sensors and monitoring tools they were testing performed far better than expected. This has resulted in some surety that even very small releases of CO_2 into a marine system





The micro profiler measures sediment chemistry at micrometer resolution, by slowly inserting electrodes into the sediments over a one hour period. This instrument allows us to look at even small changes that occur in the sediments as the carbon dioxide dissolves in the sediments.

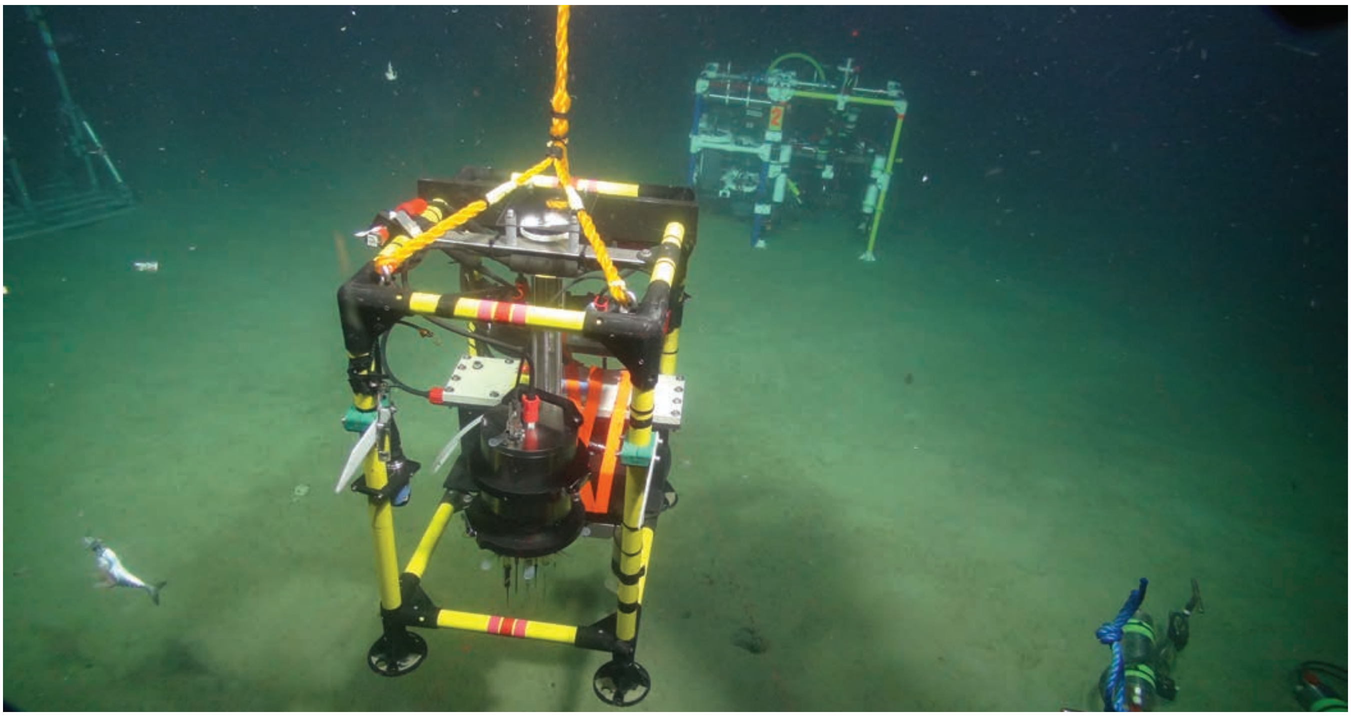


Image: Image: Copyright STEMM-CCS Project

Hydrophone wall on the seabed, listens to the sound bubbles make as they emerge from the seabed and move through the water column.

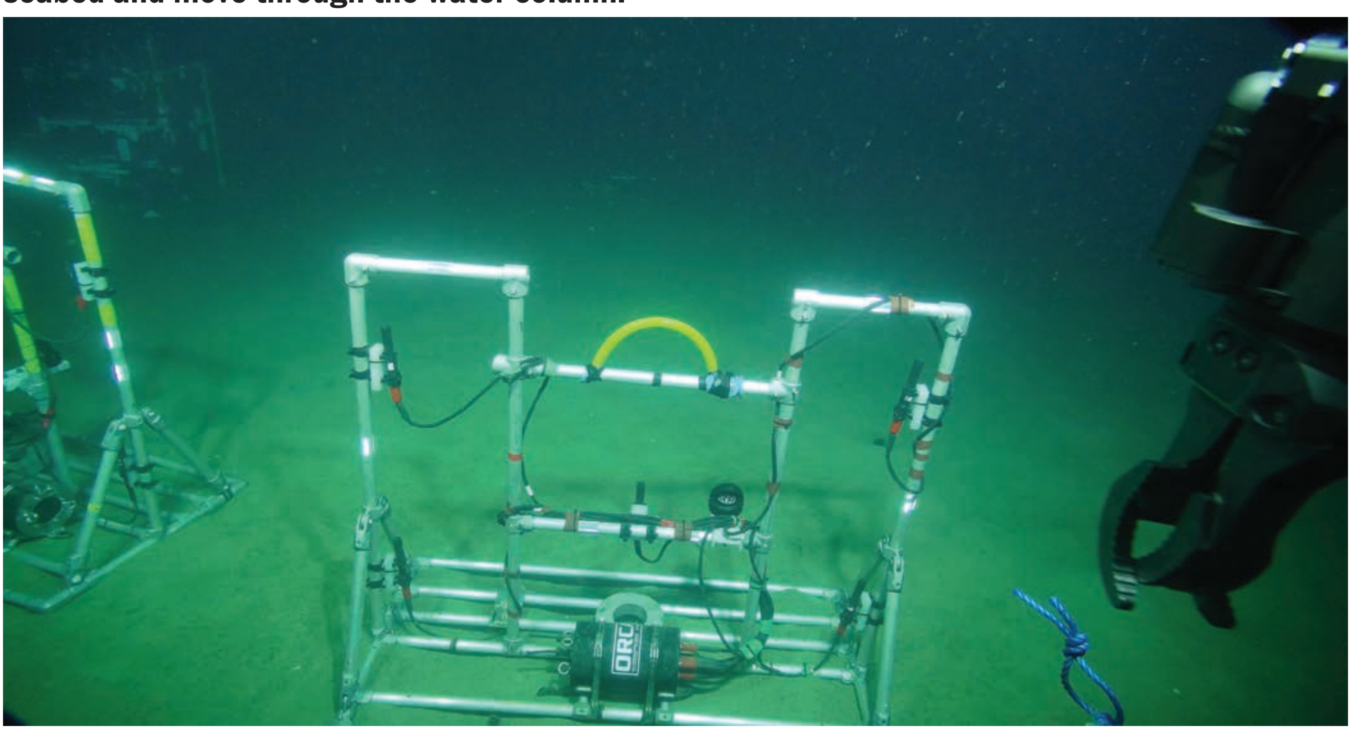


Image: Image: Copyright STEMM-CCS Project could be detected, both in the dissolved phase and as bubbles. These results have clearly demonstrated the utility of combining a number of sensing and monitoring approaches to detect leaks from CCS reservoirs. A second research ship, RV Poseidon, manned by a crew and science team from the GEOMAR Helmholtz Centre for Ocean Research in Kiel, Germany, hove to within sight of the Goldeneye platform and the RRS James Cook. Partners in the STEMM-CCS project, the GEOMAR team were engaged in more distant monitoring and seabed baseline studies linked to the experiment, combining expertise and facilities across European nations.

Professor Douglas Connelly, the NOC scientist who led the project, is delighted with the outcome: "Three years of hard work and innovative thinking have brought us to this exciting point in the STEMM-CCS project. This experiment was as near to a real leak as we could simulate and is the first time, anywhere in the world, it has been attempted. The North Sea can be a harsh environment and getting the pipe into the seabed, connected to a CO2 supply and producing a stream of gas was always going to be a challenge. This realistic scenario was critical for us to properly test the sensors that have been developed to give peace of mind in the future, that if a leak should occur, we can detect it quickly and precisely. The STEMM-CCS cruise has been an incredible success, from a technical point of view. Placing 3 tonnes of CO2 on the seabed and releasing it in a controlled manner 3 m below the seabed, in order to demonstrate the high sensitivity that the new generation of marine sensors have in detecting the dissolved and bubbling gas, was no mean feat. The success of the experiment and the performance of the sensors gives us a step change in our confidence that in a real-world situation we have the capability to detect and monitor escape of CO2 from storage sites beneath the seabed".

Although the ultimate aim of the experiment and the STEMM-CCS project as a whole is to develop sensors and methods for detecting and monitoring gas leakage in a real-world situation, there is also an educational aspect to it. Live from the cruise, postgraduate researcher Ben Roche (NOC) shared the excitement of a science research cruise, its challenges and successes with more than 200 school students from Southampton, England and Wales, via live links from the ship: "It was very rewarding chatting with the students while the scientific research was actually taking place, and I am fascinated to see how they use and analyse real-world data from the experiment in their curriculum studies." Further outreach work is planned throughout the remainder of the rest of the year and full details of the cruise and the project as a whole can be found at **www.stemm-ccs.eu**

Eelume is an undersea vehicle blurring the lines between AUV and ROV.

Image: Eelume

Inspection, Repair & Maintenance (IMR) Moves

Robotic

By Justin Manley

Unmanned maritime systems (UMS), especially autonomous underwater vehicles (AUVs), are no stranger to commercial applications. Survey of the seafloor by AUVs and subsequently unmanned surface vehicles (USVs) is now an accepted practice. UMS technology is moving into new commercial domains, notably inspection maintenance and repair (IMR). While there are no perfect definitions these tasks can be viewed as follows:

- Inspection is the task of examining a structure, perhaps a pipeline, to determine its condition.
- Maintenance is a routine task involving interaction with a structure, such as turning a valve or inserting a lead.
- Repair is typically a significant intervention, such as replacing a broken pipe.

These missions were traditionally the domain of work-class remotely operated vehicles (ROVs) and the large offshore support vessels (OSVs) they depend upon. But times are changing.

Today there are a host of new robotic approaches to IMR, all of them progressively disrupting the conventional techniques. The spectrum ranges from novel ROV deployment concepts to unmanned systems "resident" on the seafloor, and include novel robotic form factors and business models. While there are exciting developments to discuss, they are predominately focused on inspection and maintenance. Repair is currently still the domain of high power and heavily human-operated ROVs supported by OSVs. But the "I" and "M" sector is roughly half the overall IMR market and seeing rapid evolution.

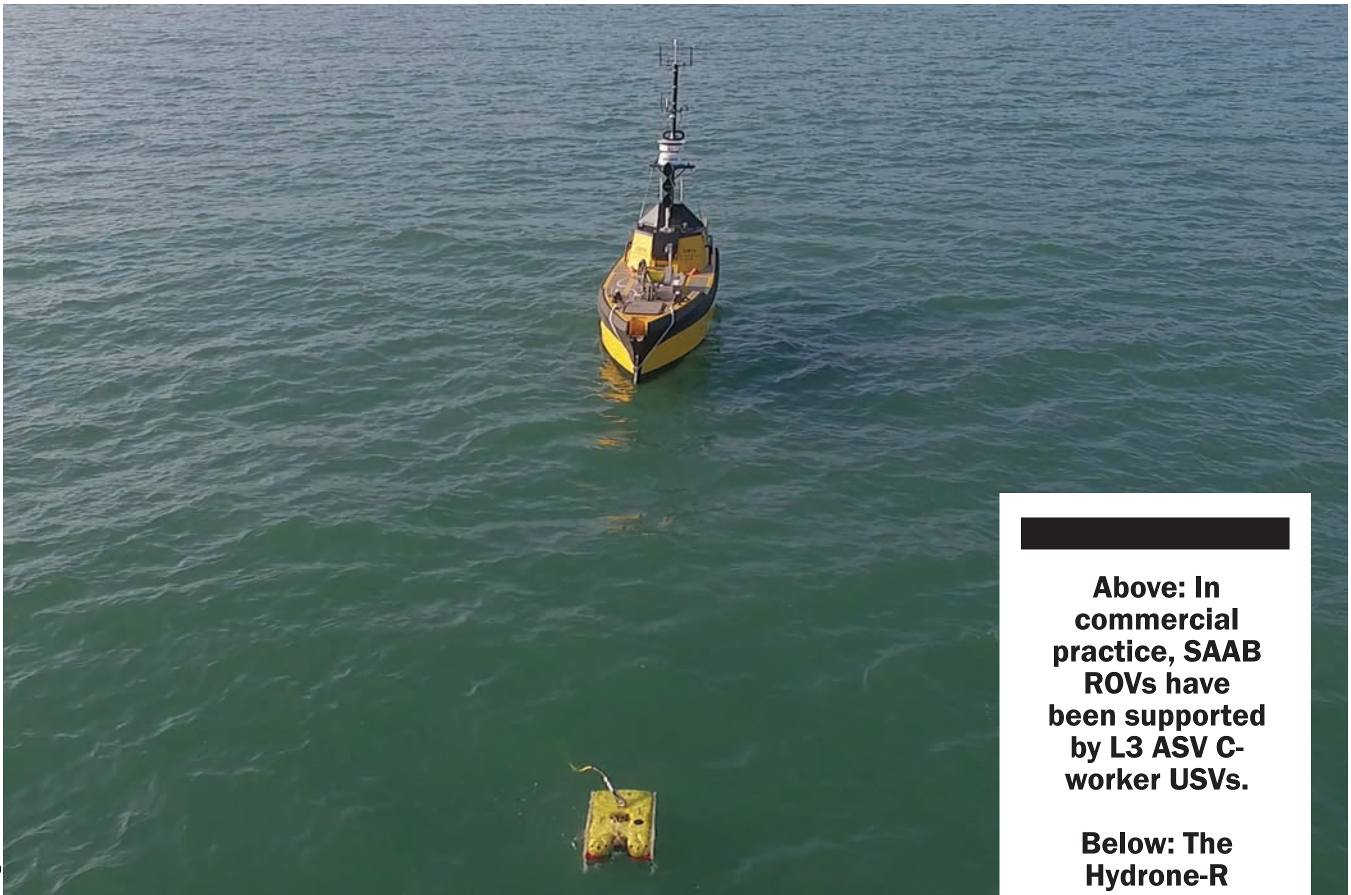


Image: L3 ASV

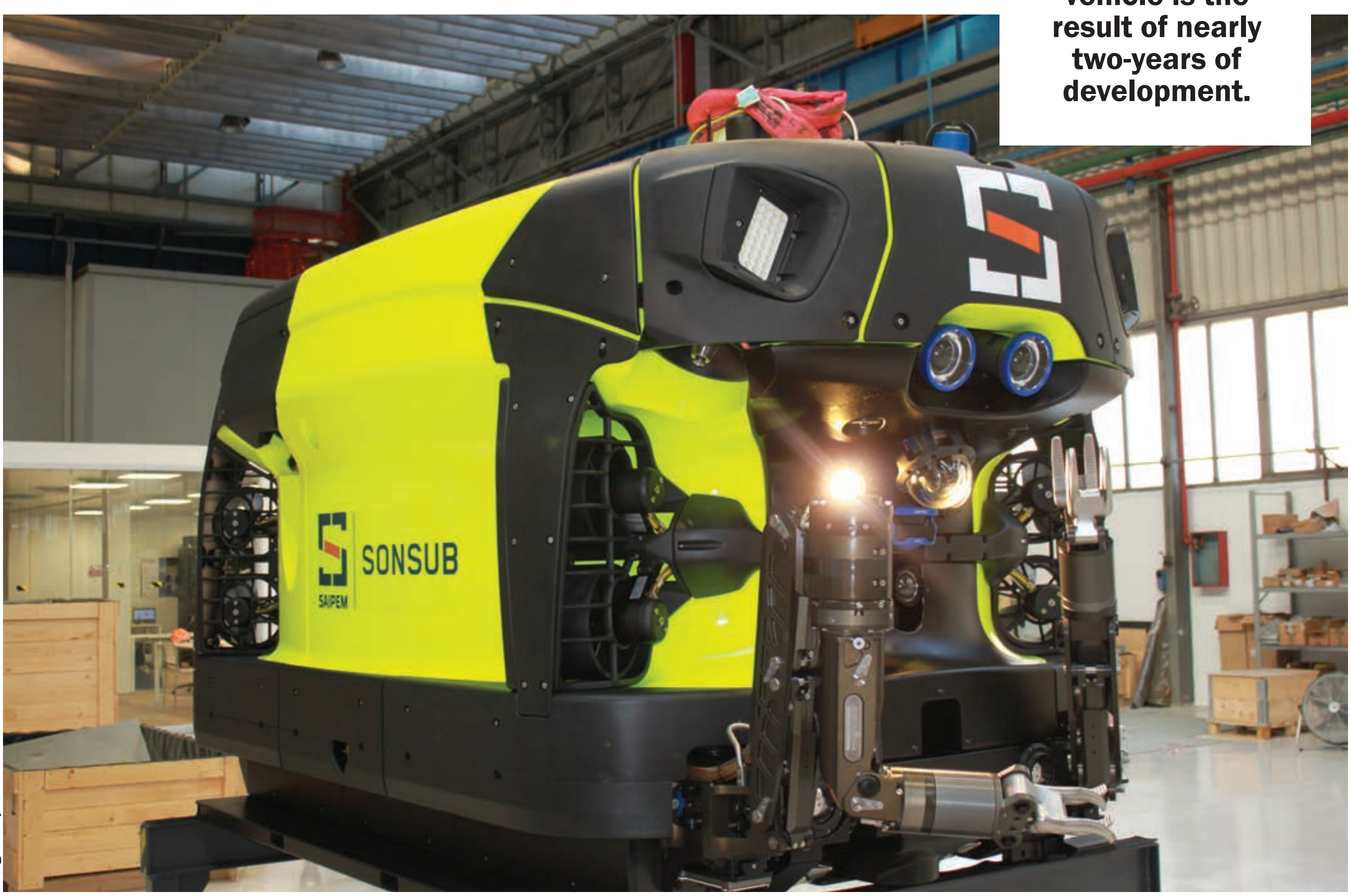


Image: Saipem

Above: In commercial practice, SAAB ROVs have been supported by L3 ASV C-worker USVs.

Below: The Hydrone-R vehicle is the result of nearly two-years of development.

New Approaches to ROVs

The most obvious element of change in current practice is to remove the ship. A logical first move is to replace a large expensive crewed ship with an USV. This approach has been demonstrated by several players. In a defense-focused demonstration Teledyne Seabotix ROVs were operated from Marine Advanced Research WAM-V USVs. In commercial practice, SAAB ROVs have been supported by L3 ASV C-worker USVs. In these configurations the objective is primarily inspection. An operator ashore, connected via radio or satellite telemetry, can use the combined systems to examine structures or the seafloor. Light intervention is feasible but typically the ROVs involved lack the physical power to engage core offshore maintenance tasks. Operations of this kind are typically measured in hours, or perhaps a few days, but not intended to be persistent.

Another concept gaining appeal is to install an ROV in a fixed location. This might be attached to a large installation providing power and data connectivity back to shore. It could also be connected via a buoy, for telemetry, and rely upon batteries for power. In either case the ROV is now a fixture on the site and does not depend upon an expensive vessel for support. This is a compelling value proposition, but it demands a significant investment in ROV reliability. Traditionally ROVs are routinely serviced and maintained on deck. Often more than one ROV is embarked on a vessel to ensure productivity. Such approaches are not viable in a more fixed, long-term concept of operations. Industry has accepted this challenge, and leading players have developed new ROV offerings. Oceaneering has developed their e-ROV, and seen positive results in early trials. Saipem has likewise invested significantly in this area. Their Hydrone-R vehicle is the result of nearly two-years of development. It is transitioning from prototype development to sea trials during the summer of 2019.

Seafloor Resident Systems

The natural evolution of ROVs trusted to operate for hours or days without ships is vehicles resident on the seafloor without tethers. SAAB's Sabertooth has been a leader in this area starting with a widely referenced demonstration in Houston's Neutral Buoyancy Lab in late 2016. This showed that a free-swimming AUV could both autonomously survey and transit and then intervene, turning a valve mechanism. This latter step was conducted under manual control using high-bandwidth wireless telemetry.

Since then others have entered this space. Oceaneering has unveiled their Freedom vehicle. This system is designed to be multi-role with the ability to execute survey and inspection tasks. It is intended to be housed in a docking station installed on the seafloor site where it will return for recharging. The vision for such systems is to be installed and left on the seafloor for months. It combines the mechanical engineering challenges of making ROVs reliable with software necessary for long-term operability. These technology concepts are slowly being developed and Oceaneering's solution had advanced rapidly to offer a market choice.

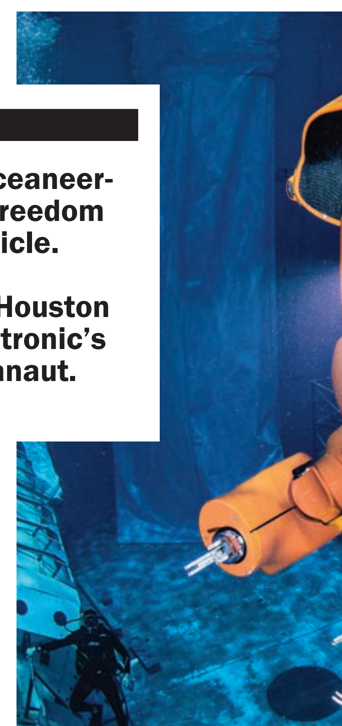
The vision of wireless seafloor resident vehicles is powerful. But it remains a future vision. Today long-duration deployments of tethered seafloor resident vehicles are imminent, notably with Eelume, an undersea vehicle blurring the lines between AUV and ROV while employing a distinctive architecture that supports modularity and maneuverability. Looking something like its eel namesake, this technology has begun offshore proving trials for subsea-residence operations. Eelume subsea-resident systems were deployed at a Norwegian Science & Technology University underwater test site in 360 m. water offshore Trondheim during May 2019. The Eelume robots were deployed to the sea-bed with a docking garage and used to perform a number of inspection and light intervention tasks on the underwater test site. After further testing and configuration trials in Trondheim later this year, it is planned that the first two subsea-resident Eelume systems will be deployed on the Åsgard subsea production field for Equinor. The two robot systems will be configured for inspection duties and intervention tasks, including torque-tool valve operations. These first subsea-resident Eelume systems will operate in battery-powered, tethered control mode, but before the end of the year are expected to demonstrate tetherless operations.

Staying "Connected"

To support widespread tetherless operations of AUVs it will be necessary to provide wireless connectivity to the systems. Acoustic modems are useful for long-range connections but offer limited bandwidth. Optical systems can provide much more robust bandwidth but over limited ranges. A collective system can offer one approach to this challenge. Ioseba Tena, Global Business Manager at Sonardyne puts it well, "At Sonardyne we have been demonstrating navigation and wireless communication cell towers, equipped with acoustics and free space optical modems, capable of providing position updates and real-time pilot control. These will be placed strategically in areas like wells, manifolds, etc. where human intervention will help mitigate for risk and improve operations. They will enable us to interface with the vehicles in real-time streaming video and joystick commands as if we were offshore with them." This approach may enable wireless vehicles to operate further afield, while still in close contact with operators.

New Robots, New Business Models

Expanding on the vision of untethered undersea robots for IMR is Houston Mechatronic's Aquanaut. This transforming system can operate in both an AUV mode for survey and transit and an ROV mode for closer inspection and manipulation. The intention for Aquanaut is for the system to arrive on a job site and execute tasks, such as valve manipulations, using its own onboard intelligence. Operators will use only high-level supervisory control to check system status and issue mission



Left: Oceaneering's Freedom vehicle.

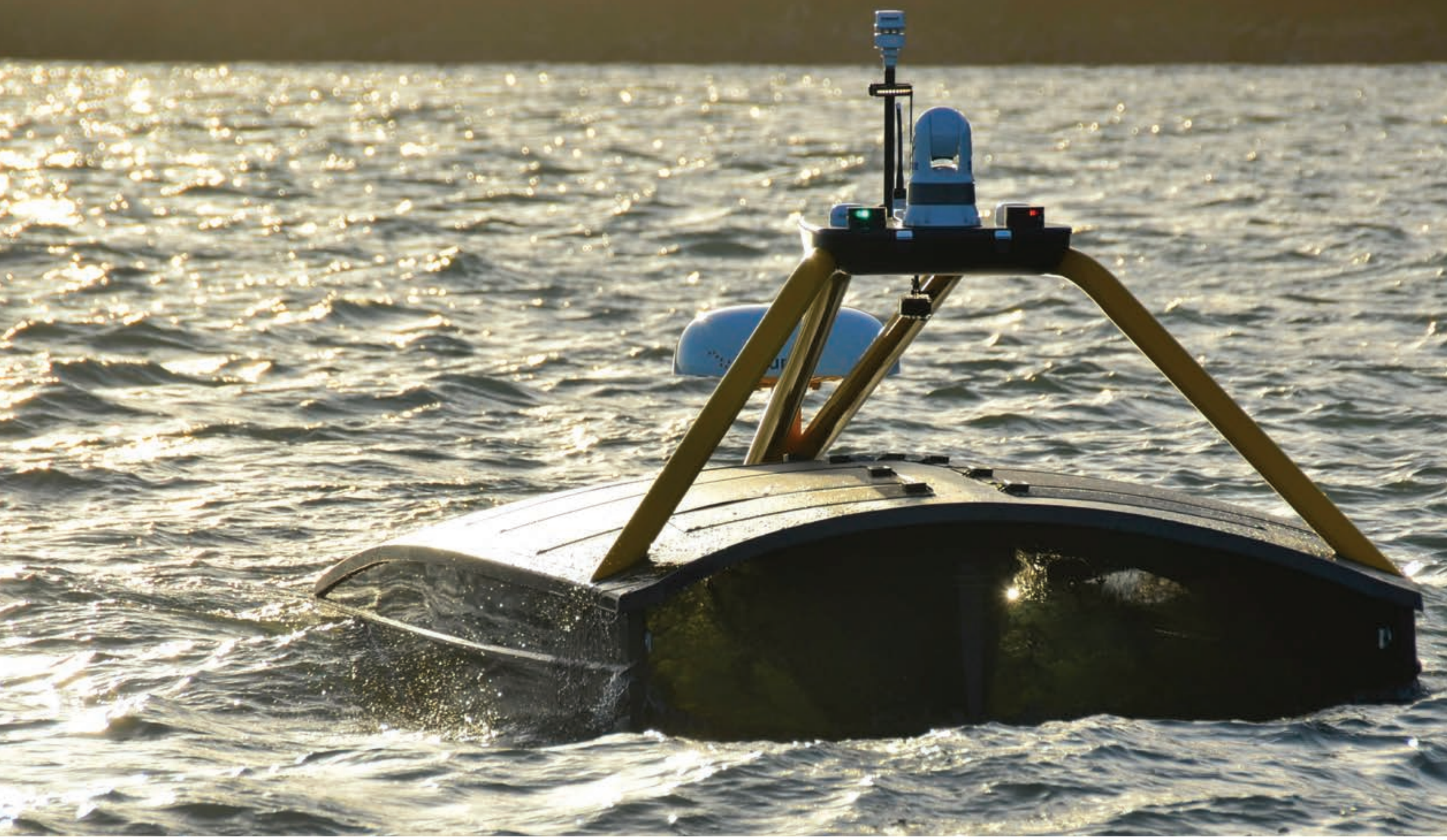
Right: Houston Mechatronic's Aquanaut.

Image: Oceaneering

commands. This concept challenges both technology and business conventions. Aquanaut's transforming capabilities are impressive mechanical developments. But the sensing and software engineering developments are equally important. Training a robotic system to perceive, understand, and engage a complex undersea environment is a significant challenge. Presuming the engineers succeed, the business challenges arise. Aquanaut is envisioned as an IMR on-call service, providing the necessary activity when and where needed, without the expensive vessels, much as a ride-share service provides transport on demand. This is a notable change of approach and may radically change the economics of IMR.

Achieving this vision will demand that engineers not simply develop the technology. They will have to prove its reliability to subjective human operators. Lawyers and accountants will not understand the code and will only be convinced by successive demonstrations and incremental progress toward a fully autonomous IMR operating environment. To combine the words of offshore operators and managers, it will be a "long slog" before the "shiny robots" can do it all.

Image: Houston Mechatronics



Going over the

Use of unmanned surface vessels is becoming a commercial reality – reducing emissions, cost and health and safety risk in the offshore industry. **Elaine Maslin** *takes a look at projects BP has been running.*

In May this year, an unmanned surface vessel (USV) made the journey from West Mersea, in Essex, England, to Oostende in Belgium.

The 22-hour journey, between the UK and the European mainland, to deliver a 5 kg box of oysters caught around Mersea Island was largely symbolic (by road, including the Channel Tunnel, it would take just under five hours, covering 200 miles). It showed that an unmanned vessel – in this case a SEA-KIT operated Maxlimer, built by UK-based Hushcraft – could transit safely across one of the world's busiest shipping lanes

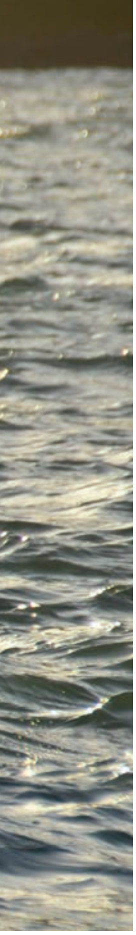


Photo: XOCEAN

XOCEAN's XO-450 operating offshore.

e Horizon

with confidence.

While the trip made headlines such as "The world's your oyster", there have been more practical advances in the use of USVs in the UK sector of the North Sea. UK-based energy firm BP has been taking a lead in this space. BP, which has a vision to achieve 100% of underwater inspection by marine autonomous systems (MAS) by 2025, has been deploying USVs for data harvesting and pipeline inspection.

Eric Primeau, a Senior Technology Specialist for BP, is clear that there are benefits, but he's not complacent about the challenges, particularly those associated with working over the horizon, when line-of-sight and radio communications are lost. Speaking at a The Hydrographic Society in Scotland meeting in Aberdeen, earlier this year, he said: "There are challenges associated with over the horizon operations, which is one of key defining factors of functionality that needs to be built in to USVs to make them commercially viable. It's the biggest challenge they face. Technically, the rest of it's there."

There are challenges around insur-

Photos: BP

The XO-450 being deployed via a slipway at Peterhead.

Photos: BP

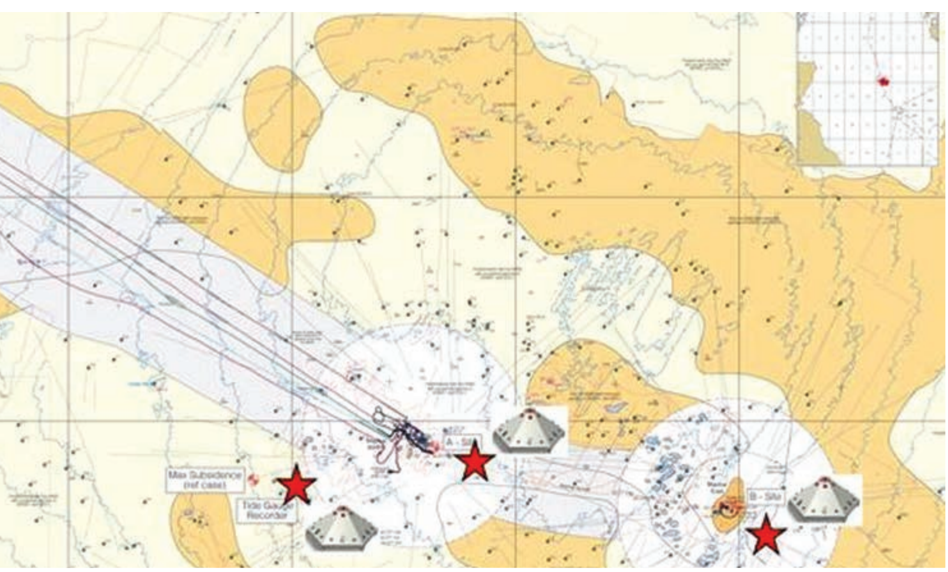
ance, as well as around rules and regulations, which are dealt with elsewhere in this issue. Setting up base facilities from where remote systems are operated, as well as vessel endurance and the ability to operate in rough weather are others – both of which are particularly pertinent to North Sea operations. For use as part of subsea inspection operations, in conjunction with underwater vehicles, the depth to which these systems are deployed, tethered or untethered, will become a factor, as will maintenance and reliability. “There are going to have to be some considerable design considerations,” says Primeau. “These vessels are going to have to be robust. There’s nobody out there to fix them.”

Then there’s communication – i.e. bandwidth and latency. “How much information do you want to transmit, what are you trying to transmit, what bandwidth do you need, what’s the delay. If you’re operating an ROV and you have 1 second delay does that induce risk?” says Primeau. There’s also a need for a level of localized autonomy – with onboard decision-making rights – to enable systems to operate with confidence, as well as emergency recovery contingencies, fail safes, etc.

Notwithstanding some of these concerns, BP this year has performed two commercial projects employing a USV manufactured and operated by Ireland-based XOCEAN.

Machar

The first project was to gather data from seafloor sensors that had been deployed in November 2018. BP has changed its reservoir management strategy at its Machar field – a subsea tieback to the Eastern Trough Area Project (ETAP) 120 km east of Aberdeen – and wanted to see if there was any change to the seabed as a result. The sensors, Sonardyne Fetch instruments, log and store depth measurements over long periods. Ordinarily, to gather the data the instruments have logged and stored, a vessel with a transceiver would need to be mobilized to the site, where it would then acoustically receive the data.



Left:
Sonardyne’s Fetch subsea sensor logging instrument.

Above:
The Machar Fetch node locations.

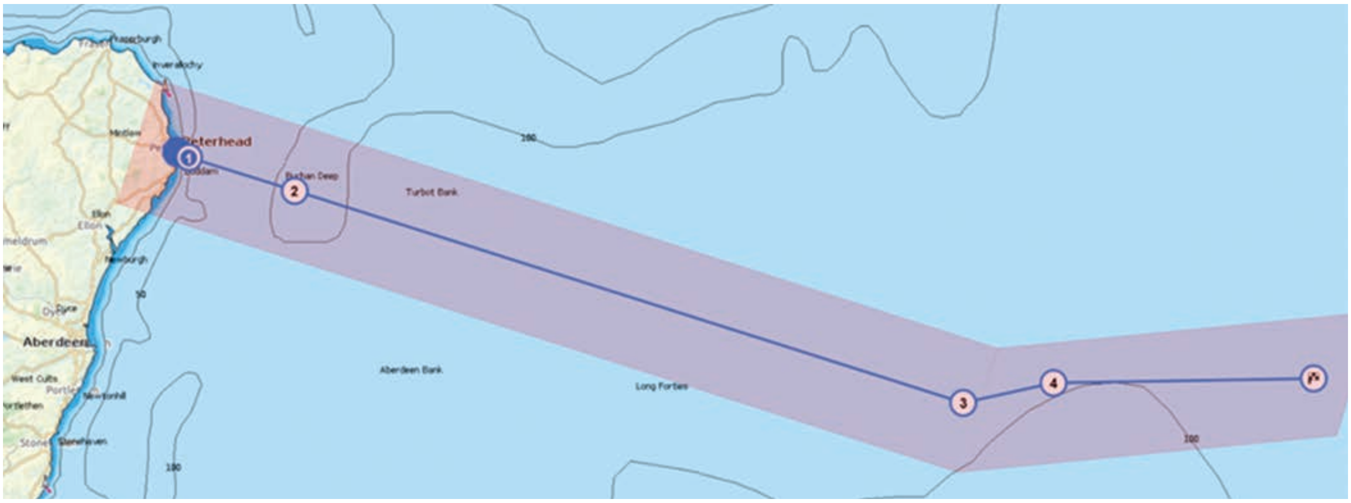


Image: BP

The Miller pipeline survey route.

Instead, BP decided to use a USV to retrieve this data – a first for the North Sea. It would significantly reduce carbon emissions and associated health, safety and environment (HSE) exposure as well as substantially reducing manned vessel costs.

In May, XOCEAN's XO-450 USV, fitted with a Sonardyne HPT 3000 Mini-Ranger 2 6G Ultra-Short Base-Line (USBL) system was driven up to Peterhead, in Scotland, and launched from the quayside. The XO-450 is a 4.5 m-long, International Marine Organization compliant USV with a hybrid pow-

The transit out to Machar covered 128 nautical miles.

Photo: BP

er system. The vessel has an 18-day endurance with full communications capability (including dual redundant satellite communications systems), cameras (including thermal imaging), and navigation lights. It's able to communicate real-time with XOCEAN's onshore control room, where pilots are based 24/7, enabling remote, over-the-horizon control.

It navigated using waypoints more than 128 nautical miles offshore to the Machar field and then transited to each seabed unit location to download the data – which was sent live to shore so that both Sonardyne and BP could do an initial check on the data. To reach of the seabed units, permission to enter a 500m exclusion zone, due to the presence of a light well intervention vessel, was required and gained – showing another benefit to using these systems. Once all the data was retrieved, the mission was deemed a success and the X0-450 returned safely back to Peterhead.

"A key reason for us going down this route, for using a USV over-the-horizon, was to eliminate health, safety and environmental (HSE) risk," says Craig Allinson, Survey and Positioning Lead for BP North Sea, also speaking at the event. "Unmanned operations with a small vessel enable us to do that. They achieve a significant reduction in carbon emissions – compared with a manned vessel – and total elimination of the need for humans offshore for this type of work. We also get a significant cost saving, compared with using a conventional vessel."

USV Inspection Operations

With the XO-450 available in Peterhead, BP had another project in mind – a shallow water survey of the Miller pipeline at St Fergus.

The Miller pipeline is a 30" export pipeline that runs from St Fergus, near Peterhead, out to the Miller field. For the survey, the USV was reconfigured from its data harvesting setup. After an initial trial, the system was refined so that it housed an R2Sonics Dual Head multibeam system, Valeport SWiFT sound velocity profiler and Applanix POSMV OceanMaster for vehicle heading, attitude, heave and velocity.

The Miller pipeline survey was conducted from just 2.5m water depth to 40m depth over a 4.75km section of pipeline. In total four runs were carried out. These comprised of two center lines acquiring multibeam data from the R2Sonic system and two wing lines acquiring pseudo side scan data using a Norbit iWBMSh system. Throughout, the operations were monitored and controlled remotely from XOCEAN's base in Ireland.

The goal was to get point cloud data, color coded bathymetry data, quality control, five point files, pseudo side scan sonar, event/anomaly listing and contours. Final data delivery was met within four weeks of demobilization and the data was deemed suitable by the integrity engineers.

"The data acquired from the USV system was of very high quality and demonstrated the ability of these systems to undertake shallow water pipeline inspections, moving the industry forward technically while realizing efficiencies in carbon reduction and HSE risk," says Primeau.

Thanks to the success of the Miller survey, the revised dual head multibeam system is scheduled for deployment in Azerbaijan for inspection of shallow water pipelines (shoreline to 25m water depth) in Q4 this year.

That's a story for another day. For now, BP is making steps towards its marine autonomous inspection vision, while also reducing its carbon footprint and HSE risk. The goal is to modernize the business and make inspection operations more efficient, says Primeau. "The offshore industry is on the cusp of great change as the use of USVs increases and functionalities develop. It's challenging the use of manned vessels for routine inspections," he says. "The USV is becoming a standard tool for performing high resolution seabed surveys and it's also a gateway for developing complementary underwater systems, such as the integration of ROVs and AUVs."

Photo: CMRE

At CMRE, it's not just about the science. It's about building trust and confidence in resilient systems

An interview with Dr. Catherine Warner, Director, NATO Center for Maritime Research and Experimentation, La Spezia, Italy

By Capt. Edward Lundquist, USN (Ret.)

ER

Tell us a little about yourself and CMRE. What does CMRE do, and how do you see your mission evolving?

I came here from the Pentagon, where I was the science advisor for the director of operational test and evaluation. My experience has been working with operators on systems that they're getting ready to field. Now that I'm here at CMRE, we are trying to make ourselves relevant to the war fighter. Science and technology doesn't always get the lion's share of the funding. Even in a military command, if the military doesn't know what you're doing, we have to show that we are relevant. We have been funded by Allied Command Trans-

Photo: CMRE

formation (ACT), but now we're a customer-funded center. ACT is still our largest customer. They fund about 75% of our work, but it's mostly basic research, at a very low TRL (technology readiness level). We are also interested in solutions for today, and we've been successful working with the NATO Maritime Command –MARCOM. For instance, we've been able to make available our expertise in anti-submarine warfare (ASW), mine countermeasures (MCM), and environmental knowledge /operational effectiveness (EKOE), which could be battlespace characterization, or an environmental assessment of military oceanography.

Environmental knowledge is basically characterizing the state of the sea and atmosphere, in real-time, on how it will affect an operation. We've had some really good recent successes participating in NATO exercises like Dynamic Mongoose, which are annual ASW trials in the GI-UK gap. We actually were part of the exercise this year, and we'll do it again in 2019. We've participated in Dynamic Monarch, a distressed submarine exercise where we were able to use our digital underwater communications protocol to chat with the submarine that was playing the distressed submarine. Instead of trying to understand the garbled underwater telephone, we used an application we called "WetsApp," which is sort of an underwater WhatsApp, based on our JANUS digital underwater communications protocol that we developed here over a period of 10 years.

We're doing another exercise right now off the coast of Portugal to look at how to incorporate this digital communications into distressed submarine doctrine and tactics. We have also been working with the Standing NATO Maritime Groups – SNMG 1 and 2 – with their exercises. So working with the operators has been a way to show our relevance. Twenty years ago people were reluctant to work with unmanned aircraft, but today they're common. We want to make operators comfortable with unmanned maritime systems now. There's a new generation of sailors who are going to be used to working with unmanned systems. But there is still some unfamiliarity and uncertainty. So it's up to us to sort of go in their exercise, show them what these systems can offer. Our new sensors are so much better, with synthetic aperture sonar and automatic target recognition. So we want to have that conversation with the operators to see what science can do for them, and for our scientists to understand what the operator needs. And that's important to go to the next step in system development.

Will you continue to do basic research?

Definitely - you have to start there. But I do see us doing more at higher TRL, up to prototypes and demonstrations in the operational environment.

You run the whole spectrum from basic to applied to prototyping?

I don't see us making systems that transition directly to

CMRE's research vessel, NRV Alliance.

being deployed in operational service in the fleet. The many integration parts haven't been solved yet. We still have to go out in the rubber boat and put them in the water.

I guess it depends on what you are trying to prove – is the concept good, or is the system able to do that particular mission?

You don't want it to fail. So you want to develop the technology, then a concept technology demonstrator. I think we can do that for NATO.

You have world-class facilities here. How would you describe that to someone who doesn't know what you do?

I'm a perfect person to describe it because I didn't know about CMRE myself before I came here. People may have been familiar with the SACLANT Center during the Cold War, and we would later be called the NATO Undersea Research Center (NURC). Today we are CMRE, but I don't think we're well known. We're not big – about 150 people – compared to NUWC Newport or NSWC Panama City. But what I find exciting is the fact that we have scientists who come here with their own ideas, and young professionals who have an opportunity to start working on a team. Our engineering department is amazing, and they are able to take concepts and turn them into real experiments that can get meaningful data for the scientists. I don't think that our engineering department gets enough praise. They can make anything, and will make it work. Right outside my window we have an underwater network of acoustic sensors mounted on tripods. It's called the Littoral Ocean Observatory Network (LOON), and a researcher can access that network from his or her office anywhere. They can send waveforms and run them on the LOON and see how they perform in an undersea environment. Our engineers build and modify systems, and take the systems to sea on the Alliance or the Leonardo, the two research vessels that we own. As you can imagine, taking science to sea is really hard and it's really expensive, and not many nations can do that. In the United States, it's kind of a normal thing, but most countries can't really afford to have that capability. When we go out on Alliance with whatever mission packages or trials we're going to do, we will have several different nations participating. Alliance is a global class research vessel and is ice hardened for operating in extreme latitudes. We've been going to the Arctic pretty much every year. This summer when we were up there we had collaborators from seven different countries and different research institutions. One just had one glider that they wanted to test a new sensor on. Someone else had a whole series of experiments where they wanted to collect solution data. We collected data from the Faeroes all the way up to Svalbard. An organization can't afford to just go there with just one glider. We had a charter from Woods Hole, funded by the National Science Foundation to operate in waters around Iceland and Greenland from January through March. We are in demand because we are one of the only ice-capable, global research vessels that is going to the high north every year.

Alliance has been around for 30 years. Do you plan to replace her?

We've already started to think about that. There's no way CMRE could ever afford to buy another Alliance. It has to be a NATO decision. We have to go to the nations and ask them, "Do you want to keep this global research capability to do science at sea in the high north?" And if they do, then we have to go through the NATO process of finding funding while writing our requirements and then finding a company to build the ship.

You must have a lot of agreements for cooperation and collaboration with partners in either government, the private sector, or in academia.

Part of our governance is the NATO Science & Technology Board, and they have a smaller committee called the Maritime S&T Committee – the MSTC – which includes the maritime nations. They are advisors who come here twice a year and we conduct a whole review of our program. The nations give feedback on our programs. Although ACT is our primary customer, all money in NATO comes from the nations, so they're ultimately the customer.

In addition to platforms, sensors or systems you develop here, do you also help the nations with testing or evaluating their own systems?

As nations increase their use of autonomous maritime systems, there will need to be some sort of range where they can go to evaluate their systems and technology. We think we could provide that capability to nations to test and certify that a particular autonomous system can operate successfully in a specific environment. We focus on interoperability. So when the nations are developing capabilities, requirements, and conducting acquisition, we can share information with each other and we can make sure it works together. We think CMRE is in a good position to provide that evaluation and certification to the alliance.

While the center used to be focused on ASW, today you pay attention to all of the domains.

We are actually developing an unmanned control system that's multi-domain: under the sea, surface, and air. Because of our experience with JANUS, which is the NATO STANAG, or NATO standard, for digital underwater communications, we actually have some experience in this area.

Do you make your own vehicles and platforms, or do you buy systems on the open market.

We have commercially available buoyancy glider UUVs and USVs, and we're doing all kinds of work with them. We have underwater vehicles such as the Bluefin 21, Ocean Explorer and the Remus. With all of our various vehicles, we get them and then we take them apart and put all our stuff in them.

So your engineers customize them.

Our engineering department are definitely the crown jewels. The scientists come up with the ideas, but the engineers actually do it. JANUS is the underwater communications protocol we developed here, which is now the NATO standard. We conducted JANUS-Fest this past year, and had all of the different companies that make underwater modems set up around our basin. Our engineers took the underwater modems apart and made them all so that they're compatible. We put JANUS on top of them. That sounds funny – because JANUS is just a protocol—but they all had their own proprietary modems, and we gave them our JANUS open source C++ protocol. By the end of the week, all of them could talk to each other using their own proprietary modem software, but with JANUS on top. It's like Google Translate. We're not competing with industry. We support the national industries – that's what we're for. We develop the concept and then we let the industries build it. And with JANUS, these different modem manufacturers can talk to each other without having to change anything, or give up anything proprietary.

Are the nations willing to come to you for help?

The nations will support us if we help their industries in their country. We helped the defense company Leonardo here in Italy by designing their towed array, and we brought them here and showed them how to make it. Now we're helping them develop the software and the decision aids that go onboard in the combat system, to use it. We cover our costs, but it's Italy's industry that's going to build and sell the system.

So let's talk a little bit about ASW and MCM. That used to be the Center's focus back when it was the SACLANT Center, the NATO Undersea Research Centre. What's the state of play here for ASW?

ASW is a very complicated mission area. ASW is about a third of our program. But many of our other programs, like environmental assessment, obviously supports ASW, too. If you know about the water column, for example, you know where to put your sensors. And I think of mine countermeasures as an extreme extension of ASW, where the target is not moving or radiating noise. So in some way, they are all related. Here at CMRE we call it "Collaborative ASW – CASW." ASW will always be hard – it will always be asset-intensive. Today we use helicopters with dipping sonars; maritime patrol aircraft dropping sonobuoys; frigates with hull-mounted sensors; and submarines with towed arrays -- that's a lot to do for ASW. I don't think a fleet of a thousand unmanned systems is going to replace all that, but I think it can do part of it. One of our big thrusts now is doing operational research studies with the nations on which parts of ASW are cost effective and operationally efficient that we should use unmanned systems for. There are many different scenarios we can look at, but one of them is to create a barrier in a certain geographically sensitive location where unmanned systems provide persistent surveillance. We're looking at different types of vehicles and sensor packages working together. We're looking at things on the floor of the sea, towed arrays, data relays, and multi-static systems. We're doing the studies and operations research to find effective, interoperable and affordable solutions. That's the studies part. And then we do the design and conduct the actual experimental and developmental part, to validate the concepts. We've developed new arrays; we've developed new algorithms for processing them; we have the new JANUS communications protocol so they can communicate with each other and back to the mother ship. We will be doing some extensive trials here in the Gulf of La Spezia, looking at some of the new pieces that we have in place this year. Then, hopefully, we can integrate our experimentation into one of these major NATO exercises, such as the Dynamic Mongoose NATO fleet ASW exercise. We're trying to figure out where the unmanned systems best fit into operations, and then we're doing the science to make them better, smarter, interoperable, autonomous, and more effective.

And mine warfare?

We've had a good year. We've now been able to deploy our kit on someone else's ship. NATO MARCOM – the Maritime Command, has a standing mine countermeasures group. And last year the UK ship – HMS Enterprise – was the flagship, and they invited us to bring our systems on board. So we took our unmanned systems, along with our scientists and engineers aboard the HMS Enterprise to participate in the mine exercises, the Spanish Minex and Italian Minex. They each have a slightly different focus, but in both cases we launched our systems from a ship. In the first one, we were looking at showing how to do the planning and evaluation – which is a huge part of mine countermeasures, and complete the post-mission analysis in more real-time, as opposed to waiting for the vehicle to be recovered and pulling the data so we can process and analyze it. We want to know as quickly as possible if we have found a mine-like object. So now we're seeing this stuff pretty much in real-time. We've done the deep learning, and have the convolutional neural networks to apply to our nearly 60 years of experience with complex acoustical data on mine shapes. We've been able to, in the lab, use that to train these algorithms to recognize mine shapes. And we can put that on the system, with the capability on the vehicles to determine on its own when it finds a real target, because it has learned. It can then talk to another vehicle with a different kind of sensor and they can decide how best to approach and collect information on that target and make collaborative decision. We've proven the deep learning; have put the automatic target recognition onboard the vehicles; and have the vehicles talking to each other. When we did the Italian Minex, the Italian Navy put their Efolaga unmanned vehicles in the water and we talked to them. We used our open-architecture MUSCLE [Minehunting UUV for Shallow Water Covert Littoral Expedition] vehicle, which is a modified General Dynamics Mission Systems Bluefin-21. We didn't do anything to their vehicles – but our MUSCLE vehicle could determine what kind of vehicles they were, and what kind of communications was needed, and MUSCLE was able to say, "Hey, Efolaga! I'm MUSCLE. Can you go take a look at this picture?" And it worked.

What can you tell us about LOON, the underwater network you have out here in the bay? What is it? How does it work?

It doesn't look fancy. It's basically a bunch of tripods that sit on the bottom, but they have acoustic sensors on them. They are nodes that can talk to each other. You can access the network from right here in the lab. In fact, anybody that has a wave form that they want to try can send it to one of our scientists and see how it performs in the water.

What can you tell me about your staff?

I've been bragging about our engineering team. We definitely have amazing engineers, with incredible ideas and a great work ethic and the ideas. We have around 50 engineers. And we have fantastic scientist too. We have always been able to attract the top-tier of scientists from the Nations. Currently we have 47 NATO civilians, as well as more than 20 "visiting researchers" who will come here for several months to work with us. We have a couple students from the French Naval Academy here right now, and they're working on deep learning and automatic target recognition. We might have a professor, a graduate student, or somebody from one of the applied physics labs in the United States. They might be here longer, up to a year. That's ongoing and rotational. And that's really the point of CMRE, to have people come here with their expertise, experience and knowledge, and go home with a better understanding of NATO's challenges and opportunities. That they can share with their colleagues. A scientist might come here for a three year contract, which might be renewed. They might even stay longer. But we really want scientists to come here and work in their field—whether its signal processing, automatic target recognition, ping stealing, whatever their field is – and go back to their country to continue to develop that work at their national research lab and then send other scientists here. That was the idea when this center was created. So we have a very diverse group of scientists and engineers from throughout the NATO nations. We have the ship office to manage Alliance and Leonardo, our research ships. And like most organizations, we have IT. But when I say IT, it's more than managing the local network and the workstations. We have the scientific network where we can do software development – because some of our products are actually software. We do a lot of big data analytics, and creating decision tools to look at the fusion of different types of sensor data. We actually develop software for our vehicles. So IT is very important, here.

Are you doing a lot with maritime domain awareness and AIS?

Yes. We have a group that is gathering and fusing together huge amounts of AIS and radar data and doing a lot of prediction, such where a ship might be going if it turned off its AIS. We do maritime patterns of life to understand what's happening in and around the sea in a certain area. We're also trying to teach machines to think like humans. When it comes to analyzing what a ship might be doing, even with conflicting information, a human is best at understanding what's happening. But a human can't assimilate such huge amounts of data. We're trying to teach our algorithms to think like a human, so we do a lot of serious gaming. One of my priorities is to make our network more robust, more resilient, and to improve and modernize it.

What kind of advice would you have to a student or an academic? Are there opportunities for them to come here?

Absolutely. That's what we're here for. We have positions for local junior scientists. We collaborate with most of the naval academies in the different countries, and they send their cadets here. Belgium had a student here this summer and they want to keep doing it every year.

You also have a very engaging STEM program.

We work with the schools in La Spezia. This is close to my heart, because we want to encourage young people, and young women especially, to get into STEM. When we look at maintaining our technological edge, one of the things we need are qualified people, and that starts with getting people educated in STEM. In La Spezia, the school system is very interesting, and different from the U.S. You get to pick which high school you want to go to, and if you want to be in the technical field, you get to pick the technical high school. In their junior and senior year, they have to work as interns, and we have worked with them to be one of those places where their high school students can come. You wouldn't believe how technically advanced they are. We've done some research here at CMRE on the impact of acoustic energy on marine mammals. We have done a long series of experiments and have accumulated a lot of data. This is of interest to our nations, because we want to avoid harming marine mammals. So we provided this acoustics data to the students and they were able to do a science project to analyze the data, and then they were able to present their findings at this very large and prestigious conference here in May with the European Cetacean Society. The students gave a series of presentations on the results of their analyses. It was a huge success, and we hope to continue that relationship. We hope to have students design their own experiments that they will be able to carry out here at CMRE.

Maybe they will eventually come here to work someday?

The woman who's leading this effort for the La Spezia School System actually worked here. In fact her father worked here.

Your ultimate customer is the warfighter. What would you want them to know about what you're doing here?

I'll go back to what I was saying in the very beginning – that it is so important for us to do these exercises. It's not just so we can do science. We can do that when we have the right environment, the targets and communications links. But there's more to it. For the warfighters, and this new generation of operators, we want them to be comfortable and confident working with autonomous systems. They need to have trust. I want them to know about what we're doing here – building resilient systems that they can trust. We want the sailors to trust them so that they will use them.

Introduction to Thruster Design for Submersible Developers

Images Courtesy Hydrocomp Inc.

By Donald MacPherson, Technical Director, HydroComp, Inc.

Many companies involved in submersible vehicle development also look to equip the vehicle with a custom thruster. These companies typically have expertise in vehicle and drive design, but will not be experienced in propulsor design. Nor would they be expected to have the specialized tools necessary for proficient thruster design, analysis, and optimization. This article will introduce submersible vehicle developers to the design practices used by HydroComp and other specialists to deliver thruster designs that are among the highest thrust-to-power ratio propulsors in service.

Propulsor Design Objectives

The ultimate objective of thruster design for vehicle development is typically a 3D CAD model of the propeller and nozzle that will support – and enhance – the technical and business mission of the vehicle. Three principal task groups make up a complete thruster design project – Vehicle-Propulsor-Drive system matching, thruster component optimization, and geometric modeling.

Vehicle-Propulsor-Drive system matching

This initial work package will determine the principal propeller and nozzle characteristics that are properly "matched to the system". Critical to the overall success of the thruster design process is to first determine the appropriate principal specifications of the propulsor and drive system, and only then can the propeller and nozzle components be designed in detail. Propulsor specifications that are determined during system design are typically: configuration (open vs. ducted), nozzle style (as needed), blade count, diameter, pitch, and blade area ratio. Critical drive parameters (that are simultaneously determined) are mechanical shaft power (not electrical power), RPM, and position of the design point on the drive's shaft power curve (such as using the electric motor performance curves to balance performance versus battery life, for example).

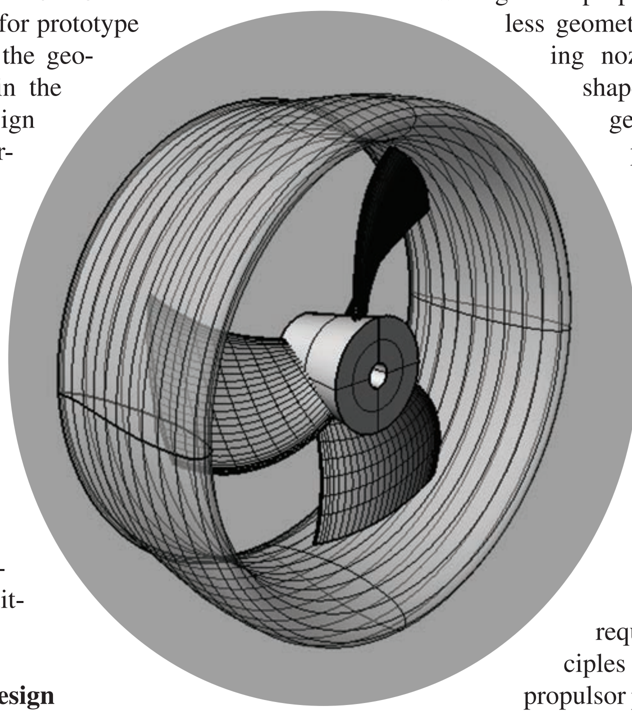
Thruster component optimization

This task group provides hydrodynamically-optimized propeller geometry (within the selected nozzle type) that is "designed for performance" for the particular vehicle's hydrodynamic properties and its interaction with the propulsor. After the principal system characteristics of the propeller and drive are defined in the prior stage, the details of the propeller component can then be designed. This process, called "wake-adapted propeller design", delivers the radial shape parameters that reflect size (chord, thickness, foil), lift (pitch, camber), and position (rake, skew). These parameters are designed to a specified vehicle speed, required thrust loading, and shaft RPM (i.e., the "design point"), with supporting evaluations for cavitation and blade strength.

A multi-duty application (such as an adaptive UUV that will carry both roles of transit AUV and workhorse ROV) might require a balanced perspective for a "compromise" design. As performance objectives change, so will the optimum characteristics of the propeller – and its nozzle. Multi-mode optimization is not difficult; it just needs some care to review the designs in the context of the total mission requirements. In many cases, a weighted calculation of overall duty-profile power demands can illuminate any problems meeting the necessary performance requirements within the expected "energy budget".

Geometric modeling

A full "designed for manufacture" 3D CAD model is then developed and delivered for prototype testing and deployment. Given the geometric parameters determined in the wake-adapted optimizing design stage, a full blade shape is generated. The blades must then be incorporated with a hub (that can have many different types of shaft attachments), with fillets and other details added during a 3D CAD process. There may also be additional considerations for specific manufacturing processes that will affect the shape, such as casting or milling. Development of the nozzle's geometry is really little more than an annular (rotational) extrusion of a suitable foil profile.



Required Tools for Thruster Design

A typical thruster designer's workbench will include the following software tools. A list of necessary tool functions and features are shown for each of the three principal design tasks.

Tools for Vehicle-Propulsor-Drive system matching will be built upon an optimizing solver that can determine propeller characteristics for maximum efficiency while considering any constraints for configuration, maximum propeller diameter, and cavitation limits. This must include both Thrust-based and Power-based loading options to handle transit and tow-pull mission roles. Suitable propulsor prediction models must be included for the propeller and nozzle styles under consideration. Finally, the performance of the optimized propulsor must be evaluated with the vehicle and drive, including prediction of the operating RPM and the required power.

Tools for thruster component optimization will typically be a blade-element calculation for the propeller, with support for various styles of nozzles and shrouds. CFD and other such codes may be used, although propeller-specific wake-adapted design tools can offer a variety of technical, financial, and workflow benefits. These including a structured "extruded foil" framework for management of the design parameters, automatic solution of optimum pitch and camber for the design objective, and the ability to alter radial loading as needed for supplemental design issues (such as for consideration of hydroacoustics, root cavitation, or strength, for example). Propeller-specific design tools also offer assessment of critical cavitation metrics (with feedback for design), and evaluation of blade strength and safety factor for various material properties.

Necessary for geometric modeling would include a tool with specific capabilities for propeller blade design, augmented with general-purpose CAD/CAM software for the less geometrically challenging roles (including nozzle shape development). Blade shape creation is very challenging for general-purpose CAD tools, so a propeller-specific tool for geometric blade design can offer mathematical functions for blade shape creation, including a library of contemporary and traditional propeller section shapes. Of course, export to general-purpose CAD/CAM is necessary for completion of the 3D CAD model (with the generated blades and hub).

Required Expertise for in-house Thruster Design

Competent thruster design does require an understanding of the principles of propulsion system interaction, propulsor performance, and propeller-nozzle geometry. That being said, it does not necessarily require a degree in naval architecture or hydrodynamics. For example, a mechanical engineer with a university course in fluids can easily develop the additional skills needed for successful thruster design. Used by nearly 200 propulsor designers and manufacturers around the world, HydroComp's suite of tools (NavCad, PropExpert, PropElements, and PropCad) provide a comfortable framework that lends itself to a "guided workflow", allowing in-house design to be both practical and cost-effective.

Partnering with a Specialist

Of course, not everyone wants or needs to have propulsor design capabilities in-house. In those cases, reaching out to a specialist with appropriate knowledge, experience, and resume' of successful projects can indeed make sense. If this sounds like you, we would be happy to discuss your project and thruster design requirements.

Blue Trail Engineering

Damon McMillan founded Blue Trail Engineering as a new source for high-quality, low-cost underwater servo actuators, thrusters, and electrical connectors. Blue Trail Engineering's 100-watt thrusters are optimized for high-efficiency applications such as long-endurance ASVs and AUVs. With magnetic shaft couplings and Swiss Maxon brushless motors, the thrusters are designed for months of continuous operation at depths of up to 300m.

www.bluetrailengineering.com

Blue Robotics Inc.

Since its founding in 2014, Blue Robotics has existed to propel marine robotics. Starting with the T100 Thruster, launched through a Kickstarter campaign, its product line has now grown to more than 250 components, with a focus on cost-consciousness and open-source. Since 2014, the company has shipped hundreds of thousands of components, including more than 35,000 thrusters, to customers globally.

Blue Robotics' product line spans a wide range of technology areas with a common theme of cost-consciousness, innovative design drawing inspiration from proven technologies, and extensive documentation and information. Its core technology is its patented thruster design, which is compact, inherently pressure tolerant and affordable. In addition to thrusters, the company offers actuators, watertight enclosures, buoyancy foam, sensors, lights, cables, control system electronics, sonars, and its flagship product, the BlueROV2 subsea vehicle. It has also developed a special geared version of its thruster that is now in use on the WHOI Mesobot project.

www.bluerobotics.com

Copenhagen Subsea A/S

The unique thruster technology of Copenhagen Subsea A/S is designed to help reduce downtime and improve the success rate of subsea operations. Copenhagen Subsea A/S saw that the market for underwater propulsion was ripe for a substantial re-thinking of technology, and its solution was to build a new product-line of electrical rim-driven thrusters. Building on the ring thruster technology, Copenhagen Subsea A/S has been able to develop and manufacture four thruster sizes – from VS as the smallest to VXL as the largest. The rim-driven thruster is a tight integration of motor parts within a housing. The electrical motor takes the form of a thin ring that has permanent magnets fixed to its rotor. This rotates within the stator arrangement of magnetic flux. The housing remains fixed to its platform on the subsea vehicle. The propeller – the only moving part in the rim-driven thruster rotates within the nozzle, eliminating the need for a drive shaft and hub. Its innovative electrical design has no gears, only one moving part and bearings that make use of the surrounding seawater for lubrication. These unique features lead to significantly reduced sound levels and minimal disturbance of surrounding marine life.

www.copenhagensubsea.com

Robo

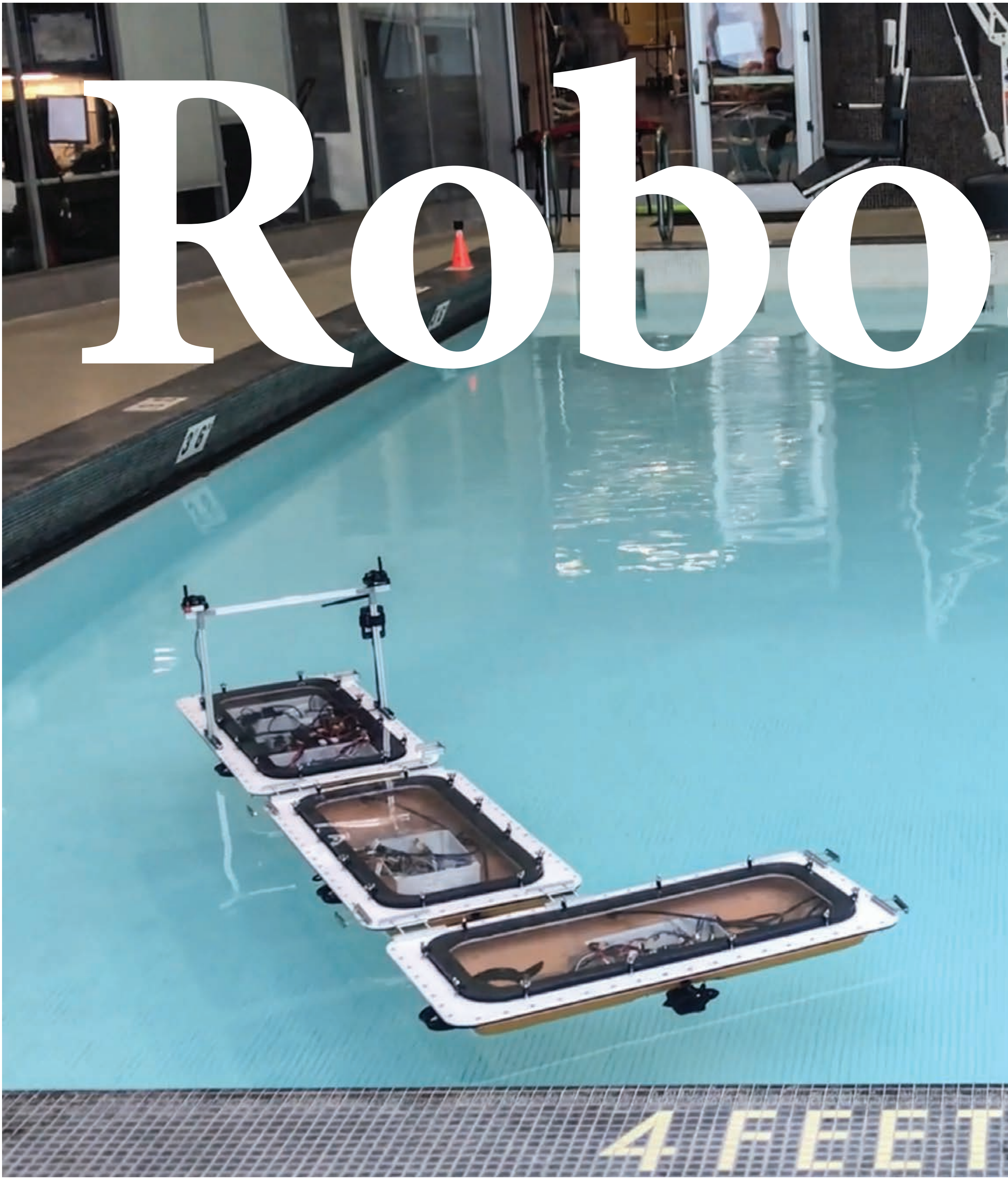
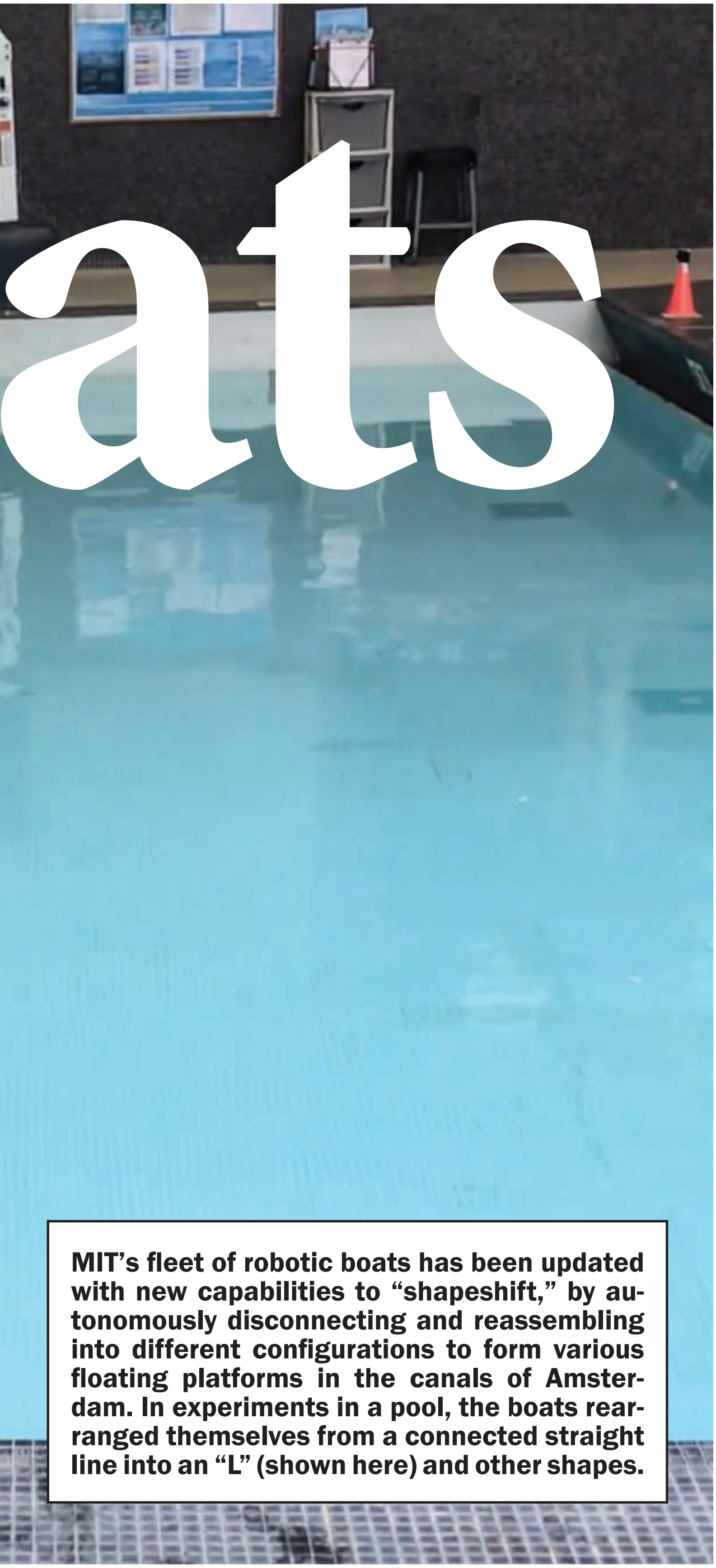


Image Credit: MIT



MIT's fleet of robotic boats has been updated with new capabilities to "shapeshift," by autonomously disconnecting and reassembling into different configurations to form various floating platforms in the canals of Amsterdam. In experiments in a pool, the boats rearranged themselves from a connected straight line into an "L" (shown here) and other shapes.

Meet the Shape-Shifting Autonomous Boats from MIT

By Rob Matheson, MIT

MIT's fleet of robotic boats has been updated with new capabilities to "shapeshift," by autonomously disconnecting and reassembling into a variety of configurations, to form floating structures in Amsterdam's many canals.

The autonomous boats — rectangular hulls equipped with sensors, thrusters, microcontrollers, GPS modules, cameras, and other hardware — are being developed as part of the ongoing "Roboat" project between MIT and the Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute). The project is led by MIT professors Carlo Ratti, Daniela Rus, Dennis Frenchman, and Andrew Whittle. In the future, Amsterdam wants the roboats to cruise its 165 winding canals, transporting goods and people, collecting trash, or self-assembling into "pop-up" platforms — such as bridges and stages — to help relieve congestion on the city's busy streets.

In 2016, MIT researchers tested a roboat prototype that could move forward, backward, and laterally along a preprogrammed path in the canals. Last year, researchers designed low-cost, 3-D-printed, one-quarter scale versions of the boats, which were more efficient and agile, and came equipped with advanced trajectory-tracking algorithms. In June, they created an autonomous latching mechanism that let the boats target and clasp onto each other, and keep trying if they fail.

In a new paper presented at the last week's IEEE International Symposium on Multi-Robot and Multi-Agent Systems, the researchers describe an algorithm that enables the roboats to smoothly reshape themselves as efficiently as possible. The algorithm handles all the planning and tracking that enables groups of roboat units to unlatch from one another in one set configuration, travel a collision-free path, and reattach to their appropriate spot on the new set configuration.

In demonstrations in an MIT pool and in computer simulations, groups of linked roboat units rearranged themselves from straight lines or squares into other configurations, such as rectangles and “L” shapes. The experimental transformations only took a few minutes. More complex shapeshifts may take longer, depending on the number of moving units — which could be dozens — and differences between the two shapes.

“We’ve enabled the roboats to now make and break connections with other roboats, with hopes of moving activities on the streets of Amsterdam to the water,” says Rus, director of the Computer Science and Artificial Intelligence Laboratory (CSAIL) and the Andrew and Erna Viterbi Professor of Electrical Engineering and Computer Science. “A set of boats can come together to form linear shapes as pop-up bridges, if we need to send materials or people from one side of a canal to the other. Or, we can create pop-up wider platforms for flower or food markets.”

Joining Rus on the paper are: Ratti, director of MIT’s Senseable City Lab, and, also from the lab, first author Banti Gheneti, Ryan Kelly, and Drew Meyers, all researchers; postdoc Shinkyu Park; and research fellow Pietro Leoni.

Collision-free trajectories

For their work, the researchers had to tackle challenges with autonomous planning, tracking, and connecting groups of roboat units. Giving each unit unique capabilities to, for instance, locate each other, agree on how to break apart and reform, and then move around freely, would require complex communication and control techniques that could make movement inefficient and slow.

To enable smoother operations, the researchers developed two types of units: coordinators and workers. One or more workers connect to one coordinator to form a single entity, called a “connected-vessel platform” (CVP). All coordinator and worker units have four propellers, a wireless-enabled microcontroller, and several automated latching mechanisms and sensing systems that enable them to link together.

Coordinators, however, also come equipped with GPS for navigation, and an inertial measurement unit (IMU), which computes localization, pose, and velocity. Workers only have actuators that help the CVP steer along a path. Each coordinator is aware of and can wirelessly communicate with all connected workers. Structures comprise multiple CVPs, and individual CVPs can latch onto one another to form a larger entity.

During shapeshifting, all connected CVPs in a structure compare the geometric differences between its initial shape and new shape. Then, each CVP determines if it stays in the same spot and if it needs to move. Each moving CVP is then assigned a time to disassemble and a new position in the new shape.

Each CVP uses a custom trajectory-planning technique to compute a way to reach its target position without interruption, while optimizing the route for speed. To do so, each CVP precomputes all collision-free regions around the moving CVP as it rotates and moves away from a stationary one.

After precomputing those collision-free regions, the CVP then finds the shortest trajectory to its final destination, which still keeps it from hitting the stationary unit. Notably, optimization techniques are used to make the whole trajectory-planning process very efficient, with the precomputation taking little more than 100 milliseconds to find and refine safe paths. Using data from the GPS and IMU, the coordinator then estimates its pose and velocity at its center of mass, and wirelessly controls all the propellers of each unit and moves into the target location.

In their experiments, the researchers tested three-unit CVPs, consisting of one coordinator and two workers, in several different shapeshifting scenarios. Each scenario involved one CVP unlatching from the initial shape and moving and relatching to a target spot around a second CVP.

Three CVPs, for instance, rearranged themselves from a connected straight line — where they were latched together at their sides — into a straight line connected at front and back, as well as an “L.” In computer simulations, up to 12 roboat units rearranged themselves from, say, a rectangle into a square or from a solid square into a Z-like shape.

Scaling up

Experiments were conducted on quarter-sized roboat units, which measure about 1 meter long and half a meter wide. But the researchers believe their trajectory-planning algorithm will scale well in controlling full-sized units, which will measure about 4 meters long and 2 meters wide.

In about a year, the researchers plan to use the roboats to form into a dynamic “bridge” across a 60-meter canal between the NEMO Science Museum in Amsterdam’s city center and an area that’s under development. The project, called RoundAround, will employ roboats to sail in a continuous circle across the canal, picking up and dropping off passengers at docks and stopping or rerouting when they detect anything in the way. Currently, walking around that waterway takes about 10 minutes, but the bridge can cut that time to around two minutes.

“This will be the world’s first bridge comprised of a fleet of autonomous boats,” Ratti says. “A regular bridge would be super expensive, because you have boats going through, so you’d need to have a mechanical bridge that opens up or a very high bridge.

But we can connect two sides of canal [by using] autonomous boats that become dynamic, responsive architecture that float on the water.”

To reach that goal, the researchers are further developing the roboats to ensure they can safely hold people, and are robust to all weather conditions, such as heavy rain. They’re also making sure the roboats can effectively connect to the sides of the canals, which can vary greatly in structure and design.


MAXIMIZE YOUR POTENTIAL.

Robotics: "A Rising Tide"

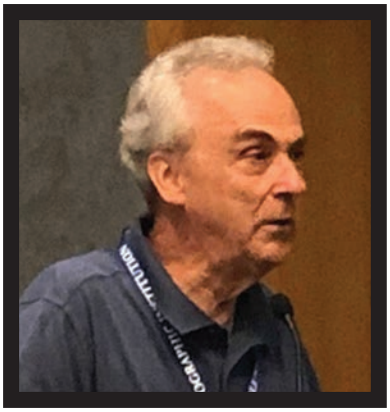
WHOI's Center for Marine Robotics (CMR) Hosts 5th Annual Entrepreneur's Forum

In mid-July 2019 the Woods Hole Oceanographic Institution's Center for Marine Robotics played host to the 5th Annual Entrepreneur's Forum, a gathering of some of the brightest minds and innovators across industries who spent two days in discussions focused on defining the challenges facing the indsutry and framing initiatives for a collective understanding and action.

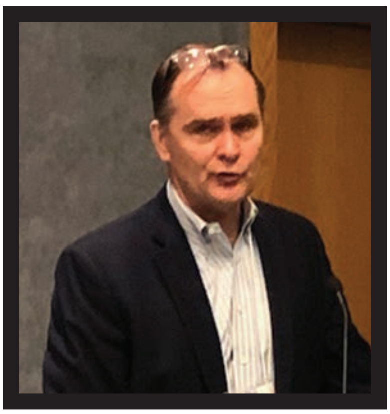
A common theme for the day was the need to increase the volume and scale of ocean-specific technology solutions, as Dr. Mark Abbott, President and Director of WHOI explained to MTR.

"The challenge (we have) is how to bring these exquisite solutions to scale, to get the numbers in the thousands, or the hundreds of thousands," said Abbott. "We need to move from these hand-made solutions to build out the size and scale" to increase the numbers and "to build networks of smart devices."

Photos: Greg Trauthwein & Rob Howard



Mark Abott, President/Director, WHOI



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All stats from 01/23/2019

Blueprint Lab

Blueprint Lab is focused on making the smallest, all-electric subsea-rated actuators available in the world. The launch of its Reach 5 Mini robotic arm represents a game changer for scientists, militaries and the oil and gas industry. The last 12 months have seen significant change and growth for Blueprint Lab. First, it commercially launched its flagship product, the Reach 5 Mini, a five-function robotic arm in September 2018. This unit has since achieved close to 20 sales in five countries. In addition, it achieved recognition by the Australian government as a promising new technology company through the award of a $240,000 grant to accelerate commercialization of its product line. The company's Reach 5 Mini builds on patented modular design to create a highly durable, tough, and incredibly small five-function manipulator, capable of performing dexterous subsea tasks including: precise placement of probes for crack and corrosion monitoring; placement and recovery of objects with minimized workload; sonar and camera scanning; and, underwater IED countermeasures.

www.blueprintlab.com

InterMoor

InterMoor's IM Release is a game-changing acoustic release connector that is available to drilling contractors and operators who are looking to save time and money not only in the case of weather or emergency avoidance but also in the context of drilling optimization, allowing for faster rig moves with simplified connect/disconnect operations from pre-laid mooring lines. It was designed using the proven platform of sister company SRP's Rocksteady mooring connector, with a control system developed in conjunction with Teledyne Marine. The advanced control system uses high-fidelity acoustic modems, and implements domain key authorization, unique addressing, network relay and frequency hopping techniques, ensuring the mooring connectors are not affected by obstructions or noise. These features eliminate the possibility of an inadvertent release and allows for the connector to be actuated individually, in clusters, or even sequenced in any order. These new features have been implemented while improving battery life. More importantly, the new connector weighs a quarter of the weight of other connectors yet can disengage at 100% of its rated break strength, a massive 900t.

www.intermoor.com

PELI Products

Since 1976, Peli has designed and manufactured both high-performance case solutions and advanced portable lighting systems. In January 2019, Peli products introduce the 9600 LED Modular Light with powerful wide beam coverage. With 3,000 lumen value per light head, the 9600 offers continuous lighting that complies with the HSE requirement for illumination. The easy way to light up long stretches of rail track, tunnels, and even a makeshift runway, without the hassles of conventional heavyweight light towers. Moreover, with fewer lights chained up the same working area as other linear lights can be covered, having a cost-effective result. June 2019, Peli Products Unveiled the PELI Air 1745 Long Case. Now pro-users can protect their long equipment in a case line that is up to 40% lighter than other polymer cases, minimizing additional travel costs. The 1745 PELI Air Case boasts more than 3.8 sq. m., making it the deepest PELI long case. It was especially designed to protect all manner of long equipment, like surveying equipment, camera tripods, weapons and archery bows, in the harshest environments.

www.peli.com

The Importance of FAIR Data in Earth Science

By Dr. Jans Aasman

Data's valuation as an enterprise asset is most acutely realized over time. When properly managed, the same dataset supports a plurality of use cases, becomes almost instantly available upon request, and is exchangeable between departments or organizations to systematically increase its yield with each deployment.

These boons of leveraging data as an enterprise asset are the foundation of GO FAIR's Findable Accessible Interoperable Reusable (FAIR) principles profoundly impacting the data management rigors of geological science. Numerous organizations in this space have embraced these tenets to swiftly share information among a diversity of disciplines to safely guide the stewardship of the earth.

According to Dr. Annie Burgess, Lab Director of Earth Science Information Partners (ESIP), the "most pressing global challenges cannot be solved by a single organization. Scientists require data collected across multiple disciplines, which are often managed by many different agencies and institutions." As numerous members of the earth science community are realizing, the most effectual means of managing those disparate data according to FAIR principles is by utilizing the semantic standards underpinning knowledge graphs.

These uniform approaches to managing metadata, data models, and terminology are the crux of the FAIR data movement, ensuring data's place as a prized asset of the scientific community.

Communal Science

The semantic standards supporting knowledge graphs are designed for uniquely identifying, immediately accessing, and sharing data in a machine readable format. They're the same standards responsible for facilitating these advantages in the World Wide Web, and are immensely beneficial for reusing data within the geological science field. This field is one of the more challenging scientific areas because it's so extensive, encompassing marine life, atmospheric concerns, land masses, and subterranean developments. The ability to rapidly share data in these different specializations is an integral aspect of advancing the field as a whole, as are the other advantages of uniquely identifying data and quickly accessing them via machine readable techniques.

Observed Dr. Lewis McGibbney, data scientist for the California Institute of Technology's Jet Propulsion Laboratory and co-chair of the NASA ESDSWG Search Relevance Working Group, "We are at an exciting stage for where there is a critical mass of experts and organizations around the globe with similar goals as well as the realization that we need knowledge-intensive applications. The semantic technology stack is a crucial piece for building intelligent apps for knowledge-intensive use cases within the geoscience area." Moreover, semantic standards enable those organizations to publish data and findings in a reusable format so different organizations directly benefit from each other's labor.

Linking Humans and Machines

The FAIR approach revolves around linking different pieces of data in a knowledge graph. Those knowledge graphs in turn can be linked between different organizations or 'published' on the web for universal access—which is critical for interoperability. This approach not only requires each individual datum to have its own unique identifier, but also a rich description of its metadata based on standardized vocabularies and taxonomies swiftly understood and accessed via machines. Semantic data models (ontologies) standardize inherent differences in schema used by different organizations for different applications, further aiding the interoperability of IT systems embracing FAIR principles.

Monterey Bay Aquarium Research Institute Senior Software Engineer Carlos Rueda commented that "the Marine Metadata Interoperability Project developed the MMI Ontology Registry and Repository (ORR), which leverages AllegroGraph to provide powerful interoperable semantic services that make the content on the web interconnected in a meaningful way for both humans and machines to consume." By enabling different scientific organizations in the Marine Metadata Interoperability Project to register ontologies of their myriad repositories in this standardized manner, data integration and accessibility are expedited.

Unified Diversity

Perhaps the capital advantage of actuating FAIR principles with knowledge graphs within the earth science community is the ability to standardize on the assortment of divers data relevant to scientists.

The sheer number of different specializations in this field requires data of seemingly infinite varieties. Sources include sensor data from water, aerial, and terrestrial sources, in addition to satellite data and those from physical samples. Furthermore, these data are characterized by many different spatial and temporal resolutions, adding to the overall complexity of managing them homogeneously. In this respect, semantic data models are considerably helped uniform vocabularies to describe data. Dr. Burgess alluded to the merit of “the ESIP Community Ontology Repository, a community platform to manage and exchange terms and vocabularies that assist scientists to publish, discover, and reuse data.”

Long Term Propagation

As the abundant use cases within the geological science community reveal, data’s true esteem is based on its enduring reusability and immediate accessibility. These priorities spawned the FAIR movement, which depends on semantic technologies for implementation. This approach delivers the same benefit when applied to contemporary organizations: an increase in data’s value as an enterprise asset.

About the Author

Jans Aasman is a Ph.D. psychologist, expert in Cognitive Science and CEO of Franz Inc., an innovator in Artificial Intelligence and provider of AllegroGraph, a leading Semantic Graph Database. As both a scientist and CEO, Dr. Aasman continues to break ground in the areas of AI- and Knowledge Graphs as he works hand-in-hand with numerous Fortune 500 organizations and governments.

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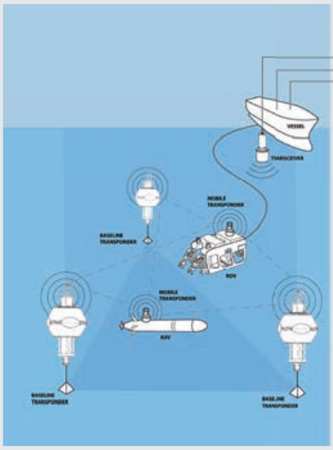

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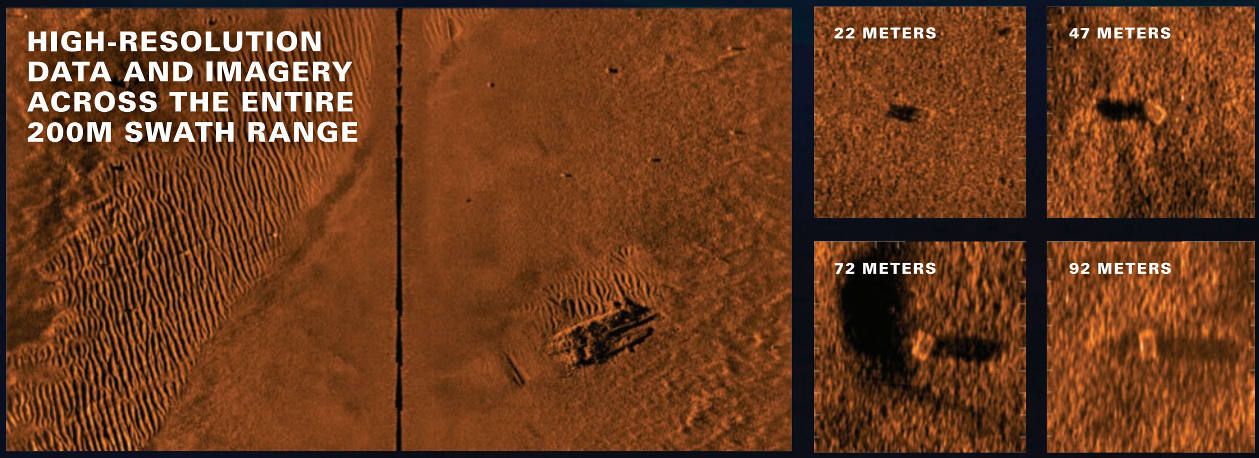

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