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AI for Interferometric Sonar Data

Sensor Calibration for Vessels





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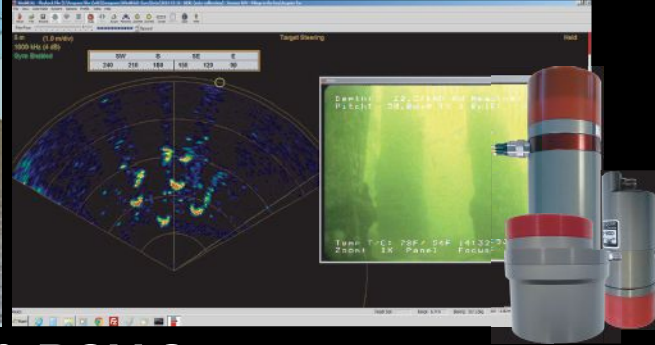
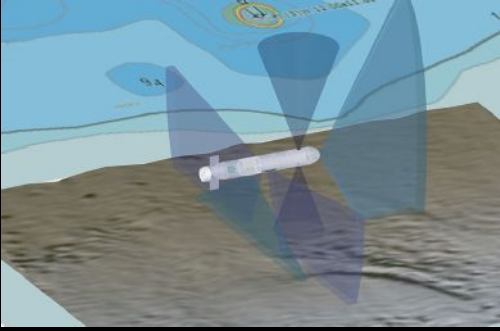
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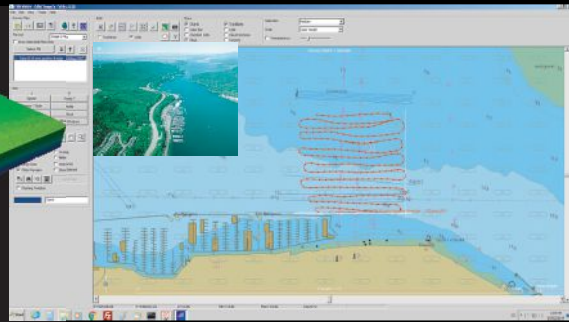
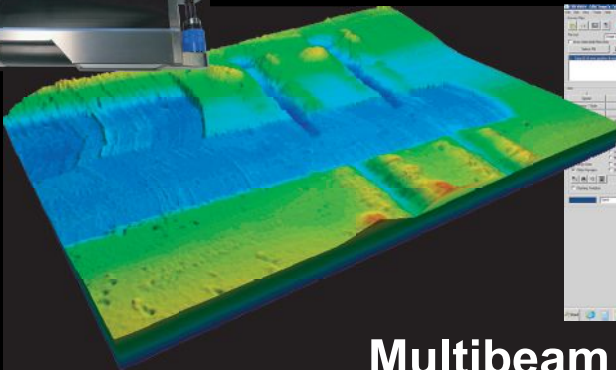
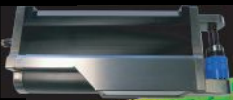
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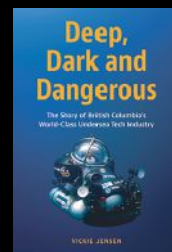


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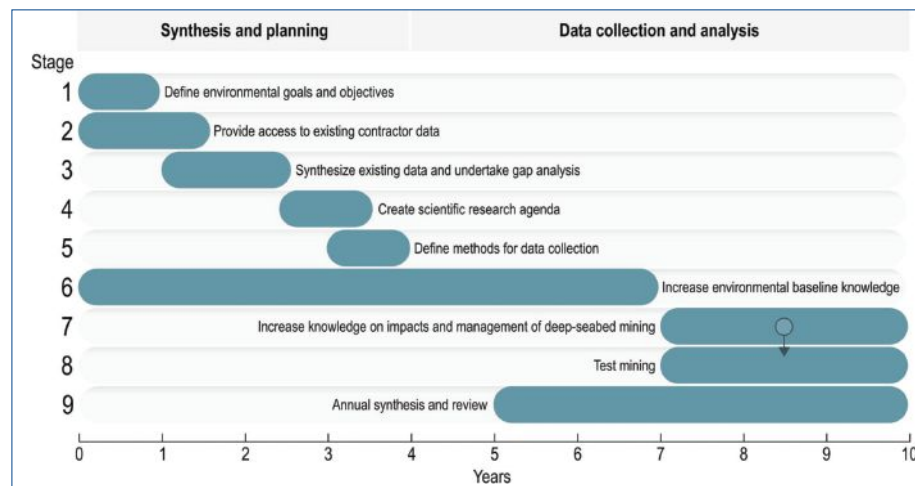
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Sea trials being conducted for an AML Oceanographic underway profiler, the Moving Vessel Profiler (MVP), in Halifax Harbour, Nova Scotia, Canada, June 2021. (Credit: Skyline Studios)

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)) Winners of NOIA Safety in Seas Awards. The National Ocean Industries Association (NOIA) has named TechnipFMC and Aker Solutions as the winners of the 2022 NOIA Safety in Seas (SIS) Awards competition. TechnipFMC is the 2022 NOIA Safety in Seas Culture of Safety Award winner, and Aker Solutions is recognized for the 2022 NOIA Safety in Seas Safety Practice Award. NOIA has held the SIS Awards competition since 1978 to recognize those who contribute to improving the safety of life in the offshore energy industry. The awards are sponsored by Compass Publications, the publisher of *Sea Technology*. TechnipFMC is recognized for its Pulse and Impact Quality programs. Impact Quality focuses on leadership behaviors that drive a culture of prevention, accountability and continuous improvement. Pulse is the company's global health, safety, security and environment (HSSE) culture and engagement program. Through training, self-assessment and communication, Pulse provides TechnipFMC with the skills, tools and behaviors needed to maintain and strengthen HSSE culture. Since its launch in 2018, the Pulse and Impact Quality programs have engaged more than 6,000 internal and external stakeholders, and the total recordable injury rate has declined from 0.44 to 0.26. Aker Solutions is recognized for its Control of Work program, developed to allow for each Aker Solutions' segment and functional area to be graded throughout the year on implementation and adherence to the use of Safe Working Essentials tools. A key aspect of the program is encouraging the use of stop-work authority in an effort to support continuous safe operations. Between 2020 and 2021, Aker Solutions' U.S. operations saw a 92 percent increase in stop works, initiated from all areas of manufacturing, offshore services, maintenance, engineering, office personnel and contractors, demonstrating strong employee ownership of HSSE performance and a culture of proactive risk identification across the business.

)) New Tool to Track Marine Species in US. NOAA Fisheries is launching a new tool to better track the location and movement of marine fish in U.S. waters: <https://apps-st.fisheries.noaa.gov/dismap>. The Distribution Mapping and Analysis Portal reveals that the ranges of many marine species are shifting, expanding and contracting in response to changing ocean conditions. The interactive website will improve data sharing and collaboration, facilitate decision making about fishery management and science, and increase overall knowledge of species distribution for stock assessments. The portal displays data from NOAA Fisheries bottom trawl surveys for five regions (Northeast, Southeast, Gulf of Mexico, West Coast and Alaska) and includes a map viewer and graphing capabilities for over 800 marine fish and invertebrate species caught during the surveys. Understanding how species are distributed in space and time and the factors that drive patterns are central questions in ecology and important for species conservation and management. The portal allows users to select a species of interest and visually examine changes in the distribution over time by looking at both location maps and graphs of key indicators of a species distribution (such as change in latitude, depth and range limits). The user can also choose to view changes in distributions at the regional level as an indicator of broader community level changes. The changing climate and oceans impact every aspect of NOAA Fisheries' mission—from managing fisheries and aquaculture to conserving protected resources and vital habitats.

)) EIB to Invest in Circulate Capital Ocean Fund. Circulate Capital, the Singapore-based investment management firm financing high-growth opportunities at the nexus of climate-tech and plastics, recycling and the circular economy, has announced that the European Investment Bank (EIB) has committed up to \$20 million to the Circulate Capital Ocean Fund I-B (CCOF I-B), which invests in disruptive innovations aligned with Circulate Capital Disrupt, the firm's climate-tech strategy, and in the South and Southeast Asia recycling value chain, alongside the firm's \$112 million Circulate Capital Ocean Fund. CCOF I-B is targeting a total raise of \$80 million and is in consideration with other investors, as recently disclosed by the International Finance Corp. The fund's inaugural investments are innovators that implement solutions in the biotechnologies, sustainable fashion and smart materials sectors, as well as digitization of the recycling value chain to combat plastic waste and climate change. These enterprises include Arzeda, Circ, Phase Change Solutions and Recykal; they represent some of today's most cutting-edge innovations that are disrupting a cross-section of supply chains and have proven technologies and ambitions to expand in Asia, where there is strong potential for financial, environmental and social returns.

)) World's First MASS Professional Certificate. Fugro personnel from its Middle East office have completed the world's first maritime autonomous surface systems (MASS) professional certified training, delivered by SeaBot XR at the training academy CEbotiX, the National Centre for Operational Excellence in Marine Robotics based in Southampton, U.K. This certification is a landmark step in the development of a recognized training program that ensures qualified marine personnel acquire the skills needed to safely and effectively operate MASS. Fugro and SeaBot XR have been working together since 2019 to develop the skills required by the connected mariner. Training focus is on critical topics such as mission analysis, situational awareness, cybersecurity and resource management. The training is based on experiential learning, where trainees are provided with in-depth theoretical knowledge before taking a staged approach to the command-and-control process. Candidates are able to apply their newly acquired skills directly to the working environment to deal with the challenges associated with emerging technologies. **ST**

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Human-Centered Digital Transformation

We have a new horizon in maritime, where highly automated systems, robotics and artificial intelligence (AI) will advance to assist or conduct more and more tasks. With this progression, we need to challenge the misconception that greater technology and automation will replace seafarers. The future of work lies in the symbiosis of human performance and technology, and we must help people to develop the necessary skills to continue working in the sector.

Maritime professionals are already working alongside narrow AI, and the future will be permeated by greater use of machine learning, presenting us with further opportunities and challenges. We need to ensure that technologies remain as tools and not as the goal itself. The application of new technologies should be consistent with legal and regulatory requirements and aligned to ethical principles that ensure implementation avoids unintended harm.

The maritime industry must upskill and champion human-centered digital transformation. We should not only look to replace humans in certain tasks but to empower them with new skills to work alongside technology, performing shared tasks and shared decision making. This requires an understanding of what humans are best at and what machines are best at. This first era of narrow AI adoption, for example, has the potential to benefit society by automating time-consuming tasks and complex data analysis.

We need to perform gap analysis to benchmark between the existing skills and new skills requirements. First, we must understand the types of technologies headed our way, then we can map and categorize new skills necessitated by new technologies. We must also look at the ways in which we train and practice both current skills and new skills, now and in the future.

We need to continue developing greater in-depth systems knowledge and expertise in systems design and systems architecture. If we do not understand the increasing complexity in systems, we cannot circumvent failure. As technology becomes more complex, so does the job of managing it, and we will need ongoing training, reskilling and upskilling.

We must also train to deal with abnormal and emergency situations. Adopting technology that provides greatly enhanced situational awareness will enable us to move forward safely and to more rapidly benefit through shared decision making that helps us make better judgments in complex situations, where accountability for those situations continue to reside with us.

Beyond technological benefits, the adoption of AI, including marine autonomous surface ships (MASS), provides us with the opportunity for greater equality, diversity and inclusion in the workforce. For example, the working group MASS People has been set up to help safeguard progression in the technology-people partnership by identifying the workforce's changing needs and providing recommendations on new competency standards. The group also proposes specialisms, training structures and qualification requirements for operators now and in the future. The Institute of Marine Engineering, Science and Technology (IMarEST), the largest marine organization of its kind, with members based in more than 120 countries, has a MASS special interest group that has worked closely with MASS People on a project to propose and gain approval in the U.K. for a new apprenticeship in uncrewed operations.

This is an exciting time of change for the maritime sector, and long-term thinking is imperative. As well as raising awareness of new advancements in technologies and regulations, it is vital that we identify skills gaps and prepare the youth of today to meet the challenges of tomorrow. **ST**

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Annual Review & Forecast

**OCEANS 2022 Chennai, February 21-24, Chennai, India

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Instrumentation: Measurement, Processing & Analysis

**Oceanology International, March 15-17, London, Excel, U.K.

MARCH

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**AUVSI XPONENTIAL 2022, April 25-28, Orlando, FL

APRIL

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**Offshore Technology Conference, May 2-5, Houston, TX

MAY

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**EUROMARITIME, June 28-30, Marseille, France

JUNE

Seafloor Mapping/Sonar Systems/Vessels

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UE DATE

JULY

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****CLEAN PACIFIC 2022**, August 23-24, Renton, Washington

AUGUST

Geophysical Exploration/Seafloor Engineering

****IMAGE '22**, August 28-September 2, Houston, TX

SEPTEMBER

Ocean Resources Development & Coastal Zone Management

****OCEANS 2022 Hampton Roads**, October 17-21, Virginia Beach, VA

****EURONAVAL**, October 18-22, Paris, France

OCTOBER

Environmental Monitoring, Remote Sensing & Pollution Control

****CLEAN GULF 2022**, November 8-10, New Orleans, Louisiana

****Offshore Energy 2022**, November 29-30, Amsterdam, The Netherlands

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AI for Interferometric Sonar Data

Artificial Intelligence in Phase-Measuring Bathymetric Data Processing

By Francisco J. Gutiérrez • Danny Websdale

For bathymetric surveying, the drive to reduce the cost of data acquisition, accelerate data processing and deliver more autonomous operations demands new workflows and technologies, as well as performance-improving upgrades for existing hydroacoustic systems. Here, the application of artificial intelligence (AI) is especially important to maximize the operational potential of the sonar systems that are already required to capture the geophysical nature of the seafloor.

If your aim is to acquire wide-swath bathymetry measurements, you have the choice of using a multibeam echosounder (MBES) or a phase-measuring bathymetric system (PMBS, a.k.a. interferometric sonar). Interferometric sonars produce an order of magnitude more bathymetry data points than multibeam systems, and new AI-powered processing is set to make the data available in real time.

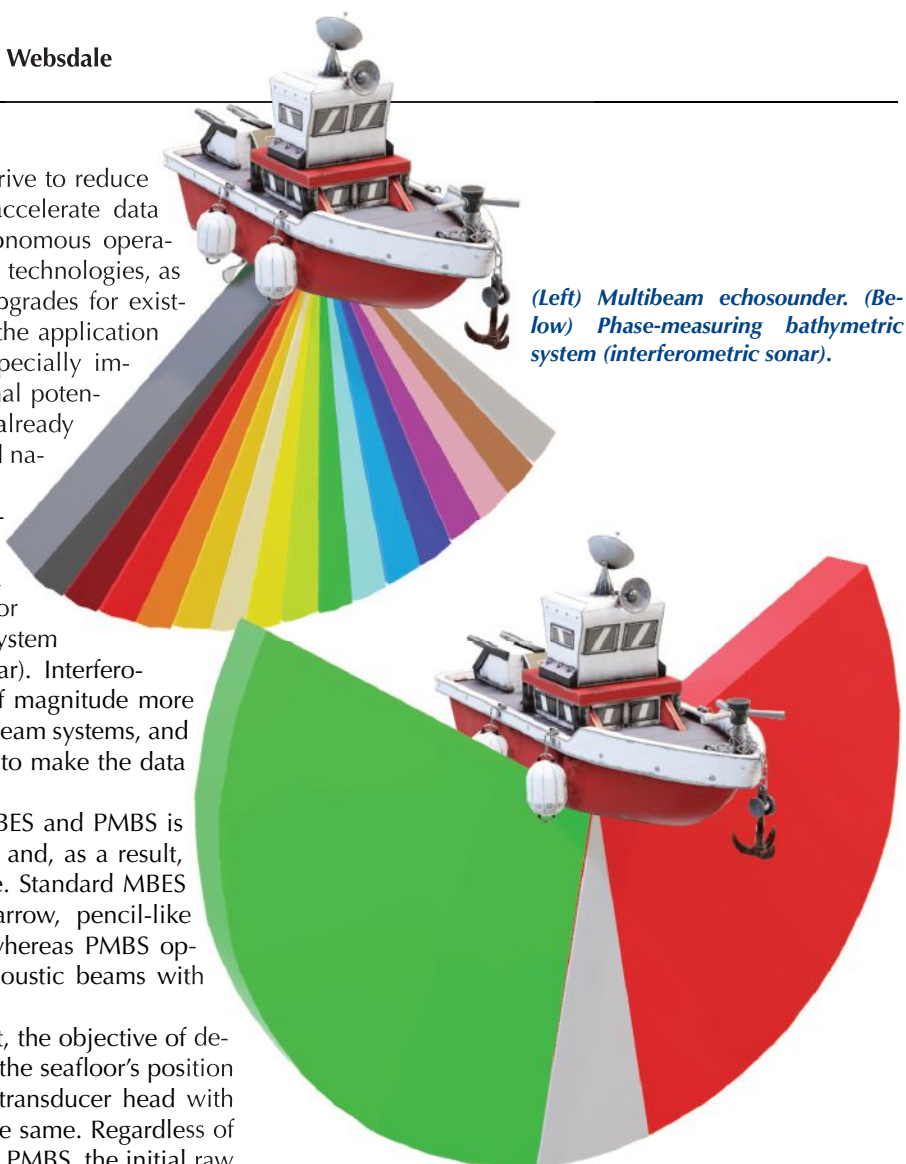
The key difference between MBES and PMBS is primarily in the transducer design and, as a result, what the acoustic beams look like. Standard MBES can produce more than 500 narrow, pencil-like acoustic beams simultaneously, whereas PMBS operates using two wide fan-like acoustic beams with partial overlap at the nadir.

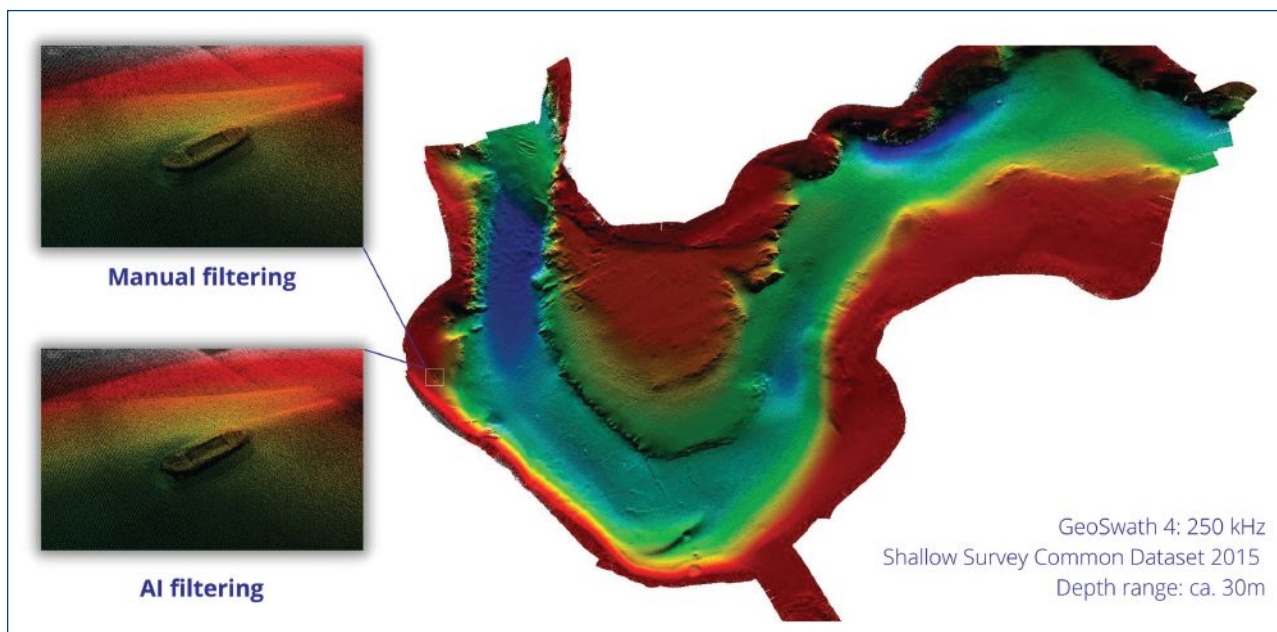
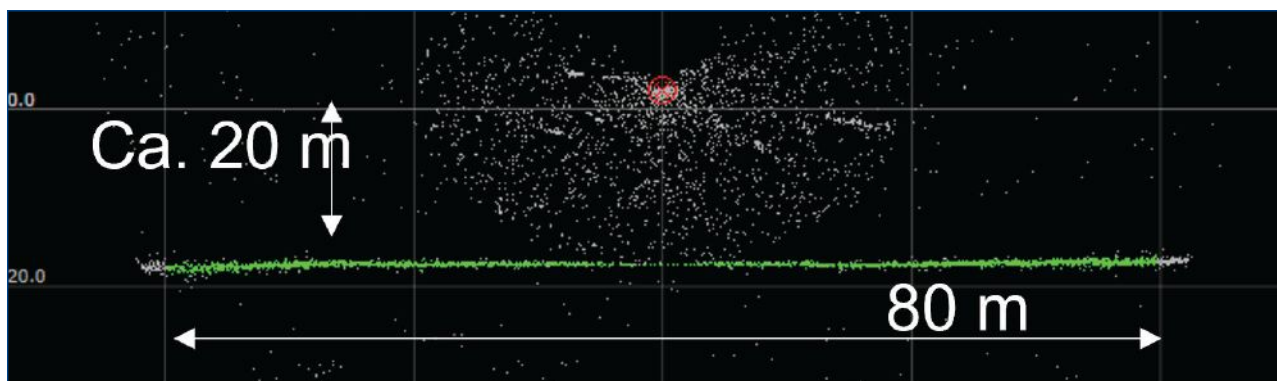
While the methods are different, the objective of detecting the bottom and measuring the seafloor's position relative to a known point in the transducer head with the highest accuracy possible is the same. Regardless of whether you are using an MBES or PMBS, the initial raw data capture the same information: time series of echo intensity and time series of phase differences.

However, because PMBS is a high-resolution, multi-stave side scan system, it produces significantly more bathymetry data points than the conventional MBES standard output, which can introduce some challenges

in data processing. And this is why applying AI to PMBS is set to deliver a radical performance boost.

Due to the nature of the data collected by PMBS, a set of filters to automate the removal of outliers must be manually configured, which has been a job that only an





experienced and trained user can perform effectively. The quality of results produced is, therefore, very much correlated to this user's experience. With the introduction of AI, any potential user-dependent inconsistencies are overcome and mitigated.

AI for Data Cleaning

In January 2020, GeoAcoustics Ltd., the manufacturer behind the long-running GeoSwath interferometric bathymetric sonar family, started looking at an alternative to traditional PMBS data-cleaning methods by using modern AI and machine learning techniques. The resulting development of the proposed "unsupervised AI outlier identificatory system" has since been ongoing in partnership with AI specialists at the University of East Anglia.

The general requirements of the proposed system design are that it must be real time, hands free and produce expert-equivalent outlier identification, without a human in the loop. Such a system would increase the quality of data collected, while making it available to survey operators as a dynamic and flexible tool for on board and, connectivity permitting, remote decision support.

Real-time data enable the survey vessel, AUV or USV to act when an object or area of interest is located, with

(Top) The results of the AI cleaning algorithm on 500-kHz GeoSwath 4 data from a survey in 20 m of water. The system achieved IHO Special Order for viewing angles bigger than 120°. (Bottom) 250-kHz GeoSwath 4 data, available from a 2015 shallow-survey common data set, reveal a wreck located to the left of the map, shown with both manual and AI filtering applied. While subtle differences are possible to spot, the images are essentially identical, showing that AI filtering matches manual filtering.

the aim being to ensure availability of the highest resolution data for further analysis. In a standard subsea survey workflow though, the target will usually not be "picked up" until data processing in the office. In this case, should further investigation be needed, a secondary survey mission must be mobilized, with project costs potentially doubling or more.

Real-time bathymetric data processing powered by AI is the only way to enable the development of truly autonomous survey platforms that can transform the speed and capacity of subsea data acquisition and massively increase operational and economic efficiencies in the

“With the introduction of AI, any potential user-dependent inconsistencies are overcome and mitigated.”

industry. While AUV and USV platforms are already operating autonomously, it's only when survey technology can operate without human intervention and talk directly to the platform's AI controller that will we see truly autonomous survey operations.

Repeatable Results

As traditional phase-measuring data filtering relies heavily on an expert user setting up filters over the raw data to “clean” it, automating some specific technical aspects of the data acquisition process has become a central focus for the GeoAcoustics Ltd. and University of East

Anglia team. The AI model has been developed to flag outliers based on essential criteria automatically. The system is designed to track the seabed in real time without missing anything important outstanding from it, much like an experienced data processor would in the workroom. Of course, such a system may work well in principle, but if the performance of the AI cannot match that of a specialist operator, then the quality of data produced may not conform to essential commercial survey requirements.

This sets the bar high. Essentially, the AI has to be better than a human operator, and tests so far prove

that this is already the case. For example, using GeoAcoustics Ltd.'s standard demo data set—collected during a survey in 20 m of water at Lowestoft in the U.K. in 2014—the results of the AI cleaning algorithm on 500-kHz GeoSwath 4 data, acquired with an Applanix POS MV real-time RTK navigation system and a Valeport miniSVP sound velocity profiler, show that the system achieves International Hydrographic Organization (IHO) Special Order for viewing angles bigger than 120°. The system is also ready to deliver data to IHO Exclusive Order for shallow-water surveys, which was introduced in the sixth edition of the S-44 standards in 2020.

The results from this 20-m survey alone demonstrate that the AI data-filtering techniques developed by GeoAcoustics Ltd. and the University of East Anglia can achieve equivalent performance and quality to standard office-based processing workflows, with the difference that the data are now available in real time on board, which increases value significantly. Additionally, as the data are acquired hands free and, therefore, user independent, it opens the door to a more systematic approach to advanced real-time processed data products, such as backscatter normalization or acoustics segmentation of the seafloor. Again, this supports efficiency in expert-led and future autonomous survey operations.

While this survey's results come from a relatively flat subsea environment, the AI filtering has also been evaluated on more challenging data and shown to match or outperform manual filtering by an expert. For example, AI filtering was applied to 250-kHz GeoSwath 4 data from a 2015 shallow-survey common data set acquired in Plymouth, U.K., re-

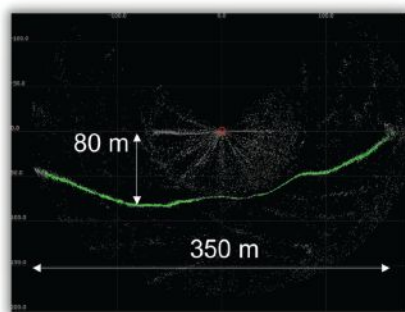
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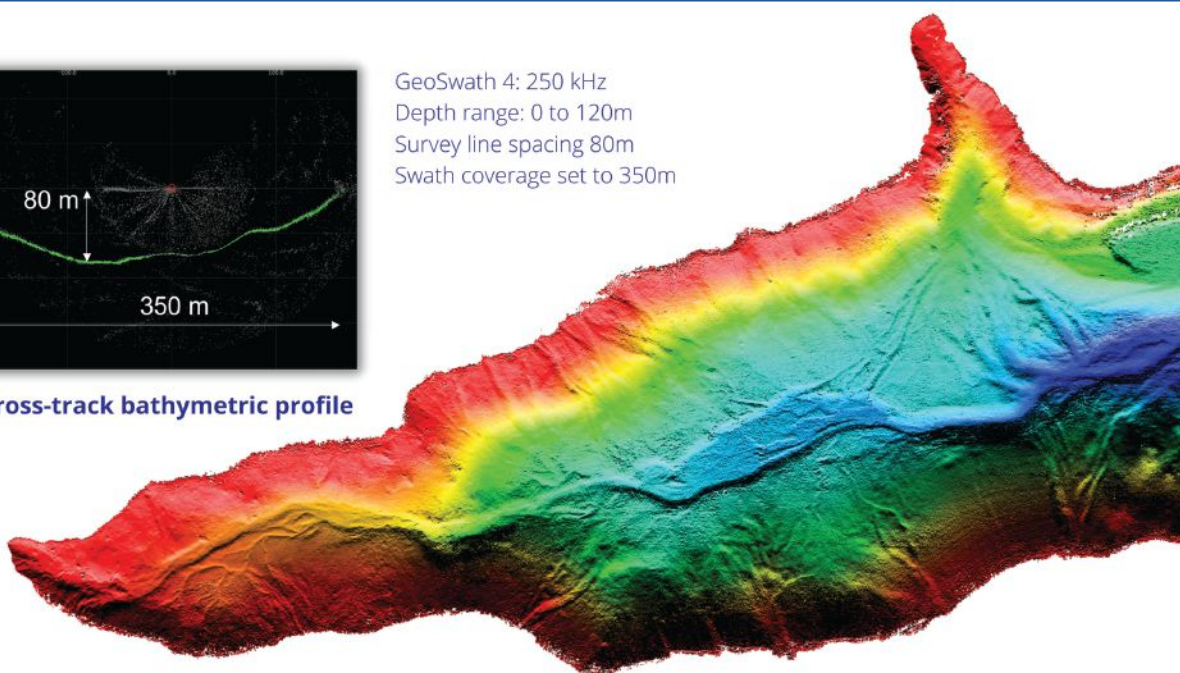
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Across-track bathymetric profile

GeoSwath 4: 250 kHz
Depth range: 0 to 120m
Survey line spacing 80m
Swath coverage set to 350m



250-kHz GeoSwath 4 data comparisons were done for an Alpine lake, from the shoreline out to 120-m depth. This across-track bathymetric profile shows that it is possible to achieve a “clean” 350-m swath width in 80 m of water.

sulting in a wreck being located at 30-m depth in the data map. The wreck can be seen with both manual and AI filtering applied. While subtle differences are possible to spot, the images are essentially identical, with both providing high quality and actionable data to the required standard. This demonstrates that AI filtering matches the results of manual filtering.

More 250-kHz GeoSwath 4 data comparisons were done in a completely different environment: on an Alpine lake in October 2021, from the shoreline out to 120-m depth. An across-track bathymetric profile from the survey shows that it is possible to achieve a “clean” 350-m swath width in 80 m of water. For this application, the results have been described as “a game changer” by the system owner and data consumer.

Real-Time Performance

Now that the AI is proven to be able to provide a sounding-acceptance solution in a repeatable and user-independent manner, it is also possible to calculate the total vertical uncertainty associated with the sonar data, which could be fed directly into TPU- and cube-based data processing workflows.

Together with improved real-time outlier identification, sonar-dependent IHO conformance can also be displayed in real time, which allows users to check that data collection likely meets the required spec and adjust

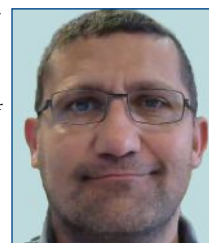
the survey on the fly, which saves both time and money.

The new AI data processing module for the GeoSwath 4 bathymetric sonar is clearly meeting the goal to optimize the acquisition and availability of precise seabed data. The AI project has delivered amazing results that can be repeated on any relevant data set without issue. A new generation of hands-free filters for GeoSwath 4 data processing will be the product of commercialization of this joint research project. The work is almost complete, and GeoSwath 4 owners will be able to integrate AI processing into their systems without charge later this year.

References

For a list of references, contact Francisco J. Gutiérrez at: francisco.gutierrez@geoacoustics.com. **ST**

Francisco J. Gutiérrez is a product specialist for the GeoSwath 4, Pulsar and TOPAS systems manufactured by GeoAcoustics Ltd. He previously worked as technologist for the Spanish Research Council and as an associate professor of electronics at University of Cadiz in Spain.



Danny Websdale is an AI/machine learning research scientist at the University of East Anglia (UEA) and GeoAcoustics Ltd. He received a bachelor's degree in computer systems engineering (2014) and a Ph.D. in audio-visual speech processing (2019), both from UEA. He is currently working on applying AI for real-time seabed classification.



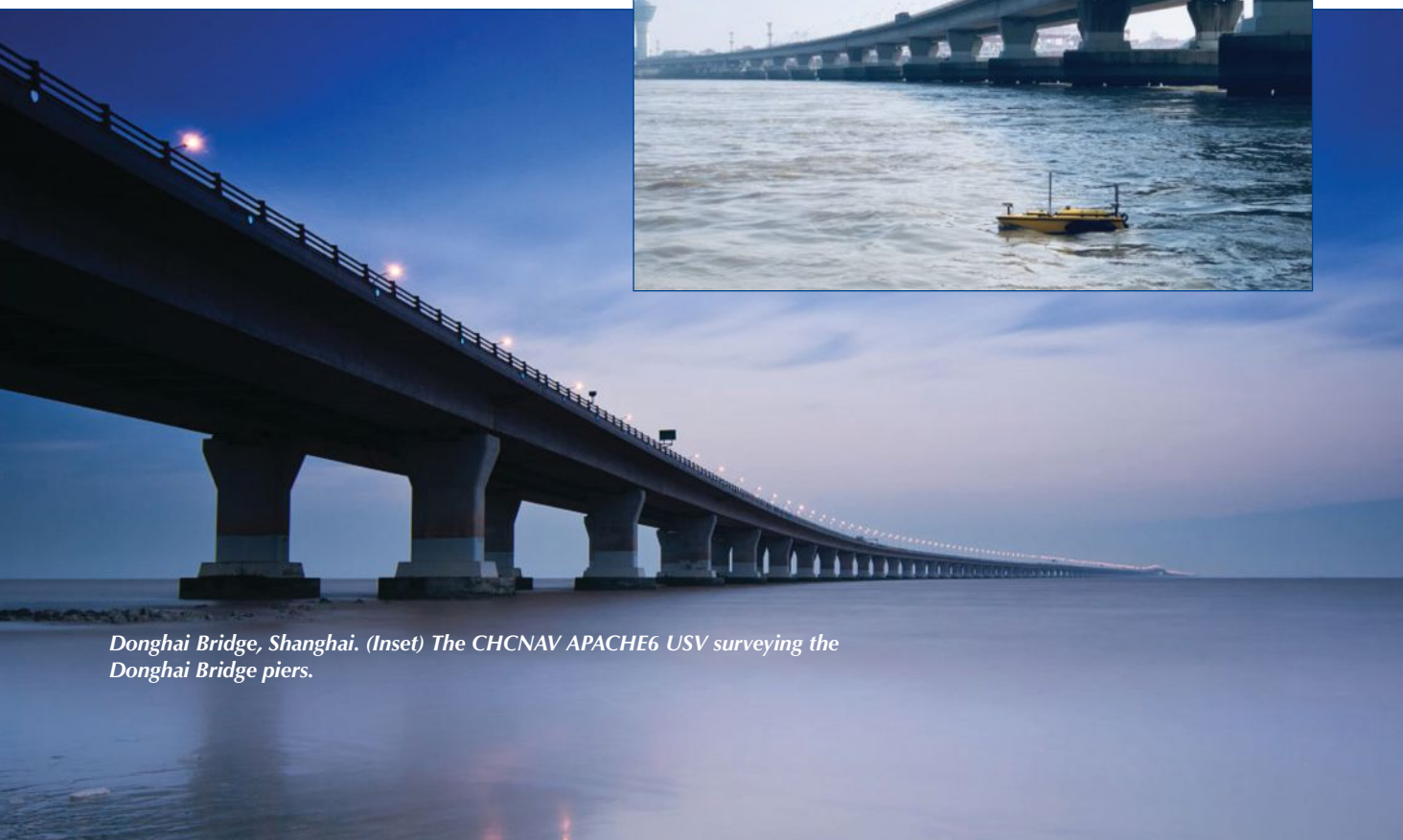
3D Bathymetry via USV

USV with Multibeam Echosounder for Shanghai Bridge Survey

By Taxiya Wang

The Donghai Bridge, located in Shanghai, China, is a key component of the Shanghai International Shipping Center's deepwater port infrastructure. Conducting underwater surveys of the bridge piers' conditions for maintenance purposes is an operational challenge. The bottom of the bridge piers is immersed in water and can be eroded by the action of sand and gravel. Hydrodynamic scour caused by rapid water

flow can create scour holes and compromise the integrity of the structure. To determine whether piers need to be protected by additional riprap, the precise sediment



Donghai Bridge, Shanghai. (Inset) The CHCNAV APACHE6 USV surveying the Donghai Bridge piers.



APACHE6 with detachable trimaran design.

The solution selected for the Donghai Bridge survey project comprises an unmanned survey vessel, the APACHE6 of CHCNAV, carrying a NORBIT iWBMS STX multibeam echosounder.

Flexible Deployment

When conducting multibeam bathymetric surveys with an unmanned surface vessel, marine survey professionals highlight three major points of concern: How secure is their investment given the cost of multibeam echosounders? Does the USV offer sufficient flexibility to handle a variety of bathymetric survey scenarios? What about the final accuracy of the high-resolution 3D bathymetric survey?

Maneuverability and ease of use in fast current situations were a key factor in the client's choice of survey platform for the Donghai Bridge project. The APACHE6 USV's hull comprises a carbon-fiber/resin composite material that minimizes weight while ensuring that the hull is strong enough to withstand potential collisions. The tight integration of the

NORBIT multibeam echosounder into the USV hull provides optimal protection for the transducer array and allows for navigation and operation in shallow waters. An extended hull width of up to 1 m improves hull balance and ensures a stable rolling attitude during multibeam data acquisition, improving data accuracy. A detachable trimaran design accommodates varying wind and wave environments.

The compact size of the USV allows for on-site transportation in a car or van and deployment by only two persons. The total weight of the complete APACHE6 USV platform is less than 40 kg, allowing for extreme portability, even in remote locations.

The APACHE6 uses a pair of dedicated outboard thrusters with a maximum power of 1,300 W. Its excellent thrust allows the hull to reach a theoretical maximum speed of 5 m/s (about 10 kt.) and a cruising speed of 2.5 m/s (about 5 kt.) in normal operation.

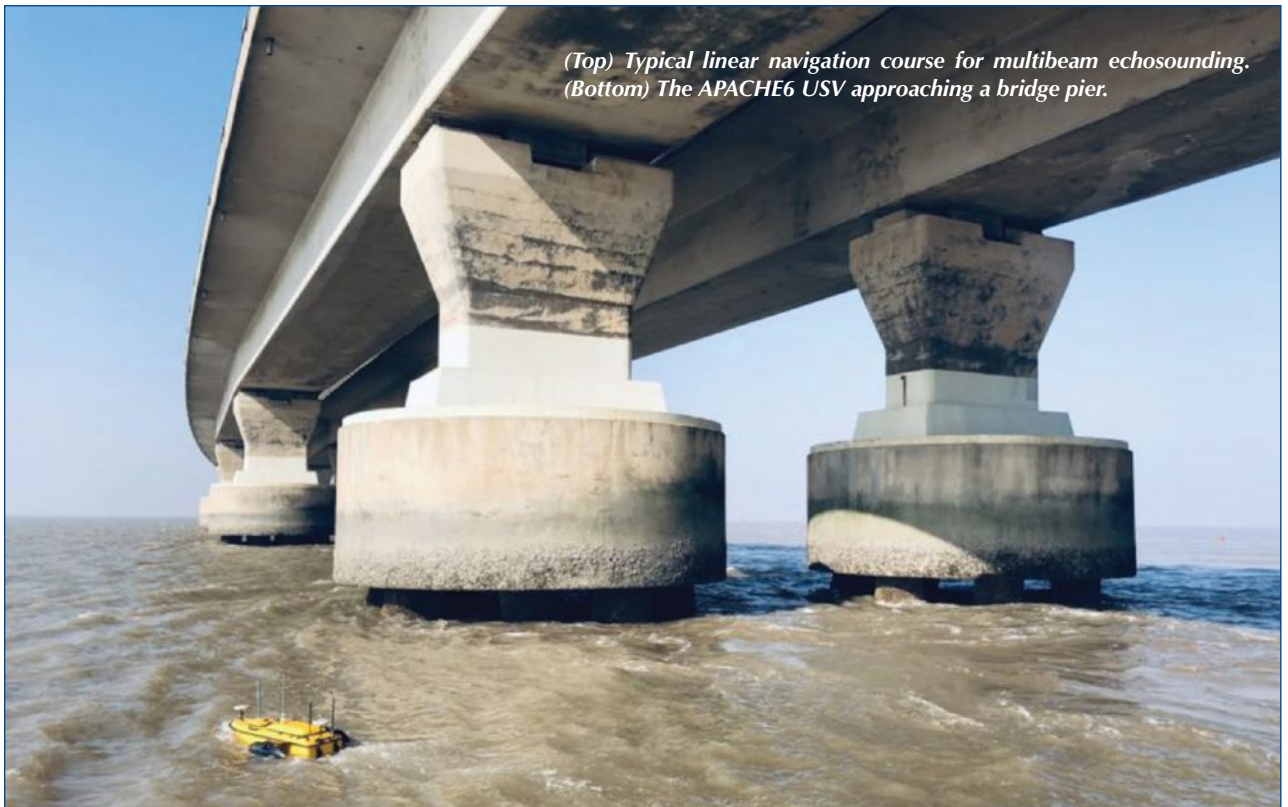
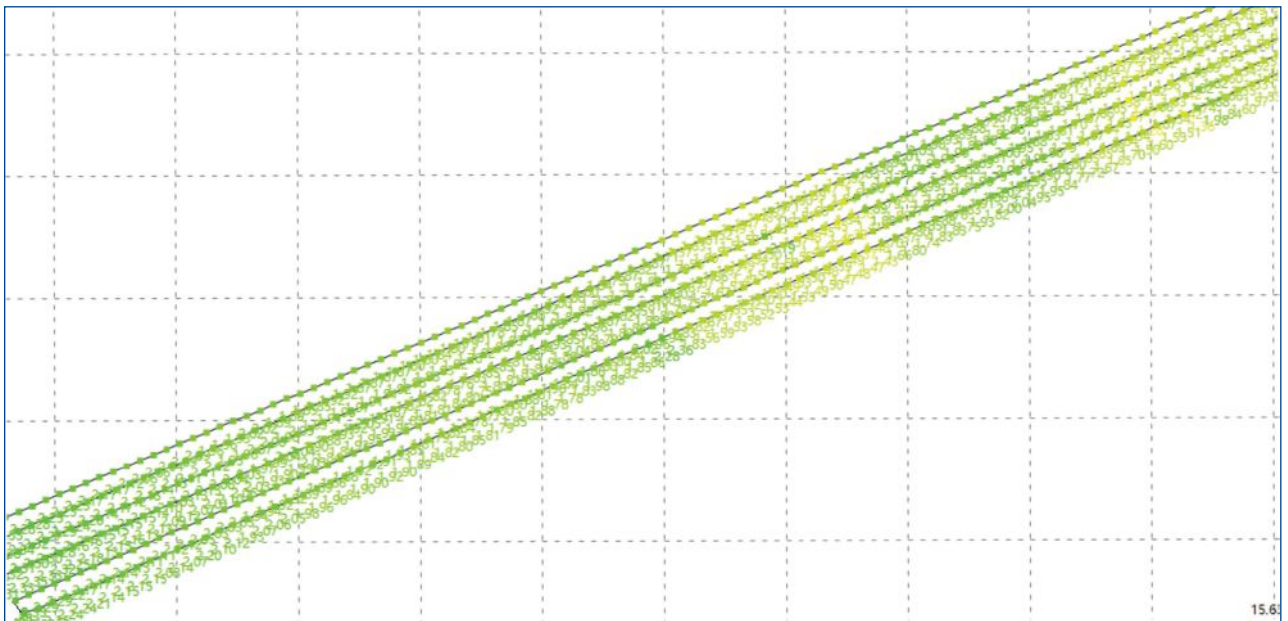
The USV's autonomy has been considerably improved with the use of 18650 cells (lithium-ion rechargeable batteries) with very high safety factor, enabling a working span of up to 6 hr. and a much larger survey area of several kilometers, compared to previous versions of the vehicle.

The implementation of new technologies, with capabilities such as absolute straight-line course, water flow adaptive propulsion, stationary hovering, shoal reversing and inertial navigation, are unique to the APACHE series, expanding the application scenarios.

These marine drones can switch between manual and automatic modes depending on survey conditions. In automatic mode, hull positioning and attitude are combined with a specific algorithm to maintain high accuracy. When the vessel encounters the current, the propellers are controlled to automatically adjust the steering based on the strength and direction of the current on the hull to ensure that the course proceeds as planned.

scour conditions need to be investigated, but this poses operational challenges for traditional 3D bathymetric surveys.

Conventional bathymetric survey solutions with a manned vessel in a marine infrastructure environment will most likely leave numerous blind spots. The use of a manned vessel does not offer enough flexibility to perform efficient and comprehensive surveys due to the density of the pile spacing and the lack of 3D data on the back areas.



*(Top) Typical linear navigation course for multibeam echosounding.
(Bottom) The APACHE6 USV approaching a bridge pier.*

During a turn, the hull automatically decelerates so that the unmanned vessel's sounding line is at the same height as the intended line to ensure underwater data integrity throughout an operation.

Multibeam Coverage

Marine drones have to incorporate efficient automatic navigation control technology to follow the planned route in a complex working environment, with different speeds and changes in flow direction. The objective is to have a trajectory deviation of less than 20 cm.

When measuring with multibeam echosounders, the strip coverage should be greater than 20 percent. The precision of perfect linear course of crewed vessels can be largely influenced by the wind and wave environment, as well as by the pilot's experience. The absolute straight-line technology integrated in the APACHE6 ensures that a predefined planned line is maintained to guarantee data integrity.

The entire NORBIT multibeam echosounder system weighs less than 10 kg and fits into a single carrying case, making it easy to transport. The transducer, attitude,

surface sound velocity and other data can be transmitted with a single interface cable for easy installation and use and to minimize the risk of damage.

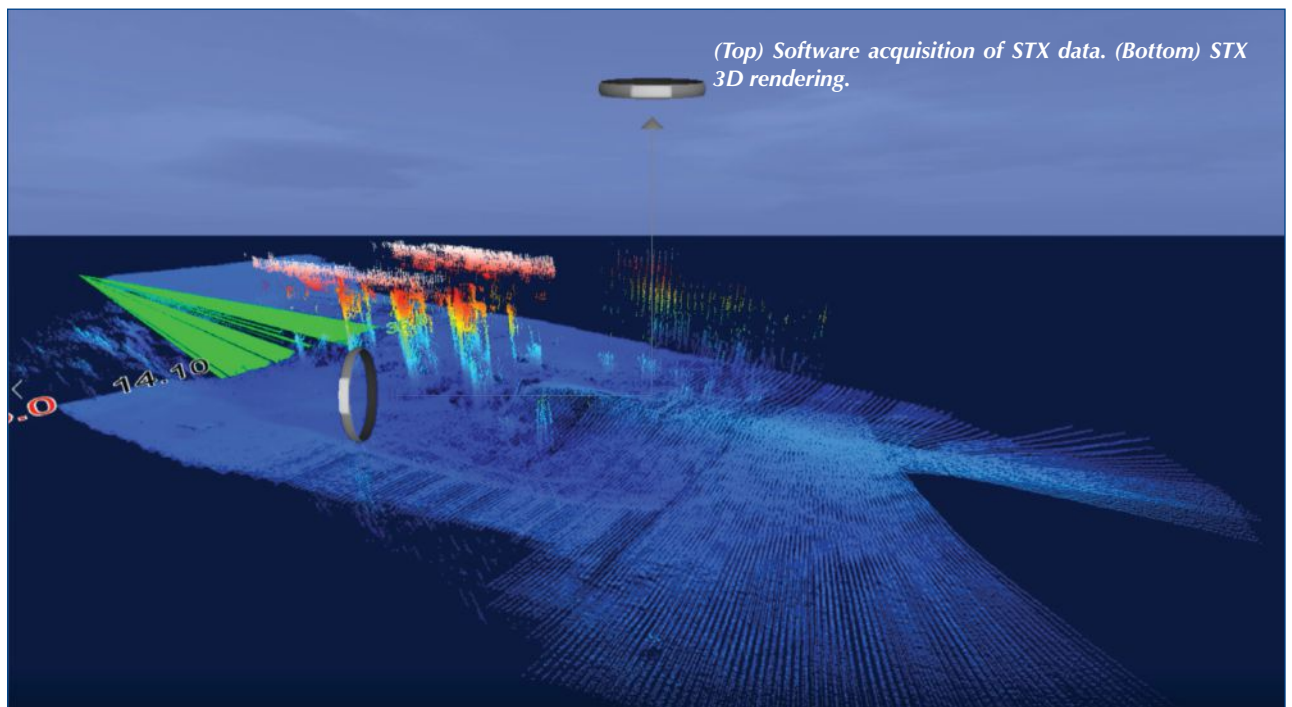
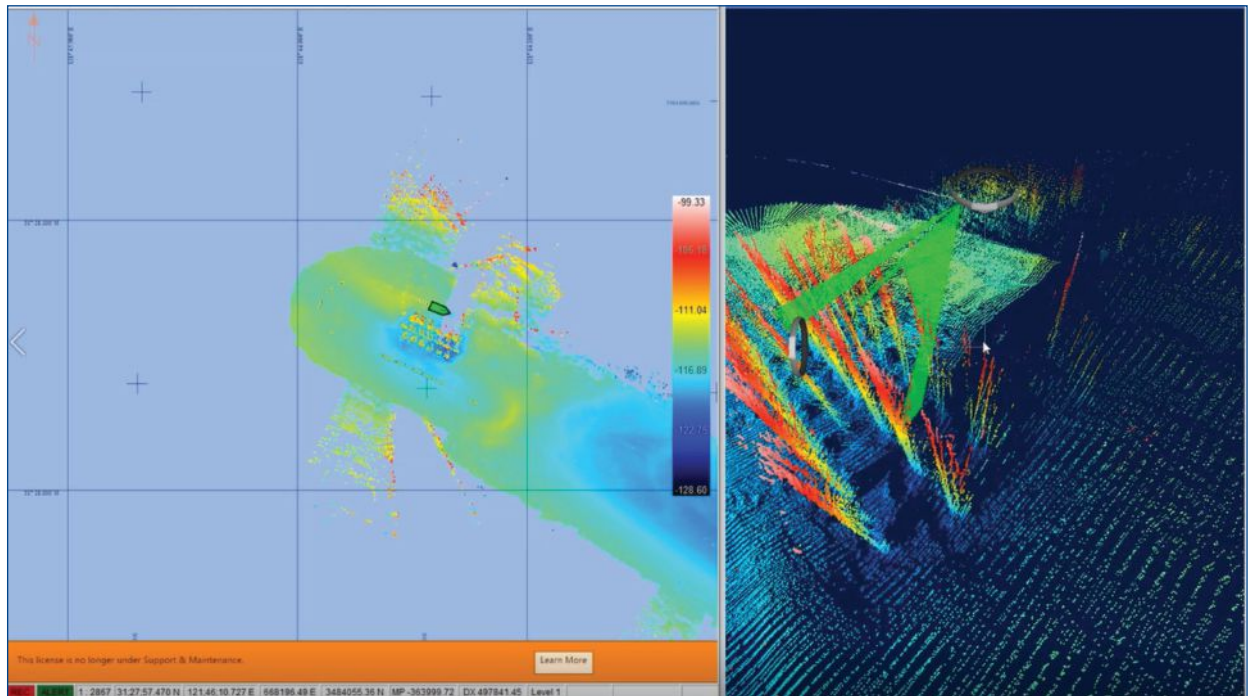
When the USV is stationary, the STX multibeam echosounder, in addition to its 210° horizontal scan coverage, also has 20° longitudinal scan coverage, so that the real-time dynamic 3D scanning effect can be achieved.

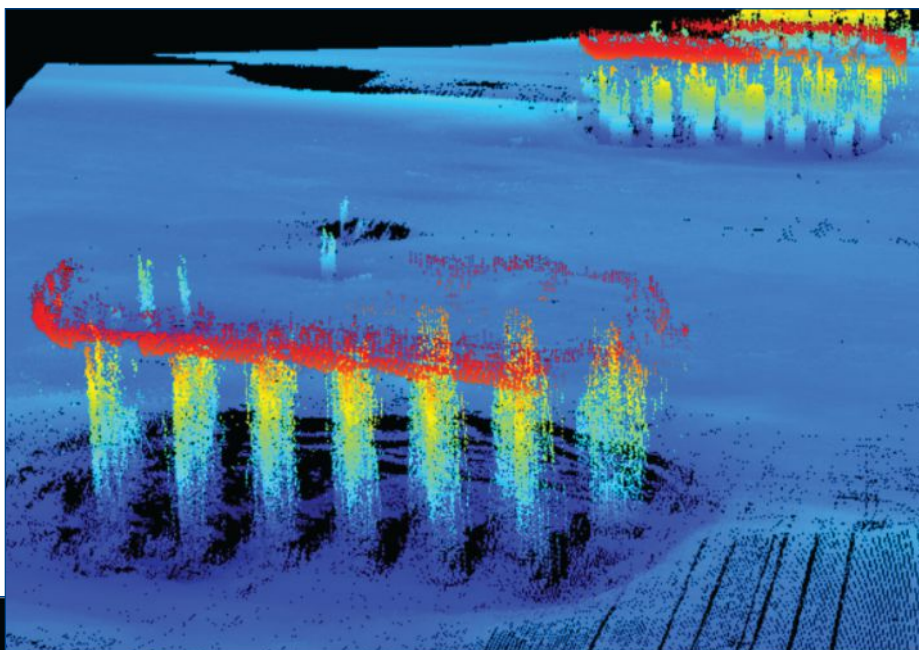
During multibeam sounding, the USV moves along the sounding line at a controlled constant speed of 4 to 6 kt. The display, control and data acquisition software that supports multibeam sounding runs on the data acquisition computer to acquire and display data and manage measurements and navigation.

Survey Results

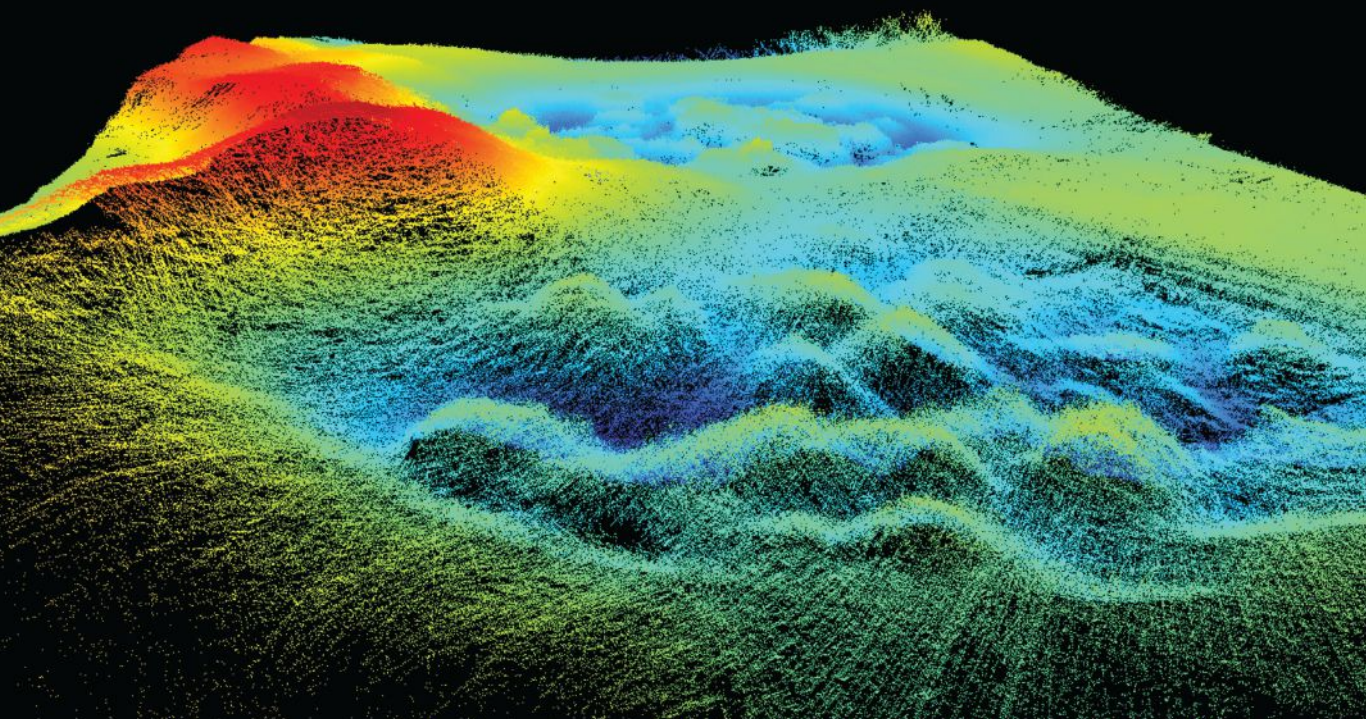
The combination of the APACHE6 USV and NORBIT multibeam echosounder enabled the Donghai Bridge survey to be completed in less than 1 hr. To obtain the best accuracy and completeness of data, the APACHE6 was operated in manual mode in the immediate vicinity of the bridge piers to collect additional data during the survey. This hybrid approach would not have been feasible with a manned vessel. The data collected were later filtered and edited by post-processing software and imported into the sound velocity profile data to obtain the outputs.

The bridge management unit compared the data ob-





(Top) Bridge section piling and water bottom scouring rendering. (Bottom) Extracted row piles to view underwater scour details.



tained throughout this survey with the original bridge construction design to determine if additional riprap was required. After data post-processing and analysis, a total of 18 piles were identified for further investigation for routine maintenance.

Conclusion

During underwater terrain mapping, marine survey professionals often need to map dense underwater structures, such as bridge piers, as in the survey case in Shanghai. One of the main problems encountered is how to survey the topography behind the piers and the internal topography of the dense structures. When it is difficult to achieve this with traditional crewed boats,

hydrographers now have the option of deploying USVs.

USVs reduce survey time, improve work efficiency and produce high-resolution 3D data to meet the requirements of the most demanding marine infrastructure projects. The CHCNAV APACHE6 USV is an innovative and fully integrated solution for 3D bathymetric surveys, underwater objects and offshore construction. **ST**

Taxiya Wang has been involved in the development of CHCNAV's international marine business since 2017. She works on the development and promotion of USV solutions for bathymetry and hydrological surveys and unmanned water exploration.

Hydrospatial Data Collection

Uncrewed Vessels Increase Survey Range, Efficiency

By Duncan Mallace • Matt Holland



XOCEAN XO-450 USV in an offshore wind farm.

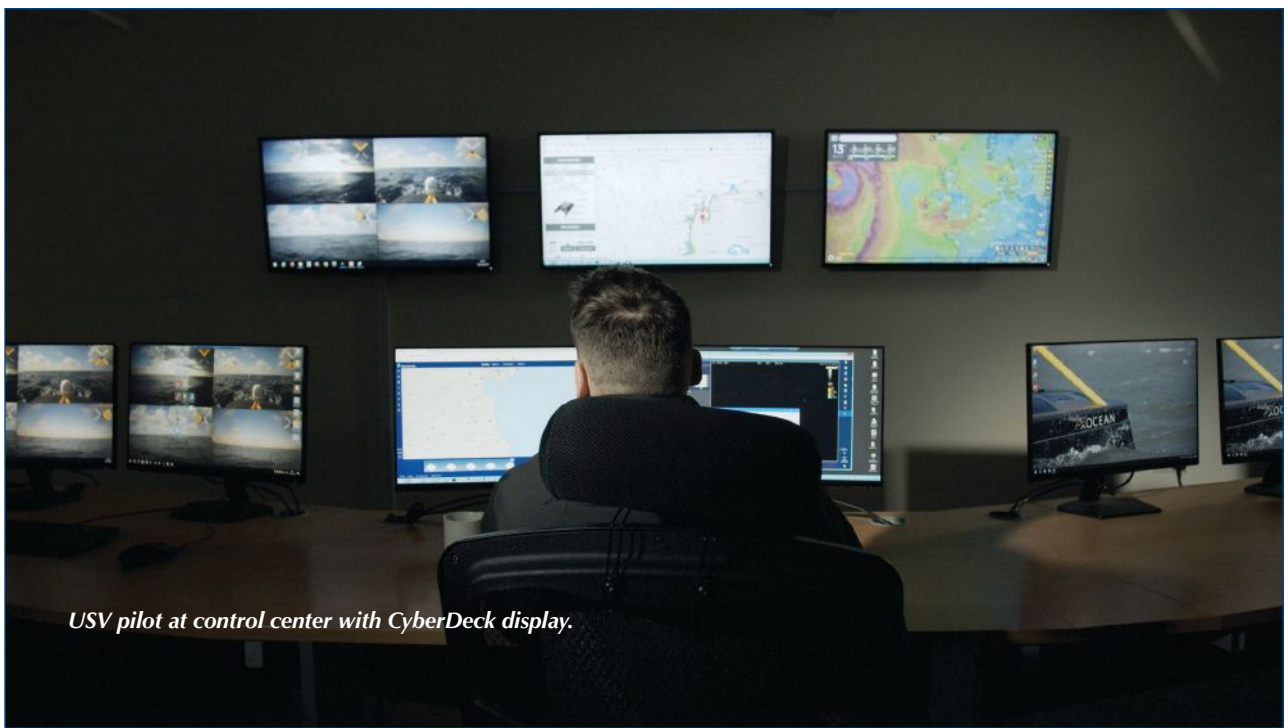
The use of USVs for hydrospatial data collection provides several key benefits over the traditional method of using crewed vessels. This includes lower health and safety risk by conducting operations without the need for personnel to be offshore and minimizing environmental impact through the use of smaller survey platforms with hybrid power systems and extremely small carbon footprints. Uncrewed operations also present various opportunities to obtain economic savings, one of which is through the allocation of multiple vessels to meet data collection objectives in a shorter time frame and with fewer additional resources.

Even with the use of a single USV, operational advantages can be realized by performing data collection 24 hr. a day, seven days a week (24/7), and in weather conditions that would not allow a crewed platform to operate safely while acquiring high-quality data. These ad-

vantages maximize productivity during available weather windows and can be further leveraged by conducting simultaneous operations with multiple USVs to address the survey scope.

The cost benefits also scale with the use of multiple uncrewed vessels by further reducing exposure to weather events, without the need to increase resources on a one-to-one basis. While one USV pilot is needed per USV for safe operation, one online surveyor can effectively oversee the data collection from multiple USVs, and two field operatives can safely and efficiently handle on-site logistics for many USVs.

An uncrewed approach to data collection also creates industry job opportunities, enabling a new way of working for mariners and surveyors. Those who have traditionally worked offshore can continue to apply their knowledge and competencies to hydrospatial data collection



USV pilot at control center with CyberDeck display.

without the need to spend extended periods offshore.

Using USVs, agencies and companies with interests in the marine environment can expedite the collection of hydrospatial data to update navigational products and publications, inspect power cables for utilities infrastructure, support site selection and proposed routes for renewable energy and carbon capture projects, and enable other activities that underpin the blue economy.

XOCEAN USV Fleet

The ability to allocate multiple platforms to a single project is a key success factor for large ocean data collection campaigns. With requirements to collect different types of data within the same project, the capability to carry multiple sensors is also an important aspect.

XOCEAN operates a fleet of USVs, which are a proprietary design and purpose built to provide a safe, low-carbon and economic solution for the collection of ocean data. With continuous electrical load of 3 kW to power the vessel systems and sensors, and up to 100-kg payload capacity, the XO-450 model USV has been designed to provide a highly flexible platform for integrating multiple proven and commercial-grade sensors. The diverse range of sensors can be used to support an equally diverse range of activities in the marine environment, including seabed mapping, environmental monitoring, integrity inspections and others.

The USVs provide full, uncrewed over-the-horizon operation, facilitated through satellite communications, or cellular or Wi-Fi connection if operating close to shore. Combining over-the-horizon communication and control with an endurance of up to 18 days enables the USVs to be safely and efficiently operated hundreds of kilometers offshore, without the need to be accompanied by a crewed support vessel. Nearshore and coastal mapping applications can also be safely addressed

with the USV's shallow draft design (approximately 0.8 m with sonar mounted) and continuous oversight of the USV operations by certified pilots/mariners.

USV pilots monitor and have full command and control of the USVs through XOCEAN's highly secure cloud-based environment, CyberDeck. Using a standard internet connection and secure virtual private network (VPN), pilots are provided with situational awareness feeds from the USV sensors (four visible light cameras, thermal camera, etc.) to make decisions and quickly access USV controls for safe operation. Access to the survey PC and sensor control units by the online survey team is also facilitated by CyberDeck.

Weather Tolerance

The composite, wave-piercing catamaran design of the USV allows for operations in adverse weather conditions (Force 6 on the Beaufort Scale) and the ability to collect high-quality data in sea states that would not be possible for a traditional crewed platform (Force 5). By operating and collecting data 24/7 with a survey platform less susceptible to the impact of environmental conditions, operational times can be maximized during any available weather windows. Conducting simultaneous operations with multiple USVs can further reduce the impact of weather events and accelerate the completion of the survey scope.

It is likely, however, regardless of the season or geographic location, that any ocean data collection project will have some risk of weather delay, so it is important that related costs be minimized as much as possible. Again, the use of uncrewed platforms for survey can help to reduce the overall project cost, which includes the costs associated with weather downtime. Without any crew on board the vessel, and the ability to reschedule project personnel on relatively short notice, weather

costs will be limited to the assets at the project site (USV and equipment), and they will be significantly less compared to a crewed operation.

The number of human resources needed to operate multiple USVs on a project also translates into savings, in addition to shortening the overall survey time. While each USV will have a certified pilot to control and maintain watch, the same number of field operatives and on-line surveyors can be allocated to safely and effectively manage the on-site logistics and data collection requirements regardless of the number of USVs in operation.

Combining USVs with a Vessel

Certain project locations and data collection requirements may require the use of a traditional vessel, e.g., in remote, hard-to-access regions or arrays of towed sensors.

Mapping efforts can, however, be furthered by combining one or more USVs with a main vessel. This approach can be used to increase data collection by all platforms for hydrographic surveys, or allow the vessels to focus on individual tasks in the case of USVs providing survey support for a renewable energy project construction vessel, for instance.

As USV pilots and online surveyors operate remotely, the data collection objectives can be met without the additional space requirements or costs for extra crew on the main vessel.

Industry Jobs

Uncrewed operations offer a different way of working, with unique opportunities for those involved (or considering becoming involved) in hydrospace data collection. Even with uncrewed technology applied to marine surveying, the demand for trained and certified surveyors and mariners remains to ensure data collection objectives are met in the safest possible way. The remote access brings the expertise of industry professionals to the uncrewed platform and project site, without the need for extended periods offshore. Global operations, with a work force that is based in different geographic locations and time zones, also reduces the need for night shifts and irregular working hours, enabling a more balanced lifestyle for workers.

Low-Impact Operations

Ocean data have traditionally been acquired using large, crewed vessels, which emit substantial amounts of carbon from the consumption of thousands, or even tens of thousands, of liters of fuel per day. With typical speeds of 5 kt. or more during operations, and much higher transit speeds, these vessels also pose a threat to marine mammals through possible collision.

The XO-450 USV is the size of an average car (4.5 by 2.2 m) and uses renewable hybrid power, consuming very small volumes of fuel. The resultant carbon emissions are minimal (approximately 0.1 percent of a con-



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ventional vessel) and reduced to the point that they are easily offset for fully carbon-neutral operations. This is achieved without compromising power or payload capacity or data accuracy requirements. The environmentally low-impact approach can address even the most stringent data collection specifications defined by energy developers and operators, hydrographic offices, and others for seabed object detection, point density, sub-bottom penetration and related requirements, as seen in the following case studies.

Offshore Wind Farm Surveys

The data collection requirements for an offshore wind farm (OWF) will vary throughout the estimated 25-year field life. This will include the collection of seabed and subsurface information for reconnaissance geophysical surveys for site development, surveys during turbine and cable installations, routine inspections through operations and maintenance to ensure integrity, and data to support assessments during decommissioning. By conducting the operations using uncrewed technology, any risks to personnel can be minimized and CO₂ emissions can be reduced.

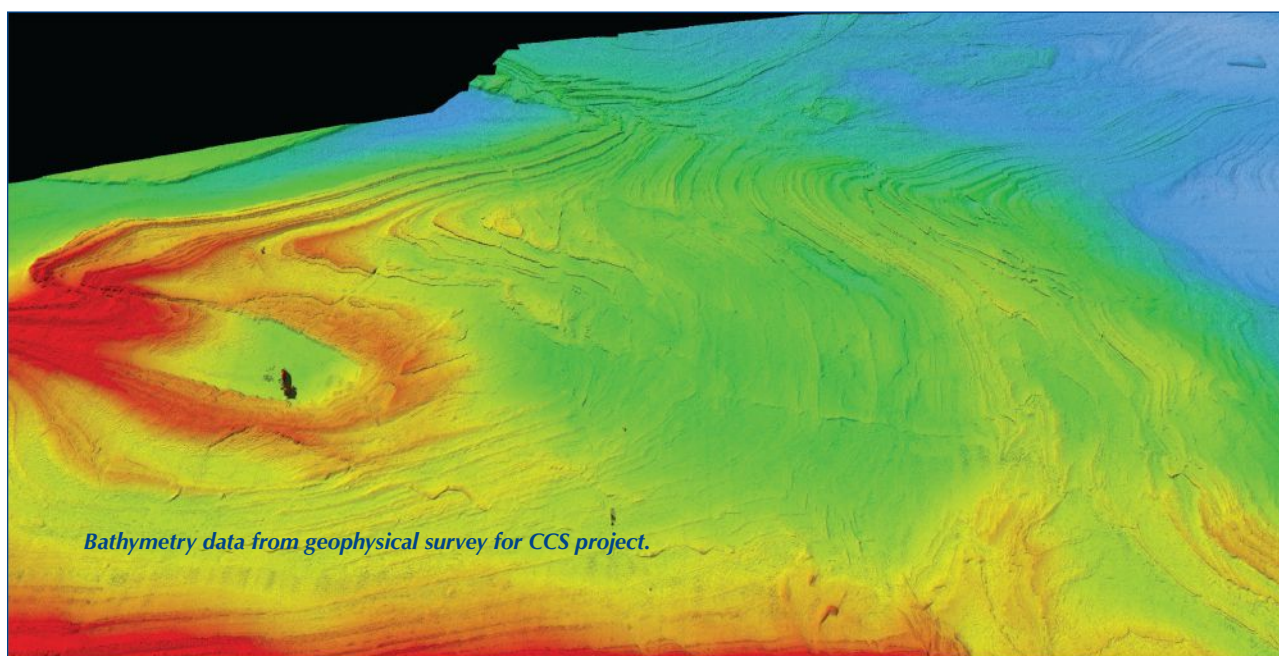
With existing and new OWFs helping to reduce global carbon emissions, ocean data supporting developments and related activities should be collected in an ocean-friendly, low-impact way. Through 2021, XOCEAN used USVs to deliver 26 OWF surveys and displace over 21,000 tons of CO₂ emissions. The company will displace 1 million tons of carbon within five years.

Hydrographic Surveys

Uncrewed systems are regarded by many as the technological development that will be the main driver for hydrography in the coming years to lower costs and enable increased coverage. XOCEAN's uncrewed approach, including the operation of multiple USVs, has been used to perform hydrosatial data collection for national mapping authorities in the United Kingdom, Canada and others to date. Data deliveries include bathymetry that meets International Hydrographic Organization (IHO) S-44 accuracy standards, plus backscatter data.

The XOCEAN USV has also been fitted with a much wider range of sensors to support marine-based science beyond traditional hydrography. During a survey of Lake Superior in 2021 with IIC Technologies for Fisheries and Oceans Canada and the Canadian Hydrographic Service, the USV acquired oceanographic data for various scientific applications, in addition to high-resolution bathymetry and backscatter. This included acoustic fish tracker observations, chlorophyll measurements from a Valeport SWiFT SVPplus chlorophyll sensor, weather station information and video footage to assist with marine mammal observations.

The USV technology has been used to successfully acquire high-quality data in remote locations and with challenging logistics and environmental conditions, such as coastal areas and lochs, inland waters and northern environments (e.g., the Canadian Arctic). The data have been used to update navigational products and publications and contribute to the blue economy in general.



Bathymetry data from geophysical survey for CCS project.

Geophysical Surveys

Uncrewed vessels offer a viable alternative to the use of crewed vessels to provide both seabed and subseabed information to support the development of clean energy and decarbonization projects. This includes the collection of bathymetry data to determine topography and gradients, detect seabed objects, and establish a baseline for seabed mobility studies. At the same time, the payload capacity of the XOCEAN USVs allows for a sub-bottom profiler (SBP) to be concurrently operated to establish subsurface soil conditions, depth of bedrock and presence of any buried boulders that could influence infrastructure design and installation.

Offshore carbon capture and storage (CCS) projects are now part of decarbonization efforts and may offer an alternative for regions with limited onshore potential. Like other offshore projects, high-quality data from multi-beam echosounders (MBES) and SBPs are needed to support the selection of routes and the design for pipes and other infrastructure. XOCEAN has used four USVs to deliver 12,500 km of geophysical survey data to support an offshore CCS development in 2021. By using USVs, the data collection objectives of the decarbonization project were met through completely carbon-neutral operations.

Subsea Asset Inspection

By performing data collection using both USVs and uncrewed aerial vehicles (UAVs), a seamless land-sea data set can be compiled for cable inspections and other subsea assets, including in landfall areas and intertidal zones. The applications for this combined approach also extend to coastal zone mapping and route surveys to identify optimal landfall locations for infrastructure before installation.

An uncrewed inspection of 35 cables was undertaken by XOCEAN in the Scottish mainland and Western Isles in 2021. Survey operations were conducted from 25 different islands to address the project scope. Two USVs

were used to complete the survey campaign and acquire bathymetry, backscatter and side scan data. Two senseFly eBee X UAVs were used to acquire the topographic data using 3D cameras. Shallow-water bathymetry was also extracted from the UAV data set using structure from motion (SfM), a photogrammetric range imaging technique.

Conclusion

Continued growth of the global ocean economy is driving the need for high-quality hydrospace data to enable informed decisions and support new developments, such as clean energy and decarbonization projects. The requirement to survey areas to modern standards is also ongoing for the creation and updating of navigational products, which support global shipping, trade and numerous other activities related to our oceans. By using USVs, we can increase the rate at which hydrospace data are collected, support the growth of the blue economy and conduct carbon-neutral operations to help use our oceans in a sustainable way. **ST**

Duncan Mallace is the chief strategy officer at XOCEAN.



Matt Holland is sales manager for the Americas at XOCEAN.



Sensor Calibration for Vessels

Calibration Reference Instruments with Extended Calibration Intervals

By Sean Nielson

Vessels of all sizes rely heavily on machinery, systems, equipment and instrumentation for smooth operation. While some of these machines may be huge, expensive pieces of equipment, often the smallest piece of instrumentation provides the information the technician uses to assure quality performance. Temperature and pressure transducers, sensors and transmitters give the critical information that controls valves, pumps, readouts and much more.

Because these small pieces of equipment are vital to so many different systems, technicians need to ensure that they remain accurate. Verifying their accuracy is important because temperature and pressure sensors degrade over time. If not checked, calibrated or replaced, these sensors could provide incorrect signals and reduce the vessel's optimal performance. Performing the calibration of these instruments does not come without its challenges.

As most vessels spend the majority of their time out at sea, the calibration of these sensors often takes place on board. Testing and calibrating while at sea requires technicians to add high-quality calibration instrumentation to their toolbox. But what to choose? A simple search for "temperature calibrator," "pressure calibrator" or "reference recorder" will return several options. A savvy buyer will consider all available options, but the difficulty lies in separating these products. Manufacturers differentiate their instruments on accuracy, features, reliability and

ease of use, but potentially the most consequential for maritime customers is the calibration interval.

Calibrating Reference Instruments

Like the sensors, transmitters, transducers and gauges they are used to test, calibration reference instruments themselves require calibration. Because of their high accuracy, unless a vessel contains costly laboratory-level equipment, the calibration of reference instruments is done onshore. This is where the difficulty begins.

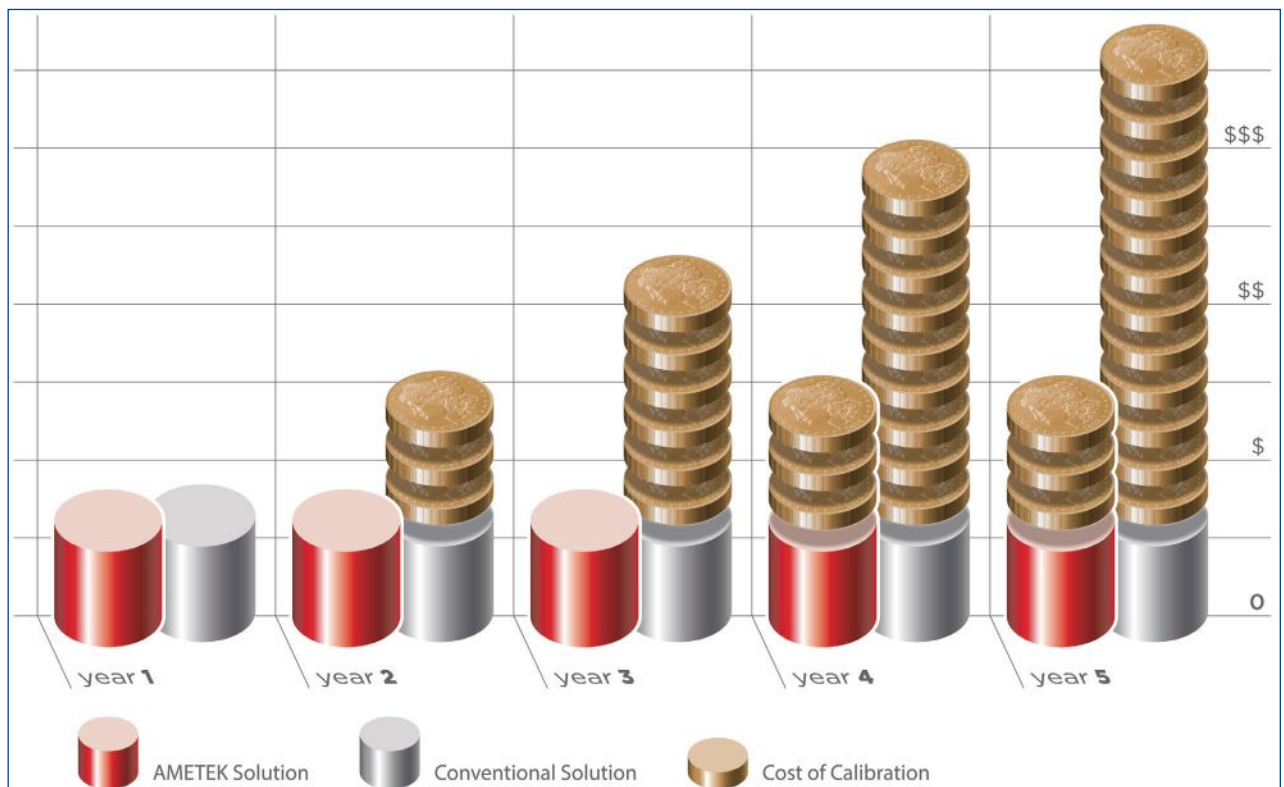
You can decide to schedule a technician to come on board with equipment while docked. However, this might not be possible if you are

AMETEK's JOFRA marine temperature calibrator (MTC).

in a quick turnaround. There also might not be a calibration house locally that can transport sensitive lab equipment. If this is the case, you're left with either driving or shipping your equipment to the technician's shop. Once it leaves the vessel, you are now at the mercy of the calibration house, and any delay may result in you having to depart without crucial equipment. And then there is the cost associated with this level of time-sensitive service.

Some manufacturers understand the challenges of calibrating reference instruments and have created special versions of their equipment that extend calibration intervals to once every three years. Choosing a three-year calibration interval instrument enables a vessel to skip this inconvenience two out of every three years. In terms of costs, the amount spent on calibration is decreased by 67 percent when only calibrating once every three years.





And, because these instruments have long lives, these savings continue to pile up year after year.

Let's consider how fast your savings would add up over five years using one of these extended calibration interval calibrators, specifically AMETEK's JOFRA marine calibrator, compared to a conventional solution. While the extended calibration product may be more expensive, the cost savings make up for this initial investment. In years two and three, the calibration cost and hassle only occur with the conventional solution. Year four marks the first time the extended calibration product requires calibration, and keep in mind that the conventional product does, too, because it requires annual calibration. Every three years, the cost savings by choosing a reference instrument with an extended calibration interval continue to grow.

Calibrating Pressure Gauges

This extended calibration interval is also available in pressure measurement instruments, such as AMETEK's m1M digital gauge that rates to 3,000 psi.

In addition to the calibration interval, some manufacturers rate the accuracy of their devices as a "percentage of reading" rather than "of scale." Most standard gauges have their accuracy rated as a percentage of the full-scale

(Above) The AMETEK MTC three-year calibration cycle saves money over time. (Left) AMETEK's m1M digital pressure gauge.

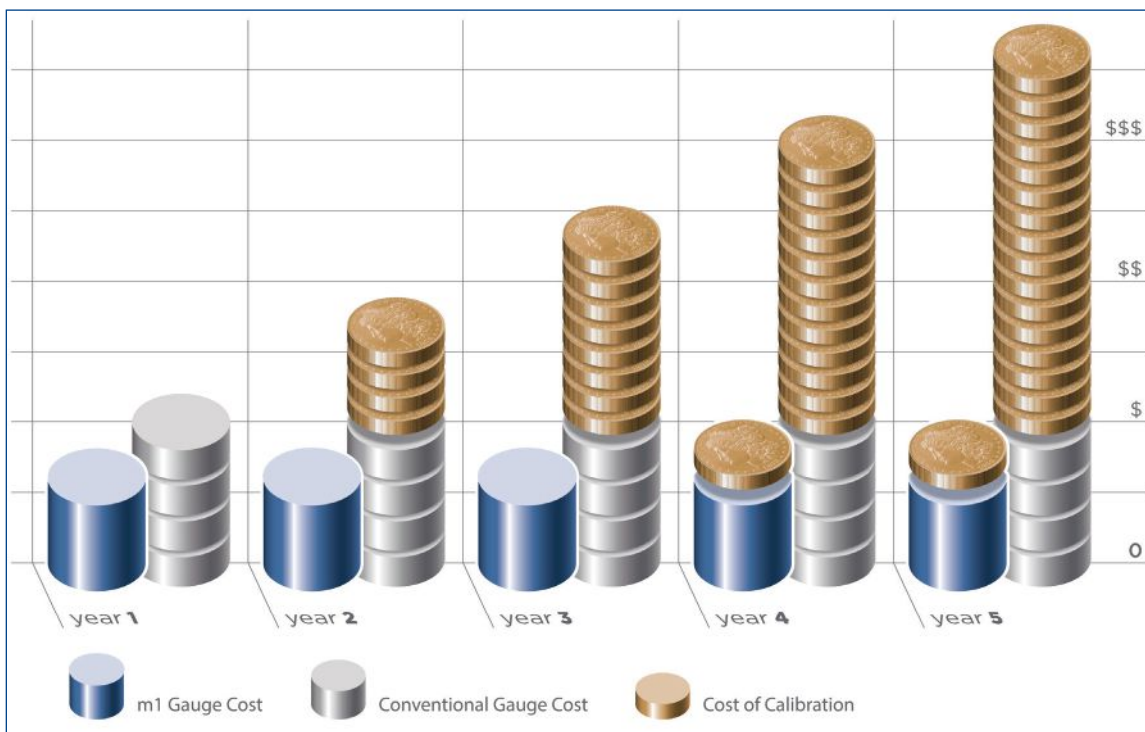


value ("of scale"), meaning that no matter where the gauge is in the range, the permissible error is the same. Considering a 100-psi-range gauge with a 0.1 percent full-scale accuracy, this results in a permissible error of 0.1 throughout its range.

When manufacturers define their accuracy as "percentage of reading," they describe the accuracy as a percentage of the reading currently displayed. For example, a gauge with 0.1 percent of reading accuracy that displays a reading of 100 psi would be accurate to ± 0.1 psi at that pressure. At 50 psi, the same gauge would have an accuracy of ± 0.05 psi (twice as accurate).

Let's consider a 100-psi-rated gauge with a 0.1 percent of reading accuracy. This gauge is twice as accurate at mid-range as the full-scale-rated gauge and five times as accurate at the lower end.

Because the accuracy improves throughout the scale, a "percentage of reading" reference instrument can often replace three to five standard "of scale" reference instruments. The result is less equipment to track and carry and less to calibrate. Combining reference instruments with both "percentage of reading" accuracy and extended calibration intervals can dramatically increase money and time savings.



Of Scale Rated Gauge

Indicated Pressure	Permissible Error	Range of Possible Actual Pressure (psi)
100	0.1	99.9 to 100.1
50	0.1	49.9 to 50.1
20	0.1	19.9 to 20.1

Of Reading Rated Gauge

Indicated Pressure	Permissible Error	Range of Possible Actual Pressure (psi)
100	0.1	99.9 to 100.1
50	0.05 (twice as accurate)	49.95 to 50.05
20	0.02 (five times as accurate)	19.98 to 20.02

(Top) The AMETEK m1M combines a three-year calibration interval and “of reading” rated accuracy. (Bottom) A comparison of “of scale” versus “of reading” rated gauges.

Considering a five-year time frame, there is an initial cost saving by purchasing one extended calibration gauge instead of four conventional gauges, and this advantage continues year after year. Each of the four conventional gauges requires an annual recalibration, whereas the user can skip this cost two out of every three years with one extended calibration gauge. And, once the user does need to calibrate the extended gauge, there only needs to be one calibration rather than four during that year. It doesn't take long before companies achieve dramatic costs savings. The upfront investment for an extended calibration gauge might be higher compared to conven-

tional gauges, but the savings are evident in the long run.

Total Cost of Ownership

The key information in deciding which reference instrument to use for vessels is the total cost of ownership. If a buying decision is made solely on the initial cost, the examples in this article show how this could be a potentially expensive mistake for companies.

All reference instruments require calibration, and in many cases, the calibration costs will outweigh the initial investment by a large margin. Avoiding the inconvenience and costs of annual calibrations by choosing reference instruments with extended calibration intervals reduces the total cost of ownership and continues to pay dividends year after year. **ST**

Sean Nielson is the marketing manager of AMETEK STC. He holds a bachelor's degree in business administration from California Polytechnic State University in San Luis Obispo, California.

Precautions: Deep-Seabed Mining

Assessing Scientific Gaps for Effective Environmental Management

By Diva J. Amon • Peter Edwards • Chris Pickens

As countries increasingly look to the ocean as a frontier for economic development, plans to exploit minerals from the deep seabed are gathering pace. In areas beyond national jurisdictions (ABNJ), extraction of mineral resources at the seafloor is managed by the International Seabed Authority (ISA), an organization established by the United Nations Convention on the Law of the Sea (UNCLOS) to organize, regulate and control seabed mining on behalf of humankind.

Recent steps taken by the Republic of Nauru, which intends to start seabed mining next year, could force the ISA to fast-track the development and adoption of exploitation regulations by July 2023. In accordance with UNCLOS (Articles 145 and 162), the ISA must prevent “serious harm” and ensure the “effective protection of the marine environment” from harmful effects, which may occur from seabed mining activities. To meet these environmental obligations, the ISA must have a comprehensive understanding of the deep sea to enable evidence-based decision making before any regulations are adopted and exploitation contracts are awarded in ABNJ.

We, therefore, conducted a study with other researchers to determine the crucial scientific gaps that should be resolved by the ISA and international community to enable evidence-based decision making about seabed mining in ABNJ. This includes gaps of scientific information needed to develop a robust and comprehensive environment impact assessment and statement (EIA/EIS); formulate an environmental monitoring and management plan (EMMP); and enable the ISA to optimize its role as an effective regulator, including the designation of area-based management tools, development of regional environmental management targets and thresholds, rigorous assessment of contractor applications and performance, and commissioning of strategic scientific studies at a regional level.

From the information gathered, we propose a potential roadmap to stimulate a much-needed discussion on

the steps that could be taken to address those scientific gaps before any exploitation occurs.

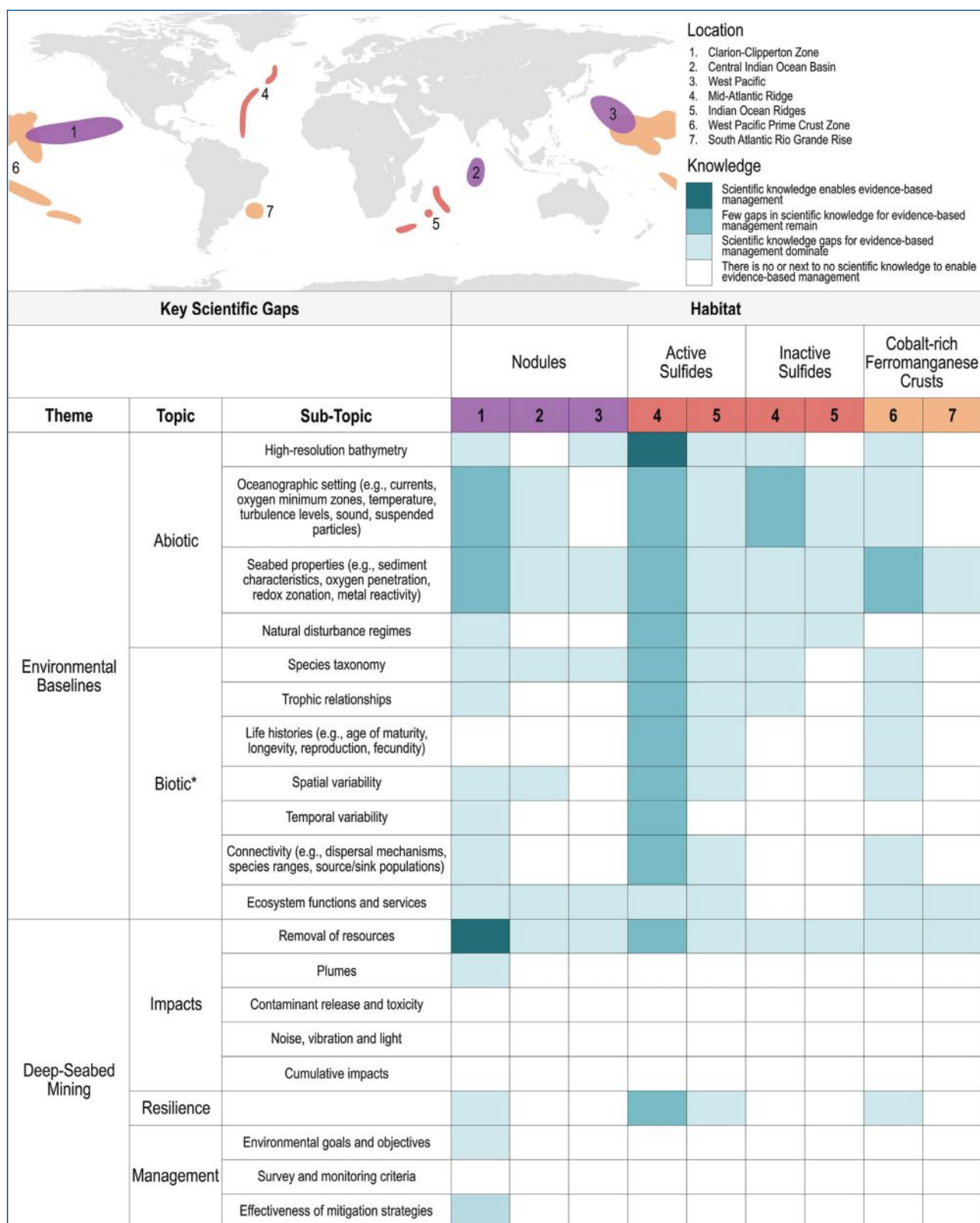
Method of Analysis

Data collection consisted of a review and synthesis of peer-reviewed literature and a stakeholder consultation. Using Google Scholar, we searched for peer-reviewed articles written in English from 2010 onward that contained various iterations of the term “deep-seabed mining.” Resulting articles were reviewed for information relevant to two key questions: What is known and unknown about the deep-sea environments and fauna where seabed mining may take place? What is known and unknown about the impacts of deep-seabed mining and its management?

A total of 306 relevant articles were qualitatively summarized, and from those summaries, responses to both questions were prepared, subdivided by resource type (polymetallic nodules, polymetallic sulfides and cobalt-rich ferromanganese crusts) and geographic regions where mining exploration contracts have been awarded. Scientific gaps were assessed at the regional scale.

For the stakeholder consultation component of this study, a spectrum of global stakeholders responded to a questionnaire delivered via virtual interviews. Participants included scientific experts, deep-seabed mining contractors, representatives from other industries, ISA member country representatives, other policymakers, members of the Legal and Technical Commission, the ISA Secretariat, and representatives of civil society organizations with a demonstrated interest in seabed mining issues. Of the 59 global experts contacted for an interview, 42 participated, three declined and 14 did not respond. Twenty-eight respondents had primarily scientific or environmental management expertise, 14 had primarily legal or other nonscientific areas of expertise, and many were multidisciplinary. Best efforts were made to ensure geographic representation.

Overall, the study showed that the scientific knowl-



Current level of scientific knowledge in relation to evidence-based environmental management of deep-seabed mining in regions where exploration contracts have been granted by the ISA. This has been compiled from a synthesis of the peer-reviewed literature and expert opinion, and includes both target and nontarget areas within each region (denotes benthic and pelagic habitats).*

edge needed to enable evidence-based management exists for only two of the 180 scientific categories assessed. Among the stakeholders consulted, most respondents (88 percent) concurred that deep-sea scientific knowledge is currently too sparse to minimize environmental risks and ensure the protection of the marine environment in the face of large-scale, deep-seabed mining.

The remaining respondents did not express an opinion on the matter (7 percent) or advocated that despite the high levels of uncertainty, decisions could still be made (5 percent). Many respondents primarily focused on polymetallic nodules, specifically the Clarion-Clipperton Zone (CCZ), given that this may be the first resource and region to be exploited in ABNJ. The most cited scientific gap was comprehensive environmental baseline information for the regions where deep-seabed mining may occur (71 percent of respondents). Many stakeholders said they were unsure how long it would take to close these knowledge gaps. The majority of those who answered that question said it would take six to more than 20 years to build the scientific knowledge needed to properly protect the marine environment from mining.

Scientific Gaps of Environmental Baseline Information

Polymetallic Nodules. Polymetallic nodules are found on abyssal plains at depths of 3,000 to 6,500 m and over a global area spanning 38 million km². Most of the mining exploration contracts for nodules have been awarded in the CCZ, with other contracts awarded in the Central Indian Ocean Basin (CIOB) and West Pacific Ocean. Although baseline understanding of the CCZ is relatively more advanced than in the CIOB and West Pacific, the relevant literature suggests that all nodule regions require further sampling to gather enough baseline information to enable evidence-based management.

The CCZ is arguably one of the most studied mining regions of the deep sea; however, considerable gaps remain, as approximately 70 to 90 percent of species collected from the region are new to science (and include new genera), and species-richness estimators predict a further 25 to 75 percent of total species remain to be collected at sites already sampled. At all sizes, species collected are diverse and dominated by rarity, with most macrofaunal and meiofaunal species only collected once or twice, making it difficult to draw sound conclusions on species abundance, diversity, ranges, relationships with other species, contribution to overall ecosystem function, and vulnerability to and recovery from deep-sea mining. In addition, many CCZ species appear to only occur within ranges up to 200 km, which may make them more vulnerable to threats, especially given the size and scale of impacts from a single nodule mining operation.

Polymetallic Sulfides. Polymetallic sulfide deposits are produced at active vents and are retained at inactive or extinct vents after hydrothermal activity ceases temporarily or permanently, respectively. Most vents and associated deposits can be found near midocean ridges and back-arc basins at depths from 1,000 to 4,000 m. Areas of potential polymetallic sulfide deposits are estimated to cover 3.2 million km² globally, with 58 percent of the known sulfides in ABNJ. Mining exploration contracts targeting sulfides in ABNJ have been granted in the Atlantic and Indian Oceans.

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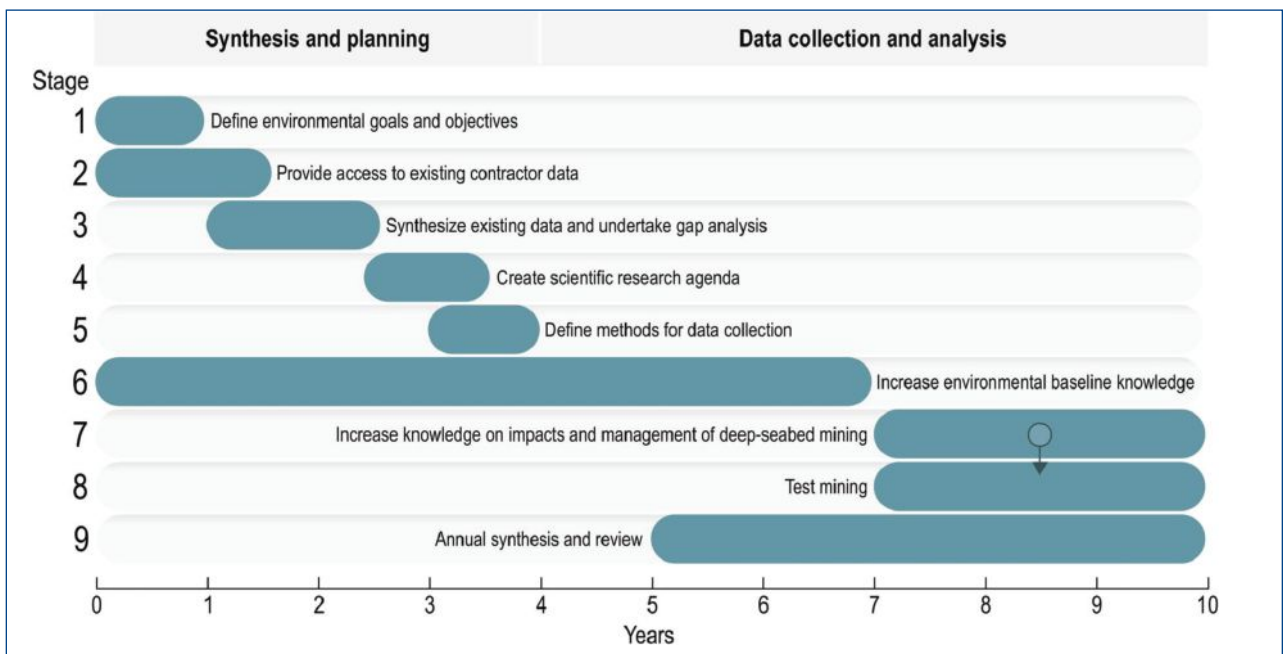


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A proposed roadmap for closing key scientific gaps related to deep-seabed mining. This roadmap is applicable to any resource (polymetallic nodules, polymetallic sulfides, cobalt-rich ferromanganese crusts) in any relevant region (Clarion-Clipperton Zone, Central Indian Ocean Basin, West Pacific, Mid-Atlantic Ridge, Indian Ocean Ridges, West Pacific Prime Crust Zone, South Atlantic Rio Grande Rise). It is broadly anticipated that a decade (or more) could apply to each resource in each region. Regions with more scientific knowledge than others (e.g., the Clarion-Clipperton Zone) may require less time. This process can occur concurrently for each resource in each region, shortening the potential multidecadal time frame, although this will depend on resources available.

Inactive polymetallic sulfides are the sulfide deposits most likely to be mined. This is because mining an active vent is technologically more challenging, with high temperatures (350° C) and acidic fluids present. Inactive polymetallic sulfides are suggested to be more abundant and larger than active polymetallic sulfide deposits.

There have also been increasing calls for the global protection of active vents. Despite the possibility of inactive vents being the first polymetallic sulfide deposits mined, there have been few published studies characterizing inactive polymetallic sulfide ecosystems, with most studies reporting anecdotal evidence. As such, inactive polymetallic sulfides have one of the highest knowledge deficiencies of any of the deep-seabed mining resources for environmental baseline categories. This paucity of information is not only because research emphasis has been focused on active vents and their unique characteristics, but also because inactive polymetallic sulfides are difficult to find; they do not emit a hydrothermal plume and associated chemical signals, which are the primary means for discovering new vents.

Greater research emphasis on active vents has led to a doubling of known active vent fields over the last decade; yet current estimates project that two-thirds or more of all hydrothermal vent fields are still waiting to be discovered. Most species inhabiting active vents, especially those of small size classes, remain poorly understood. Significant knowledge gaps remain for many of the baseline categories assessed, such as variability, connectivity and ecosystem functions and services.

From a scientific perspective, active hydrothermal vents are unique ecosystems and meet multiple criteria for vulnerability, sensitivity and ecological or biological significance, and classify as vulnerable marine ecosystems in need of protection. Active hydrothermal vents exhibit high biomass of a few dominant species, species rarity (many species comprise less than 5 percent of total abundance in samples), and high endemism, with about 70 percent of mega- and macrofaunal species endemic to vents and/or symbiotrophic. Active vents may provide a source of minerals, but also provide substrate and shelter to deep-sea biodiversity, which can translate into provisioning services (e.g., pharmaceuticals and biomaterials), as well as regulating services (e.g., the global cycling of carbon, minerals and nutrients, contributions to surface primary productivity).

Cobalt-Rich Ferromanganese Crusts. Cobalt-rich ferromanganese crusts with sufficient mineral content to be of interest to commercial mining occur between 800 and 2,500 m on seamounts and occupy 1.7 million km², with 46 percent of known crusts found in ABNJ. Exploration contracts have been granted by the ISA in the South Atlantic and West Pacific Oceans. These are the least explored of all three resource types targeted for mining, with only 0.4 to 4 percent (or 200 to 300 globally) of total large seamounts (more than 1,000 m in height) directly sampled for scientific purposes globally. For cobalt-rich seamounts in targeted regions, baseline conditions are not yet even partially characterized.

Seamounts (like active vents) often support productive hotspots of biodiversity and are considered vulnerable marine ecosystems (VMEs) subject to special protection from fishing activities. Most of the seamounts and ridges in the South Atlantic and West Pacific have not been taxonomically or ecologically characterized. Uncertainty remains regarding differences between fauna associated with crusts and similar non-crust areas, the rarity of inhabiting species, what pelagic fauna are present, and whether chemical components of the crusts are dominant drivers of benthic assemblage.

Scientific Gaps of the Impacts of Seabed Mining

Serious concerns have been raised over the potential environmental impacts related to deep-seabed mining, especially given the vast number of unknowns about the relevant habitats. In lieu of actual tests at commercial scale, some knowledge has been gleaned from small-scale, low-intensity experiments in nodule regions only. Peer-reviewed studies of small-scale mining tests that include details of environmental assessment do not exist for sulfides or crusts, and thus most of the potential impacts and effects have been extrapolated from other extractive activities, such as fishing, and natural events. Due to limited or no data across all three resources, the impacts and associated effects of deep-seabed mining have not been directly evaluated, although ecosystem characteristics provide important insights into likely sensitivities to mining disturbance. Overall, scientific knowledge gaps of the impacts of seabed mining remain significant.

Based on current mining techniques, it is generally expected that they will produce environmental impacts in five categories: removal of the resources together with the biologically active benthic zone, i.e., fauna and seafloor surface; generation of sediment plumes created from the disturbance on the seafloor, as well as from the return water that may cloud the water column or smother/blanket unmined seafloor areas; chemical release (including metals) and changes to water properties; increases in noise, vibration and light; and cumulative impacts. The resulting environmental effects may include loss of seafloor integrity, reduced biogeochemical process rates and biodiversity, as well as species displacement, and, in turn, modified trophic interactions and loss of connectivity, which could lead to species extinctions and loss of ecosystem functions and services. There may also be conflicts with existing activities; for example, the fishing industry could see reduced fisheries catch, displacement of fishing effort and/or spatial concentration of fishing effort, promoting depletion of background areas.

The impact category that is best understood (relatively) is that of removing the resources together with biologically active benthic zone. Studies in the CCZ and Peru Basin have shown that after small-scale, mining-type disturbance (nodule removal), reduced faunal biodiversity and altered species composition and ecosystem functions remain over two to four decades later. This could lead to an irreversible change, decline or loss in key ecosystem functions, such as nutrient and carbon cycling, habitat provision, maintenance of population connectivity and

regulation of food webs, especially in directly disturbed areas, and lead to local extinctions of species reliant on nodules.

Closing the Scientific Gaps: A Proposed Roadmap

Deep-seabed mining, if it moves forward, will be a new industry in a relatively unexplored part of the planet. The literature review and stakeholder survey described in this study reflect a host of scientific knowledge gaps that must be addressed as a precursor to effective management in accordance with the environmental obligations set forth in UNCLOS. It also makes it clear that it would be impossible for all necessary scientific gaps to be addressed by July 2023. Even the most well-studied habitats of the deep ocean are still characterized by a paucity of information concerning the ecology and connectivity of deep-sea species and ecosystems, their roles in the provision of ecosystem functions and services, as well as the scope and scale of mining's potential impacts. Given that deep-sea scientific research is challenging as well as time and resource-intensive, closing these gaps is likely to require substantial time and a capacity-intensive, coordinated scientific effort.

Recognizing the scope of investigation still required, collaboration, under the direction of strategic and regional environmental goals and objectives, will be needed. As a result, we have proposed a potential roadmap for closing the key scientific gaps related to deep-seabed mining in ABNJ. This roadmap, illustrated in this article, offers nine stages for ameliorating identified knowledge gaps related to deep-seabed mining under timelines based on estimates from survey respondents. These timelines will be influenced by capacity and resources invested in the relevant research, including by contractor contributions to regional research initiatives.

The proposed roadmap seeks to identify, compile and enable, in the most expedited manner possible, the scientific understanding that most experts have deemed to be essential for evidence-based decision making. It also assumes that a precautionary approach will be applied throughout, which is in alignment with the ISA's environmental obligations.

Acknowledgments

This work was supported with funding from The Pew Charitable Trusts.

For a more detailed version of the study, see "Assessment of scientific gaps related to the effective environmental management of deep-seabed mining" in *Marine Policy* at: <https://tinyurl.com/6tcjntza>.

References

For a list of references, contact Diva Amon at: divaamon@gmail.com. **ST**

Divia J. Amon works at the nonprofit SpeSeas in Trinidad and Tobago.

Peter Edwards and Chris Pickens work at The Pew Charitable Trusts.

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Argeo Buys Another HUGIN

The Norwegian subsea survey and inspection company Argeo AS has acquired another of Kongsberg Maritime's HUGIN AUVs. Depth-rated to 6,000 m, the HUGIN AUV uses cutting-edge battery technology to enable survey mission durations of up to 50 hr. at a speed of 4 kt. Capable of being launched and recovered either from shore or a ship of opportunity, it can map an area of 120 km² per dive using the combined survey functionalities of a HISAS1032 and EM2040. The HUGIN AUV is also compatible with third-party sensor integrations.

Green Credit Guarantee for Furetank

As the first shipping company in Sweden, Furetank has been granted a green credit guarantee by the Swedish Export Credit Agency for financing a vessel of top-class environmental and climate standard. The approval is pioneering for shipping, enabling vast investments in the green technology required to achieve European climate goals.

This is the first time a green credit guarantee has been granted to the shipping industry and only the second time that the Swedish Export Credit Agency grants this guarantee overall. The possibility was introduced in 2021 to enable critical investments in sustainable industry.

AiP for PCO2 Tank System

DNV has given Knutsen NYK Carbon Carriers (KNCC) an approval in principle (AiP) for its new PCO₂ tank system for the transportation of liquefied CO₂ (LCO₂). KNCC is a new joint venture company established by the Knutsen Group and the NYK Group to provide CO₂ transportation and storage solutions.

Many of the world's decarbonization goals can only be met through use of carbon capture and storage (CCS) technologies. But to make a meaningful impact on the climate challenge, all of the CCS chain must be deployed and then scaled rapidly. Transport of CO₂ is an essential part of this chain, and shipping will be a vital part of this emerging industry.

Banning Russian Seafood

With the crisis unfolding in Ukraine, almost every sector of the global economy has pushed economic sanctions on Russia, and seafood is no exception. In the U.S., President Biden issued an executive order in March 2022 banning the import of Russian seafood and other goods. To enforce this ban, traceability of seafood and transparency of fishing are needed to ensure that the ban is truly effective so Russian seafood does not slip through regulatory loopholes.

The Seafood Import Monitoring Program (SIMP) requires seafood at risk of illegal, unreported and unregulated (IUU) fishing and seafood fraud to have catch documentation and traceability to the point of import. This program currently only applies to 13 species groups, amounting to about 40 percent of the seafood imported

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into the U.S. Russia can easily evade the ban due to the lack of seafood traceability requirements, according to Oceana.

Ship Recycling Trends

With an increasing global demand for shipping, ship recycling volume in 2021 did not grow as expected and was at 24.3 million deadweight tonnage (dwt). The numbers are expected to be about the same in 2022, according to the Asian Shipowners' Association.

However, according to Clarksons Research, the projection for 2023 is 45.5 million dwt due to the impact of more stringent environmental regulations and wider "green" pressure, which will lead to the recycling of many aging ships.

White Paper on Vessel Reporting, Data Quality

Industry working group Impact Today has released its new "Vessel Reporting and Data Quality" white paper, which calls for the maritime sector to create a new data standard aimed at evolving noon reports into holistic vessel reports to support vessel and voyage optimization, thus propelling industry decarbonization.

The white paper follows Impact Today's earlier efforts to create a methodology for assessing fuel performance model accuracy within shipping. These models, like the data fed into them, ensure that optimization decisions are based on the reality that a vessel faces while sailing at sea in a range of speeds and conditions.

Sea Machines Robotics Joins One Sea

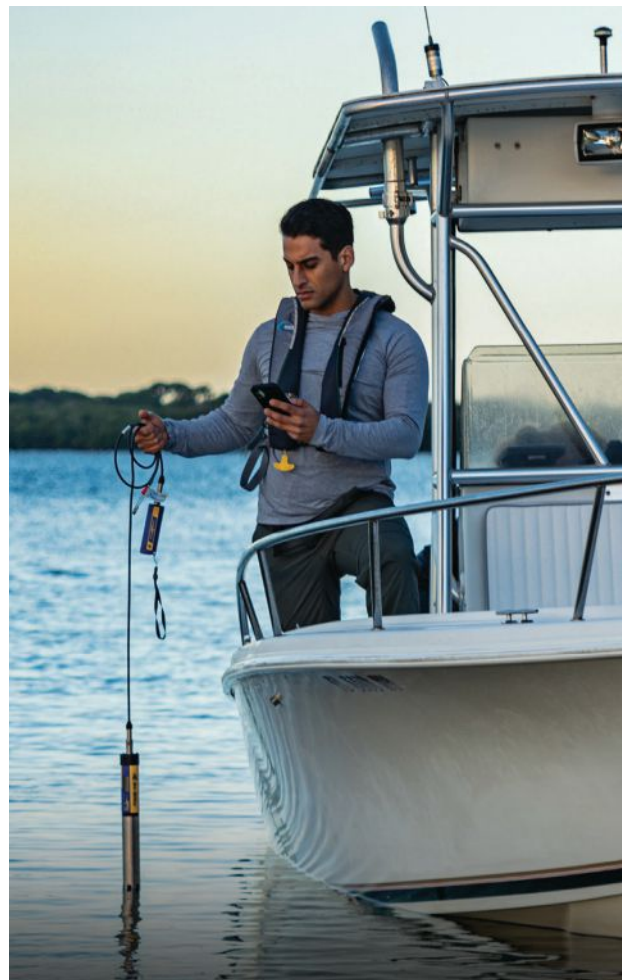
One Sea, aiming toward an operating autonomous maritime ecosystem by 2025, has welcomed Sea Machines Robotics as its latest recruit and management board member. Sea Machines Robotics is a developer of autonomous command, control and advanced perception systems for vessels. Based in Boston, with an international office network, Sea Machines operates one of the most active fleets testing autonomous ship technologies worldwide.

Equinor's Energy Transition Plan

Equinor has published its first energy transition plan, which provides an overview of how the company is progressing toward its 2050 net-zero ambition through short-term actions and medium-term ambitions. Equinor also proposes to amend its object clause by eliminating the sole focus on petroleum and introducing the wording of "energy," which is in line with the current strategy and the company's ambition to deliver energy that has lower, and eventually net-zero, emissions. Equinor's strategy is to continue to create long-term value while supplying reliable energy with progressively lower emissions. The plan is informed by climate science and scenarios from the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC).

Marine Propeller Market Will Reach \$8.52 Billion

A report by Allied Market Research states that the global marine propeller market amounted to \$5.07 bil-



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lion in 2020 and is estimated to total \$8.52 billion by 2030, growing at a CAGR of 5.5 percent from 2021 to 2030. A rise in adoption of electric application technology, a surge in shipbuilding and repair activities, and an increase in demand for maritime travel and tourism will boost the growth of the market.

While high maintenance costs and the advent of strict environmental regulations will limit market growth, marine technological innovations and increased naval expenditure worldwide are expected to open new market opportunities.

Woolpert to Open in New Location

Woolpert is combining its staff from two Hampton Roads offices and will open a new location in Virginia Beach. The move will strengthen the firm's expanding public and private architecture, engineering and geospatial projects and initiatives throughout Virginia.

Caterpillar Marine Expands Power Delivery

Caterpillar Marine has expanded delivery of advanced propulsion and power solutions. The company will leverage deep hybrid and electric expertise from across its enterprise, selectively incorporating technology from machine and off-highway products to further expand Caterpillar Marine's capabilities for delivering advanced hybrid and electric power systems that help minimize customers' fuel usage, environmental impact and total cost of ownership.

Slocum Gliders for OceanPact

Teledyne Marine has delivered three Teledyne Webb Slocum G3 Gliders to OceanPact, located in Rio de Janeiro, Brazil. OceanPact offers services for the study, protection, monitoring and sustainable use of the sea, coast and marine resources for clients from various sectors, including offshore energy, mining, telecommunications, ports, navigation, tourism, fishing and aquaculture.

Canada's 2030 Emissions Reduction Plan

The government of Canada has released the 2030 Emissions Reduction Plan, which outlines a sector-by-sector path to reach the emissions reduction target of 40 percent below 2005 levels by 2030 and net-zero emissions by 2050.

The plan includes a projected contribution from the oil and gas sector of emission reductions to 31 percent below 2005 levels in 2030, or to 42 percent below 2019 levels. The plan also includes developing a carbon capture, utilization and storage (CCUS) strategy; funding to support achieving the broad emission reductions targets; and supporting renewable energies.

Chevron to Join Decarbonization Group

Chevron has agreed to join the Global Centre for Maritime Decarbonisation (GCMD). Chevron will help support GCMD's efforts to develop potentially scalable lower carbon technologies, including those that enable the use of ammonia as a maritime fuel, and the commercial means to enable their adoption. **ST**

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New Offshore Wind Port In Brooklyn, New York

Equinor and bp have agreed to turn the storied South Brooklyn Marine Terminal (SBMT) complex in Brooklyn, New York, into a major regional hub for offshore wind.

Under the agreement, the terminal will transform into a world-class offshore wind port capable of staging and assembling the largest, most sophisticated offshore wind technology components for the Empire Wind and Beacon Wind projects and for the growing U.S. offshore industry on the East Coast.

The agreement was co-signed by terminal operator Sustainable South Brooklyn Marine Terminal and New York City Economic Development Corp.

The offshore wind projects on the U.S. East Coast are key building blocks to accelerate profitable growth in renewables and Equinor's ambition to install 12 to 16 GW of renewables capacity by 2030.

Equinor and bp will create an operations and maintenance (O&M) hub and staging area at SBMT, with a total investment of \$200 million to \$250 million in infrastructure upgrades, while also pursuing the development of SBMT as a low-emissions facility. The port will become a cutting-edge staging facility for Equinor and bp's Empire Wind and Beacon Wind projects that will supply 3.3 GW of energy—enough to power nearly 2 million New York homes—as well as become a go-to destination for future offshore wind projects in the region. Equinor and bp's activities at SBMT are anticipated to support over 1,000 jobs annually in the region. At approximately 73.1 acres, SBMT will be one of the largest dedicated offshore wind port facilities in the U.S.

Trial for AI to Optimize Hydrogen Production, Storage

Funding has been awarded to trial real-time usage of artificial intelligence (AI) software to optimize hydrogen production and storage at the European Marine Energy Cen-

tre (EMEC) in Orkney, Scotland. The HyAI 2.0 project aims to trial the use of an AI platform called HyAI by integrating the system into EMEC's hydrogen plant on the island of Eday, Orkney. HyAI is an AI-powered hydrogen management platform developed by project lead H2GO Power, innovators of hydrogen-based solutions for renewable energy storage. The cloud-based software uses machine learning and optimization algorithms to make intelligent, data-driven decisions to ensure system safety and reliability and identify the most cost-effective times for hydrogen generation and storage.

The 12-month project will trial the software in two phases. The first phase involves running proof-of-value simulations with the AI software using data from commercial use cases provided by project partners EMEC and National Grid Gas Transmission. In the second phase, the platform will be integrated into EMEC's hydrogen production plant on Eday and tested as a fully integrated pilot.

The HyAI system aims to control hydrogen production in real time by combining historical and forecasted data on weather, renewable energy (e.g., wind and tidal), hydrogen storage capacity and electricity prices. Tests will progress from advisory to semiautonomous control.

3D Biomass Assessment In Block Island Wind Farm

NOAA's Northeast Fisheries Science Center has successfully tested iXblue's SeapiX 3D volume sonar in the Block Island wind farm off the coast of Rhode Island. The objective of the evaluation was to observe and monitor the pelagic ecosystem, often overshadowed by the demersal and benthic communities in wind farm areas.

Marine renewable energy installations require specific biomass assessment surveys to qualify impact. Active acoustic technologies such as the SeapiX 3D volume sonar can survey large areas quickly and effi-

ciently to map spatiotemporal distributions and estimate abundance and biomass.

Transocean, Ocean Minerals To Mine Polymetallic Nodules

Transocean Ltd. has purchased a minority interest in Ocean Minerals Ltd., a company engaged in the exploration of seabed resources containing metals critical to the growing renewable energy market.

Ocean Minerals, through its affiliate, Moana Minerals Ltd., has been awarded a license by the Cook Islands Seabed Minerals Authority for exploration of polymetallic nodules within the application area located in the Cook Islands Exclusive Economic Zone.

Critical minerals such as cobalt, nickel, copper, manganese and rare earth metals found in the nodules are essential for the production of high-capacity batteries. Transocean is working with Ocean Minerals on the technology and services that will be required to collect nodules from the seabed upon receipt of a production license.

The Cook Islands is one of several offshore locations worldwide with large, accessible deposits of nodules containing a high content of these critical minerals. Responsible recovery of the nodules would provide additional supply to support growing demand.

NextGeo Completes Offshore Wind Route Surveys

In support of TenneT TSO B.V. and the Dutch government's program to increase offshore wind capacity by 2030, NextGeo has successfully completed the final reporting phase of offshore route survey activities (non-UXO) for a project covering the Hollandse Kust West Beta; Ten Noorden van de Waddeneilanden; and IJmuiden Ver Alpha, Beta and Gamma export cable routes. The routes extend from the beach to the offshore platform area. More than 37,000 hectares of survey data have been acquired using geophysical and geotechnical techniques, six offshore vessels, six nearshore vessels and three tidal vessels. **ST**

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Oyster Aquaculture Could Improve Potomac River Estuary
Oyster aquaculture in the Potomac River estuary could result in significant improvements to water quality, according to a new NOAA and U.S. Geological Survey study published in *Aquatic Geochemistry*. All of the nitrogen currently polluting the Potomac River estuary could be removed if 40 percent of its oysters were used for shellfish cultivation, according to the joint study. [2-23-SeaTech.com](#)

Navy's Laser Weapon Ready For Summer Deployment
Navy engineers are making final adjustments to a laser weapon prototype that will be the first of its kind to deploy aboard a ship late this summer. The prototype, an improved version of the laser weapon system, will be installed on the USS Ponce for a test in the Persian Gulf. Navy leaders have made directed-energy weapons a top priority to counter what they call asymmetric threats. The system is expected to be ready for deployment in summer. [2-23-SeaTech.com](#)

Ferry Sinks Off Coast of South Korea
With 462 passengers onboard, a ferry sailing from Incheon, South Korea, to the island Jeju sank near the southern tip of South Korea Wednesday, according to the Korea Coast Guard. Most of the more than 100 people on the ship were high school students. The ferry sank in the morning. [2-23-SeaTech.com](#)

Pay Increase for Sailors Soon to Come
Sailors serving on the U.S. Navy could see a pay raise in the coming weeks, reported the Virginia Pilot. On May 1, sailors serving aboard ships will receive a pay raise. The increase in pay comes as an effort by the Navy to recruit and retain sailors. [2-23-SeaTech.com](#)

US Senate Reviews US Budget Request
For fiscal year 2015, the Department of Energy requested \$20.8 billion. The U.S. Senate Appropriations Committee, Subcommittee on Energy and Water Development, held a hearing last week to review the funding request and discuss financial priorities. According to Lamar Alexander (R-Tenn.), research should be a focus of spending. [2-23-SeaTech.com](#)

US Technology Helps in Search for Flight 370
More than a month after Malaysia Airlines Flight 370 went missing, crews are hard at work trying to uncover what happened to the plane's black box, which houses records from the flight, provides a lead to the location of the plane, and might help investigators determine the cause of the crash. [2-23-SeaTech.com](#)

2014 Sea Technology Buyers Guide Now Available
Published annually by Compass Publications, the 2014 edition of the *Sea Technology Buyers Guide* is now available. The Buyers Guide features a market analysis and sector sub-directories, including industrial firms, services, federal government organizations, educational institutions, oceanographic research vessels and specialty survey vessels. [2-23-SeaTech.com](#)

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With a glass lens, gaskets to keep water out and gore patch to eliminate fogging, this combination masthead all-round light is easy to wire for both new and retrofit installations. The light is USCG 3-nm certified. Fairweather Innovations LLC, DBA SEAVIEW.

Marine Snow Catchers

These large-volume water samplers come in sizes of 50, 100 or 300 L, in either traditional PVC or stainless steel. The separable top and bottom sections enable researchers to collect and characterize suspended and sinking particles in the water column. The particles collect in the bottom chamber, which can be removed separately for recovery and analysis of the accumulated samples. OSIL.

Ship Automation

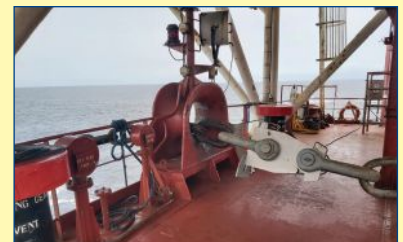
mtu NautIQ CoDirect is a wireless, remote-helm system that can control a vessel's engines, steering and transmission, and payload functions from a distance of up to 1,000 m. mtu NautIQ CoOperate is an optionally autonomous ship navigation command system that enables off-boat remote command, including all payloads, for routine and monotonous vessel tasks. mtu NautIQ CoPilot can autonomously control a planned voyage from start to finish, or guide the operator without intervening. Rolls-Royce Holdings plc and Sea Machines Robotics Inc.

Anti-Spoofing Technology

OSNMA (open service navigation message authentication) functionality has been added to mosaic

GNSS receiver modules for end-to-end authentication on Galileo's civilian signals, protecting receivers from GNSS spoofing attacks. This capability complements AIM+, Advanced Interference Mitigation, technology for assured PNT solutions and critical infrastructure, such as 5G network synchronization. Septentrio N.V.

Manual Quick Mooring Release



The significant safety risks associated with the manual emergency release of mooring systems during FPSO tandem offloading ocean towage, heading control, positioning and decommissioning are minimized with PODx (powered offshore disconnect), an innovative new automatic actuation system. PODx utilizes release bolt technology that automatically separates on demand, reliably releasing in under 100 milliseconds, for various offshore applications. Gall Thomson/Trelleborg Group.

Marine Cylinder Oil

Mobilgard 540 AC is a premium 40BN marine cylinder oil granted Category II status by MAN ES for use in Mark 9 and higher two-stroke marine engine designs. It has been formulated to deliver advanced cleanliness to meet the needs of these newer engines. ExxonMobil Corp.

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transparent backgrounds, HTML for interactive 3D web documents, and interactive or static 3D PDF files. QuadriSpace Corp.

Carbon Measurement



MODICA (multifunctional dissolved inorganic carbon analyzer), combined with CM5017O coulometer, provides highly accurate, absolute determination of dissolved inorganic carbon. MODICA can automatically process up to 10 samples using predefined routines according to sample types. The software can read temperature and barometric pressure with optional pH channel and/or salinity probe. UIC Inc.

Remote Data Display

RD50 has been updated with software version 1.16, introducing three-axis speed indication when connected to a satellite compass. Critical for towboats, ferries and other commercial vessels, this indication simultaneously displays longitudinal speed (ahead-astern), transverse speed (port-starboard at the stern), and transverse speed

(port-starboard from a user-determined reference point). Furuno USA Inc.

Immersive Reality Training

Smart Realities is a cost-effective, easily scalable, fully immersive extended reality (XR) training and assessment solution for ship handling, bridge and marine engineering applications. It provides multi-player capability. Wärtsilä Voyage.

Portable, Remotely Operated Drill

PROD5 nearly doubles the tool load of previous systems, enabling casing to approximately 100 m below seabed when sampling and about 150 m below seabed when performing cone penetration tests. The drill enhancement package (DEP) provides a second drive head, elevator cylinder, cuttings pump and clamp set. Benthic/Acteon.

Grillage Structure Evaluation

SeaTrust-Frame3D software enables a complicated ship structure to be simply modeled by representing it as a grillage structure. The software enables the designer to conduct and analyze structural strength and rule-based buckling strength evaluations, the results of which are displayed as 3D images, tables and graphs. It can automatically generate reports based on the analysis results and offer support for CAD interfaces. Korean Register.

Combating Maritime Cybercrime

Fleet Secure Unified Threat Management (UTM) is now a standard option on the Fleet Xpress service, protecting vessel networks against cyberattacks. It is based on consolidation of multiple network security tools in a single application. Inmarsat Ltd. and Port-IT B.V.

GNSS-Aided INS

Combining navigation performance and SWaP-C, Quanta Micro leverages a survey-grade IMU for optimal heading performance in single-antenna applications and high immunity to vibrating environments. An optional secondary antenna enables fast heading initialization in low-dynamic applications. It has a quad-constellation, multi-band RTK GNSS receiver and smooth post-processing workflow with Qinertia. SBG Systems S.A.S.

Offshore Crew Change Solutions

A new service for the offshore access market combines Damen's Fast Crew Supplier (FCS) 7011 *Aqua Helix* with the S-type motion-compensated gangway system from Ampelmann. The fast and comfortable vessel can transport up to 120 people, and the height-adjustable gangway facilitates rapid crew changes to and from *Aqua Helix*, allowing it to service multiple offshore installations during its tour. OceanXpress. **ST**

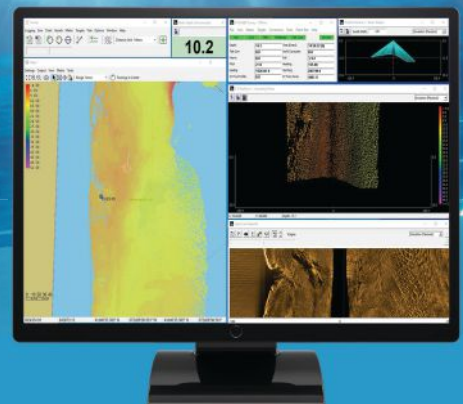
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Europe Glider Service Center

Working in partnership with Teledyne Marine, the U.K. National Oceanography Centre (NOC) has a new European Glider Service Centre at its Southampton, U.K., headquarters, which will offer an official service, support and repair facility for Teledyne Slocum Gliders.

The NOC has been equipping, servicing and operating gliders on extended scientific missions for over 15 years, as well as designing and building its own novel AUVs.

As autonomy increasingly leads the way in oceanic research, weather forecasting and naval operations, gliders are becoming an increasingly popular platform for sensor deployment because of their range, duration and low cost. This is leading to an increase in the size of the European fleet and, with it, increased demand for glider servicing

(including sensor calibration, pressure testing and ballasting), piloting and training, all of which can be done at the NOC.

The NOC can also perform CTD and many Wetlab sensor calibrations in house to dramatically improve lead times and reduce the risk to sensors caused by additional transport and handling.

Two hyperbaric pressure testing tanks are available to the Glider Service Centre for testing down to 6,000-m-water-depth equivalent to ensure a payload bay is properly tested prior to deployment.

Technical Report on Batteries For Primary Propulsion

The use of batteries as a main source of propulsion power for inland and coastal ships has passed a significant milestone with Foreship's delivery of its Ship Applicability

Type Technical Report to partners of the EU-funded research and innovation Current Direct project.

The naval architecture and marine engineering firm is developing specifications and requirements for the waterborne system and optimized ship design for the project, whose 13 partners aim initially to demonstrate and commercialize a swappable "e-house" containing one or more batteries to power inland vessels. A second study for the project, covering coastal ships' applicability, is under consideration.

The Horizon 2020 Current Direct project has estimated that the use of swappable batteries and energy-as-service platform could cut as much as 482,000 metric tonnes of CO₂ equivalents from water transport emissions in Europe each year. With the average age of vessels operating on the Rhine standing at 50 years, the new Foreship analysis identifies a market size of up to 6,000 inland vessels as eligible for



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a battery-power electric solution. Foreship is developing a framework for standardized interfaces to support the mechanical and electrical infrastructure that will be needed to enable such ambitions. This part of the Current Direct project was cited as providing the basis for guidelines covering interfaces for both swappable and fixed battery containers under development by the Maritime Battery Forum.

Foreship was also instrumental in the core development of the Current Direct Voyage Energy Planner Tool, which provides vessel owners with a battery-swapping energy plan for inland waterway vessels based on a limited number of vessel and journey parameters.

The EU is considering a marine tax on residual fuel oil from 2023.

Trials for S-100 Navigation Data for Autonomous Vessels

The UK Hydrographic Office (UKHO) is the provider of S-100 navigation data for the Mayflower Autonomous Ship (MAS) project. This marks the first time that S-100 data are being tested aboard an unmanned or autonomous marine vessel. The MAS has been in Plymouth Sound in the U.K., undergoing an at-sea trial to test the ability of the ship to read, integrate and use S-100 data.

The UKHO is funding the integration and testing of S-100 Universal Hydrographic Model data into the artificial intelligence (AI) and machine learning (ML) software stack for the MAS project. The UKHO's S-100 data is designed to be machine readable and higher resolution than S-57 electronic chart data, which MAS previously relied on to inform the onboard mission manager.

S-100 data will be the future standard supporting digital navigation products globally. This project will provide feedback on the utility of the S-100 data and format, identify gaps in the data and method of deployment and integration, and provide real-world operational testing to inform future deployments of S-100 data for other manned and unmanned vessel operators.

Wärtsilä Invests in Japan's Digital, Autonomy Market

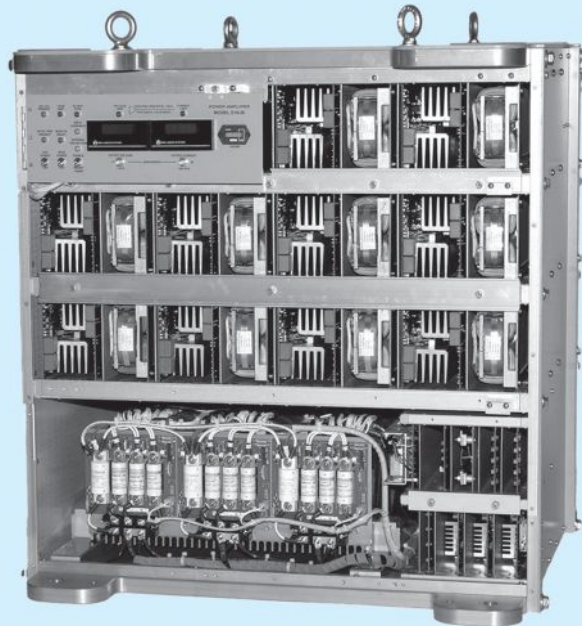
Wärtsilä Voyage has completed an investment in Marindows, a Japanese company delivering an open digital platform for Japan's marine industry. Founded in March 2021, Marindows focuses on the development of a marine digital platform, linking edge computing on ships with cloud services and shore-based applications.

Marindows and Wärtsilä Voyage share a vision of digitalization as a means to accelerating decarbonization and efficiency in the global marine industry.

Their collaboration will include vessel optimization and autonomy by leveraging a digital ecosystem of applications that run on board and ashore. Safer, greener and more efficient operations will be among the benefits. **ST**

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How Underwater Noise Pollution Affects Turtles

Underwater noise pollution can cause turtles to experience hearing loss that can last from minutes to days, according to new research.

Activities such as shipping and construction create a lot of noise in both fresh and saltwater environments. Previous studies have focused on the effects of noise in a range of animals, from squids to fishes to whales, but less work has been done on reptiles, such as turtles, said Andria Salas, a researcher at Woods Hole Oceanographic Institution.

"Our preliminary findings are the first to support that these animals are vulnerable to underwater hearing loss after exposure to intense noise," Salas said. "We have assumed that turtles experience hearing loss when exposed to sufficiently intense sounds as observed in other animals, but there hasn't been any data collected specifically on turtles."

Hearing is essential for turtles to communicate and avoid predators. The new findings could have implications for the conservation of some threatened turtle species.

"Over half of turtle and tortoise species are threatened, and noise pollution is an additional stressor to consider as we work towards protecting these animals," Salas said.

Salas and her colleagues focused their experiments on two nonthreatened species of freshwater turtles. They used a minimally invasive electrode, inserted just under the skin above a turtle's ear, to detect very small electrical voltages created by the turtles' auditory system when they hear sounds. Before exposing the turtles to loud (high-amplitude) white noise, the researchers first determined the lower threshold of turtles' underwater hearing and which tones (frequencies) they heard best.

After exposing the turtles to noise and then removing them from the noise, the researchers kept measuring turtle hearing for about an hour

to see how they recovered their underwater hearing in the short term, and then checked two days later to see if recovery was complete. While the turtles always recovered their hearing, hearing loss could last for about 20 min. to over an hour. However, sometimes hearing had not recovered by the end of the testing hour, indicating they needed more time to fully recover from the noise exposure. The hearing of one turtle was affected for multiple days.

Hawaiian Corals Show Some Resilience to Climate Change

The longest experimental study on corals to date, a 22-month project that replicated current and future ocean conditions, suggests Hawaiian corals can remain resilient as climate change makes seawater warmer and more acidic. Led by Oregon State University postdoctoral researcher Rowan McLachlan, the study, published in *Scientific Reports*, is important because understanding the factors behind coral health is crucial to efforts to save the Earth's embattled reefs, the planet's largest and most significant structures of biological origin. Between 2014 and 2017 alone, more than 75 percent of the planet's coral reefs experienced bleaching-level heat stress, and 30 percent suffered mortality-level stress.

Coral reefs are found in less than 1 percent of the ocean but are home to nearly one-quarter of all known marine species. Reefs also help regulate the sea's carbon dioxide levels and are a potential source of new medicines.

The researchers collected samples of the three most common species of Hawaiian corals: *Montipora capitata*, *Porites compressa* and *Porites lobata*. The scientists placed the samples in four different outdoor tanks: a control tank with current ocean conditions; one with more-acidic water (-0.2 pH units); one with warmer water (+2° C); and one with warmer water that was also more acidic. Results suggest that warming oceans will harm cor-

al species: 61 percent of the coral samples exposed to the warming conditions survived, 31 percent less than those exposed to current ocean temperatures. The *Porites* species showed more resilience than *M. capitata* in the combined warming/acidification treatment, with survival rates at 71 percent for *P. compressa*, 56 percent for *P. lobata* and 46 percent for *M. capitata*.

"The results provide hope that if we can mitigate climate change and keep within the targets of the Paris Climate Agreement, coral reefs will persist in some form, albeit with reduced abundance and genotypic diversity," McLachlan said.

Partnership for UK Robotic, Autonomous Systems

The University of Plymouth and Sonardyne have agreed on a strategic partnership to drive innovation in the U.K.'s growing marine robotic and autonomous systems sector. The partnership will advance ocean data-gathering technologies and platforms by developing emerging technologies on the university's fleet of crewed and uncrewed surface and underwater platforms, all underpinned by a suite of Sonardyne's technologies.

The initial three-year collaboration will also explore funding opportunities for joint research in ocean exploration, hydrography, ropeless fishing, offshore renewable energy and defense.

DriX USV for NOAA Ocean Exploration

The University of New Hampshire's Center for Coastal and Ocean Mapping, as a member of the Ocean Exploration Cooperative Institute (OECI), funded by NOAA Ocean Exploration, has taken delivery of an iXblue DriX USV and its universal deployment system.

Selected by OECI for its endurance, high speed and offshore sea-keeping ability, DriX will conduct mapping and characterization and support other autonomous vehicles. Research using the DriX will inform NOAA on the potential use of autonomous systems to support the broad NOAA mission. **ST**

Seaweed Trial to Clean New Zealand Waters

A pioneering nationwide land-based seaweed trial aiming to clean up New Zealand's waterways is about to get growing beside the Firth of Thames in the Hauraki Gulf.

Paeroa seaweed innovation company AgriSea is working with University of Waikato on a two-year sea lettuce (*Ulva*) growing trial at Kopu marine precinct in the Coromandel.

Backed by the Ministry for Primary Industries' Sustainable Food and Fibre Futures fund, seaweed will grow for 12 months in three tanks drawing water from the Waihou Estuary, with data collation and analysis the final year.

The seaweed can be turned into high-value products, and the process of growing it has a multitude of benefits. Seaweed doesn't have root systems; it grows by pulling nitrogen from the water.

Known as "bioremediation," the project will use seaweed in an attempt to clean excess nutrients from the Waihou Estuary. The seaweed in tanks will act as a sponge and filter feed on excess minerals, such as nitrogen, phosphorous and other heavy metals, thus cleaning up the water, which then flows to the sea after being filtered.

The two-year project is a collective effort, with University of Waikato environmental research fellow Marie Magnusson leading the research team.

The locally present species of *Ulva* will be cultivated at the University of Waikato's aquaculture facility, where researchers will use DNA barcoding to confirm its genetic identity.

If this pilot proves successful, the next step is to upscale the on-land bioremedial systems in the Hauraki area.

AgriSea, in partnership with Farm Source, is already helping farmers improve soil and water quality using AgriSea's seaweed bio stimulants as an alternative to chemical fertilizers. Bio stimulants made from seaweed are high-value macroalgal

products used on dairy, sheep and beef farms, as well as in the apiculture, horticulture and viticulture industries.

Fugro Survey for NIOT

India's National Institute of Ocean Technology (NIOT) has commissioned Fugro to carry out a bathymetric survey along the Andhra Pradesh coast in southeastern India.

The six-month project started in November 2021. Fugro surveyed around 56,000 line km of coastline in total, collecting bathymetric data in water depths between the high-tide line and 30 m.

To gather insights about the seabed, Fugro's specialist team used a shallow-water boat equipped with a dual-frequency echosounder and a differential global positioning system for data acquisition. In very shallow water (up to 5 m) and the surf zone area, the Fugro team used a jet ski equipped with a differential global positioning system (DGPS) and a single-beam echosounder. Real-time kinematic positioning (RTK) technology was used for topography survey.

The survey will facilitate the Indian government's plans to develop and manage the exclusive economic zone to benefit the coastal community and protect marine living resources. The data will also be used for scientific research projects and coastal resilience studies, such as assessment of coastal vulnerabilities, geohazard potential and ocean climate change.

Remote Inspection Techniques

Bureau Veritas (BV) can now provide owners and operators with new ways to survey their ships through remote inspection techniques (RIT) conducted by BV's own surveyors in France.

BV's key objective with the use of RIT is to limit the use of costly and dangerous means of access by replacing them with safer and more efficient technologies during the structural inspection of a hull.

RIT provides additional value to shipowners and operators by supporting the optimization of survey time, facilitating the preparation and planning of drydock repairs, and saving costs.

BV has invested in aerial drones and the training of BV surveyors to operate those drones. The first surveys with aerial drones operated by BV surveyors took place earlier this year, on a cable-laying ship and a container ship, for renewal and intermediate surveys.

Caterpillar Invests in Methanol Engine Tech

Caterpillar is working on additional development of alternative fuels with an investment in methanol engine technologies.

This commitment supports the development of decarbonization efforts in the marine industry by offering cost-effective methanol-powered solutions.

Caterpillar Marine's products are being designed to be upgradeable for future methanol utilization to further enable the energy transition.

Ammonia 2-4 Project

A consortium of shipping stakeholders aims to develop demonstrators for two-stroke and four-stroke marine engines running on ammonia fuel as part of the Ammonia 2-4 project to advance viable concepts for ammonia fuel.

The project is coordinated by technology group Wärtsilä, with participation from naval architects C-Job, classification society DNV, shipowner MSC and the National Research Council (CNR) of Italy. It has secured funding of €10 million from the European Union through the Horizon Europe research funding initiative.

The outcomes of the project will include a lab-based demonstrator for the four-stroke ammonia engine and a lab-based test engine, followed by a vessel retrofit, for the two-stroke version by 2025.

The Ammonia 2-4 project will further develop concepts around fuel handling and safety, as well as contributing inputs toward a regulatory framework for ammonia. **ST**

contracts

Singapore Shipping Association, Singapore, has signed a partnership agreement to support industry decarbonization, such as green corridors and pilot programs, to help accelerate the adoption of low- or zero-carbon solutions. Global Centre for Maritime Decarbonisation.

FuelTrust, Houston, Texas, has signed a memorandum of understanding for its fuels and emissions digital technology to validate vessels for the Green Ship scheme and collaborate on further projects to incentivize and enable emissions reductions. Isle of Man Ship Registry.

National Marine Electronics Association, Severna Park, Maryland, has been awarded contracts to train personnel on installation of marine electronics. U.S. Coast Guard and Canadian Coast Guard.

Great Lakes Dredge & Dock Corp., Houston, Texas, has signed an agreement to provide funding and technical support for what will become the Great Lakes Dredge & Dock Laboratory of Dredging and Coastal Studies. College of Engineering at Texas A&M University.

Kames, Oban, U.K., operating in the lochs and estuaries round the Western Isles in the Scottish Sea, has taken delivery of the Damen LUV 2208 to improve waterborne operations at its steelhead trout farm. Damen.

Antisink, Kristiansand, Norway, has chosen lightweight and durable gas cylinders to be integrated into its self-inflating buoyancy bag to keep a boat afloat for weeks to help prevent shipwrecks and save lives at sea. Luxfer.

Norwegian Ministry of Climate and Environment, Oslo, Norway, has awarded a contract to develop a roadmap for the introduction of sustainable zero-carbon fuels across the Nordic region. The Nordic Roadmap aims to accelerate the transition to zero-carbon fuels by

reducing the key barriers to their uptake and creating a platform for cooperation across the region. DNV and partners.

The Korean Register, Busan, South Korea, has signed a memorandum of understanding to jointly research the development of maritime autonomous surface ships technology. Daewoo Shipbuilding & Marine Engineering Co. Ltd. **ST**

meetings

Note: The coronavirus (COVID-19) pandemic could affect event dates. Check event websites for the latest updates.

JULY

July 3-8—International Coral Reef Symposium, Bremen, Germany. www.icrs2022.de.

July 20-21—Advanced Machinery Technology Symposium, Philadelphia, Pennsylvania. www.navalengineers.org/AMTS2022.

AUGUST

August 23-24—CLEAN PACIFIC, Renton, Washington. www.cleanpacific.org.

SEPTEMBER

September 6-9—SMM, Hamburg, Germany. www.smm-hamburg.com/en.

September 13-14—Antifouling Conference, Gothenburg, Sweden. <https://innovatum.confetti.events/antifouling-conference-2022>.

September 18-23—International Marine Debris Conference, Busan, South Korea. www.7imdc.org.

September 19-22—Moored Systems for the Future Buoy Workshop, Wilmington, North Carolina. <https://mtsociety.memberclicks.net/buoy-workshop>.

September 20-22—Fleet Maintenance & Modernization Symposium, Virginia Beach, Virginia.

703-836-6727 or www.navalengineers.org/Symposia/FMMS2022.

September 26-29—SNAME Maritime Convention, Houston, Texas. www.sname.org/smc-2022-general-information.

OCTOBER

October 3-7—National Marine Electronics Association (NMEA) Conference, Anaheim, California. 410-975-9425 or www.nmea.org.

October 9-12—Maritime Cyprus, Limassol, Cyprus. <https://maritimecyprus.dms.gov.cy>.

October 16-19—AAPA Annual Convention & Expo, Orlando, Florida. <https://my.aapa-ports.org/AC2022/Home/AC2022/Home.aspx>.

October 17-18—Sustainable Ocean Summit, Barcelona, Spain. www.sustainableoceansummit.org.

October 17-21—OCEANS 2022 Hampton Roads, Hampton Roads, Virginia. hamptonroads22.oceansconference.org.

October 18-20—International Ocean Conference on Ocean Energy and Ocean Energy Europe, Donostia/San Sebastián, Spain. <https://icoeoe2022donostia.org>.

October 18-21—EURONAVAL, Paris-Le Bourget, France. euronaval.fr.

NOVEMBER

November 2-4—MAST Med 2022, Athens, Greece. <https://mastconfex.com>.

November 8-10—CLEAN GULF, New Orleans, Louisiana. www.cleangulf.org.

November 17—Deepwater Executive Summit, Houston, Texas. <https://deepwaterexecsummit.com>.

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

people

Washington Maritime Blue has expanded its Joint Innovation Project team with the addition of **Cassidy Fisher**. She will be responsible for supporting members and partner organizations in the development and project management of key demonstration projects through a collaborative and whole systems design process. She has a degree in mechanical engineering and has led teams of engineers on projects in the renewable biogas industry.



MacArtney has a new office in Mölnlycke, near Gothenburg, Sweden, an ideal location for interacting with renewable and defense enterprises and supporting ocean science initiatives involving industrial, academic and scientific institutions. **Emil Andersson**, who has worked for MacArtney over the last three years in global sales, will lead the sales efforts of the new office. He has a background in sonar and underwater video technology.

Echandia, a developer of battery systems for maritime electrification, expands in the Danish market through the appointment of **Morten Larsen** as head of business development in Denmark. Larsen adds technological and regulatory knowledge to the team. Denmark aims for climate neutrality in the maritime sector in 2050, with the first ocean-going zero-emission vessel in commercial operation by 2030.

AIRMAR Technology Corp., specializing in ultrasonic transducers and chirp technology, has welcomed **Anita Hatherley** as director of global operations planning and supply chain. Hatherley will work with cross-functional teams to develop strategies for continuous improvement

to supply chain and logistics execution, processes and synergies to improve customer satisfaction.

Dan Ammann, former General Motors president and CEO of Cruise autonomous vehicle company, has been appointed president of Exxon Mobil Low Carbon Solutions. Ammann replaces **Joe Blommaert**, who will retire after 35 years of service.

Kevin M. Sligh Sr. is the new director of the Bureau of Safety and Environmental Enforcement (BSEE) at the U.S. Department of the Interior, overseeing BSEE's efforts to promote safety, protect the environment and conserve offshore resources through vigorous regulatory oversight and enforcement. He previously served at FEMA, the Navy and the Coast Guard.

FarSounder has welcomed **Aaron Joseph** as a business development associate. He will work with the director of marketing and business development on customer outreach, dealer relations and industry awareness.

Berg Propulsion has opened a new office in Istanbul, responsible for new sales, contract management, product support and service. It is led by **Mustafa Müslüm**, who has been appointed general manager of Berg Propulsion Eurasia. He holds a degree in naval architecture.

Greensea has appointed **Rob Howard** as chief growth officer, a newly created role. He was previously vice president of growth and strategy for Greensea's sister company Armach Robotics.

The National Ocean Industries Association (NOIA) Board of Directors has elected **Paul Danos**, owner and CEO of Danos, as the NOIA chair and **Starlee Sykes**, senior vice president for the Gulf of Mexico and Canada for bp America Inc., as the NOIA vice chair for the 2022 to 2023 term.

ASL Environmental Sciences Inc. has appointed **Julek Chawarski** as a biological oceanographer to develop consulting services for ocean monitoring clients and new tools for hydroacoustic studies of aquatic ecosystems. **ST**

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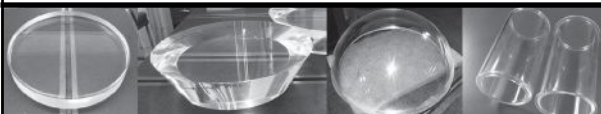
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Working with Industry to Reduce Underwater Noise Pollution—Patrick Gallagher

Patrick Gallagher is the executive director of the Marine Exchange of Puget Sound and a member of the Quiet Sound Leadership Committee. He is also



a retired Coast Guard commander, with more than 25 years of maritime experience. Gallagher is deeply committed to ocean conservation efforts, and he is intent on promoting the future of the maritime industry with conservation as a priority.

Right now, there is a small cohort of people in Washington state leveraging technology in attempt to make things right with an ancient community: the Southern Resident killer whale. Formally known as Quiet Sound, this cohort seeks to reduce underwater noise pollution and integrate vessel tracking with whale monitoring to save an endangered orca population.

Why does underwater noise pollution matter? Studies have shown that killer whales spend less time feeding and mating in the presence of transiting ships, as the sounds from the vessels interfere with the whales' ability to echolocate and communicate.

And yet noise has doubled every decade for the past 60 years. Layer this with an overall lack of salmon and increased levels of toxins in the water, and these endangered animals become increasingly at risk of population decrease, with only 74 Southern Resident killer whales populating the Salish Sea today.

What's the solution to reducing ambient vessel noise emissions? It's as simple as two words: slow down.

Although studies reveal that other factors besides speed (draft, size, loading) may influence underwater noise emissions, approximately every lessened knot of speed by large, commercial vessels leads to one less decibel of obtrusive ocean sound. Generally speaking, the

slower the speeds, the greater the killer whales' probability of effectively foraging and thriving.

Working in the Coast Guard for over 22 years, I had the privilege of experiencing killer whales first hand while underway up and down the west coast of the U.S. Consequently, I've also followed their struggle as more pressure has been placed upon marine mammals and ocean resources at large—further stoking my commitment to conservation while promoting the maritime industry. While not altogether easy, there are solutions that allow both to thrive. Industry does not have to oppose conservation.

Quiet Sound is working in tandem with our friends in Canada: the Enhancing Cetacean Habitat and Observation (ECHO) Program, who have already established a robust and proven model for successful voluntary ship traffic slowdowns.

Quiet Sound's Vessel Operations and Incentives Work Group is considering options for a voluntary vessel slowdown during peak presence of Southern Resident killer whales returning to Puget Sound, examining what is safe for vessels, practical for pilots and meaningful for whales. At the onset, stress must be placed on the words "voluntary" and "trial," as there are still many unknowns that require careful measuring and feedback within a collaborative working environment.

Instead of a blanket seasonal slowdown, another strategy to reduce noise impact is to build out a robust whale detection system using hydrophone technology to listen to underwater acoustics, send notifications automatically and verify whale sightings.

While there are several organizations that use whale sightings to inform seasonal habits, there are obvious limitations with this method, including limited night-time or inclement weather sightings and establishing the validity of the source.

To verify and model the impact of reducing transit speed, Quiet Sound can determine baseline and historical vessel speeds using automated identification system (AIS) data, which Canada's ECHO program is already doing. Integrating AIS data with hydrophone monitoring is a more targeted strategy that could provide ships and pilots better information about whale presence and how to proceed once the vessel knows its track line is in the vicinity of active whales.

Other tactics to reduce underwater noise could consider propellers, hull design and even paint. For instance, the International Maritime Organization's Sub-Committee on Ship Design and Construction recently began a new round of work to address the harmful impacts of underwater noise. All this activity is a strong indicator of the commitment the maritime community has adopted in order to conserve whale populations. Similar noise reduction programs are already being used strategically where high concentrations of vessels impact whales.

As we continue to learn more about the impact of underwater noise pollution and noise suppression policy, these programs remain voluntary. But I suspect that if we cannot manage the situation voluntarily, or if the demands on the shipping industry—which is crucial to sustaining our global economy—and the offshore wind industry—another potential underwater noise polluter—put our Southern Resident killer whale populations at further risk, then mandates to control underwater noise pollution may eventually follow.

Noise reduction alone cannot conjure a healthy, sustained population of orca whales. Continuous effort and research are necessary. With monitoring and acoustic technologies, Quiet Sound hopes to do its part for whale conservation. **ST**

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