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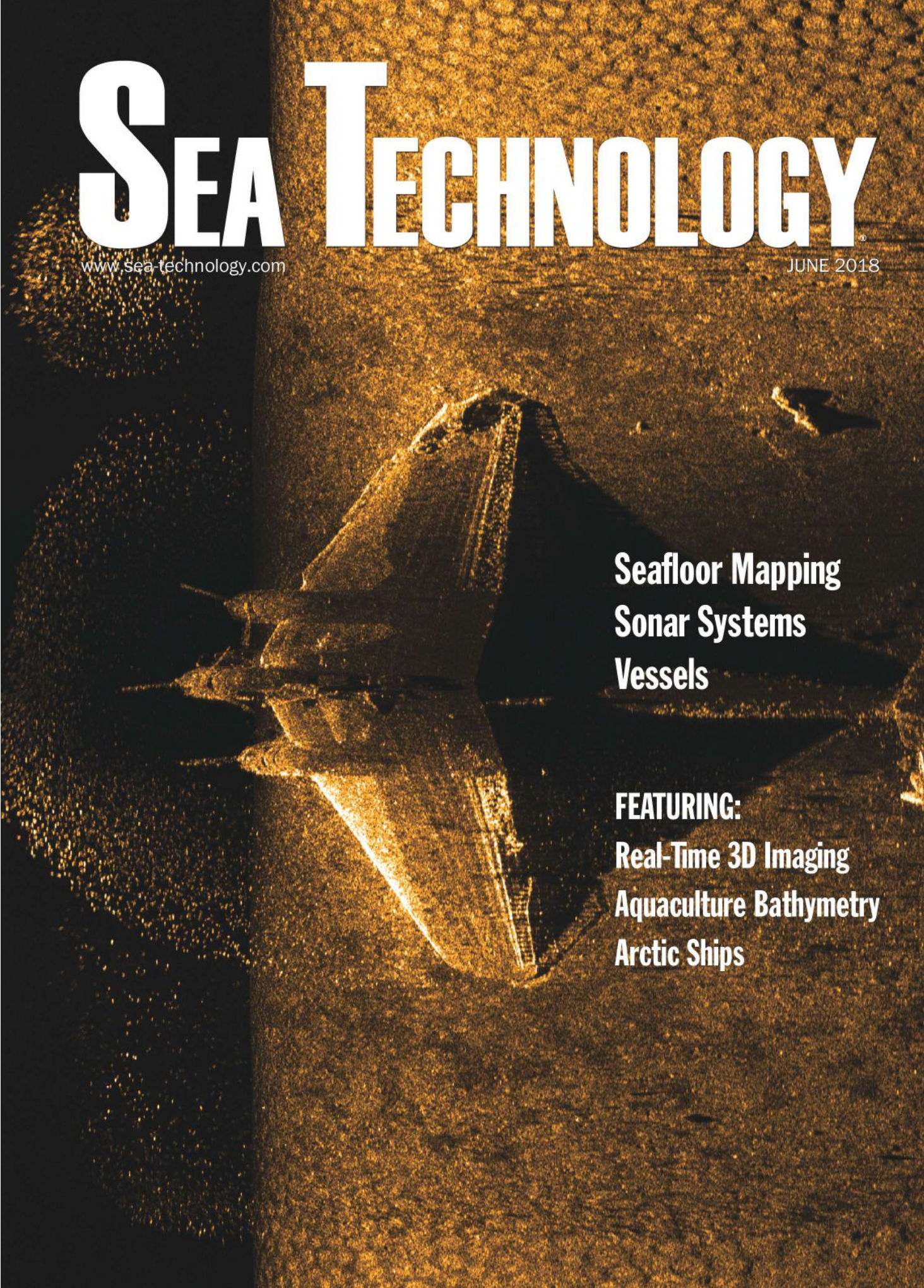

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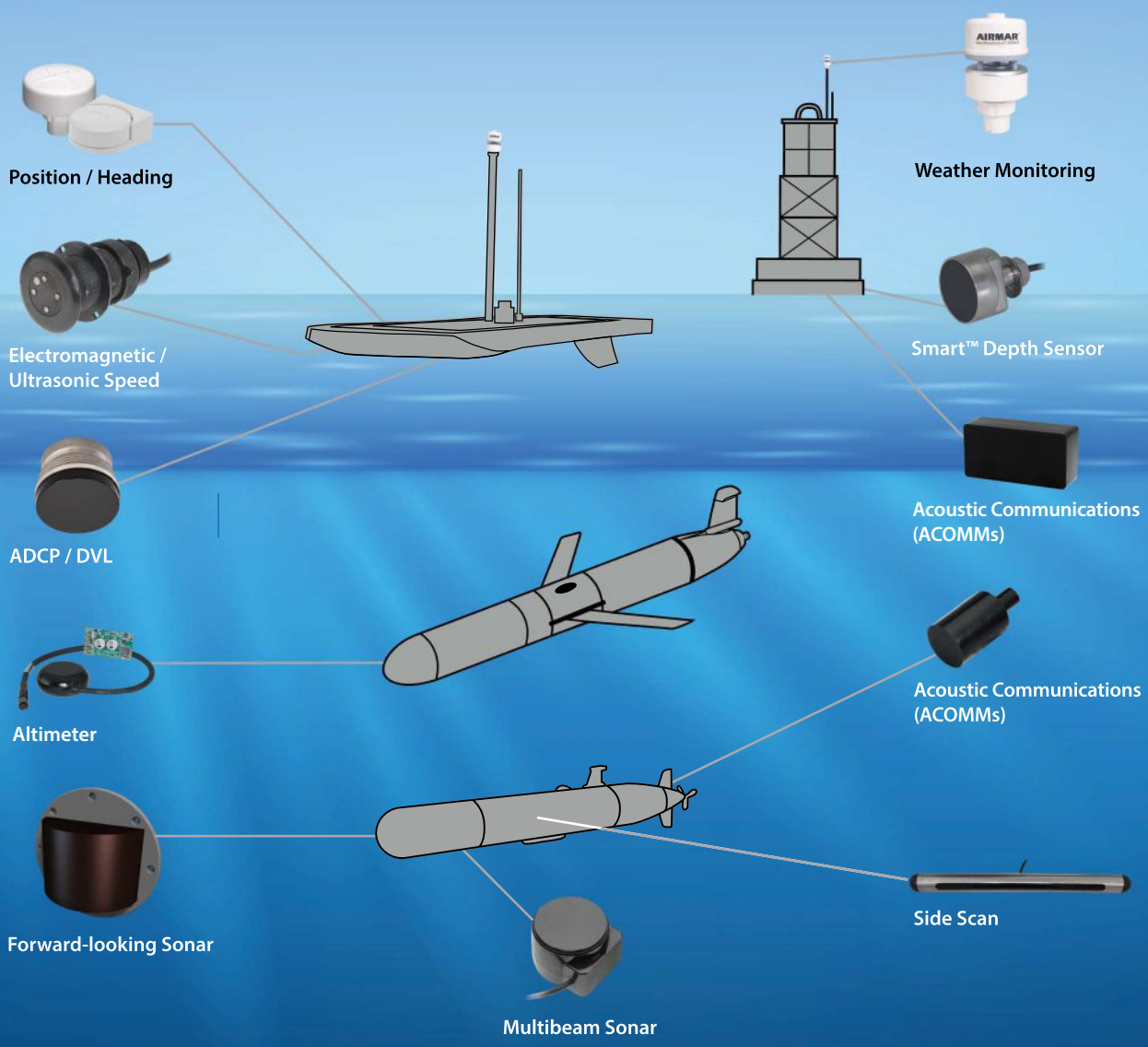

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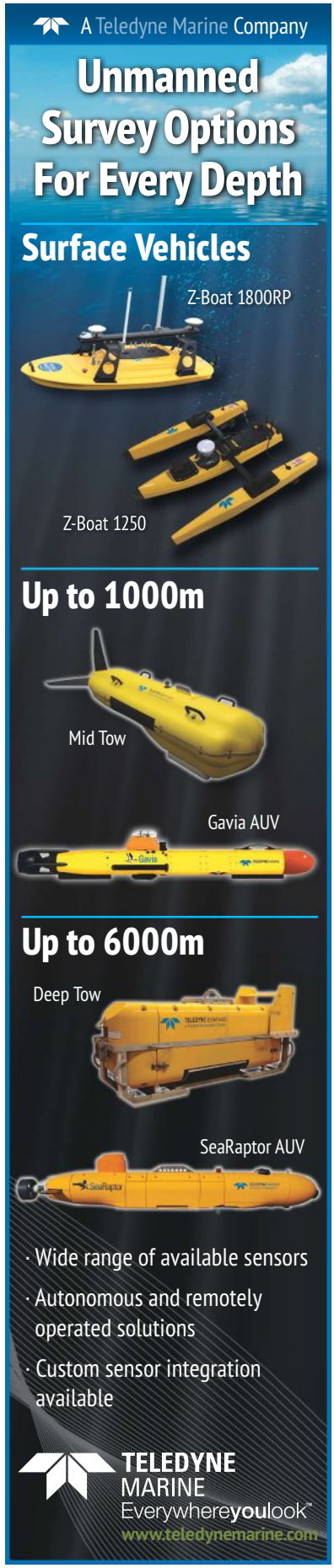

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editorial

***Peter Keller**, Chairman, SEA\LNG, Executive Vice President, TOTE*

Funding the Maritime Fuel Of the Future

As the use of liquefied natural gas (LNG) as a marine fuel gradually becomes a global reality, the industry must continue to collaborate to ensure a sustainable long-term financial framework. Clearly, financial institutions will have a key role to play, and the recent news by SCF Group that it has secured $252 million in financing with a consortium of six leading international banks for six LNG-powered Aframax tankers is a step in the right direction.

For SEA\LNG, the multisector industry coalition aiming to accelerate the widespread adoption of LNG as a marine fuel, LNG presents an ideal solution to the ongoing emissions debate. LNG emits zero sulfur oxides (SOx) and virtually zero particulate matter (PM) emissions, and reduces nitrogen oxides (NOx) emissions by 90 percent compared to conventional heavy fuel oils. It is currently the only viable and commercially available compliant solution to combat emissions at their source: the fuel itself.

Throughout 2017 and the beginning of 2018, the uptake of LNG as a marine fuel has dramatically increased in momentum as more of the industry's top influencers invest in the fuel—culminating in CMA CGM's decision to power its nine ultralarge container ship newbuilds with LNG. We are also seeing orders for deep-sea shipping extending beyond Emission Control Areas (ECAs); Sovcomflot has ordered six Aframax tankers, Siem has two transatlantic car carriers on order for charter to Volkswagen, and Polaris Shipping confirmed orders for 10 LNG-ready, very-large ore carriers (VLOCs).

Meanwhile, the supply side is gearing up significantly alongside the boom in demand for LNG-powered vessels, with investments in the next tier of bunker vessels. Shell and Gas4Sea commissioned state-of-the-art LNG bunker vessels in 2017, which are both now conducting ship-to-ship bunkering operations in their respective home ports of Rotterdam and Zeebrugge. Going forward, ENN Group's plans for an LNG-bunkering hub at Zhoushan, near Shanghai, includes an 8,000-m³ LNG bunker-supply ship, and the Wärtsilä-built Tornio Manga LNG terminal project in northern Finland plans to provide bunkering for LNG-fueled ships visiting the northern Baltic Sea waters.

Investment and funding from financial institutions is essential in facilitating the boost in LNG projects and bunkering infrastructure. Innovative financing is a core component to breaking down barriers to LNG adoption, and the addition of Société Générale to the SEA\LNG coalition in January this year further strengthens the ability to leverage knowledge, networks and real-life examples in the financial sector. Société Générale recognizes the benefits of LNG in lowering local pollution and greenhouse gas emissions when compared with traditional marine fuels. The bank is a pioneer for its involvement in the first transaction for the EU's recently instituted Green Shipping Guarantee program. Société Générale also acted as the sole mandated lead arranger, lease investor, facility and security agent, hedge provider and lender in a €142.6 million French lease financing of *Honfleur*, the first LNG-powered ferry commissioned by Brittany Ferries, with a funded guarantee from the European Investment Bank, one of the six financial institutions to provide funding for SCF Group's six LNG-fueled Aframax tanker newbuilds.

The collective goal is to develop a long-term financial framework that will contribute to, and supplement, the work of industry leaders to deliver a competitive global LNG value chain for cleaner maritime shipping. We would be pleased to see other banks engage in the conversation on how LNG will continue to become a commercial and conventional reality for vessels and their owners. **ST**

TOTAL OCEAN MARKET COVERAGE 2018

JANUARY
Annual Review & Forecast

FEBRUARY
Instrumentation: Measurement, Processing & Analysis
****Oceanology International,** March 13-15, Excel London, U.K.
****Canadian Hydrographic and National Surveyors' Conference,** March 26-29, Victoria, Canada

MARCH
Electronic Charting/Vessel Management/Ports & Harbors/Dredging/Homeland Security

APRIL
Offshore Technology/Alternative Energy & Ocean Engineering
****Offshore Technology Conference,** April 30-May 3, Houston, TX
****AUVSI XPONENTIAL 2018,** April 30-May 3, Denver, CO
****OCEANS '18 MTS/IEEE Kobe / Techno-Ocean 2018,** May 28-31, Kobe, Japan

MAY
Communications, Telemetry, Data Processing
****BlueTech Expo,** June 4, Washington, DC
****CLEAN PACIFIC 2018,** June 19-21, Portland, OR
****UDT 2018,** June 26-28, Glasgow, U.K.

JUNE
Seafloor Mapping/Sonar Systems/Vessels

JULY
Deck Gear, Cable, Connectors, Power Systems & Salvage
****SNA West Coast Symposium,** August 23, San Diego, CA

AUGUST
Geophysical Exploration/Seafloor Engineering
****Dynamic Positioning Conference,** October 9-10, Houston, TX
****SEG 2018,** October 14-19, Anaheim, CA

SEPTEMBER
Ocean Resources Development & Coastal Zone Management
****Offshore Energy 2018,** October 22-24, Amsterdam, The Netherlands
****EURONAVAL 2018,** October 22-26, Paris Le Bourget, France
****OCEANS '18 MTS/IEEE Charleston,** October 23-25, Charleston, SC

OCTOBER
Environmental Monitoring, Remote Sensing & Pollution Control
****International Water Conference,** November 4-8, Scottsdale, AZ
****Naval Submarine League Annual Symposium,** November 7-8, Arlington, VA
****CLEAN GULF,** November 13-15, New Orleans, LA

NOVEMBER
Undersea Defense/Antisubmarine Warfare
****SNA Annual National Symposium,** January 15-17, Arlington, VA

DECEMBER
Diving, Underwater Vehicles & Imaging
****Underwater Intervention 2019,** February 5-7, New Orleans, LA

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1963 - 2018 Celebrating More Than 54 Years of Serving the Global Ocean Community

)) IMO to Phase Out GHG Emissions in This Century. Countries that met recently at the United Nations International Maritime Organization (IMO) in London have adopted an initial strategy on the reduction of greenhouse gas (GHG) emissions from ships, setting out a vision to reduce GHG emissions from international shipping and phase them out as soon as possible in this century. The vision confirms IMO's commitment to reducing GHG emissions from international shipping and, as a matter of urgency, to removing them from the industry picture. The initial strategy envisages, for the first time, a reduction in total GHG emissions from international shipping, which should peak as soon as possible; more specifically, a reduction in the total annual GHG emissions by at least 50 percent by 2050 compared to 2008, while pursuing efforts toward phasing them out entirely. The strategy includes a specific reference to "a pathway of CO_2 emissions reduction consistent with the Paris Agreement temperature goals," which include limiting global temperature rise in this century to well below 2° C above pre-industrial levels. The initial strategy was adopted by IMO's Marine Environment Protection Committee (MEPC) during its 72nd session at IMO headquarters in London. The initial strategy represents a framework for member states and includes candidate short-, mid- and long-term further measures, with possible time lines and their impacts on states. The strategy also identifies barriers and supportive measures, including capacity building, technical cooperation and research and development.

)) World's First AI-Powered Situational Awareness System Aboard a Container Ship. Boston-based Sea Machines Robotics signed a contract with A.P. Moller-Maersk of Copenhagen, Denmark, to trial its perception and situational awareness technology aboard one of the company's newbuild *Winter Palace* ice-class container ships. The deal is significant not only to Sea Machines and Maersk but also to the larger maritime industry as the installation marks the first time computer vision, LiDAR and perception software will be utilized aboard a container vessel to augment and upgrade transit operations. The solution uses artificial intelligence (AI) to improve at-sea situational awareness, object identification and tracking capabilities. Similar to advanced driver-assistance systems (ADAS) commonly found in automobiles, which alerts drivers of roadway hazards and prevents accidents, Sea Machines' system uses advanced sensors to collect a continuous stream of information from a vessel's environmental surroundings, identify and track potential conflicts, and efficiently display the knowledge in the wheelhouse. The system facilitates safer and more efficient maritime operations. Maersk's goal of the collaboration is to prove the technology aids seafarers, can remove the line-of-sight restriction from the bridge and provides the infrastructure for a future autonomous collision avoidance system.

)) Report Examines Mid-Atlantic Vulnerability to Climate Change. The Mid-Atlantic Regional Council on the Ocean (MARCO) released a first-of-its-kind report at the Mid-Atlantic scale that examines the vulnerabilities of several critical economic sectors to climate change. The report quantifies the potential impacts of threats such as sea level rise, increasing ocean temperatures and changes in the ocean's chemistry to communities and businesses in 63 counties and independent cities along the coast from New York to Virginia. The challenges are especially pronounced in the Mid-Atlantic, the most densely populated stretch of coastline in the U.S. The region's waterfront is home to the largest U.S. city, New York; two of its busiest ports in New York/New Jersey and Hampton Roads, Virginia; and iconic beach destinations. The analysis considers the ramifications of both temporary flooding events and the permanent inundation of some areas that would occur if sea levels were to rise by 3 or 6 ft. by the year 2100—two scenarios that are commonly assumed by planners throughout the region. Among the findings: approximately 14.6 million people live in census tracts adjacent to the ocean, Chesapeake or Delaware bays—in the 3-ft. scenario, the resulting flooded area could affect 1.7 million people and in the 6-ft. scenario, 2.1 million people; today, 912,000 housing units would be vulnerable to flooding in the 3-ft. scenario and 1.1 million in the 6-ft. scenario; and approximately 557,000 jobs would be vulnerable in the 3-ft. scenario and 974,000 in the 6-ft. scenario. "No community or business in the Mid-Atlantic will be spared from the impacts of climate change," said lead author Charles Colgan of the Center for the Blue Economy of the Middlebury Institute of International Studies at Monterey, California. "This is not simply a threat to waterfront areas. With everything from jobs to the housing market being tightly bound to ocean-dependent industries, every coastal community, whether beachfront or further inland, has some vulnerability."

)) Finland-Singapore Maritime Innovation Camp. MacGregor, part of Cargotec, is one of the partners participating in the Finland-Singapore Maritime Innovation camp, which has been designed to accelerate developments within the maritime industry and create value for stakeholders. It will take place in the third quarter of 2018 in Singapore. During the innovation camp, a challenge will be presented to students by the corporate partners. The University of Turku (UTU) and the Singapore Maritime Institute (SMI) will facilitate the multi-day session where students will solve the given challenge. The benefit for universities and students is the possibility to test theories on real-life problems. Universities facilitate situations where new ideas can be created and new questions can be generated, potentially leading to new opportunities. MacGregor values the importance of collaboration and co-creation with stakeholders, such as universities, to innovate and develop solutions that benefit the maritime and offshore industries. **ST**

Echoscope^{4G} Surface

The Future of Visualization, Mapping Sonars

By Richard Adams

The uncertainty that lies below the surface of the sea provides a number of industries with incredible challenges when conducting their daily business. From offshore structure installation and inspection to the defense of ports and construction of national power generation assets, all subsea industries are plagued with a dynamic set of problems they must address.

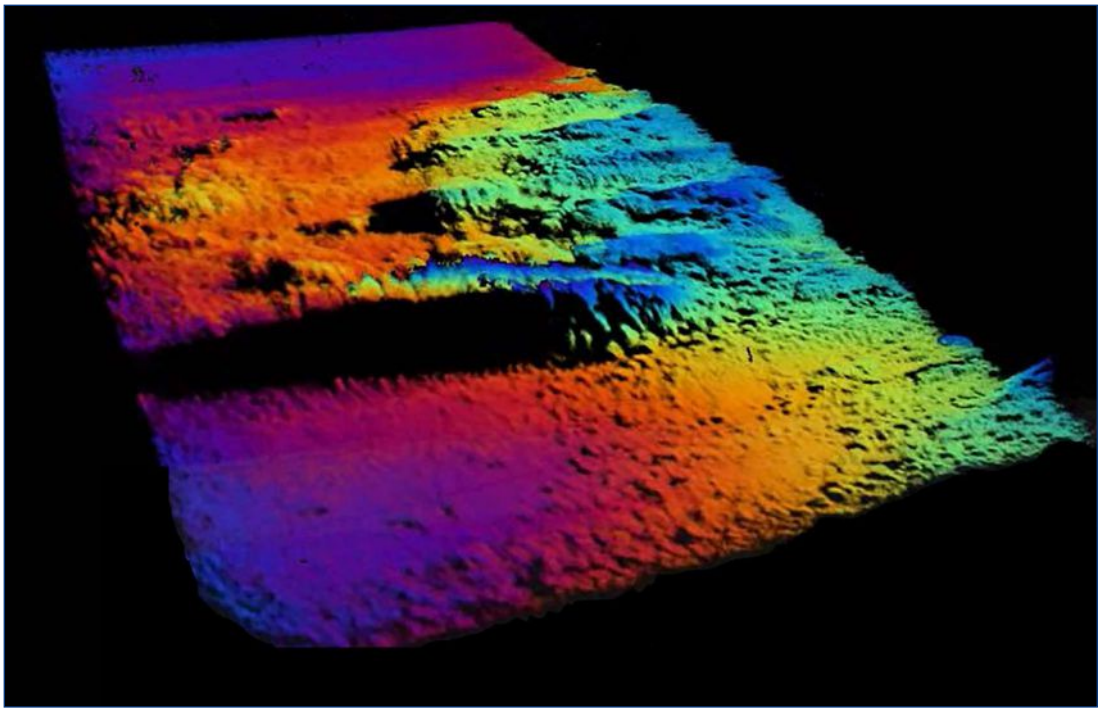
The industry standard technology that is utilized for underwater inspection is the multibeam sonar, which was introduced to the market around 20 years ago. At the time, the multibeam was revolutionary because it could generate clearer images of the underwater environment than the precursor technology, the single beam. The multibeam, however, has limitations as its outputs require post-processing to render useful 3D images of the area being inspected and cannot image moving objects. Many subsea applications require technology that can facilitate real-time 3D decision making of both static and dynamic operations.

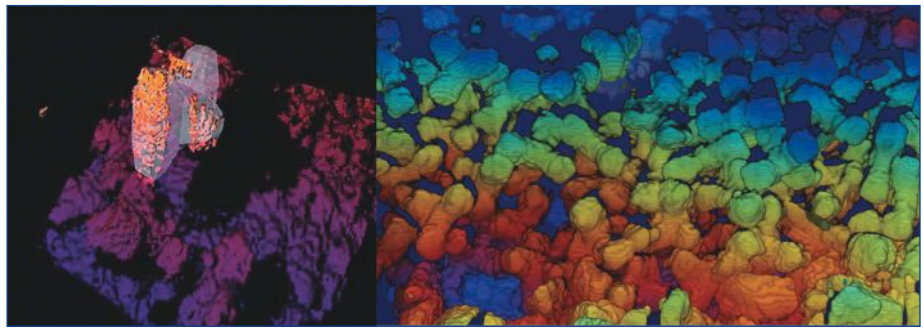
Background

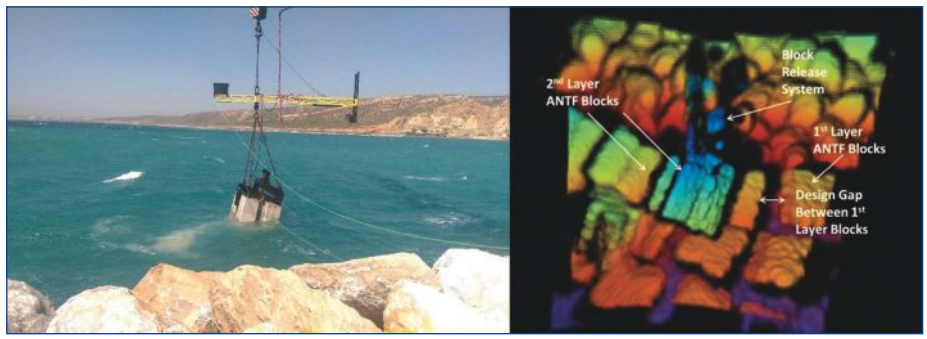
Coda Octopus Products Ltd. has recognized this market requirement and has been at the forefront of marine survey operations for nearly 25 years. The company started as a pioneer of digital acquisition and processing for geophysical survey, and this innovation and emphasis on research and development (R&D) has characterized the company ever since. Coda Octopus has continued to lead the geophysical acquisition and processing market with its GeoSurvey, DA and Survey Engine product ranges. In addition, it has developed a range of patented real-time 3D volumetric sonar systems marketed under the brand name of Echoscope. This technology allows the user to generate a real-time 3D image of the underwater environment, even with low- or zero-visibility conditions, and has been successfully used on a wide variety of complex subsea projects and operations across the globe, including in oil and gas applications, breakwater construction, asset placements and landings, port and harbor security, defense, mining and diving applications. Our real-time 3D and geophysical product ranges are complemented by GNSS-aided inertial navigation systems. The F180 series, for example, has a proven track record in the marine survey industry for accuracy and reliability and is found on survey vessels across the world.

Echoscope^{4G} Surface real-time 3D sonar.

Our third generation of real-time 3D sonar products includes the standard Echoscope and Echoscope C500. They have a standard depth rating of 600 m and can be supplied with 3,000-m ratings; we also have the capability to take these down to 6,000 m on request. We continue to innovate and develop new application products within the real-time 3D sonar arena. All of our real-time 3D sonars transmit a large volumetric pulse of sound energy that generates typically more than 16,000 beams for every acoustic transmission or "ping."







(Top to Bottom) Real-time 3D bathymetric data. Real-time 3D block tracking and 3D as-laid survey. Safi wire crawler crane/Echoscope antifer block data.

The Latest Generation

We have taken significant steps forward in innovating the fourth generation (4G) of the Echoscope and have launched the new Echoscope^{4G} Surface sonar in January 2018. The Surface was presented to the general public for the first time at Oceanology International 2018 in London, where it was met with excitement from customers from a variety of subsea industries.

The reimagined, reengineered and repackaged Echoscope^{4G} Surface comes in a new form factor and is 50 percent lighter, 40 percent smaller and draws 30 percent less power than our third-generation (3G) of technology. This new Surface product is designed for underwater operations not exceeding 20-m water depth. The new Surface is also more a plug-and-play application, as it requires less tuning than the older Echoscope.

Benefits of the Surface for shallow-water applications and small platform operations are huge, all without compromise on image fidelity and performance or capability. The Echoscope^{4G} Surface generates true real-time 3D images and mapping equal to the larger Echoscope.

Technology

The Echoscope offers simultaneous imaging and mapping, generation of survey-grade mosaics and bathymetry of subsea areas without any post-processing, and visualization of both static and moving objects. With the recent introduction of our XD model, we now provide wide-swath volumetric mapping over and above real-time 3D camera imaging and high-resolution 3D real-time inspection.

There are many benefits over conventional multibeam systems, including "eyes" underwater even in poor-visibility conditions; the ability to visualize moving objects

in 3D, so precise control of dynamic operations is possible; the ability to instantly visualize complex structures; and the ability to generate survey-grade bathymetric data without post-processing.

The patented Echoscope range of real-time sonars is more than visualization tools, as they enable the capture of hydrographic-quality data in real time from the same sensor. This allows an operator to use the sonar for a multitude of purposes, such as visualization of a valuable asset on the seabed and simultaneous use of data to provide an as-built or as-laid survey.

The new Echoscope^{4G} Surface is available in single-, dual- and triple-frequency models offering unique combinations of frequency at 240, 315 and 630 kHz and opening angles of 90° by 44°, 50° by 50° and 24° by 24°.

This combination of frequencies and opening angles enables the Echoscope^{4G} Surface to be deployed in a wide range of operations and tasks.

Software

Our standard USE software operates with all of our sonar systems. USE offers additional features to enhance operations, including the ability to insert georeferenced models to enhance and visually augment the acoustic sonar data, the ability to operate with and without GNSS position and motion data, and the ability to export raw or binned point-cloud data for processing in third-party hydrographic software.

We have further developed our proprietary visualization software to add the ability to track targets for the breakwater construction market and our construction-specific software CMS. This software enables both the visualization of large concrete blocks as they are placed in the water and automatic tracking and overlay of a 3D model of the block to assist the operator with accurate placement of the block. Our software also records the as-laid x, y, z position and the orientation of each block, building up a 3D model of the constructed breakwater. The versatility of the sonar/hardware combination has been validated by block design consultants.

Applications

Coda Octopus has successfully demonstrated the Surface during a U.S. Navy training exercise in 2018 as part of a Naval Sea Systems Command (NAVSEA) 3D HUD System. The greatly reduced weight, size and power requirements of the Surface are ideally suited for launch on small rapid-response rigid inflatable boats (RIBs) and additional inflatable craft used in law enforcement, salvage and underwater construction. During the live demonstration, tethered divers were able to hand carry the near-neutrally buoyant Echoscope^{4G} Surface underwater and use it in two critical operational modes: navigation (first-person, real-time 3D navigation and scene awareness) and observation (third-person, real-time 3D scene observation).

With the ability to visualize and map data and image moving objects in 3D under the water in low- or zero-visibility conditions, our range of sonars have a large number of market applications across the world. One of our key markets has been subsea construction, such as imaging and survey of dredging and construction sites, ROV-based oil and gas projects for key infrastructure installation and installation of breakwater construction. The ability to "see" what is happening under the water can significantly improve the speed and safety of a project.

The new Echoscope^{4G} Surface has been designed with these types of shallow-water construction projects in mind, offering a cost-effective route to delivery. The new Surface system can be used with our proprietary software packages, USE and CMS software, giving the option of deployment on cranes, barges or survey vessels to image and map breakwaters, inshore bridges, piers and complex structures, providing real-time assessment of the accuracy of asset placement, damage to a structure and the effects of any environmental condition such as scour. Our breakwater customers,

"The world of subsea engineering will always be challenging, but with the right approach, equipment and ability to visualize operations in real time and 3D, the challenges can be managed and reduced to acceptable levels."

such as Van Oord and SGTM-STFA, have reported significant project success using the Echoscope. Van Oord has deployed it on a Kuwait National Petroleum Co. project to construct a port and breakwater. The breakwater was armored with 24,000 Core-Loc concrete blocks, and the Echoscope real-time 3D sonar was mounted on the installation excavator to provide imaging of each block. Productivity rates of up to 200 blocks per day were reported by Van Oord. On the Port of Safi project in Morocco, the operator SGTM-STFA installed three separate Echoscope systems on wire crawler cranes. By removing the requirement to use divers to monitor the blocks underwater, it was able to work 24-hr. shifts, thereby tripling the productivity rate on the site.

Future Developments

The launch of the new Echoscope^{4G} Surface is an important milestone for Coda Octopus, and we continue to innovate our products with the aim of standardizing real-time 3D solutions in the subsea market for various applications and different price points. The unique volumetric pulse, the wide field of view and volume of data generated by this unique technology make it well suited to autonomous operation, including assessment, identification and classification of unknown objects by autonomous underwater and surface vehicles.

The world of subsea engineering will always be challenging, but with the right approach, equipment and ability to visualize operations in real time and 3D, the challenges can be managed and reduced to acceptable levels. The new Echoscope^{4G} Surface is an example of how Coda Octopus will continue to innovate and develop both hardware and software to continue to be at the forefront of subsea engineering and survey operations. **ST**

Richard Adams joined Coda Octopus Products Ltd. in 2014 and is now the sales director. He looks after the European, African and Asian markets.

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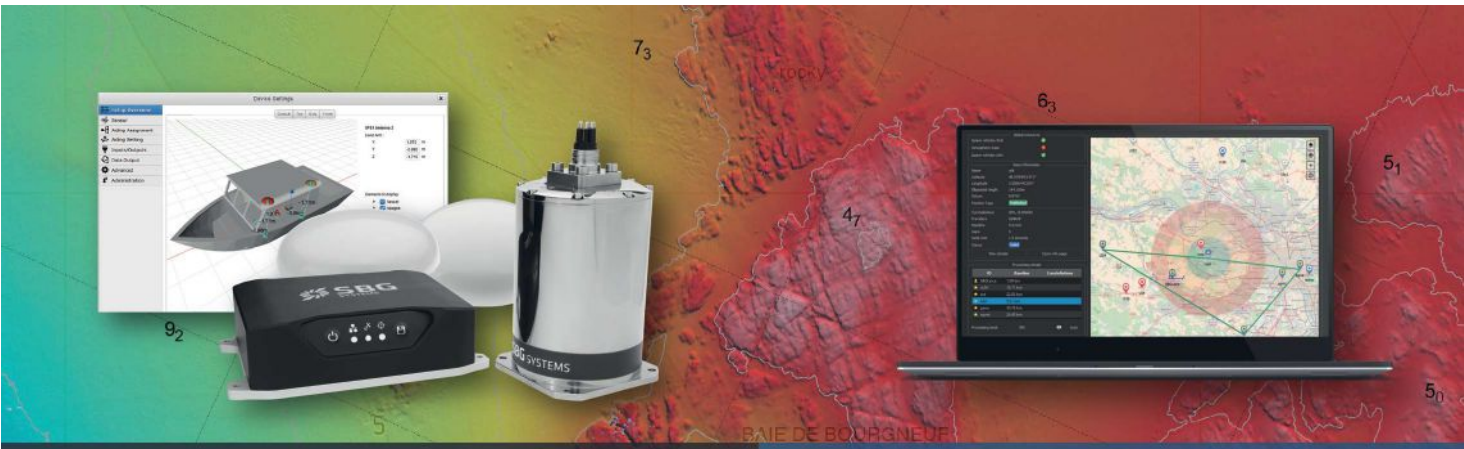

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Mapping Seafloor Shallows

Vessel-Based, Nearshore Surveys Using Phase-Measuring Side Scan

By Dr. Mark Borrelli • Bryan Legare • Theresa Smith

For many years, extreme shallow water areas (0 to 5 m) were considered to be so dynamic that mapping them, given the survey inefficiencies, navigation hazards and operational costs, was prohibitive. The maps are obsolete before the boat makes it back to the dock, was the commonly heard maxim. However, nearshore shallow-water environments are invaluable coastal resources; estuaries in particular are among the world's most productive ecosystems, and mapping the seafloor can provide useful information with regard to benthic habitats, ecosystem state, aquaculture status, sediment transport and other biological, chemical and physical characteristics and processes. These data, while critical to other scientists, modelers and engineers, are becoming increasingly central to coastal resource managers.

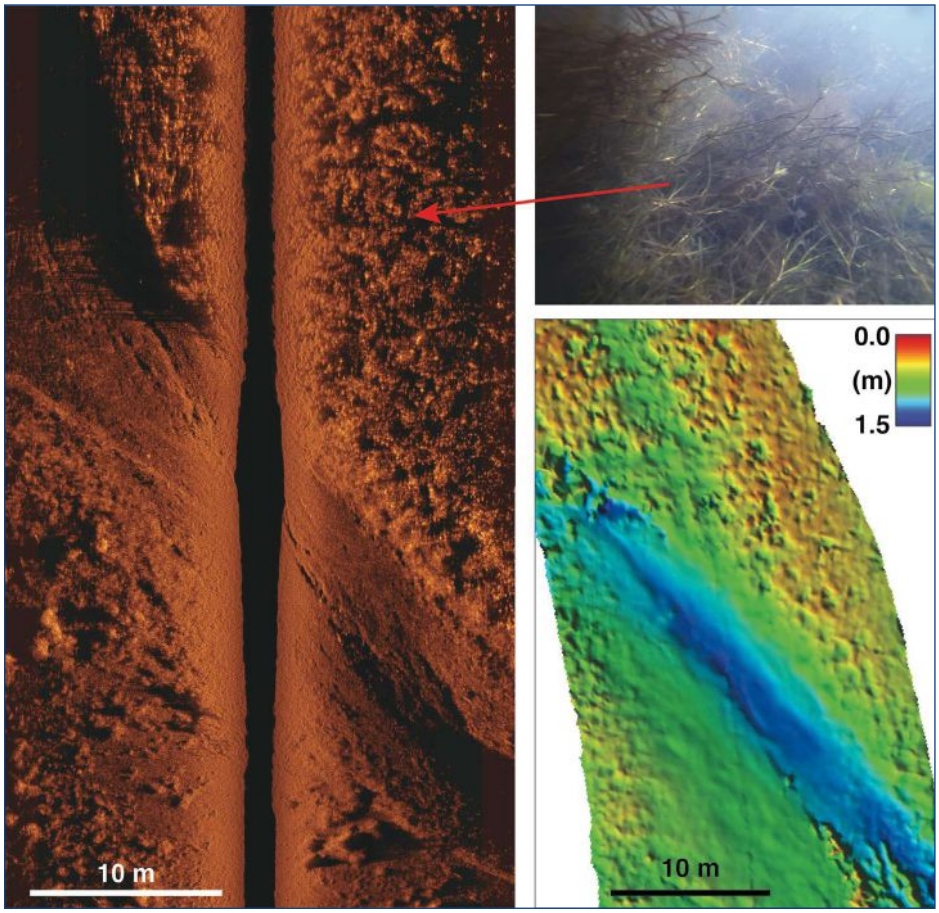
The combination of extreme shallow-draft survey platforms and phase-measuring side scan sonars (PMSS) allows for mapping of the seafloor in areas otherwise difficult to obtain synoptic, quantitative 2D and 3D data. Further, acoustic methods have long been used to map in environments inhospitable to optical methods such as LiDAR, vertical aerial photography and other multispectral data. Turbid waters in many nearshore environments prevent optimal performance due to limited penetration through the water column. In addition, LiDAR, as of yet, provides only elevation information, though experimental data layers similar to side scan imagery are in the early stages of development. A PMSS allows for both high-resolution side scan imagery and bathymetric data in extreme shallow and/or turbid waters.

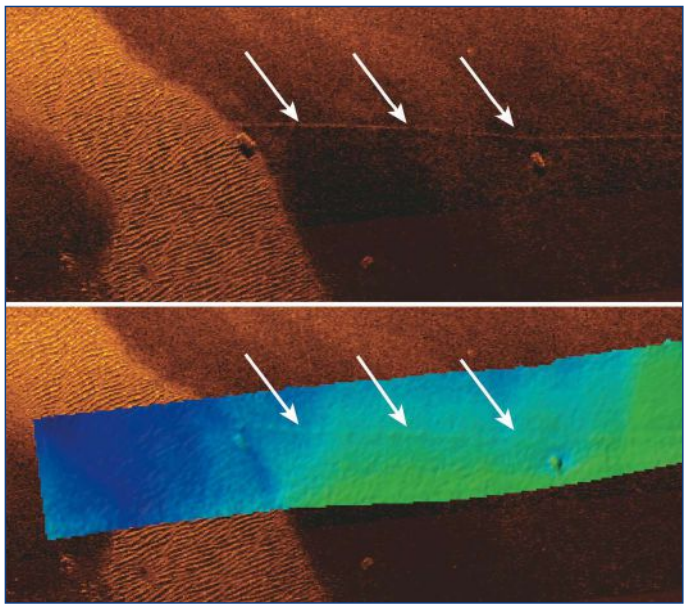
The Coastal Processes and Ecosystems (CAPE) Lab, a joint research laboratory between the School for the Environment at University of Massachusetts, Boston and Seafloor Mapping Program at the Center for Coastal Studies in Provincetown, Massachusetts, is working on projects in extreme shallow waters, mainly 0- to 5-m depth.

Shallow-draft survey vessels. Left: two-person, custom-built, pontoon boat (15-cm draft). Below: customized, 8.2-m Eastern. A bow-mount is preferred to reduce noise from hull and to maximize distance from engine. Both vessels pictured are using the EdgeTech 6205.

Terminology

The primary acoustic instrument for shallow-water seafloor mapping in the CAPE Lab is the EdgeTech 6205, a phase-measuring side scan sonar, which has been in use since 2014. Given the evolving nature of the industry, terminology continues to evolve and has led to confusion when referring to this newer technology. The term "interferometric sonar," while prevalent, refers to an older method of measuring the phase difference of the returning acoustic energy. The term "phase-differencing bathymetric sonar" could be construed as redundant, as all phase-differencing sonars yield bathymetry, but perhaps





(Top) Data from Herring River Estuary, Wellfleet, Massachusetts. Left: raw side scan imagery (1,600 kHz). Height above bottom ranges from 10 to 50 cm. Upper right: still imagery taken from underwater video of widgeon grass, approximate location denoted by arrow. Lower right: single line of bathymetry from same area shown in side scan imagery to the left. (Bottom) Upper: side scan imagery (550 kHz) of lobster pot trawl. Lower: same area with single line of bathymetry overlain. Line can be seen in bathymetry, denoted by arrows.

more importantly does not emphasize that a "true" side scan sonar is the primary instrument. We propose to use the term "side scan sonar" and the modifier "phase-measuring," yielding: "phase-measuring side scan sonar." "Phase-differencing side scan sonar" is also used, and seems synonymous with PMSS, but we prefer the latter. EdgeTech refers to these instruments as multiphase echosounders (MPES).

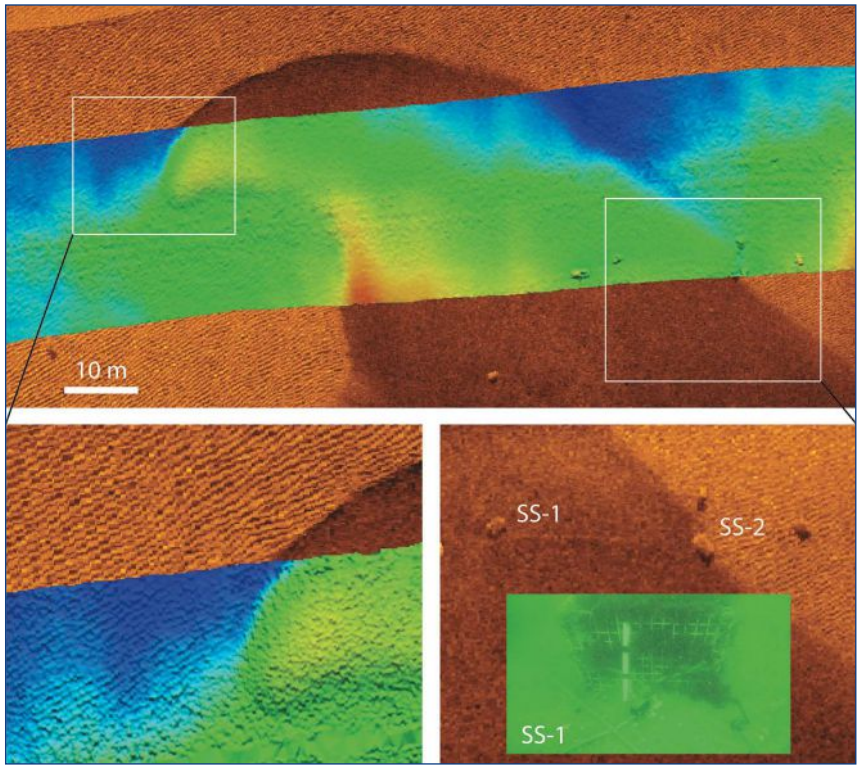
Setup

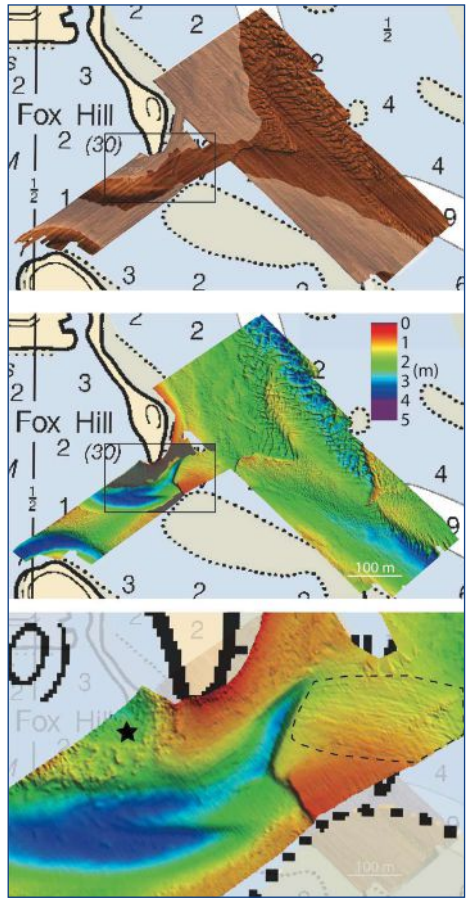
The operating frequencies for our instrument are 550 and 1,600 kHz for backscatter (collected simultaneously) and 550 kHz for bathymetry. The side scan sonar range resolution is 1 cm, and the horizontal beam width is 0.5° at 550 kHz. The corresponding quantities at 1,600 kHz are 0.6 cm and 0.2°. The bathymetric range and vertical resolution are both 1 cm. The respective bandwidths at 550 and 1,600 kHz are 67 and 145 kHz. A Teledyne TSS DMS-05 motion reference unit (MRU) mounted on the sonar collects data on heave, pitch and roll, measuring heave to 5 cm and roll and pitch to 0.05°. A Hemisphere GNSS V110 vector sensor is used to measure heading. Two differential GPS receivers spaced 2 m apart yield heading accuracies of less than 0.10° RMS. A Trimble GNSS receiver utilizing real-time-kinematic GPS (RTK-GPS) is used for positioning and tide correction for vessel-based surveys. Ideally, both GPS units are mounted onto the survey pipe that holds the sonar and MRU. The Cape Lab has multiple research vessels from which to conduct acoustic surveys, ranging from medium-sized, shallow-draft vessels (e.g., 8.2 m loa, 0.5-m draft) to an extreme shallow-draft pontoon boat (4.3 ft. loa, draft 0.15 cm).

Projects

A tidal restoration project for the Herring River in Wellfleet, Massachusetts, is in the design and analysis stage. Salinity in this small tidal estuary ranges from 0 ppt at the head of the river to 32 ppt at the tidal restriction that controls flow between the estuary and Wellfleet Harbor. The estuary is largely within Cape Cod National Seashore, is very shallow and has no boat ramps or access points. The pontoon boat was deployed and retrieved via a low sloping hillside into the water.

The survey was funded by the Massachusetts Division of Ecological Restoration (Mass-DER) and conducted on board the pontoon boat June 2016. More than 9 km of





(Top) Upper: single line of bathymetry overlain on 550-kHz side scan imagery at approximately 5-m water depth. Lower left: inset of bathymetric high 50 cm. Note small ripples (30- to 40-cm spacing) can be seen in bathymetry. Lower right: inset of pots and different grain bottom sizes. SS-1, coarse sand (D 50 = 0.31 mm). SS-2, fine sand (D 50 = 0.16 mm). Underwater photo of lobster pot, 2.54-cm line at site SS-1. PVC pipe for scale (30-cm length). (Right) Nearshore resource assessments. Upper: side scan mosaic (1,600 kHz); white transparent polygons denote extent of eelgrass. Middle: swath bathymetry (10-cm grid cell); gray transparent polygons denote extent of eelgrass. Lower: inset from middle panel; dashed polygon delineates areas of prop scars, and black star denotes areas of eelgrass visible in bathymetry.

survey lines were needed to map 10.6 hectares with an average depth of 0.8 m. The average height above the bottom at nadir was 0.73 m and ranged from 0.10 to 4.9 m. The sonar performed well at these shallow depths. Typical swath widths of side scan imagery were 40 and 24 m for the 550 and 1,600 kHz, respectively, with approximately 90 percent of that swath width being usable.

At 0.10 m above the bottom, approximately 90 to 95 percent of the 24-m swath from the 1,600-kHz frequency was usable.

The changes in salinity in the Herring River estuary mentioned above did not render the data unusable or noticeably degraded. Some survey lines were collected from the head of the river to the mouth, and changes in salinity were not detectable based on visual inspection of the side scan imagery or bathymetric data.

With regard to bathymetric data, our experience with this instrument suggests a consistent usable swath width to depth ratio between 6:1 and 8:1, in 0 to 10 m of water. While the data are noisier than those from multibeam echosounders, and hand cleaning of PMSS data is more time-consuming, our operators have found that 6 hours' worth of survey data will require approximately 8 to 10 hr. of processing, including filtering and hand cleaning. This is a generalization, and the time needed can be much longer given equipment problems, environmental conditions and other expected survey complications. However, it should be noted that the PMSS technology can map the seafloor at a higher rate than the MBES, in most cases two to three times faster. Therefore, the ratio of area mapped versus processing times is comparable to MBES, and the survey times are significantly reduced and have the added benefit of co-registered side scan imagery. The processing times for the imagery are consistent with traditional side scan instruments.

Recent and ongoing projects funded by NOAA and the National Fish and Wildlife Foundation (NFWF) to locate, identify and retrieve derelict fishing gear using vessel-based acoustic methods have demonstrated the utility of PMSS. The co-location of these data sets allow for detailed 2D and 3D spatial analyses of these areas and are often complementary. For example, the side scan imagery is of high enough resolution to clearly identify lobster pots, the connecting line (2.54-cm diameter), slight variations in bottom grain sizes and small oscillatory ripples (30- to 40-cm spacing). However, the bathymetry shows that the areas of finer grain sizes are up to 50 cm higher than the surrounding area; this is at first counterintuitive.

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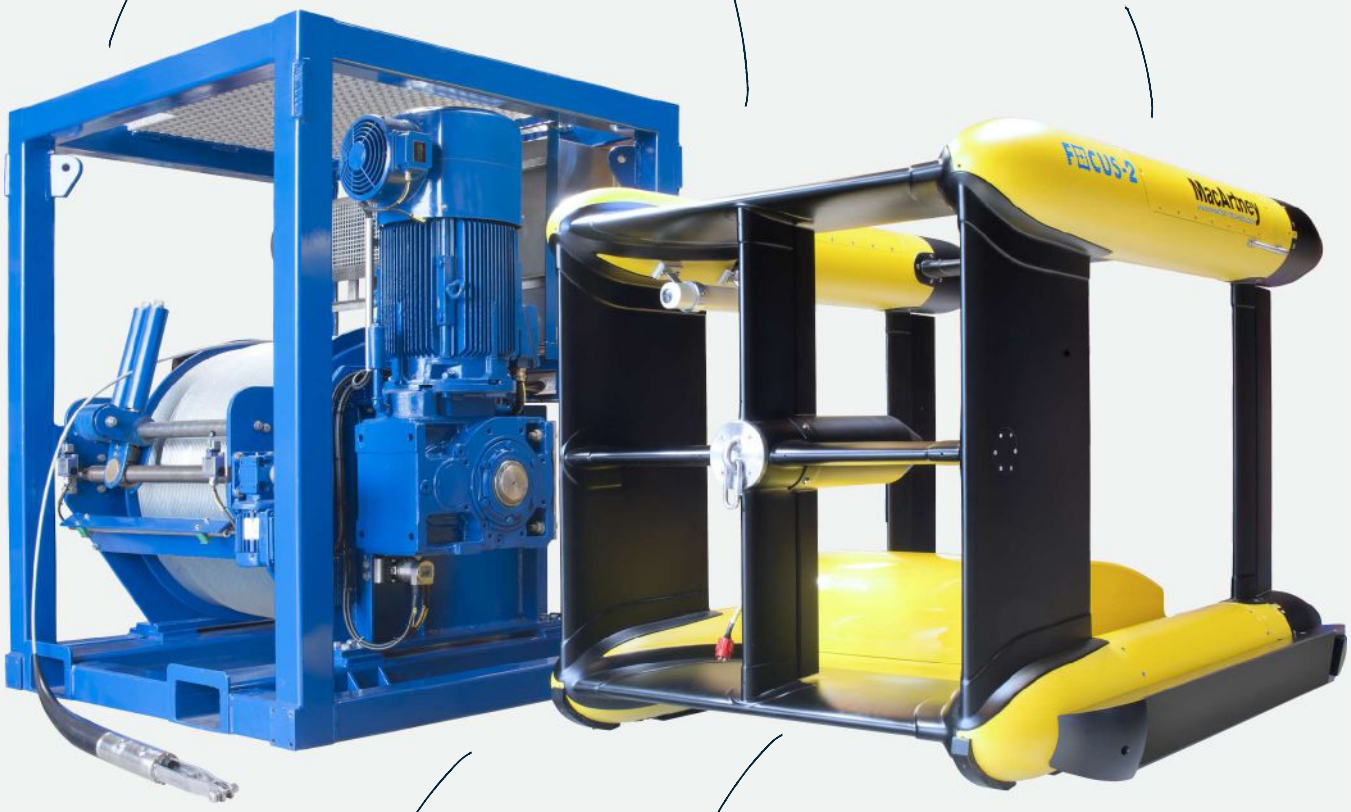

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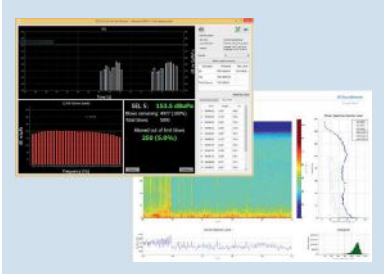

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Cape Cod, in southeastern New England, is a glaciated coast, and these finer-grained areas are likely outcrops of more erosion-resistant glacial material. The bathymetry alone would still allow for identification of targets that may or may not be lobster pots, but the bathymetry coupled with the side scan imagery is determinative and together provides information not attainable with either data set alone.

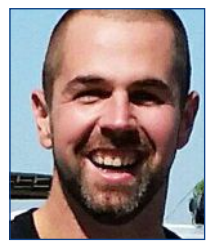
Some of this derelict fishing gear has been submerged for decades and now provides habitat for aquatic life. Scuba divers were used to collect information about the state of the gear and surrounding habitat, collect images and video and sediment samples, and aid in retrieval. Combining diver and acoustic surveys has provided useful information to ascertain the habitat value and extent with regard to derelict fishing gear, as well as ground-truthing the acoustic data.

Coastal municipalities are performing more nearshore resource assessments in order to balance the economic drivers of coastal and ocean tourism with responsible stewardship of these ecosystems. Keeping shallow navigation channels open while avoiding protected submerged aquatic vegetation (SAV) is difficult to perform and document. Typically, one would collect bathymetry to do a pre-dredge survey in a navigation channel or a traditional side scan sonar to map eelgrass beds, however, when both were needed, the PMSS allowed one survey to collect both co-located data sets.

The Town of Chatham, Massachusetts, was concerned about maintaining a heavily used, shallow navigation channel and potential impacts to eelgrass beds. A shallow-water survey was done August 2017, and the eelgrass beds were clearly identified on the side scan imagery, as well as in the bathymetry. The identification of the SAV as eelgrass would have been problematic with only the bathymetric data, and a pre-dredge survey with a side scan sonar would not provide the 3D data needed. These co-located data sets also provide useful information with regard to sediment transport pathways (erosion and accretion), anthropogenic impacts to SAV, and other issues of interest to managers.

Coastal resources are under increasing pressure from development, tourism and competing uses. These stressors are compounded given the current regime of climate change and projected rates of sea level rise and the increasing frequency and magnitude of coastal storms. Mapping these extreme shallow water environments provides much needed quantitative, spatial data to develop largely unavailable baseline inventories of these resources but also to measure future change in a rigorous and repeatable way. Phase-measuring side scan sonars coupled with shallow-draft survey platforms is one way to collect these data rapidly, efficiently and safely. **ST**

Dr. Mark Borrelli is the director of the CAPE Lab. His research interests include coastal sedimentary processes, seafloor and benthic habitat mapping, and understanding how storms, sea level rise and anthropogenic impacts affect the coast.



Bryan Legare, M.S., is a marine researcher at the Center for Coastal Studies. His research interests include benthic habitat mapping, fish movement and habitat use, and marine habitat assessments. He specializes in technical field operations of data loggers, monitoring instruments, survey equipment and biologic sampling in the marine environment.

Theresa Smith is a research geologist and hydrographer at the Center for Coastal Studies. She is interested in the physical processes of coastal and marine environments, nearshore geomorphology, barrier spit evolution, and understanding littoral systems with respect to sea level rise and increasing storm intensities of the northeast U.S. coast.

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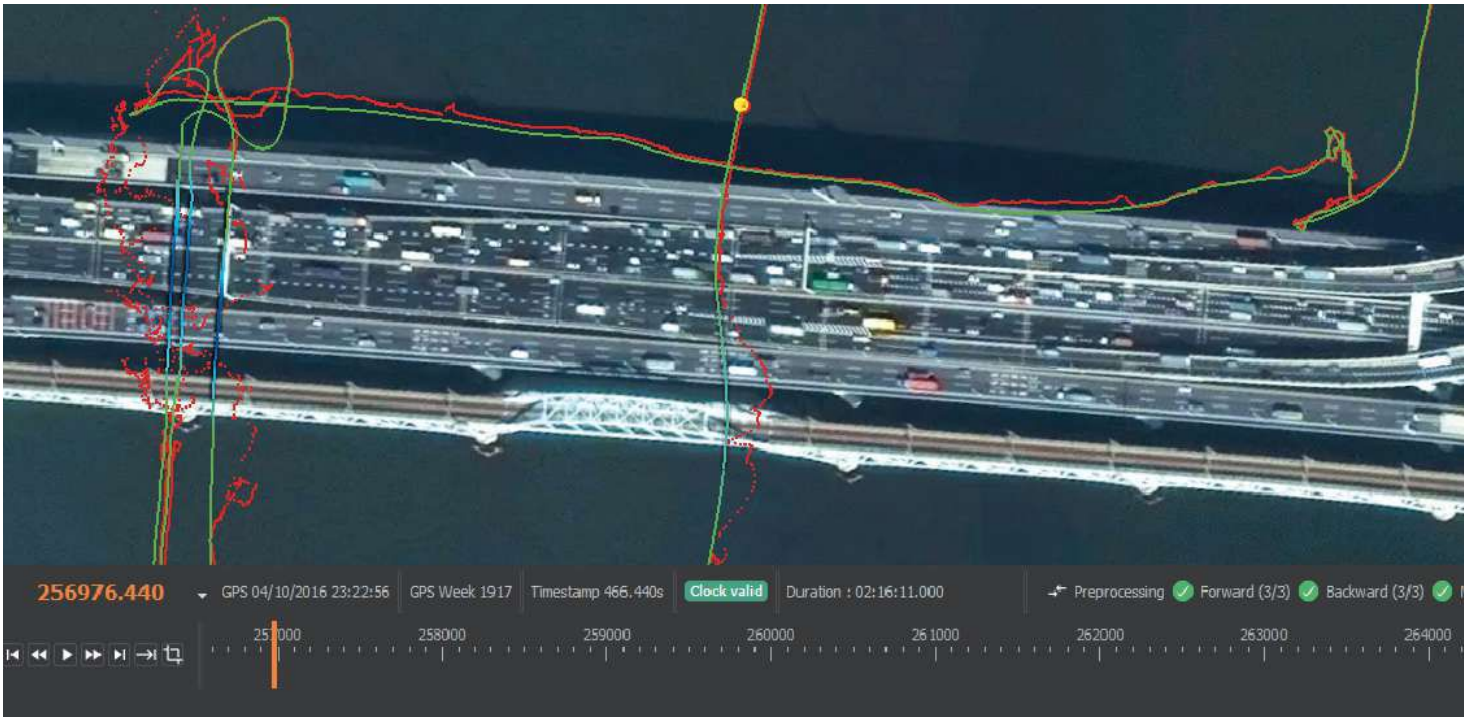

Quality: *Green -> centimetric position; Blue -> decimetric < 30cms; Red -> Raw GNSS data*

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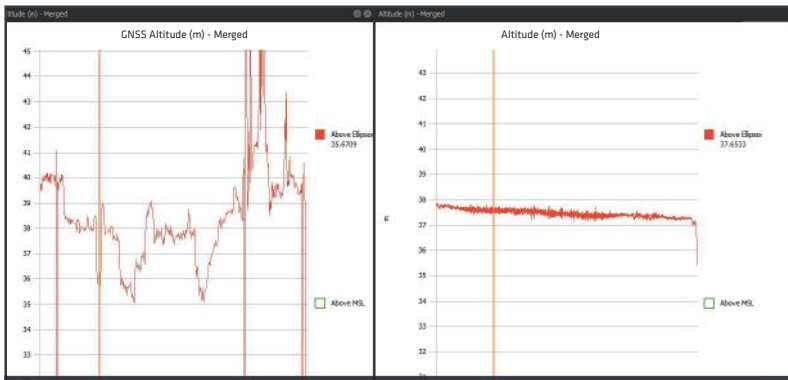

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Aquaculture Goes High Tech

Satellite-Derived Bathymetry for Fish Farm Site Selection

By Richard Flemmings

With the global market for farm-raised fish forecast to exceed $200 billion by 2020, the aquaculture industry is seeking new technologies to both improve efficiencies and minimize downstream environmental impacts. One U.K.-based engineering company has recently begun looking to Earth-observation satellites to gather the seafloor data needed to find optimal sites for new fish farms.

"The fish you eat are now more likely to come from a farm than from traditional wild-capture fisheries," said Dr. Glenn Shiell, principal marine ecologist at BMT, an international science and engineering company. "And the gap between farm-raised and wild-caught fish is widening all the time."

Shiell explained that as the world's population heads toward 9 billion people, producing adequate sources of high-quality food will become increasingly important. In comparison to other common protein sources—such as cows, pigs and chickens—fish offer a tremendous advantage because they require fewer feed resources to raise.

"Compared with most other organisms, it is so much more efficient to grow fish," said Shiell, who works in BMT's Perth, Australia, office.

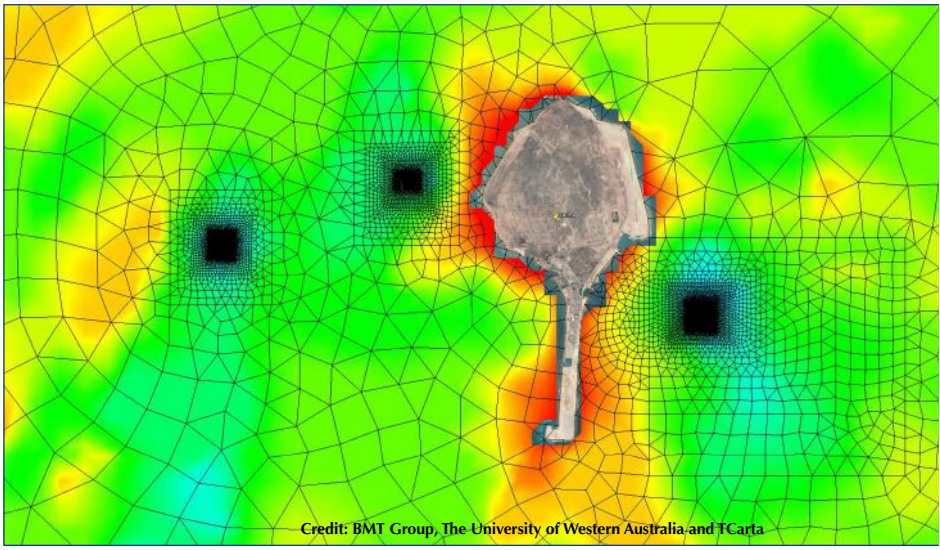
Since its inception in 1985, BMT has focused on applying advanced engineering technologies to the marine environment. It has developed numerous algorithms to model complex processes in the world's oceans and rivers. Over the past two years, BMT, in collaboration with its partner, the University of Western Australia, has developed a suite of customized tools to meet the complex demands of the growing aquaculture industry, encompassing numerical modeling, marine habitat mapping and environmental management strategies.

"BMT's modeling tools assist managers to determine the carrying capacity of the marine environment," said Shiell. "In simpler terms, [the models determine] how many fish you can farm without seriously affecting the health of the marine environment, or its dependent ecosystems. Despite the social benefits that come with aquaculture, it is important that its expansion is carefully managed—and this is the key starting point," he added.

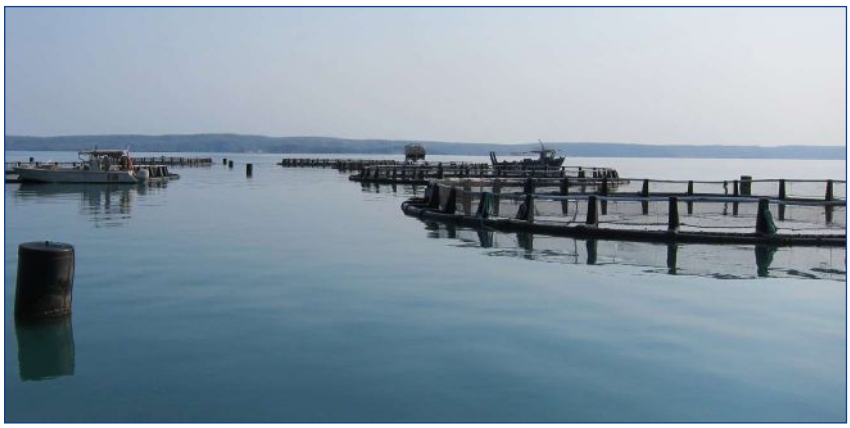
To apply and calibrate their models, BMT needs a variety of high-quality data, ranging from water depth to current direction and speed. Familiar with the advantages of satellite-derived bathymetry—relatively new technology—BMT learned these products were available for a project area in the Arabian Gulf, and, as a starting point, decided to try them in its fish farm models.

Bathymetry from Satellites

TCarta, a geospatial products and services company based in Bristol, U.K., has seen a surge in inquiries from



Proposed fish farming sites modeled using TCarta's satellite-derived products and services.



Efforts are underway with a focus on the sustainable development of marine aquaculture. (Photos Credit: BMT Group)

the fish farming sector over the past two years. "We have definitely experienced a spike in interest from aquaculture organizations," said David Critchley, TCarta CEO. "They are on the lookout for more cost-effective sources of bathymetric data in coastal areas where their fish farms will be located. For their purposes, they want data that's produced quickly, consistently and globally."

TCarta built its business on creating terrestrial and marine geospatial products generated from diverse and often hard-to-find source data. Its flagship product line is satellite-derived bathymetry (SDB), which is extracted from high-resolution digital satellite imagery.

TCarta had delivered SDB data, along with a related seafloor Habitat Map layer, of the Arabian Gulf to Environment Agency – Abu Dhabi (EAD) during a 2015 environmental project. Just two years later, in 2017, EAD contracted BMT for the aquaculture siting study around the Island of Delma in the Gulf and offered the data sets for use in that project as well.

Critchley explained that SDB products are appealing to aquaculture organizations because they deliver accurate water depth information in the relatively shallow coastal areas where many fish farms are located that can be difficult to map with other methods. Operation of ship-borne sonar, for example, is often dangerous in the dynamic nearshore environment, while airborne LiDAR is expensive. Both methods can be time consuming to deploy.

"Satellites have the advantage of capturing data very quickly on short notice with no impact on the ecosystem…in areas that might be inaccessible for a number of reasons," said Critchley. "And the satellite-derived data costs about one-tenth of the ship and airborne methods. Just as importantly, our process derives data sets that are consistent worldwide."

TCarta uses a proprietary processing technique to extract seafloor information from multispectral satellite imagery. Depending on the detail requirements of the project at hand, the geospatial firm has applied the technique to most commercially available space-borne remote-sensing data sets. The point spacing and accuracy of the derived depth measurements correlate directly to the spatial resolution of the digital imagery.

For broad-area planning projects requiring coarse detail, TCarta uses the 30-m-resolution U.S. Landsat data, while the 10-m Sentinel-2 data from the European Space Agency and 5-m RapidEye data from Planet suffice for planning in smaller areas, according to Critchley. But for a site selection project, where one or more specific locations must be selected for a given application, the most detailed seafloor information available must be used.

"For some projects, we use a combination of image data," said Critchley. "We start with the less expensive lower resolution data to get a regional perspective for planning and then switch to finer detail data for final site selection."

An aquaculture study like the one in the Arabian Gulf, as well as many engineering evaluations related to coastal infrastructure and oil and gas development projects, requires high-resolution imagery. For these jobs, TCarta utilizes data acquired by the DigitalGlobe WorldView-2 and -3 satellites. From an orbit of 383 mi., these platforms capture 1.3-m-resolution data in eight spectral bands and 0.3-m data in one panchromatic band.

The two near-infrared (IR) bands collected by the WorldView satellites are vital to the seafloor extraction algorithms because these wavelengths penetrate the water column. Additionally, the WorldView satellites have what is called a coastal band, which sees through the haze often associated with optical image collection over shoreline environments. Optical imaging sensors, however, are not capable of capturing data through clouds.

In the SDB process, TCarta technicians use a heavily customized digital image processing workflow to isolate specific segments of the two near-IR bands and digitally combine them with other bands from the multispectral data to derive water depth and seafloor classification information.

"Quality of the derived data depends on the clarity and turbidity of the water. The Arabian Gulf has moderately clear water around Delma," said Critchley. "In that area, our SDB data provided depth measurements at a two-meter spacing with two-meter accuracy to a depth of about twelve meters."

In addition, the extraction process differentiates several types of seafloor surfaces from the spectral bands of the satellite data. For the coastal area around Delma, TCarta delineated five seafloor classes: sand, seagrass, macro-algae, coral reef and hard rock, also to a depth of about 12 m. TCarta refers to this data set as a Marine Habitat Map, and it was included in the 2015 product delivery to EAD, which was subsequently built upon by BMT in the more recent aquaculture project.

Modeling Water Flow

Fish farm operations come in many shapes and sizes and are developed in both fresh and saltwater, explained BMT's Shiell. An offshore saltwater farm like the one being assessed near Delma will likely comprise numerous individual cage clusters potentially containing tens of thousands of fish. The maximum number of fish, as well as the marine monitoring and management strategies required to manage future operations, will be among the recommendations provided by BMT.

BMT began running data through its models for Abu Dhabi in September 2017. For the relatively shallow coastal zones around Delma, BMT used the SDB and digital Marine Habitat Map from TCarta. In some of the deeper waters, Shiell's team acquired ship-borne bathymetric data. A digital GIS layer containing seafloor depth data assembled from multiple sources was purchased from TCarta to serve as the project basemap.

For a proposed aquaculture project of this type, the shallow-water data are an important model input, according to Shiell.

"The bathymetry around the coastline is often some of the most complicated…and that is where we need resolution to predict the speed and direction of water movement around the island," said Shiell.

He elaborated that the flow of water and the shape and depth of the seafloor are important variables in the aquaculture model because they influence flushing rates, one of the key factors for identifying which sites are most favorable for fish cages.

"Our models aim to determine the environmental footprint the proposed operation might look like, what proportion of organic waste will fall to the seafloor and what kind of environmental management approaches are needed to develop a sustainable industry," said Shiell. "Most of the fecal matter is heavy and falls to the seafloor. Provided there is sufficient water movement and oxygen, the waste material is broken down by bacterial activity."

The danger, however, is that without sufficient water flow and oxygen, the waste builds up on the seafloor. The model balances the ability of the marine ecosystem to naturally assimilate the waste against the number of fish in the cages above.

The modeling is complex because the water movement is influenced and constrained by various factors, including tide, wind and the topography and composition of the seafloor.

"The TCarta SDB data was critical in helping us build the hydrodynamic model, which allows us to understand how the water is moving through the system," said Shiell. "The accuracy and resolution of the data, combined with our own in-situ measurements, allowed us to build a robust model."

Once the flow modeling has been completed, BMT will pinpoint several potential fish farm zones, each several kilometers in diameter to accommodate periodic relocation of the cages within site. BMT will then overlay the results with the Marine Habitat layer on the GIS basemap to further evaluate environmental impact.

"A key outcome of the modeling will be to make sure the footprint of the farm zone does not encroach on sensitive marine habitats like corals or sea grasses," said Shiell.

Delivering Results

BMT expects to deliver the modeling results to EAD by late 2018. Outputs are expected to include recommendations on the optimum siting of cage clusters and the maximum carrying capacity of the environment based on different finfish species. In addition, the model will provide key management recommendations including how often the cages should be moved under a process of fallowing.

"The initial results with the SDB data in the Arabian Gulf, as well as other projects by our clients, tell us that aquaculture will be a huge emerging market for marine geospatial data," said Critchley. **ST**

Based in Bristol, U.K., Richard Flemmings is a partner in TCarta and responsible for company operations and management. He has been involved in the geospatial industry for more than 16 years. He has an M.S. in geographical information science and significant worldwide experience in offshore, airborne, land and satellite-based surveys and mapping. Flemmings is a qualified project manager and is experienced in project design, workflow development and lean management principles. He is a fellow of the Royal Geographical Society (FRGS) and a chartered geographer (CGeog GIS).

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New Approaches Using Combined USV-AUV Method

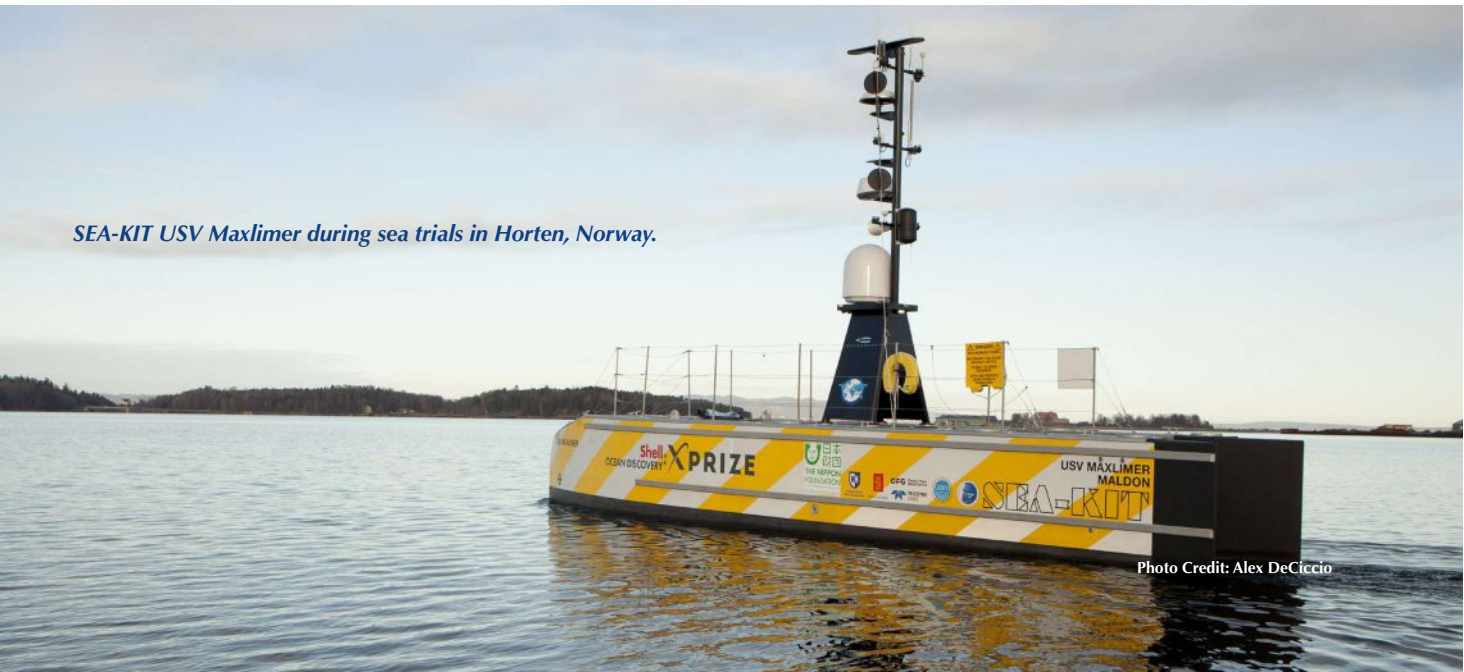
By Dr. Rochelle Wigley • Dr. Alison Proctor • Benjamin Simpson

The GEBCO-NF Alumni Team is one of the nine teams that have progressed to the final round of the Shell Ocean Discovery XPRIZE challenge. The international team is working toward a solution for autonomous ocean mapping operations. It was initiated and led by alumni of the Nippon Foundation/GEBCO Training Program at the Center for Coastal and Ocean Mapping of the University of New Hampshire. The alumni worked closely with partners Ocean Floor Geophysics Inc. (OFG), Hush Craft Ltd., Teledyne CARIS and Earth Analytic, as well as equipment supplier Kongsberg Maritime AS, to develop and advance the team concept.

The Shell Ocean Discovery XPRIZE competition aims to push the boundaries of ocean technologies by generating solutions to the grand challenge of mapping our oceans through incentivized competition. The competition encourages the development of platforms for ocean exploration that can demonstrate the combination of capabilities critical to expanding discovery of the world's oceans: improved autonomy, faster speeds and the ability to explore at significant depths.

The Shell Ocean Discovery XPRIZE Round One challenge was to develop a complete system that could map 100 sq. km in 16 hr. at 5-m horizontal resolution grid and produce images that would excite the general public. The designated survey area for the XPRIZE challenge could be up to 50 nautical miles (nm) offshore, and operations had to be remotely coordinated from a land-based operations center. The entire mapping system had to fit into a standard 40-ft. shipping container.

The GEBCO-NF Alumni Team concept was to leverage existing technologies wherever possible and to integrate them to achieve the competition requirements. The strategic approach was to develop strong partnerships with technology and service providers to address the hardware, integration and software needs of the team. The concept was a two-vehicle system: an AUV and USV to autonomously map the seafloor in a wide



SEA-KIT USV Maxlimer during sea trials in Horten, Norway.

Photo Credit: Alex DeCiccio

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(Top to Bottom) OFG's HUGIN AUV Chercheur launching from the USV. A closeup of OFG's HUGIN AUV Chercheur. The AUV Chercheur lining up for retrieval onto the USV Maxlimer.

variety of ocean environments. The AUV-USV idea will lead to more efficient, safer and cost-effective seafloor mapping operations.

The Concept

The core of the team's technology innovation was the design of an ocean-capable USV with capabilities for the launch, management and recovery of a deepwater-capable AUV.

The USV acts as the mothership and operational control hub with no offshore human involvement. It rapidly transits to a survey site, launches the AUV, and provides surface support, communication/control links and AUV tracking during the survey. The USV then recovers the AUV to return it back to shore. This allowed the team to maximize survey time by conserving AUV battery power during transit.

Hush Craft SEA-KIT USV. The USV SEA-KIT Maxlimer was designed and built by Hush Craft Ltd. to act as the surface support vessel for the AUV. As per Shell Ocean Discovery XPRIZE requirements, the SEA-KIT USV is transportable using a standard 40-ft. ISO container to allow for rapid deployment.

The team was the first client for the new Kongsberg Maritime K-MATE Autonomy Controller, which was installed on Maxlimer. The software was developed through collaboration between Forsvarets Forskningsinstitutt (FFI) and Kongsberg Maritime AS, with ongoing development having occurred during sea trials in Horten, Norway.

K-MATE provides adaptive waypoint following for survey and AUV operations, as well as providing other autonomous functions required for safe offshore unmanned operations. K-MATE is an autonomous system that can execute a mission plan for globally supervised operations. The USV Maxlimer was also coded through the U.K. Maritime and Coastguard Agency as a Small Commercial Vessel Category 3 that allowed it to carry two people on board up to 20 nm offshore. Having crew on board reduced complexity during sea trials and the technology development stage.

The USV SEA-KIT Maxlimer can be operated in four modes: manual (from the physical helm of the USV), remote control (from a dedicated handset for short-range unmanned control), autonomous remote (operator commands vessel functions from remote station using K-MATE interface), or fully autonomous (waypoint and/or AUV following with the vessel fully controlled by K-MATE).

These multiple modes of operation were utilized during AUV launch and recovery, where Maxlimer acts as the traditional AUV host vessel to allow remote access to manage AUV operations. Maxlimer utilizes live-streaming hi-definition CCTV cameras (with IR for night vision) mounted on the mast to maintain situational awareness during operations. Maxlimer's operating mode can also switch from autonomous to remote controlled as required during the mission. Maxlimer was fitted with the Kongsberg HiPAP 351P-MGC SSBL system, which was used for AUV positioning and as a command and data link for the AUV. Maxlimer is equipped with the Kongsberg Seapath 130 positioning system, which enabled accurate position data to be transmitted to the AUV.

The SEA-KIT USV was designed to exceed competition goals, not only for sustainable bathymetric surveying operations but also as a multi-role vessel with uninhabited and autonomous capabilities over and above the competition brief as an AUV mothership. It was designed as an offshore-capable vessel that can operate in significant sea states and carry a deployable and retrievable payload of up to 2.5 tons. At 11.75 m (38.55 ft.) in length, with a beam of 2.2 m (7.218 ft.), the USV

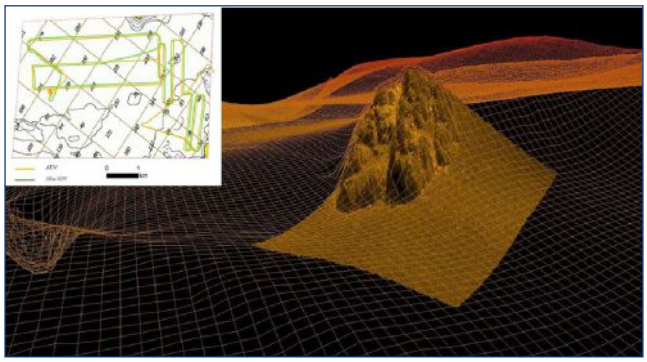


Photo Credit: Kelly Duncan

(Top) High-resolution spot-processed HISAS imagery of a rock outcropping draped onto gridded bathymetry. Inset: The trajectory of the AUV and USV during the Technology Readiness Test. (Bottom) SEA-KIT USV during sea trials in Horten, Norway.

SEA-KIT Maxlimer uses a Hushcraft diesel/electric hybrid propulsion system providing 20 kW of propulsion power. It is designed to have a range of 12,000 nm and endurance of 130 days at 4 kt., with standard fuel capacity of 2,000 liters. The SEA-KIT USV was designed to DNV GL ST0342 Craft standards for operations in any waters not requiring ice-class vessels. The maximum design speed for the SEA-KIT USV is 8 kt., with endurance linked to speed and daily charge. The development of the offshore operational models required for this new type of vessel is currently being undertaken by SEA-KIT International Ltd. to ensure that all unmanned operations are conducted in accordance with safe working practices. This will benefit the rapidly developing rule sets for commercial autonomous maritime operations and will ensure that the investment in the development of SEA-KIT USV Maxlimer for the XPRIZE competition is fully realized and utilized in the future.

OFG's HUGIN AUV Chercheur. The GEBCO-NF Alumni Team chose the industry-leading HUGIN AUV developed by Kongsberg Maritime AS for this project, specifically Ocean Floor Geophysics' HUGIN AUV Chercheur. This vehicle is equipped with the Kongsberg HISAS 1032, a high-specification deepwater interferometric synthetic aperture sonar that was used to collect bathymetric and imagery data. Ocean Floor Geophysics also brought considerable experience in operating a commercial AUV, and their personnel have diverse AUV experience in all aspects of operations, system integration and design, as well as mission planning. OFG had a compatible philosophical approach with an R&D background focused on selection, design and integration of sensors.

Sea Trials

The Shell Ocean Discovery XPRIZE Round One challenge was originally scheduled to take place in Puerto Rico during the fall of 2017. However, Puerto Rico (along with the rest of the northeastern Caribbean) was hit hard by Hurricane Maria in the 2017 hurricane season. Maria was the worst storm they had seen in 90 years and resulted in the postponement of Round One. On October 20, 2017, XPRIZE management informed teams that due to infrastructure damage in Puerto Rico, the Round One field test would be replaced by Shell Ocean Discovery Technology Readiness Tests and would be conducted individually in a location chosen by each team. The 11 criteria for judging were announced later that month.

Sea trials for the GEBCO-NF Alumni Team were conducted at the Kongsberg Maritime AS facilities in Horten, Norway, in the second half of 2017, and the Technology Readiness Test was held November 2017. The extended sea trials allowed the team to fully research the capabilities and limitations of the concept system, maximize sonar coverage and performance, and understand the integration and management of the AUV and USV systems to ensure reliable operations without physical intervention at sea.

The survey operations, including launch and recovery, were managed from the land-based operation center—with an operations manager, an AUV pilot and a USV control team. Communication between the operation center and the USV and AUV was facilitated by a Kongsberg Maritime marine broadband radio (MBR).

At the start of a mission, the USV began autonomous waypoint following and obtained a steady course. Once the USV was at the launch point and the AUV operator gave the go-ahead for launch, the USV pilot started the conveyor and launched the AUV. The AUV waited for approximately 45 sec. and then started running on the surface in line with the path of the USV. The AUV then dove quickly so that the USV could pick up the AUV's HiPAP signal and locate it. Once the USV was tracking the AUV underwater, the USV was put into AUV-following mode. In following mode, the USV attempts to maintain a fixed position with respect to the AUV as it completes its mis-

sion. For the Technology Readiness Test, the USV was to maintain a constant range and bearing of 75 m and 225° from the AUV's estimated position.

The AUV dive was conducted on day two of the Shell Ocean Discovery XPRIZE Technology Readiness Tests. The dive lasted 4 hr., and 11 sq. km of seafloor data (bathymetry and imagery) were collected. The surface vessel was actively under control of K-MATE (unmanned) for more than 9 hr. while underway during that day.

At the end of the AUV mission plan, the USV was switched back into waypoint-following mode. The AUV surfaced behind the USV and was set on a parallel course to the USV in waypoint mode with matching speed. The relative speeds of the AUV and USV were adjusted to allow the AUV to catch up to the USV. Once the AUV could be seen in the side camera of the USV, the speeds of the two vehicles were equalized, and the AUV was guided in behind the USV by adjusting the AUV's across-track offset. The AUV across-track fine adjustment continued until it was in alignment with the USV and confirmed using Maxlimer's onboard cameras. Once the USV slowed, the AUV drove into the back of SEA-KIT, and the mission came to an end. The USV then resumed its normal speed and continued to the next waypoint, heading back toward the dock with the AUV on board.

Conclusion

The launch, tracking, control and recovery of the Ocean Floor Geophysics' HUGIN AUV Chercheur from the SEA-KIT USV Maxlimer demonstrated a new level of autonomy and remote-control operations in seafloor surveying. The technology, processes and procedures developed by the GEBCO-NF Alumni Team for this Shell Ocean Discovery XPRIZE project are a step toward larger-scale implementation of these concepts.

During the Technology Readiness Test, the GEBCO-NF Alumni Team successfully met all 11 readiness criteria and produced exciting high-resolution bathymetry and images of the seafloor. The GEBCO-NF Alumni Team is one of nine Shell Ocean Discovery XPRIZE finalists that were chosen from a field of 19 semifinalists by an independent judging panel of seven experts. Next up is the Final Round of the Shell Ocean Discovery XPRIZE challenge in October and November 2018.

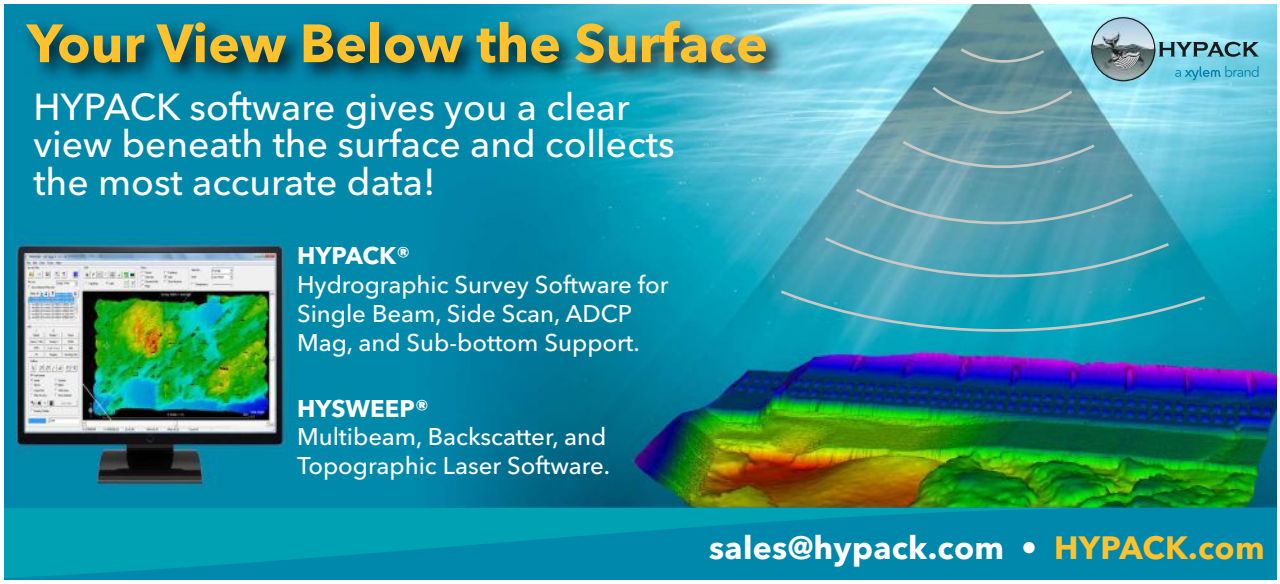
Acknowledgments

This work would not have been possible without the partnership and support of the Nippon Foundation, the Sasakawa Peace Foundation, University of New Hampshire, Ocean Floor Geophysics, Hush Craft Ltd., SEA-KIT International, Kongsberg Maritime AS, Teledyne CARIS and Earth Analytic. The authors would also like to thank the 55 individuals from 13 countries who all dedicated themselves to ensuring the success of this project. **ST**

Dr. Rochelle Wigley earned her Ph.D. in geological sciences in 2005 from the University of Cape Town, South Africa. Wigley is project director for the Nippon Foundation/GEBCO Training Program at the University of New Hampshire and coordinated the Shell Ocean Discovery XPRIZE Round One project team.

Dr. Alison Proctor earned her Ph.D. in mechanical engineering from the University of Victoria. Proctor led the collaboration with the GEBCO-NF Alumni Team for OFG. She is a certified operator of the Saab SeaEye Falcon ROV, Bluefin-12, ISE Explorer 3000, WHOI REMUS 6000, OceanServer IVER and the Kongsberg HUGIN.

After achieving B.S. (honors) at Southampton University, Benjamin Simpson spent 10 years as a captain/engineer, sailing more than 100,000 nm, including a circumnavigation. He achieved Master 3000GRT at 23. Simpson has created two successful companies, building and operating more than 30 offshore vessels. He was elected as a fellow of the Royal Institute of Naval Architects in 2015.



A Frigid Reception

US Navy Looks to Bolster Ship Capabilities in Arctic Ocean

By Warren Duffie Jr.

Among the world's last great frontiers, the Arctic Ocean has seduced generations of hardy explorers seeking adventure, wealth and glory.

For centuries, the thick sea ice encasing this desolate polar region offered seafarers only limited entry each summer—creating an aura of frigid impregnability and mystery. But that's changing as Arctic sea and air temperatures rise, and summer sea ice melts and fails to refreeze as quickly.

As this frozen cover diminishes, it opens previously inaccessible waterways for extended periods of time each year.

Since 1979, when satellite monitoring of sea ice began, the Arctic has lost a substantial amount of its ice volume, which has shrunk in both overall area and thickness. Less of the ocean is covered in ice, which now tends to be thinner, seasonal ice instead of thick, older floes (known as white ice). As white ice gives way to dark ocean water, which absorbs more sunlight, the water heats further—accelerating the melt.

This thaw provides once unimaginable access to the Arctic—an ocean with territorial claims by multiple surrounding coastal nations, including the United States. It also opens more commercial shipping lanes; increases opportunities for oil and natural gas exploration, fishing and tourism; and raises potential security concerns.

With such accessibility comes the need to increase readiness for Arctic operations and develop capabilities to ensure the safety of the U.S. fleet.

To meet that challenge, the U.S. Navy needs to learn more about the changing Arctic environment, improve sea and weather forecasting for safer operations, and address ship vulnerabilities during extreme cold-weather operations.

"As the Arctic opens for more human activity, there will be greater requirements for the U.S. Navy to operate in the area," said Dr. Richard Carlin, head of the Office of Naval Research's (ONR) Sea Warfare and Weapons Department. "Collaborative efforts among partner nations will enhance knowledge of, and capabilities in, this unique theater—ensuring a safe, stable and secure Arctic region. It's a challenging proposition, but one that must be faced."

Armed with Arctic Knowledge

The "U.S. Navy Arctic Roadmap, 2014-2030" assigns tasks to various naval organizations to prepare the fleet for future Arctic operations. To satisfy these requirements, ONR—which oversees science and technology initiatives for the Navy and Marine Corps—is sponsoring diverse

U.S. Navy Ship's Serviceman Seaman Recruit Jamal Powell, left, and Seaman Recruit Stephen Harmon stand forward lookout watch aboard guided-missile cruiser USS Normandy *(CG-60) as the ship navigates an ice field north of Iceland.*

Photo Credit: U.S. Navy, Lt. j.g. Ryan Birkelbach

Dr. Joan Gardener, right, and Dr. Rick Hagen, with the Naval Research Laboratory, drill a hole into 6 ft. of ice to collect water samples, ice cores and temperature readings as part of an ongoing research project for ice characterization during Ice Exercise (ICEX) 2016, a five-week exercise designed to research, test and evaluate operational capabilities in the region.

Arctic research. With support from ONR's Arctic and Global Prediction program, scientists use unmanned underwater vehicles and other autonomous technologies—equipped with high-tech oceanographic and atmospheric sensors—to record sea, ice and weather conditions and provide higher-resolution data fields to forecasting computer models. In addition, ONR's Warfighter Performance Department is looking at human physiological responses to extreme cold and the development of better cold-weather clothing.

While analyzing physical changes in the Arctic and human vulnerabilities to cold are vital, it's equally important to determine how well the Navy's surface vessels will function in this extreme environment. Arctic operations require ships to have reinforced hulls capable of breaking through ice and superstructures designed to endure heavy ice buildup. ONR's Sea Warfare and Weapons Department is sponsoring this research.

How Much Arctic Can Navy Ships Handle?

Despite the Arctic's current warming trend, it still consists of vast, frozen tracts of land and ocean, often impenetrable without the help of icebreakers. This poses a formidable obstacle to the Navy—which has had few ice-capable warships since the 1960s, when it turned over its eight World War II-era icebreakers to the U.S. Coast Guard, which remains America's primary naval presence in the Arctic.

ONR-sponsored scientists and engineers are using sophisticated computer modeling and material science to evaluate how capably the present fleet might perform in volatile, sub-zero polar regions—particularly in the Marginal Ice Zone, a dense patchwork of ice floes sitting between solid sea ice and the open ocean.

"There is a great likelihood that, after a long absence since the Cold War, the Navy will send surface ships into polar regions again," said Dr. Paul Hess, an ONR program officer. "By increasing our understanding of issues like ice loading or the ability of existing ship hulls to withstand ice strikes, we can help the Navy understand how to safely operate existing ships—and what types of vessels it will need to build both in the near future and decades from now."

Specific research areas include ice buildup and special coatings to prevent the frozen stuff from sticking to exposed metal; interaction between sea ice and ship hulls; and propellers that are less vulnerable to ice damage.

Intimidating Ice

Among the worst hazards of Arctic sailing is topside icing (also called ice accretion), where water blown from the ocean freezes on contact with a vessel. Weight accumulated through ice accretion can affect a ship's speed, turning radius and tactical maneuverability. It could even disrupt the center of gravity and cause capsizing.

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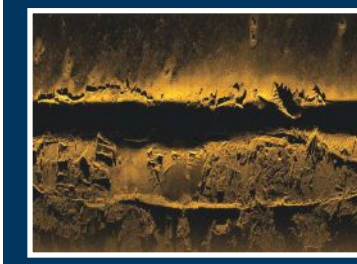
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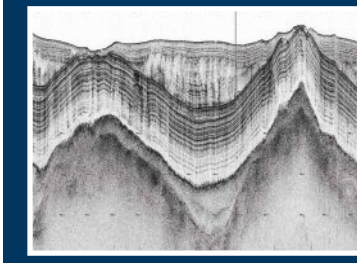
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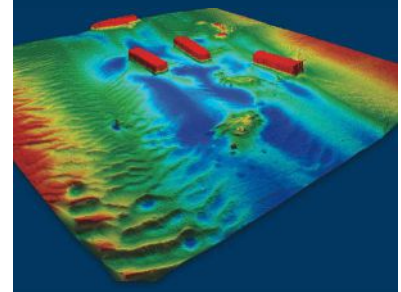
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(Left) A dangerous coating of ice on the NOAA Ship* Miller Freeman *in the Bering Sea, Alaska. Such icing can affect a ship's stability and cause capsizing. (Photo Credit: NOAA Library Ship Collection, Courtesy of NOAA NMAO Pacific Marine Center) (Right) During a winter research cruise to the Labrador Sea in 1997, waves washing over the decks of the RV* Knorr *caused continual ice buildup. It took six to eight people the better part of a day to bang all the decks, bulkheads and bulwarks free of tons of ice. (Photo Credit: George Tupper, Woods Hole Oceanographic Institution)

Getting rid of ice buildup is tough work. Current removal methods include baseball bats, heavy mallets, scrapers and chemical melting agents.

"Not only are these methods labor-intensive or corrosive, they can harm high-value equipment like radars and antennas," said Dr. Ki-Han Kim, an ONR program officer.

ONR is sponsoring several research efforts into anti-icing and de-icing coatings that can be sprayed on large areas and make ice removal easier. Prominent among these is the work by Dr. Anish Tuteja, a professor at the University of Michigan.

Tuteja's team developed a spray-on "ice-phobic" coating that causes ice to slide off surfaces. Thin, clear and composed of synthetic rubbers, the coating operates through a phenomenon called interfacial slippage.

Usually, two rigid surfaces—think of ice and a windshield—freeze together tightly. That's why scraping ice off a car can be laborious. However, the rubbers created by Tuteja's team display both solid- and liquid-like properties, enabling ice to slip off with very low applied force. This makes for easy and effective ice removal.

So far, the spray-on coating has been successfully tested at the Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL) in New Hampshire.

Home to the nation's primary ice tank facilities, CRREL features 26 deep-cold rooms that can maintain temperatures as low as -40° F—as well as large test basins where scientists and engineers can recreate the icy and snowy conditions of the Arctic Ocean.

In addition to sponsoring Tuteja's coating research, Kim collaborates with the North Atlantic Treaty Organization's Applied Vehicles Technology Panel—to assess existing anti-icing and de-icing technologies for air and sea vehicles, and recommend ways to improve those technologies. Besides the United States, this partnership includes Canada, the United Kingdom, France, Norway and New Zealand.

What Affects Hull-Sea Ice Collisions?

Another major Arctic threat is collision with sea ice, which may cause severe dents, cracks and ruptures.

To figure out how much impact, or ice load, a Navy ship can endure, ONR's Hess is sponsoring specialized research at Naval Surface Warfare Center (NSWC) Carderock Division in Maryland.

Researchers design ice load prediction models on a sophisticated computer system called ICELOAD. They enter data and equations about the physical and chemical properties of metallic hulls and sea ice—and create various computational models outlining how much ice load a ship might encounter during Arctic operations.

"The risk of structural damage due to ice load and impact depends on many factors, including vessel speed, ice thickness and the shape of a ship's hull," said Dr. Judy Conley, a science and technology coordinator at NSWC Carderock. "Our objective is to characterize this interaction in the simplest terms possible and determine the most efficient, damage-resistant structure capable of Arctic operations."

After creating the computer prediction models, scientists travel to CRREL to test their accuracy on physical-scale models of Navy ships.

Although ICELOAD has been in use since the 1980s, the renewed international focus on the Arctic bolstered a partnership among NSWC Carderock; the American

Captain A.D. Colburn, right, crew member Bill Dunn and others wield their ice mallets on Knorr's foredeck during the 1997 Labrador Sea cruise. (Photo Credit: George Tupper, Woods Hole Oceanographic Institution)

Bureau of Shipping (ABS), whose classification system denoting strength levels of ice-capable hulls is widely respected in the marine industry; and Canada's Memorial University of Newfoundland, home to ABS's Harsh Environment Technology Center, where researchers study how ships can be designed and operated more effectively in polar regions. The three organizations are comparing their respective ice load research tools to determine areas that need further evaluation and develop collaborative methods for testing prediction models.

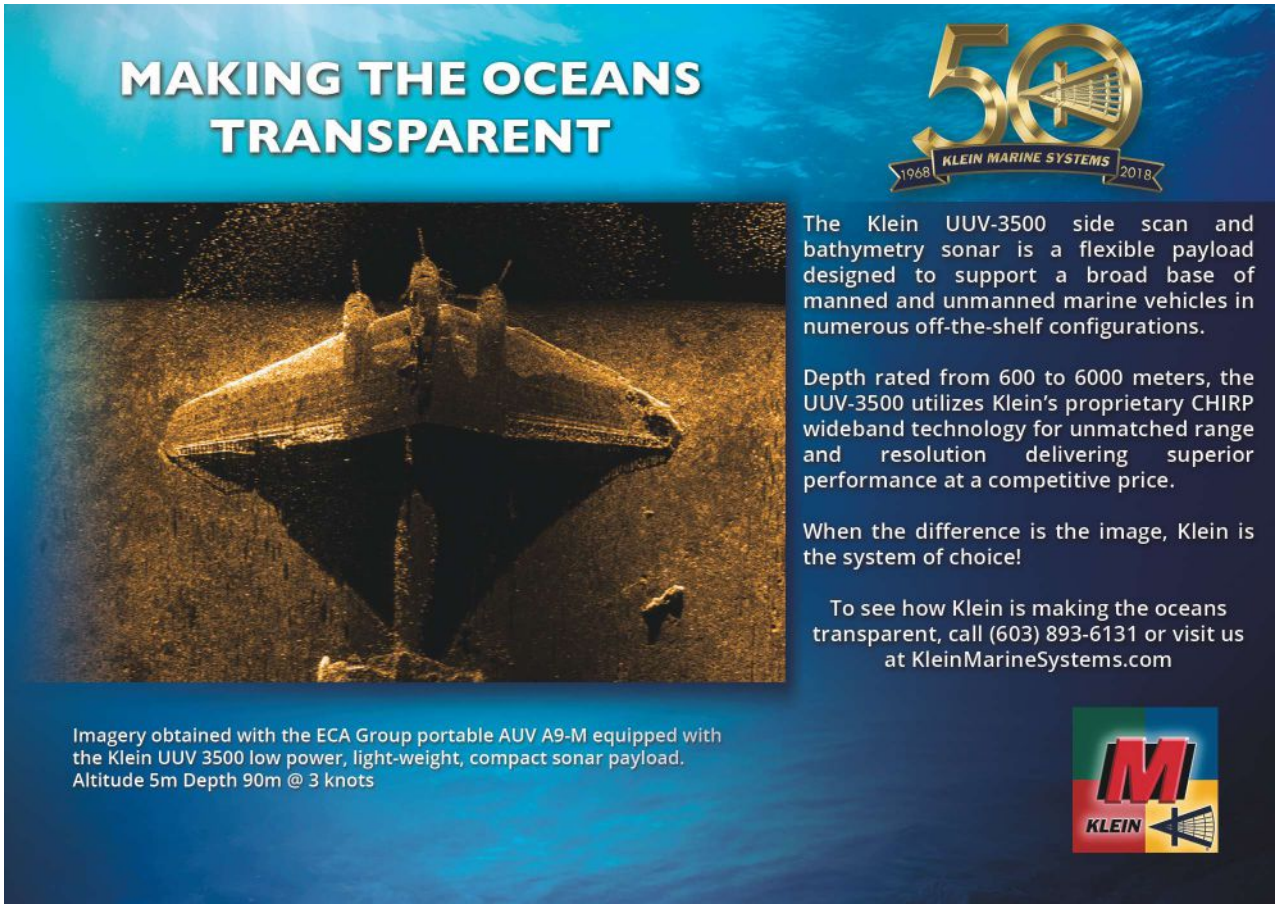
Building on ICELOAD and other prediction models, Hess also is sponsoring Douglas Lesar's work at NSWC Carderock, using high-fidelity computational mechanics to analyze potential damage from ship collisions with ice.

"In polar environments, there's floating ice of varying sizes and shapes," said Lesar, a modeling and simulation expert. "Collisions should be accepted as inevitable, but the main thing is to avoid big hits and manage risk by effectively controlling vessel speed and direction."

Lesar's research involves advanced numerical computer modeling on how much ice trauma a hull can take. His calculations use motion data and equations measuring the mechanics of metallic hulls and ice breakage to create different collision scenarios and their structural damage outcomes.

"Ice is a very complicated material whose properties vary with thickness, salinity and age," said Lesar. "All these factors contribute to the overall strength of sea ice. The modeling of ice crushing and fracturing also is computationally challenging."

Lesar hopes to correlate his computer modeling data to physical experiments conducted at CRREL, or by an international research partner like the Memorial University of Newfoundland.



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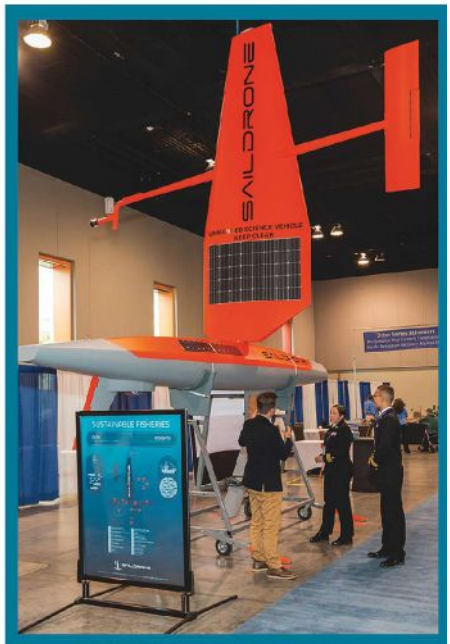

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Hefty Hulls

ONR program officer Dr. Roshdy Barsoum is overseeing hull research that builds on an ancient idea: ice belts.

Since the earliest days of polar exploration, sailors used iron bands or double wooden planking around ship waterlines to traverse treacherous Arctic waters. Today, ice belts are made of durable, hardened rubber composites.

Barsoum sponsors work at NSWC Carderock dealing with "polymer sandwiches" as a type of ice belt. In this sandwich, a section of a ship's outer hull would be covered with a strong, lightweight layer of polymer material—similar to a truck bedliner—encircling the waterline. This layer then would be sheathed underneath a reinforced steel plate, creating a cushioned barrier against ice.

Engineers at NSWC Carderock test the sandwich's fortitude using a machine that drops heavy weights on separate steel plates, some strengthened with the polymer layer, some not. The weight is dropped at different speeds and intensity to mimic the force of ice collisions. Plates fortified with the polymer withstand the hits with less dents or buckling.

Barsoum hopes to fund future tests at CRREL, as well as outfit a retired Navy ship for Arctic trials.

"The tests at Carderock have been very successful, but they've been conducted at room temperature," he said. "Steel becomes more brittle in extreme cold, so it's important to test the plates and polymers in the most realistic conditions possible."

Powerful Propellers

In addition to ice-phobic coating, Ki-Han Kim sponsors research to assess the vulnerability of existing ship propellers in Arctic waters and quantify the risks to vessels and their propulsion systems.

Under a project agreement between the U.S. Department of Defense and the Ministry of Defence of Finland, the American and Finnish navies are investigating ways to improve propeller design, including alternative manufacturing materials like stainless steel alloys and titanium, which are extremely strong and perform well in polar environments.

"Most Navy surface ships currently have propellers made of an alloy of nickel, aluminum and bronze, called NAB," said Kim. "When considering alternative materials, we need to trade off between manufacturing cost and performance to reach an optimized solution, because stainless steel and titanium are more difficult and expensive to manufacture than NAB."

International Partnerships

Most of the Arctic research efforts featured in this article involve international collaboration. This is by design.

ONR, together with its international command, the Office of Naval Research Global, has been a key player in the recent establishment of the International Cooperative Engagement Program for Polar Research (ICE-PPR). This proposed framework between the United States, Canada, Denmark, Finland, Iceland, New Zealand, Norway and Sweden is part of ONR's answer to the requirements of the Arctic Roadmap.

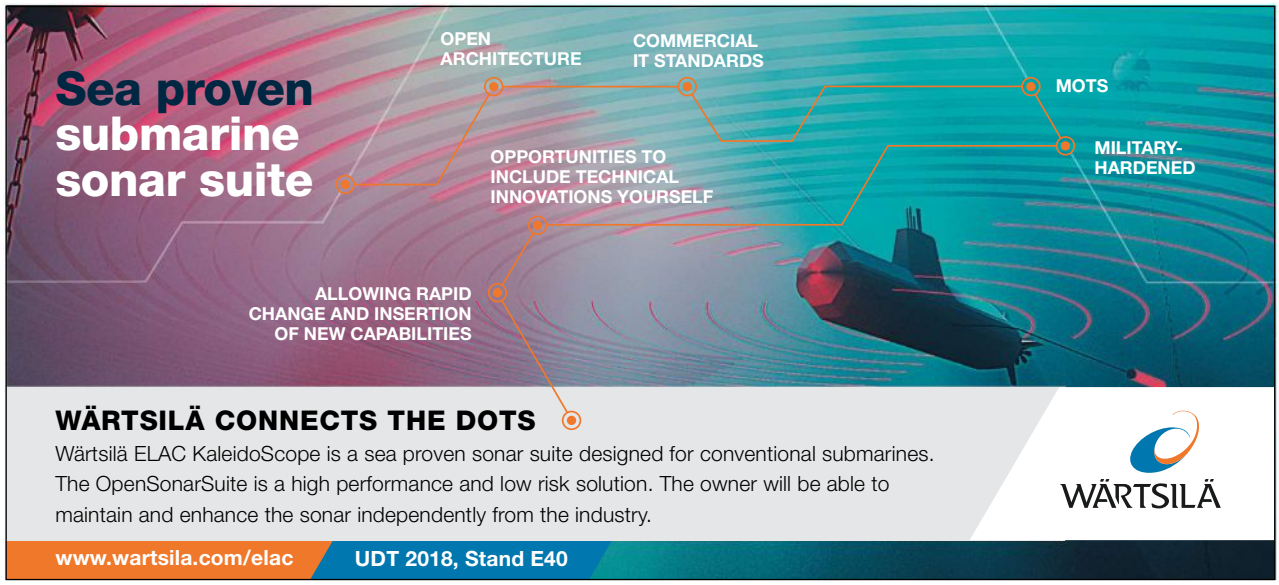
Several research areas will be front and center for ICE-PPR, including human performance, platforms and the environment. While the U.S. Navy has much to bring to the table—including its own existing research programs and extensive submarine experience beneath the Arctic Ocean—it also has much to learn from the cold-weather operational experience and capabilities of other nations.

Looking Ahead

The Arctic is a daunting, fascinating frontier—ripe with potential benefits for those who study it and apply its lessons carefully. Acquiring knowledge of this imposing region will ensure the safety and effectiveness of future scientific activities, improve forecasting capabilities, and expand the operational reach of surface vessels.

Naval science and technology research efforts are already embracing this challenge. **ST**

Warren Duffie Jr. is a writer and editor at the U.S. Office of Naval Research.



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Military Supplier of Performance Inflatables Acquires Avon Engineered Fabrications

Avon Rubber sold Avon Engineered Fabrications (AEF) to Performance Inflatables Co. LLC. AEF is a major supplier of industrial coated fabric goods to the U.S. military, including the Army, Air Force, Marines, Navy and Coast Guard. The performance inflatables portfolio also includes Subsalve USA. AEF will be based in the U.S.

Fire and Blast Safety Systems Company Opens New Office in Houston, Texas

InterDam, a supplier of fire- and blast-resistant architectural products for refineries, oil and gas platforms and offshore wind platforms, opened a new office in Houston, Texas. InterDam specializes in fire-resistant and post-blast walls, windows and doors in prefabricated systems that fit modular and standardized buildings. The systems conform to fire and blast regulations and are designed to withstand a fire outbreak in a post-blast situation.

Scottish Offshore and Coastal Consultancy Launches US Subsidiary in Houston

The Scottish marine survey and coastal consultancy group Partrac Ltd. launched its U.S. subsidiary, Partrac GeoMarine Inc., based in Houston, Texas. Partrac GeoMarine delivers services and consultancy for complex engineering and environmental projects in challenging marine environments. Its market sectors include both conventional and renewable offshore energy, including oil and gas, decommissioning, wind, wave and tidal, dredging including contaminated sediments, ports, harbors, rivers, waterways and coastal engineering.

Oregon State University Tests and Invests In Cabled UV Biofouling Control Systems

Following a successful test in which AML Oceanographic's Cabled UV prevented marine growth on oxygen sensors and cameras deployed in situ for six months, Oregon State University (OSU) has purchased 20 Cabled UV biofouling control systems. Cabled UV was selected for the Endurance Array, a multi-scaled array developed under the Ocean Observatories Initiative (OOI). OSU's trial is the latest deployment successfully completed through the use of AML's biofouling control solutions.

New Mars-Bound SpaceX Rocket To Be Developed in the Port of Los Angeles

SpaceX will produce its Big Falcon Rocket (BFR) in the Port of Los Angeles. Falcon 9 and Falcon Heavy rockets were built in Hawthorne, California, but the company will need to build the big rocket near the water due to its size and space requirements, SpaceX told *Bloomberg*.

Los Angeles Mayor Eric Garcetti announced the selection of the city's port in a tweet, saying, "This vehicle holds the promise of taking humanity deeper into the cosmos than ever before." The Port of Los Angeles will play an increasingly important role in operations, SpaceX President Gwynne Shotwell said in a *Bloomberg* report. The Big Falcon Rocket is intended to fly people into orbit around the Earth and eventually to Mars.

AI Startup Earns $900K Investment to Continue Development of Self-Driving Ship Technology

Buffalo Automation, an artificial intelligence (AI) start-up that is developing technology for self-navigating boats, has secured $900,000 from investors to expand testing of a system called AutoMate that integrates real-time sensor data about waterways with static information such as nautical charts to enable vessels to pilot themselves. AutoMate enables early detection of obstacles such as other boats and debris and saves fuel with algorithms that enable more efficient routes. The AutoMate system is currently testing with two lake freighter operators and an international container liner.

ROV Used in Nevada to Assess the Health of Lake Mead and Water Infrastructure

The Australian infrastructure inspections and management company Abyss Solutions is piloting its high-fidelity imaging underwater ROV at Lake Mead to inspect the condition of water infrastructure within the lake. Abyss Solutions is also conducting an assessment of an SNWA reservoir facility through 3D modeling. The data will help affirm the effectiveness of SNWA's efforts to control quagga mussels in the raw water intake system and evaluate the efficiency of water treatment and disinfection.

Panama Expects to Quintuple LNG Transports

The Panama Canal Administrator said the waterway expects to transit five times its current volume of LNG by 2020.

The LNG trade's role in Central America and the Caribbean is growing as the regions are increasingly interested in natural gas to meet their energy needs. In 2018, Peru transited 575,529 tons of LNG to Europe, and Trinidad and Tobago exported 1,340,396 tons to Asia, Mexico and Chile. Since the opening of the Neopanamax locks, Mexico has imported an estimated 3.1 million tons of LNG, while Chile has imported about 1.1 million.

Dual-Channel Waveform LiDAR Mapping System Added at GPI

GPI Geospatial Inc. has added the RIEGL VQ-1560i to their toolbox of advanced digital sensors: an ultra-high-performance, dual-channel waveform processing, airborne LiDAR mapping system for complex airborne mapping missions. The calibrated system is equipped with a high-performance GNSS/IMU system and a primary phase one 100-megapixel RGB camera. The system is capable of online waveform processing and recording, producing information-rich data for post-processing.

Newmar and ASEA Form MCE Marine Group

ASEA Power Systems and Newmar DC Power Onboard have aligned under the newly formed MCE Marine Group. Both ASEA and Newmar retain their brand names. David Brown was named president of MCE Marine, with all operations now headquartered in Huntington Beach,

California. Eric Herman will be MCE Marine director of engineering. Brian Giannini has been promoted to MCE Marine Group sales manager, and Gabriel Vargas was promoted to service manager and application engineer.

DeepOcean Expands into Gulf of Mexico With Delta SubSea Acquisition

DeepOcean acquired Delta SubSea LLC, which provides inspection maintenance and repair and construction services with international operations in locations such as West Africa, Trinidad and Tobago and Guyana. The company owns and operates 10 Schilling-manufactured ROVs from its operating base in Montgomery, Texas. This acquisition will allow DeepOcean to expand its operations in the Mexican segment of the Gulf into the U.S. segment. Delta SubSea will also be DeepOcean's vehicle for offshore renewables projects in U.S. waters.

Virgin Islands Port Authority Receives New Pilot Boat and Port Security Boat

Metal Shark has delivered two new custom welded aluminum vessels to the Virgin Islands Port Authority (VIPA). The vessels were recently delivered to St. Thomas and transferred to VIPA. Both vessels are now operating from the Edward Wilmoth Blyden IV Marine Facility on the Charlotte Amalie waterfront, where they serve the island of St. Thomas and also nearby St. John.

New Study Compares Mineral Oil-Based and New 'Environmentally Acceptable Lubricants'

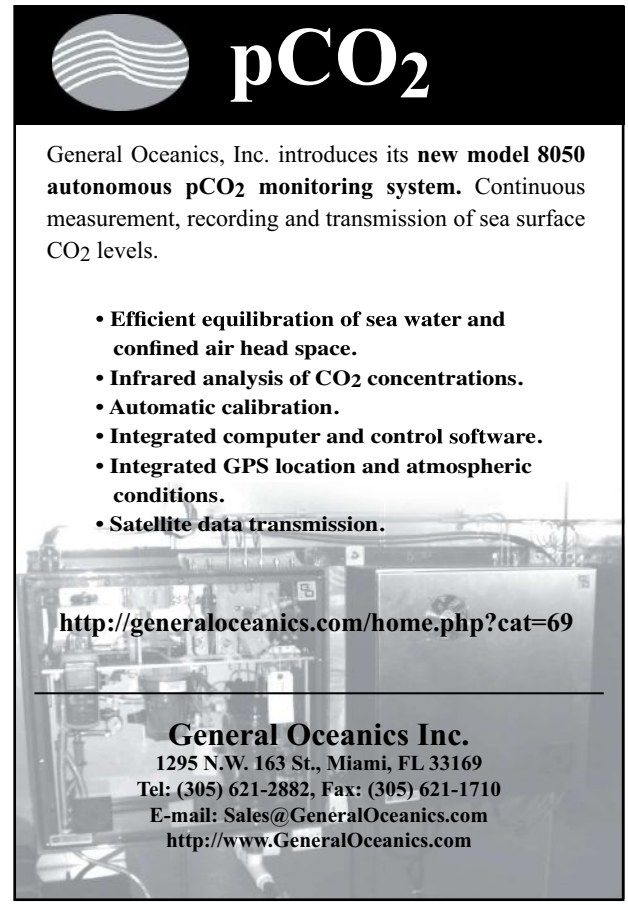
ABS, in partnership with Vickers Oil and Imperial College London, completed a study on the use of environmentally acceptable lubricants (EALs) on stern tube bearings. The study evaluated EAL relative to mineral oil-based lubricants and concluded oil viscosity is the primary property in selecting an EAL. Primarily driven by 2013 U.S. EPA requirements, EALs were intended to replace mineral oil lubricants in marine vessels.

Antarctic Research Will Assess Krill Biomass

The U.S. Antarctic Marine Living Resources (AMLR) Program has implemented a krill research program that will utilize an array of moorings and gliders around the Antarctic Peninsula. Data collected will replace traditional ship-based surveys and will provide standardized spatial and temporal data to understand the consequences of overlap among krill, predators and the krill fishery. The gliders will be equipped with ASL acoustic zooplankton fish profilers (AZFP) and record backscatter of krill biomass.

Piezoceramic Manufacturer Joins Canada's Marine Tech Innovation Campus in Nova Scotia

Sensor Technology Ltd. is expanding into Atlantic Canada by joining the Centre for Ocean Ventures and Entrepreneurship (COVE), a collaborative community for the ocean technology industry. Sensor Technology has served for more than 35 years as a piezoceramic manufacturer and designer for ocean technologies, producing ceramic materials, custom acoustic transducers and hydrophones in Collingwood, Ontario. **ST**



international

Funding Awarded for UK Deep-Learning Research

ASV Global is leading a £1.2 million research project to enhance the safety and reliability of autonomous navigation using deep-learning machine vision systems that are trained with a combination of simulated and real-world data.

The Synthetic Imagery training for Machine Vision in Extreme Environments (SIMVEE) project will build upon ASV's existing, COLREG cognizant, autonomous collision avoidance and path planning capability. The project will use BMT's REMBRANDT simulator to train vision algorithms to detect and classify objects.

Major Expansion for Samson's Spain Distributor

Samson is increasing its presence in Spain as major distributor Baitra S.L. expands its facilities. Baitra has been a partner distributor of Samson products since 2015, supporting the commercial and recreational marine industries in Spain, Portugal and the Mediterranean Sea and Bay of Biscay regions. Baitra's new location on the northwest coast of Spain in Nigran (Pontevedra) increases the size of their facility six-fold.

Chelsea Technologies Transitions to Higher Accreditation Standard

Following a triennial two-day audit by inspection, verification, testing and certification company SGS, Chelsea Technologies Group has transitioned to ISO 9001:2015 accreditation. Based on quality management principles, the ISO 9001:2015 certification defines the way an organization operates to meet the requirements of its customers and stakeholders, including customer focus, leadership, engagement of people, process approach, improvement, evidence-based decision making and relationship management.

Singapore ROV Outfitted with New Multiplexer

A custom version of MacArtney's EMO DOMINO-7 fiber-optic multiplexer system (MUX) was built for installation on an ROV in Singapore with the aim of upgrading its subsea survey and camera interfaces. The DOMINO-7 MUX is a compact fiber-optic system with a range of MUX channel and power supply configurations. Offering three videos with 10-bit data channels, the design also offers gigabit Ethernet (GBE) communications coupled with 48-VDC supply voltage.

Mining Deep-Sea Polymetallic Nodules

Fugro is supporting deep-sea polymetallic nodule mining in a contract with Nauru Ocean Resources Inc. Polymetallic nodules are potato-sized concretions enriched in nickel, copper and cobalt that also contain metals and nonmetals important to green tech enterprises. The surveys involve high-resolution imagery, geophysical data and sampling of minerals from the seafloor, as well as geotechnical properties, cataloging mineral resources and determining optimal mining areas in water depths of up to 4,500 m over a 400-sq.-km area. The field work will employ the Echo Surveyor VII AUV.

New Partnership Brings Advanced Cybersecurity Education to Malaysia

Naval Group, Universiti Pertahanan Nasional Malaysia (UPNM) and EURECOM are developing cybersecurity training in Malaysia with a high-level digital security program The project involves human capital development at the master's, Ph.D. and postdoctoral levels. The master program will be available at the UPNM campus by 2019.

The project will enable students from UPNM to take master's courses and Malaysian professors to train at the French institute EURECOM in Sophia Antipolis.

Offshore Pipeline Company Installs Acoustic Positioning Systems

Allseas is installing two Sonardyne GyroUSBL acoustic positioning technology systems on its 236-m lay vessel, *Lorelay*. Used in conjunction with a Ranger 2 USBL (ultrashort baseline) topside, the GyroUSBL transceivers will be installed on the end of the *Lorelay*'s stinger to acoustically track an ROV deployed to ensure a pipe is accurately touching down in the permitted corridor.

New Ballast Manufacturers' Association Formed

Following the announcement of further delay of the 2004 IMO Ballast Water Convention implementation dates, a group of industry insiders gathered to draw up the framework for the Ballastwater Equipment Manufacturers' Association (BEMA), which held its first annual meeting and elected its inaugural board of directors in April. The need for this association arose from a growing demand for well-founded information on the practicability of ballast water treatment technologies, as well as on the technical and environmental aspects of implementing ballast water management regulations worldwide.

OSM Opens Operations Center in Singapore

OSM is opening a Singapore-based Maritime Operations Centre, a maritime innovation hub with an ecosystem of digital partnerships. The operations center will enhance 24/7 fleet support through data management, descriptive analytics and predictive model optimization paired with machine learning. Onboard and shore-based crews will be able to access the same information, while incident response abilities will be assisted through 24/7 access to all operational data and full-time monitoring.

Decommissioning Consortium Launches

A new global decommissioning consortium that includes Lloyd's Register (LR), WorleyParsons and Ardent brings together collective experience to reduce the interfaces, costs and risks of decommissioning for the oil and gas industry. The consortium includes experts on all aspects of decommissioning, from late life management to planning, readiness for removal, execution, waste management and monitoring post-removal. The consortium has the capability to take well operatorship, duty-holdership and title of offshore structures, in addition to providing independent third-party assurance.

Lloyd's Classes First FSRU for Indian Waters

Lloyd's Register (LR) will class the first floating storage regasification unit (FSRU) for Indian waters. Stationed at Jafrabad port and operational 24 hr./day, year-round, it will be built by Hyundai Heavy Industries and adhere to LR's rules for the classification of offshore units. The new 180,000 m³ FSRU project will help meet the demand for LNG in the region: Natural gas is projected to make up 20 percent of India's total energy consumption by 2030.

Collaboration Focuses on Communication, Sustainable Innovation in Private Sector

The World Ocean Council (WOC) and the GEF LME:LEARN project are collaborating to enhance communication between regional marine projects and institutions to better work with the private sector on sustainable development. GEF LME:LEARN is a project implemented by the UNESCO Intergovernmental Oceanographic Commission (IOC-UNESCO) focused around the Large Marine Ecosystems (LME).

Dongle-Free SonarWiz License Available

Chesapeake Technology Inc. now offers SonarWiz licenses that do not require a dongle. Users can buy secure SonarWiz post-processing licenses with an electronic code, eliminating the risk of missing or lost dongles. Licenses can be moved from one PC to another in seconds and are available with SonarWiz 7.1 and later.

Selektope Anti-Fouling Creators Go Public

i-Tech AB, the company behind the development of the anti-fouling ingredient Selektope, has applied for admission to trade shares on the Nasdaq First North Stockholm exchange. The first day of trading of the i-Tech AB (publ) company on Nasdaq First North began in May. The listing was preceded with a share issue of a maximum SEK 44.1 million. The company is valued at approximately SEK 200.4 million.

Arctic Natural Resources Institute Installs Extended-Range Multibeam Sonar

Greenland's Institute of Natural Resources has taken delivery of a Teledyne SeaBat T50-R extended-range multibeam sonar system on RV *SANNA*. The physical sonar installation was carried out in March, and a full dimensional-control survey was performed. Sea trials were undertaken north of Greenland's capital, Nuuk, the northernmost capital on the planet.

Gas Hydrates Survey Completed in Japan

Ocean Floor Geophysics Inc. (OFG) has completed its third high-resolution controlled-source electromagnetic (CSEM) survey of near-surface gas hydrates for the National Institute of Advanced Industrial Science and Technology (AIST) in Japan.

Following successful CSEM surveys and 3D inversion models in 2014 and 2015, the 2017 survey comprised more than 413 line km of high-resolution data collected in depths up to 1,640 m from the Fukada vessel *Shin Nichi Maru*. **ST**

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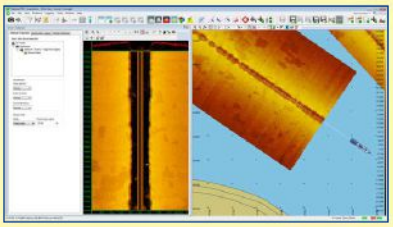
Sonar Backscatter Mosaicking



Teledyne PDS now supports side scan sonar backscatter mosaicking with a backscatter logging tab on the sonar side scan waterfall and snippets display and a layer to show port and starboard swath coverage and sailing direction. Teledyne RESON.

Shape-Shifting AUV-ROV Robot

Aquanaut is a multipurpose subsea robot that employs a shape-shifting transformation from an AUV to an ROV, removing the need for vessels and tethers. The vehicle enables both data collection over long distances and manipulation of subsea objects. Houston Mechatronics.

Adaptable Sonar Software

Discover Blue's target-adaptive software automatically configures the side scan sonar system for common targets and features a coverage mapper module with survey line planning and left and right steering indicators to assist in survey line control. EdgeTech.

Sound Velocity Meter

INSEA2 is a portable sound velocity meter for measurements in all types of sediments with on-site analysis. Four transmitter/receivers provide up to 12 acoustical pathways for data collection in the presence of obstacles, and the frequency sweep system collects data in less than 30 sec. RTsys.

Mini High-Speed Connectivity

The MiniMax connector 08 provides full-speed Ethernet with eight AWG24 pins in a receptacle of 12-mm diameter. It has an anthracite coating with <5 mΩ panel grounding and is rated to 20 m for 24 hr. A new flashdrive is also available with a USB 3.0 and nine contact poles. Fischer Connectors.

Port State Control App

PSC Ready is a cloud-based mobile app to assist in preparation for port state control inspections and ensuring compliance with applicable requirements. The app allows training crews to detect, correct and avoid deficiencies and access statistics, data and news on PSC developments. Bureau Veritas.

High-Power Sub-Bottom Profiling

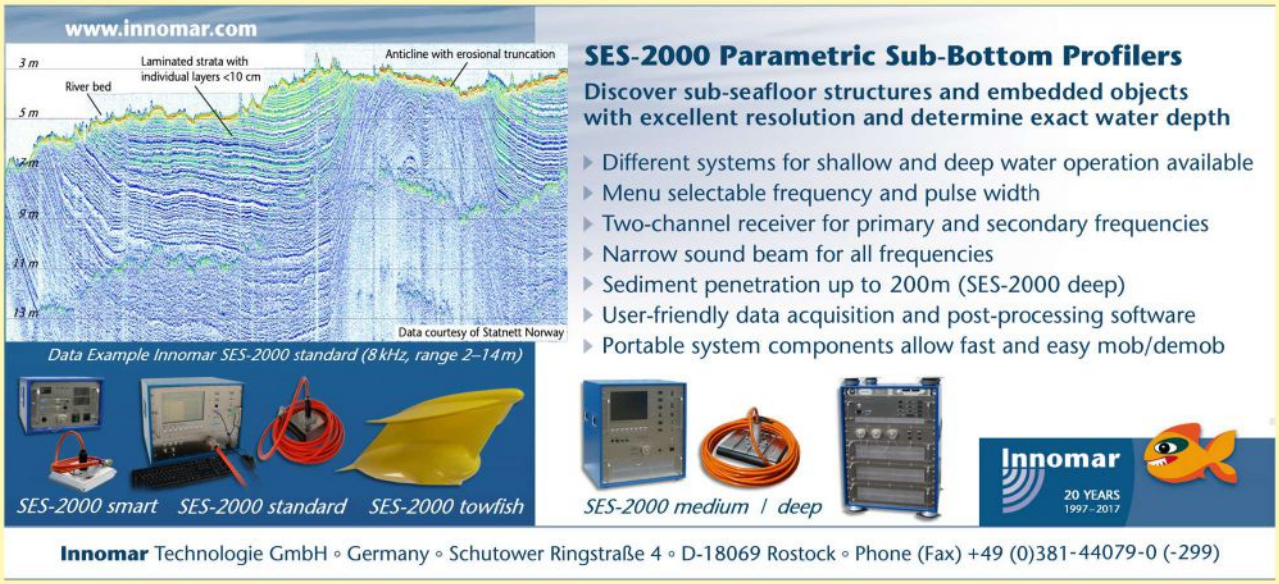
Stratabox3510 HD is now available in a 1,000-W configuration for greater power and deeper sediment penetration. For example, data from Stratabox3510 HD operating at 10 kHz revealed boulder and reef formations in subsurface substrate in a King Island survey. Syqwest Inc.

Portable Sulfur Test

The X-ray Fluorescence Analyzer is a portable testing device that measures the sulfur content in fuel in less than 3 min. Ideal for on-site spot checks to quickly confirm compliance at any stage of the bunkering process, the analyzer can store test results electronically for audits. Parker Kittiwake.

Rugged Embedded Computing

SabreCom mission computers are based on I/O-rich SBCs and COM-based SBCs and feature a full IP67 rating and MIL-STD-810G compatibility. Systems are available in five processors and are customizable with PC/104 modules or PCIe mini-



cards and optional flash storage. Diamond Systems.

Automatic Network Router

Hubba X4 Global is a multiband, multiprotocol, dual SIM, LTE data router that interoperates with existing VSAT systems to switch networks when out of range of shore-based networks. The router connects across multiple networks up to 20 mi. offshore and selects the vessel's VSAT system when out of mobile range. Buzz Wireless.

Magnetometer for AUV

The Explorer AUV magnetometer is an omnidirectional sensor towed behind the vehicle, allowing it to operate outside the AUV's magnetic signature. The Explorer's exceptional accuracy and sensitivity, small size, low noise and minimal power requirements make it ideal for use with AUVs. Teledyne Gavia.

Wireless Personnel Locator

In:Range is a wearable sensor for locating personnel in real time. Signals triggered by alarms or distress movements are picked up by sensors that plug into standard power points, and data are transmitted to the bridge or emergency services or nearby ships. ScanReach.

IMU-Enhanced GNSS

AsteRx-i is a compact, multifrequency, multiconstellation GNSS engine with an external industrial grade MEMS-based IMU. It can deliver GNSS/IMU integrated positioning to centimeter level and 3D attitude at high update rates and low latency. With a UAS-tailored carrier board, it integrates into light UAVs for optical inspection and photogrammetry. Septentrio.

Vessel Tracking Upgrades

ShipView 2.0 is a vessel tracking platform with a real-time satellite AIS data service that plots ship positions on map layers for easy viewing. It captures thousands of open-ocean vessels with positions less than 1 min. old. Recent upgrades include a three-year vessel track toolkit with playback functionality. exactEarth.

Deep-Rated Sonar

ARIS Voyager 3000 is the latest model in the ARIS (Adaptive Resolution Imaging Sonar) product line. It is depth-rated to 4,000 m and available with 3.0 MHz and 1.8 MHz operating frequencies with a titanium design. Sound Metrics.

Multitouch Monitors

A new series of multitouch monitors, the 17-in. MU175T, 19-in. MU195T, and the 24-in., wide-aspect-ratio MU245T, make up the "Hi-Brite" line of marine monitors. Based on the NavNet TZtouch gesture and interface systems, the new line features high brilliance and increased sensitivity. Furuno U.S.A.

Offshore Data Analysis

Ability Process Performance Dashboard is a cloud-based service that measures the performance of oil and gas facilities against indicators, including start-up time and operator interventions. Data are then analyzed by operations experts using advanced data analysis technology, and results are fed back via the dashboard. ABB Ltd.

Asset Management Platform

NeoSight is an asset integrity management platform that integrates with existing systems. Digital twin models allow for the integration of inspection, analysis and measured data for insight into asset behavior. Stress Engineering Services Inc.

Positioning for Small Systems

Compact, high-precision positioning solutions include PwrPak7D-E1, a dual-antenna, multifrequency enclosure available with IMU and INS. The OEM7600 receiver board comes with protective shielding in order to isolate from electronics emissions. Waypoint Inertial Explorer Xpress is post-processing software for GNSS+INS data sets. NovAtel Inc. **ST**

Electric Workboats Clean Up Suzhou River

The City of Suzhou in eastern China has deployed a fleet of electric workboats powered by Torqeedo motors as part of a program to clean up its canals and waterways.

Suzhou is home to more than 10 million people. The 2,500-year-old city is noted for its many canals, rivers, lakes, ancient stone bridges, pagodas and gardens. Suzhou Creek, which flows through the city to Shanghai, was at one time said to be the most contaminated waterway in China. Over the past decade, the river has undergone a major transformation and is an acclaimed environmental success story.

As part of the cleanup program, the Suzhou River Management Administration commissioned the construction of 177 vessels designed specifically to remove floating debris from the water. The administration specified electric-powered boats for the project because of their environmentally friendly footprint, and after a competitive evaluation the builder selected Torqeedo to supply electric motors.

Torqeedo has now completed outfitting the entire fleet, which includes 18 9-m steel catamarans with twin Cruise 4.0 outboards, 22 7-m steel catamarans with twin Cruise 2.0 outboards and 137 5/6-m wooden boats with Cruise 2.0 outboards. The boats were designed and built by China Ship Scientific Research Center, owned by the Suzhou River Management Administration and operated by private contractors.

Partnership for Advanced Machine Learning Subsea

Acteon Group and Arundo Analytics announced a partnership to deliver machine learning models for subsea applications on the Arundo Enterprise platform. Using its industry insight and subsea expertise, Acteon, will work with Arundo as one of its preferred partners to develop high-value advanced analytics for its operating companies. This will be used to support its global customer base, using tools including machine learning and artificial intelligence to help reach Acteon's ambition of reducing the cost of asset ownership by 30 percent.

Ashtead Adds SPRINT-Nav To Rental Fleet

Ashtead Technology has selected acoustic and inertial navigation technology from Sonardyne International Ltd. to add to its rental fleet. The multiple SPRINT-Nav systems will be made available to support survey and construction projects using ROVs and AUVs in water depths down to 4,000 m.

SPRINT-Nav makes optimal use of acoustic aiding from data sources including USBL, sparse LBL and DVL and pressure sensors to im-

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prove the accuracy, precision and reliability of subsea vehicle navigation. Its all-in-one design tightly couples Sonardyne's SPRINT inertial and Syrinx Doppler technologies to enable marine robotic platforms to remain precisely on course over many kilometers traveled, even if one or two DVL beams become unavailable.

iXblue INS, USBL Chosen For *Titanic* Expedition

OceanGate Inc. and iXblue are combining forces to conduct the first manned submersible expedition to the wreck of the RMS *Titanic* since 2005. iXblue's Phins 6000 inertial navigation system and Posidonia USBL positioning system will be used for the accurate and reliable navigation and positioning of OceanGate's Titan, the newest addition to the company's fleet of deep-sea manned submersibles and the first privately owned manned submersible capable of reaching *Titanic* depths.

iXblue's strap-down fiber-optic gyroscope (FOG) technology, Phins 6000 subsea inertial navigation system (INS), provides accurate position, heading, attitude, speed and depth information as the manned submersible captures laser data and the first-ever 4K images of the RMS *Titanic* shipwreck and debris fields. Its high-accuracy inertial measurement unit is coupled with an embedded digital signal processor that runs an advanced Kalman filter for optimum positioning of the subsea vehicle.

Increased positioning precision of Titan on the shipwreck site will be provided by Posidonia, iXblue's long-range, high-accuracy USBL system operated from the surface ship and calibrated thanks to a Phins surface INS. Designed to track subsea vehicles to depths of 6,000 m at ranges reaching more than 10,000 m, Posidonia uses advanced acoustic modulation and digital signal processing technology and operates in the low frequency band for deep-sea tracking operations. To communicate with Posidonia, Titan is equipped with iXblue's MT8 compact low-frequency transponder.

AI Development for Oil, Gas E&P

Total and Google Cloud have signed an agreement to jointly develop artificial intelligence (AI) solutions applied to subsurface data analysis for oil and gas exploration and production (E&P). The agreement focuses on the development of AI programs that will make it possible to interpret subsurface images, notably from seismic studies (using computer vision technology), and automate the analysis of technical documents (using natural language processing technology). These programs will enable Total's geologists, geophysicists, reservoir and geoinformation engineers to explore and assess oil and gas fields faster and more effectively.

Total geoscientists will work with Google Cloud's machine learning experts in the same project team. **ST**

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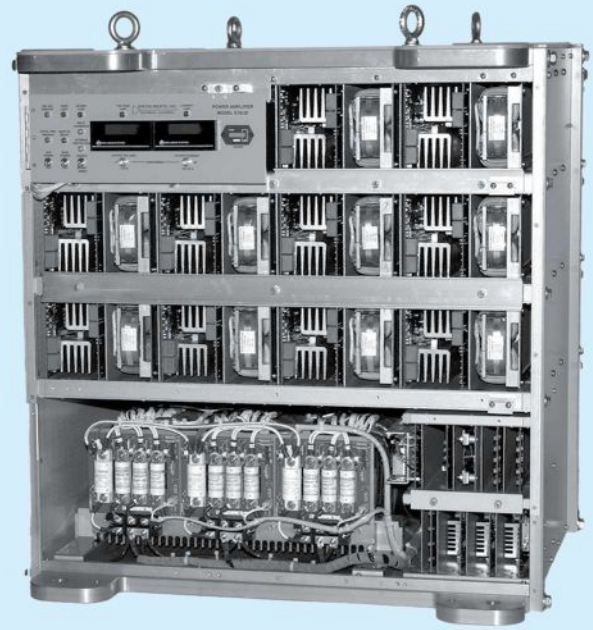

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AZFP Orders Continue For Japan Fisheries

The National Research Institute of Fisheries Engineering of the Japan Fisheries Research and Education Agency has deployed an ASL Environmental Sciences Inc. multifrequency acoustic zooplankton fish profiler (AZFP 125, 200, 455 and 769 kHz) in Yamada Bay, 450 km north of Tokyo since 2013 to understand seasonal variations of zooplankton in the water column.

To help the scheduling of the release of hatchery-reared juvenile salmon and increase their survival in the sea, upgrades were purchased in 2016, including a solar-powered data logger with a cellular modem for the AZFP and a conductivity temperature sensor. The deployment of this upgraded system was successful, and, as a result, FRA purchased a second ASL-built solar-powered data logger with a cellular modem in 2017 for deployment in spring 2018.

Algae Biofuel Research Progresses to Field Study

ExxonMobil and Synthetic Genomics Inc. are in a new phase of their algae biofuel research program that could lead to the technical ability to produce 10,000 barrels of algae biofuel per day by 2025. This includes an outdoor field study to grow naturally occurring algae in several contained ponds in California. The research will help to better understand fundamental engineering parameters, including viscosity and flow. The results are important for scaling the technology for potential commercial deployment.

Maritime Clusters and Sustainable Development

The World Ocean Council (WOC) and Economic Transformations Group (ETG) have released the white paper "Ocean/Maritime Clusters: Leadership and Collaboration for Ocean Sustainable Development and Implementing the Sustainable Development Goals." By combining purpose in innovation, competitiveness, productivity, profit and environmental benefits, ocean/maritime clusters can lead ocean sustainable development and realize economic benefits.

Key recommendations include: enhancing and expanding the role of ocean/maritime clusters in implementing sustainable development; accelerating the networking of ocean/maritime clusters for collaborative learning and action in support of sustainable development; and supporting the development of ocean/maritime clusters for developing countries.

JW Fishers Celebrates 50 Years

In 1968, Jack W. Fisher began developing underwater search equipment as an avid diver in need

of an underwater metal detector for use on a salvage project. He discovered that there was no such device available and built his own: the Mark 1. The detector quickly gained popularity, and customer demands for new and more powerful models developed. As a result, the company expanded the product line from diver-held detectors to boat-towed metal detectors (Mark 7) and magnetometers (Proton 1). In the following decades, the company introduced the DV-1 dropped camera system, Pulse 8X hand-held underwater metal detector, SeaOtter ROV, SeaLion ROV, side scan sonar system, acoustic pingers, cable and pipe trackers and sub-bottom profiler. Recently, Fishers introduced the SAR-1 search and recovery wireless metal detector. JW Fishers will celebrate its milestone 50th year with a tribute on www.jwfishers.com.

Assessment of Alternative Fuels for Global Sulphur Cap

DNV GL has issued the white paper "Alternative fuels and technologies for greener shipping," examining the price, availability, regulatory challenges and environmental benefits of alternative fuels and technologies, including LNG, LPG, hydrogen, fuel cells and hybrid and battery technologies, and comparing them to the use of conventional fuel with scrubbers and new low-sulphur alternatives. The paper offers insights to the shipping industry in preparation for the upcoming Global Sulphur Cap, due to come into effect January 1, 2020.

For newbuilds, the sulphur cap could be a major driver for alternative fuels, and LNG is the prime contender.

Earth Challenge 2020 Encourages Citizen Science

Earth Day Network, the Woodrow Wilson International Center for Scholars and the U.S. Department of State, through the Eco-Capitals Forum, announced Earth Challenge 2020, a Citizen Science Initiative, a collaboration with Connect4Climate—World Bank Group, Conservation X Labs, Hult Prize, National Council for Science and the Environment (NCSE), Open Geospatial Consortium (OGC), Reset, SciStarter, UN Environment and others. Millions of global citizens will collect data points for air and water quality, pollution and human health.

In 2019, hackathons will be hosted around the world.

The initial data collection campaign will launch April 1, 2020, with the objective of collecting 1 billion data points by Earth Day.

Higher Bandwidth Trend For Vessels

Demand for higher bandwidth is rising in the shipping industry, according to World-Link Communications. The number of ships switching to improved connectivity is also increasing. The per gigabyte cost is dropping, but the monthly spend is roughly the same because of higher bandwidth usage. Some vessels are now running 40 to 50 GB per month. **ST**

Mooring Rope Recycling In Florida

Lankhorst Ropes has set up a mooring rope recycling initiative for the cruise industry. Available at the main cruise terminals in Florida, the retired ropes can be repurposed as picnic sets, plastic poles, planks and even complete landing stages, riverbank bank protection boards and bridges.

Cruise lines use some of the most innovative recycling, reducing and reusing strategies in the world. The mooring rope recycling initiative will assist the cruise lines in going further by repurposing synthetic-fiber mooring lines previously sent to landfill. The Lankhorst rope recycling initiative is scheduled to become available at the following cruise terminals: Port of Miami, Port Everglades and Port Canaveral.

More than 15 years ago, Lankhorst Ropes introduced the rope industry's first recycling scheme for retired maritime ropes.

Turbulence Characteristics From Tank to Tidal Channel

The recently completed InSTREAM project assessed fundamental differences in turbulent flow measured in the field, generated in a tank and simulated in a numerical model.

To mitigate the risk and uncertainty associated with turbulent flows in tidal channels, developers often use tank experiments and numerical simulations to assess the power and loading performance of a turbine. However, it remains unclear if these controlled flows can be accurately scaled up to represent the natural turbulence present in tidal channels.

The difficulty in translating between model, tank and field environments motivated the In-Situ Turbulence Replication, Evaluation And Measurement (InSTREAM) project. The three-year project was conducted by a research consortium comprising six commercial and academic entities in the U.K. and Canada. The project was given the prestigious EUREKA designation and was co-funded by the Offshore Energy Research Association and InnovateUK.

As expected, the InSTREAM project found significant differences between the turbulence characteristics in the tank and in the field. The 3D eddies observed in the field were about three times larger than those generated in the tank, resulting in considerable differences in power and fatigue loading.

A scaling method has been developed to allow direct comparison and translation between the two flow regimes. This scaling greatly increases the usefulness of tank testing and numerical modeling and can be reproduced for other test tanks. It also allows site-specific field measurements to be translated to tank experiments, enabling numerical models (validated by tank experiments) to be used for reliable and realistic estimation of turbine and array performance.

GRT for Siemens Turbine Nacelles

MacArtney will supply another generator rotation tool (GRT) to Siemens Gamesa Renewable Energy. The GRT creates efficient solutions for long-term storage of nacelles and helps ensure max lifespan of turbines.

The nacelles are subject to long-term storage and therefore require maintenance to prevent bearing degradation during standstill. If not regularly rotated, the main bearings may suffer corrosion and quality damage, so it's important to keep components well lubricated at all times.

The battery-powered, radio-controlled mobile unit supplied by MacArtney is remotely driven under the nacelle with hub and mounted generator, while the nacelle is stored on its transport frame.

Site Survey for Netherlands Wind Farm

Fugro has commenced a site characterization program at the Hollandse Kust (noord) Wind Farm zone. Carried out under a further contract for the Netherlands Enterprise Agency (RVO.nl, part of the Ministry of Economic Affairs and Climate Policy), the geotechnical workscope comprises seabed investigations and borehole drilling at two lots. Other deliverables include standard and advanced laboratory testing and an integrated geological/geotechnical soil model that will be used by future developers of the wind farm to prepare their bids.

The fieldwork runs from April to June from Fugro vessels. Deployment of two of Fugro's most recent technical innovations will enhance safety and bring improved operational efficiency to the project. The team of geophysical, geological and geotechnical experts will complement the technology to optimize an integrated deliverable.

With a total capacity of 700 MW, the Hollandse Kust (noord) Wind Farm Zone is located 10 nautical miles off the west coast of the Netherlands.

Management System For Wind Turbines

Independent wind asset operations management specialist OutSmart BV has selected Kongsberg Digital AS to provide an integrated management system on the innovative Kognifai digital platform and ecosystem. The sophisticated digital solution will be used to manage OutSmart's extensive onshore and offshore wind turbine portfolio.

OutSmart provides services to wind farm owners, fund managers and wind project companies in northwestern Europe to maximize the revenues of their wind assets. Part of Deutsche Windtechnik Offshore and Consulting GmbH, OutSmart currently operates more than 400 onshore and offshore wind and solar assets (1.8 GW in total) in Germany, the Netherlands and the U.K.

With a common digital platform providing data storage and data security for the asset owner, the new applications will rationalize the operations of OutSmart and its clients and provide access to proven tools, including advanced analytics. **ST**

Microplastics Discovered In Bottled Water

Microplastics can be found in bottled water from around the world, according to a major new study using methodology developed by researchers from the University of East Anglia (UEA). The investigation found that most of the 259 bottles of water tested were contaminated with microplastics.

This study analyzed more than 250 bottles from 27 lots and 11 different brands from around the world, and almost all were contaminated to some degree.

Microplastics come from a variety of sources including cosmetics, clothing, industrial processes, packaging materials and degradation of larger plastic items. They are found in the environment at high levels, particularly in aquatic and marine ecosystems. Because plastics do not break down for many years, they can be ingested and accumulated in the bodies and tissues of many organisms. The entire cycle, movement and lifetime of microplastics in the environment is not yet known.

Whales Are Social Creatures Like Humans

Groundbreaking research from Florida Atlantic University's Harbor Branch Oceanographic Institute is the first to demonstrate that, just like human societies, beluga whales appear to value culture as well as their ancestral roots and family ties.

Through a detailed genetic study of kinship published in *PLOS One*, an international team of collaborators has demonstrated that related whales returned to the same locations year after year, and even generation after generation. This involves some form of social learning from members of the same species, most likely from mother to calf.

Findings from this study pin down the fundamental structure of the building blocks of beluga whale society and provide compelling evidence that migratory culture is inherited. The study expands the understanding of how sophisticated nonprimate societies can be and how important culture is for the survival of these species and how they are going to adapt to dramatic environmental changes.

Atlantic Ocean Circulation at Weakest Point in 1,600 Years

New research led by University College London (UCL) and Woods Hole Oceanographic Institution (WHOI) provides evidence that a key cog in the global ocean circulation system hasn't been running at peak strength since the mid-1800s and is currently at its weakest point in the past 1,600 years. If the system continues to weaken, it could disrupt weather patterns from the U.S. and Europe to the African Sahel and cause more rapid increase in sea level on the U.S. East Coast.

When it comes to regulating global climate, the circulation of the Atlantic Ocean plays a key role. The constantly moving system of deepwater circulation, sometimes referred to as the Global Ocean Conveyor Belt, sends warm, salty Gulf Stream water to the North Atlantic where it releases heat to the atmosphere and warms Western Europe. The cooler water then sinks to great depths and travels all the way to Antarctica and eventually circulates back up to the Gulf Stream.

This study provides the first comprehensive analysis of ocean-based sediment records, demonstrating that this weakening of the Atlantic's overturning began near the end of the Little Ice Age, a centuries-long cold period that lasted until about 1850.

First Carbon Budget For US East Coast

Coastal waters play an important role in the carbon cycle by transferring carbon to the open ocean or burying it in wetland soils and ocean sediments, a new study shows. The research helps establish how coastal processes influence atmospheric carbon dioxide levels and, in turn, climate.

The study team, which includes Virginia Institute of Marine Science researchers, constructed the first known carbon budget for the U.S. East Coast. They tracked the flows of organic and inorganic carbon into and out of coastal waters from the southern tip of Nova Scotia, Canada, to the southern tip of Florida.

About 20 percent of the carbon entering coastal waters from rivers and the atmosphere is buried, while 80 percent flows out to the open ocean.

Efforts like this help fill gaps in knowledge and inspire further research to help refine carbon budgets for the region. Carbon burial is an important metric when it comes to predicting future atmospheric CO_2 levels because, once carbon is in the sediments, it has the potential to remain there and not contribute to the greenhouse effect. However, as sea level continues to rise and disturb the coasts, some of the buried carbon could be respired and released to the atmosphere in the form of carbon dioxide.

Flow Analyzer to Study Eastern Mediterranean

Researchers at Haifa University's Marine Biological Station in Israel are exploiting the ultralow detection limits of advanced laboratory equipment to measure extremely low nutrient concentrations in marine water. The Eastern Mediterranean has the lowest regional concentration of dissolved nutrients in the global ocean. The researchers use SEAL Analytical's AutoAnalyzer 3 (AA3), a four-channel system measuring phosphate with a long flow cell that has a detection limit of 2 nM. Ammonia is measured using a JASCO fluorometer with a similar ultralow detection limit, and silicate, which has a higher concentration, is measured using SEAL's high-resolution colorimetric technology.

The measurement data are being used to determine the season nutrient cycling in the system, which will help understand the nature of the food web and the effects of global environmental and climate change. **ST**

contracts

Rolls-Royce Power Systems AG, Friedrichshafen, Germany, is co-operating in the local manufacturing of 16- and 20-cylinder MTU Series 8000 diesel engines in India, including localizing of engine components, engine assembly, testing, painting and major overhauls. Goa Shipyard Ltd.

MacArtney A/S, Esbjerg, Denmark, is completing an order of connectors for high-power submersible pumps, a total of nine sets of four-pin power connectors. Four Sub-Conn one-pin power connectors have been installed and molded to a power cable. Undisclosed.

Soil Machine Dynamics Ltd., Wallsend, England, will supply its Atom Mk1 1,000-m, 100-hp work-class ROV system to a Chinese power specialist for inspection of the 31-km physical power cable connections in the Qiongzhou Strait between Hainan Island and mainland China. China Southern Power Extra High Voltage Power Transmission Co.

Marlink, Brussels, Belgium, announced a partnership with a leading pure-play engineering services company to deliver new Internet of Things (IoT) solutions that leverage the power of satellite networks for extended connectivity in remote locations. L&T Technology Services.

Shell International Trading and Shipping Co. Ltd., London, England, signed a contract for an in-house license of the navigation simulator, REMBRANDT to support a range of projects involving navigation and STS operations, including expansion of its training facility in London next year. BMT Ship & Coastal Dynamics.

Cox Powertrain Ltd., Lancing, England, signed an agreement with a distributor located in South Korea for its 300-hp diesel outboard engine, CXO300. SoungJin Marine Co. Ltd.

i-Tech Services, Aberdeen, Scotland, announced a five-year digitalization partnership to increase efficiency and provide insights into operations throughout the field lifecycle. The relationship will leverage expertise in digitalization and enable significant automation of manual processes. Leidos. **ST**

meetings

JULY

July 3-5—Seawork International, Southampton, England. +44 1329 825335, info@seawork.com or www.seawork.com.

July 5-6—Oil Spill India, New Delhi, India. +91 11 43013474, ravi@itenmedia.in or www.oilspillindia.org.

July 17-19—Multi-Agency Craft Conference, Baltimore, Maryland. 703-836-6727, meetings@navalengineers.org or www.macc2018.org.

AUGUST

August 23—SNA West Coast Symposium, San Diego, California. 703-960-6800, navysna@aol.com or https://navysnaevents.org/wcs.

SEPTEMBER

September 4-6—ENGenious, Aberdeen, Scotland. chris.brand@bigpartnership.co.uk or www.engeniousglobal.com.

September 4-7—SMM, Hamburg, Germany. +49 40 3569 2445, nora.ebbinghaus@hamburg-messe.de or www.smm-hamburg.com.

September 9-12—IFAC Conference on Control Applications in Marine Systems, Robotics, and Vehicles, Opatija, Croatia. zoran.vukic@fer.hr or http://ifac-cams2018.com.

September 22-25—SEG 2018, Keystone, Colorado. 720-217-5692, kathybasel@gmail.com or www.seg2018.org.

September 24-26—Submarine Networks World, Singapore. +65 6322 2701, yeelim.tan@terrapinn.com or www.terrapinn.com/conference/submarine-networks-world/index.stm.

September 25-28—The National Marine Electronics Association and the Radio Technical Commission for Maritime Services International Conference & Expo, Palm Beach Gardens, Florida. 703-527-2000, info@rtcm.org or www.nmea.org.

OCTOBER

October 1-3—Shallow Survey, St. John's, Canada. 709-778-0556, Paul.Brett@mi.mun.ca or www.shallow-survey.com/Home.

October 1-5—PLOCAN Glider School, Gran Canaria, Spain. carlos.barrera@plocan.eu or http://gliderschool.eu.

October 3-4—International Conference on Marine Renewable Energy and Maritime Hydrogen Technology, Florø, Norway. maria@maritimsfj.no or https://bit.ly/2GW2Eo2.

October 3-4—OilComm and FleetComm, Houston, Texas. 713-343-1875, tle@accessintel.com or www.oilcomm.com.

October 9-10—Dynamic Positioning Conference, Houston, Texas. http://dynamic-positioning.com.

October 9-10—RECSO EnviroSpill, Abu Dhabi, United Arab Emirates. +44 203 463 1023, marco@bme-global.com or www.recsoenvirospill.com.

October 9-11—Sea Tech Week, Brest, France. Jacqueline.rosec-despres@lequartzcongres.com or www.seatechweek.eu.

October 22-24—Offshore Energy Exhibition & Conference, Amsterdam, Netherlands. +31 (0) 10 209 2600, ns@navingo.com or www.offshore-energy.biz.

For more industry meetings, visit sea-technology.com/meetings. **ST**

people

The late **Edwin A. Link**, a driving force behind Harbor Branch Oceanographic Institute, has been inducted into the Florida Inventors Hall of Fame. Link was a pioneer in aviation, underwater archeology and submersibles and inventor of the Link flight simulator. Link helped to create Harbor Branch as an independent research institution and designed tools to explore marine environments, including the Johnson-Sea-Link submersibles.

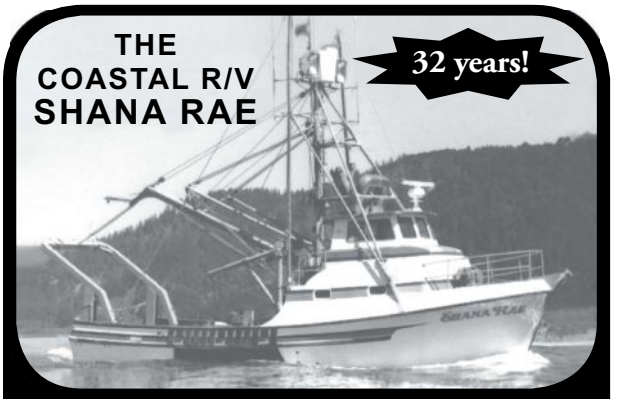
RBR Ltd. has hired **Gavin Scandlyn** as its business development manager to be based in New Zealand and primarily involved in New Zealand, Australia and Japan. Scandlyn has lived and worked in Japan, South Korea and Australia, and has a background in business communications, marketing and sales.

Trevor Hughes has been named business development officer at the International Geomatics Group. Hughes brings more than 30 years of experience in the U.K., Middle East and the Americas with Racal, Thales and Ashtech. Hughes will focus on the DGNSS service line and the Hemisphere Atlas technology.

ORPC Inc. has hired **Alexandre Paris** as president and CEO of its Québec subsidiary, Énergies Marines Renouvelables Québécoises Inc. (EMARQ). Paris was most recently senior manager of growth and innovation at Hydro-Québec's research institute, IREQ. He has more than 20 years of experience as an entrepreneur and executive in Canada, the U.S., Europe and Asia.

EOM Offshore LLC has appointed **John Flynn** and Flynn Technical Solutions LLC as its representative in the Southeastern U.S. to focus on data transmission and management of moored buoy systems. Flynn's background is in technical sales and marketing for marine interconnect, instrumentation, imaging, software, vehicles and anti-biofouling coatings products throughout the Mid-Atlantic and Southeast U.S.

The National Ocean Industries Association (NOIA) has promoted **Justin Williams** to the position of senior director of digital and public affairs. Williams is responsible for media relations on legislative issues and staffs NOIA's Public Affairs and Education Committee. The NOIA Board of Directors has elected **John Gellert**, the CEO of SEACOR Marine Holdings, as chairman and **Richard Clark**, a founder of Deep Gulf Energy, as vice chairman for the 2018 to 2019 term. **ST**



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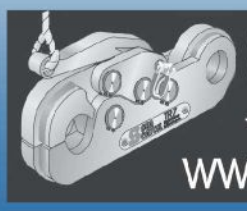

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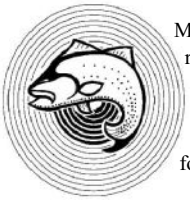

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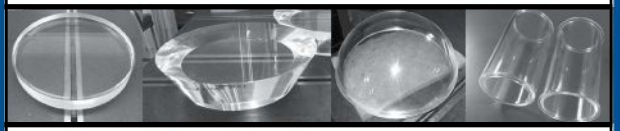

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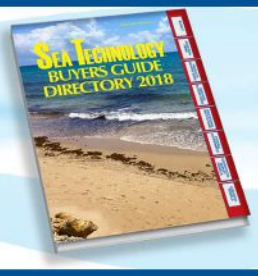

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Harnessing MRE While Protecting the Ocean Environment—*Dr. Andrea E. Copping*

Dr. Andrea E. Copping is a senior research scientist at Pacific Northwest National Laboratory's Marine Sciences Laboratory in Sequim, Washington, and a Distinguished Research Fellow at the University of Washington. Her research is on environmental effects from wave, tidal, offshore wind, ocean current and riverine energy installations and how installations may influence technology development.

Marine renewable energy (MRE) is expected to become a key player in the U.S. and international renewable energy portfolio. It's still a relative "youngster," with technology development and testing of wave and tidal devices occurring in just the past 10 to 15 years. The most developed technologies include tidal turbines and wave energy converters (WECs). While these technologies can significantly contribute to energy production, the industry has a responsibility to protect marine animals, their habitats and essential ecosystem services.

As technologies are tested and evaluated, regulators are requesting data to investigate impacts to the marine environment. But collecting significant amounts of pre- and post-installation monitoring data in turn impacts this young industry—posing substantial costs, delaying permits and threatening its financial viability. A solution is to leverage data from existing marine technology deployments.

MRE development requires data collection to satisfy licensing requirements. Data from existing marine technology deployments, versus exhaustive data collection, could bolster knowledge about potential effects of wave and tidal device deployments. An example is buoys, platforms, piers and docks. Their hard substrates attract biofouling communities made up largely of invertebrates and algae. These structures function as fish-aggregating devices or artificial reefs. Data from these structures provide understanding that no obvious harm would occur from MRE devices, but some changes in nearby populations is possible.

Another example is export cables for MRE installations that generate electromagnetic fields (EMF) that could affect the orientation, navigation or hunting ability of sensitive species. EMF signatures are not new to the marine environment. Many existing undersea cables used for power and telecommunications, bridges, tunnels and offshore wind farms emit measurable electromagnetic signatures. These existing cables on the seafloor can better inform researchers of impacts on marine animals from exposure to MRE export cables.

Another example is that anthropogenic noise has been shown to affect marine animal communication, navigation and hunting. The sounds emitted by operational MRE devices are found to be of lower amplitude than sounds made by other marine industries like commercial shipping.

But while the impacts of some MRE components can be determined with existing data, there isn't typically an apples-to-apples comparison for other components; for example, conventional hydro turbines and ship propellers are far more dangerous to marine species than tidal turbines. Understanding how marine mammals, fish, diving seabirds and sea turtles behave around these devices may be the key to determining whether they will be harmed.

WECs and associated floating tidal devices could also introduce the risk of marine animal interaction with mooring lines and draped electrical cables in the water column. There is concern that large marine mammals can become entangled in them, but they are under tension and have no loose ends. This makes entanglement less likely than encounters with lost fishing gear or other ropes and nets in the marine environment.

There are ecosystem concerns as well. Researchers have found that tidal turbines capture kinetic energy from the movement of water caused by tidal currents, causing deviations in water flow and potentially resulting in changes to sediment transport, basin flushing and marine food webs. WECs capture energy from wave propagation and may affect shoreline erosion. Both effects appear to be unmeasurably small with the addition of small numbers of turbines or WECs.

The path forward for responsibly developing MRE involves key activities. Sharing existing information among developers, regulators and researchers can help accelerate the deployment process. One such information-sharing outlet is Tethys, https://tethys.pnnl.gov, which houses all known environmental risk information. The effort to transfer and consistently collect data is underway through the International Energy Agency's Ocean Energy Systems/Annex IV, with international partners examining how their learning can inform new projects in their jurisdiction and apply to other locations and countries. The industry relies heavily on numerical models that simulate environmental impacts at proposed MRE locations, but better models are needed to more closely describe real-world interactions. More importantly, monitoring data from existing and planned projects is needed to calibrate models. Finally, we need strategically planned international research studies to rapidly and accurately build on the existing knowledge base. Governments must help shoulder the funding burden with industry to help move MRE forward as a viable energy resource and industry. **ST**

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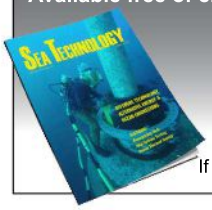

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S2C TECHNOLOGY: COMMUNICATION AND TRACKING COMBINED

- time, space and cost-saving solutions
- low power consumption for autonomous operations
- advanced data delivery algorithms, addressing and networking, remotely configurable settings
- extendable platform with multiple configuration options: power-saving Wake Up module, acoustic releaser, additional sensors, custom solutions, OEM versions available

USBL POSITIONING SYSTEMS

simultaneous positioning and communication - no need to switch between positioning mode and modem mode

- flexible SiNAPS positioning software
- reliable data transmissions
- range: up to 8000 m
- accuracy: up to 0.04 degrees

UNDERWATER ACOUSTIC MODEMS

reliable data transmissions even in adverse conditions, customizable R-series modems, light and compact M-series "mini" modems, **new S2CM-HS high-speed modem**, special editions for developers, S2C communication and positioning emulator - remote access or standalone device

- range: up to 8000 m
- depth: up to 6000 m
- data rate: up to 62.5 kbps

LBL POSITIONING SYSTEMS

highly accurate, precise and stable performance, simultaneous positioning and data transmissions

- flexible SiNAPS positioning software
- reliable data transmissions
- range: up to 8000 m
- accuracy: better than 0.01 m

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