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DECEMBER 2020

**Diving, Underwater
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FEATURING:

The Law of More

Accelerating Hydrographic Survey

Hadal Imaging





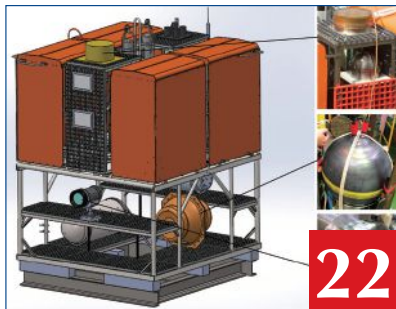
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Mariscope Diavolo II in Nahuel Huapi Lake (Bariloche, Cordillera de los Andes, Argentina) in 2017. (Credit: Mariscope)

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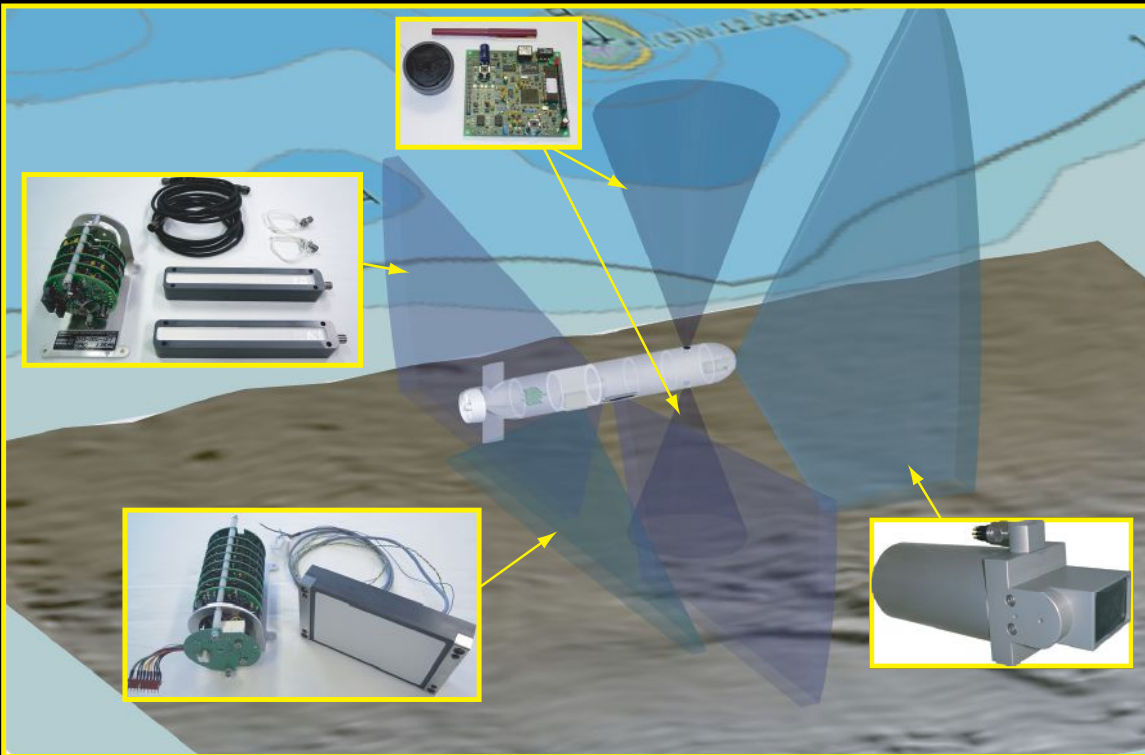
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April Burt, DPhil Candidate, Queen's College, Oxford University

Islands Pay Unfair Price For Plastic Pollution

Islands all over the world are accumulating vast quantities of plastic pollution. Aldabra Atoll, a UNESCO World Heritage Site in the southwest Indian Ocean is no exception. A recent study in *Nature Scientific Reports* (<https://rdcu.be/b7uYi>) documents the costs to clean the atoll of the 500+ tonnes of plastic that has arrived there. The estimated cost is around £5 million and 18,000 hr. of labor, and this is only one of 115 islands in the Seychelles.

It is reasonable to ask: Given the extreme cost, should cleanup efforts happen at all? We are not predicted to reach global "peak waste" before 2100, and it's simply unimaginable that plastic litter be allowed to accumulate on Aldabra at current rates for another 80 years. The arrival of tonnes of plastic litter compromises the integrity of this near-pristine system and potentially increases its vulnerability to climate change. The evidence of the negative impacts that plastic has on ecosystems is ever-growing, and these are ecosystems we rely on for food and other services.

The Seychelles, like other island states, are faced with a difficult choice. They cannot leave their islands covered in trash, but how do they pay for these cleanups, and what do they do with the huge amounts of plastic litter?

The Seychelles' own waste generation is around 48,000 tons per year, and current waste management is restricted to landfills and small-scale initiatives, such as collections of aluminum cans and PET bottles, which are then exported for recycling. At present, there are no in-country recycling options for any plastics, and marine-degraded plastic requires specialist recycling. The amount of plastic arriving on the coasts from the ocean each year is yet to be quantified, although there are ongoing accumulation rate studies in place.

Recycling solutions exist elsewhere in the world to enable a circular economy for the majority of plastic types. Investment is needed to set up these facilities in the Seychelles to support a circular economy, reduce harmful landfill alternatives, and create revenue through jobs and products created from this new industry. Further research is certainly needed to scope the feasibility and financial returns from such an investment; the question is: Who will take up the gauntlet?

The study of Aldabra also showed the huge proportion of waste that was coming from the large industrial fisheries operating in the region. The industrial tuna fishing industry operating in the Seychelles is one of the most important sources of foreign-currency earnings. The fishery is composed of licensed vessels, both Seychelles and foreign registered, that fall under two main categories: purse-seiners (mainly EU-owned vessels) and longliners (mainly Taiwanese and Chinese vessels). The majority of tuna is either directly exported or goes to the canning factory in the Seychelles. Of this, 95 percent of the canned tuna produced at the factory in the Seychelles is exported to Europe under brands such as John West or Petit Navire. This is food for thought: We as consumers are mostly aware of the impact that overfishing is having worldwide, but I don't think many of us realized that the fishing industry, at least within the Seychelles, also greatly contributes to the plastic pollution problem.

The authors of the Aldabra study suggest there should be some financial accountability for the negative impacts to marine ecosystems and the financial burden of cleanups on local organizations like the ones that manage Aldabra. With investment in long-term waste management solutions, coupled with large-scale cleanups of these biodiversity-rich islands, there is hope that we can reduce the impact of plastic pollution in the future. **ST**

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)) US Navy Welcomes College Students' Ideas on Naval Challenges. Naval Horizons, a new video educational series from the U.S. Department of the Navy's Naval STEM education and outreach program, has launched at: <https://navalhorizons.asee.org/videos>. Topics thus far include: discovering how to move energy over large distances, including outer space; designing the future through additive manufacturing; and enhancing human capabilities in an underwater environment. This effort is designed to inspire college students by raising their awareness of the real-world science and technology challenges of today. "Naval Horizons is looking for talented, passionate students who are interested in exciting, impactful career possibilities in naval science and technology," said Chief of Naval Research RAdm. Lorin C. Selby. "We need their vision as we re-imagine naval power. A crucial part of Naval STEM is diversity," Selby, who is also the Naval STEM executive, said. "The Navy and Marine Corps are looking for students with diverse backgrounds and perspectives. Many breakthroughs in human history have occurred by bringing together people with different insights and thought processes. This kind of collaboration will help us address naval challenges of the future." Naval Horizons is designed to introduce students to cutting-edge topics impacting the Navy and Marine Corps through online videos covering nearly 20 research areas. College students are invited to learn about naval topics by watching the videos and submitting a report on the state of the art and a futurist vision of the Navy and Marine Corps in 2040. Submissions will be reviewed for technical sufficiency on a rolling basis, and the first 3,000 submissions to meet the evaluation criteria will be awarded a \$200 stipend. Learn more at: <https://navalhorizons.asee.org>.

)) Accelerating Carbon Capture and Storage. Three international organizations specializing in technology research, testing, advisory services and standardization have joined forces to find new ways to accelerate the adoption of carbon capture, utilization and storage (CCUS) technology in emissions-heavy industries. DNV GL, SINTEF and Technology Centre Mongstad (TCM) have signed a memorandum of understanding to further develop carbon capture, utilization and storage technologies to make full-scale CCS a reality globally. CCS is the only currently available technology to deeply decarbonize hydrocarbon use. Scaling the technology will be critical to a range of industry sectors' ability to align with national and international climate targets. DNV GL's 2020 Energy Transition Outlook forecasts that the technology will help mitigate more than 2 gigatonnes of CO₂ emissions by mid-century. However, the forecasts also indicate that CCS will not begin to scale until 2030, and not to a significant level until 2040, without government incentives and industry focusing on finding ways to reduce the cost of CCS technology. In September, the Norwegian government announced its decision to provide 13.8 to 16.8 billion NOK in funding to support the realization of the Norwegian Longship CCS project, which includes capture of CO₂ emissions from the cement industry, transport of CO₂ by ship, and temporary storage of CO₂ prior to pipeline transportation and storage.

)) Monopile Installation for First Wind Turbines in US Federal Waters. Fugro has used its integrated augmented-reality solutions, QuickVision and InclinoCam, to support Jan De Nul Group's offshore installation of two monopiles for the first two offshore wind turbine foundations in U.S. federal waters. By combining a range of vision technologies, Fugro ensured that the project's challenging installation tolerances were met in full and both monopiles at the Coastal Virginia Offshore Wind project off the East Coast of the U.S. were safely positioned. Jan De Nul Group engaged Fugro's offshore survey and positioning expertise because monitoring the position, verticality and height of the monopiles in near real time was crucial for successful installation. Fugro's expert surveyors supported the installation offshore on Jan De Nul Group's jack-up installation vessel and onshore from a nearby temporary real-time kinematics (RTK) base station set up on the shoreline specifically for the project.

)) UK Subsea Industry Survey Shows Cautious Optimism, Growing Interest in Renewables. A snapshot survey of the U.K.'s £7.8 billion subsea supply chain has revealed that small and medium enterprises (SMEs) operating in the underwater engineering industry are cautiously optimistic about the next six to 12 months. Industry body Subsea UK recently surveyed its smaller member companies to find out how they have been dealing with the fall-out from the COVID-19 pandemic. Almost 75 percent of respondents do not anticipate making redundancies in the near future, and 56 percent are fairly optimistic about the next six to 12 months. However, almost 23 percent of respondents are making redundancies, with only 3.5 percent actively recruiting. The last business activity review into the sector in 2019 reported that the subsea industry in the U.K. employed 45,000 people. The top three priorities for subsea SMEs at this time are the health and well-being of employees, cash flow, and lack of visibility over project work and their order books. Respondents also revealed that their target markets remain unchanged as a result of the global pandemic. In terms of geography, Europe remains a key market, followed by the Gulf of Mexico, Asia Pacific and the Middle East. While oil and gas is still the largest market for the subsea industry, diversification into other areas of underwater engineering is more important than ever. Offshore renewables now account for almost 25 percent of all subsea revenues (around £1.8 billion), and income from aquaculture, defense and subsea mining is growing. Survey respondents were most interested in receiving market intelligence on offshore wind and other marine renewable opportunities. **ST**

The Law of More

How to Advance Industry and State of the Art for Undersea Vehicles

By Robert Wernli, Sr.

I've had the pleasure of writing several articles on underwater vehicles and technology for this magazine in the past. In a June 2006 Soapbox article, I compared the upcoming development of AUVs to Moore's Law, i.e., the number of transistors on a microchip doubles about every two years, while the cost of computers lowers by half, essentially forecasting an exciting time of advancement of AUVs worldwide.

In the decade prior to my 2006 Soapbox, the use of AUVs was beginning to advance, but that was slowed by the financial crisis of 2007 to 2008. The academic community of researchers, however, continued developing smaller vehicles on tight budgets. Such successful developments led to spinoffs such as Hydroid (from the Woods Hole Oceanographic Institution's Oceanographic Systems Lab) and Bluefin (from the Massachusetts Institute of Technology's AUV Lab), two of today's most successful AUV companies, which will be addressed later in this article.

The larger-diameter AUVs, such as Kongsberg's HUGIN, were projected to possibly have only 28 or so operating by 2008. This slower growth was affected by the fact that they were very efficient in their planned surveys, especially when compared to towed systems. Because of such efficiency, companies like C&C Technol-

ogies were completing surveys so fast that the vehicles, at that time, were often sitting at the docks waiting for additional work.

On the military side, the focus was more on large vehicles, such as 21-in.-diameter systems that could be launched from a submarine's torpedo tubes. None of these were inexpensive endeavors—and they still aren't. The government and military are the users of about 75 percent of today's AUVs. Mine countermeasures (MCM) and intelligence, surveillance and reconnaissance (ISR) are leading missions in today's battlespace.

The U.S. Navy is still investing heavily in very large, mission-specific systems. One example is Boeing's Echo Voyager vehicle, the third in a line of large UUVs (the military's term for AUVs). It is a fully autonomous, extra large unmanned undersea vehicle (XLUUV). Because of its size (8.5 by 8.5 by 51 ft. without a payload) and energy capacity, it can be used for a variety of missions for months at a time. These aren't cheap vehicles; Boeing received a \$274 million contract in 2019 to build, and deliver by 2022, five of these Echo Voyager-based whale-sized vehicles, which are appropriately named Orcas.

Another example of expensive programs is the Navy's desire to launch and recover AUVs from a submarine's torpedo tube. One such program was Boeing's AN/BLQ-

The Riptide UUV-12 off the coast of Plymouth, Massachusetts, during design validation testing in July 2020. (Credit: BAE Systems)





*Iver3 AUV being launched from a RHIB.
(Credit: L3Harris OceanServer)*

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11, which was a 21-in. heavyweight system capable of being launched and recovered from a submarine or a surface ship. This five-year \$100 million program ended in December due to technical and engineering limitations, which has been the case in most sub-launched AUVs.

Miniaturization

The problem with so many government programs is that they are expensive, take a long time, and often end up depending on technology that has become obsolete. So, how do you solve such a problem?

One company that took these issues to heart was Rip-

tide Autonomous Solutions, which launched in 2015 and was acquired by BAE Systems last year. They took a page from the decades-earlier playbook where the goal was to spin off the vehicles and technology from academic institutions and a few companies and develop a line of successful small AUVs. The problem was that the technology at that time had not advanced to a level of miniaturization to allow such cost-effective solutions, especially when taking into account the miniaturization of the payload and sensors required to complete the missions.

Enter Riptide with a goal of producing a micro-UUV for \$10,000 initially. Optimistic, yes. Successful, also yes.

A photograph of a Sabertooth AUV (Autonomous Underwater Vehicle) with an underwater docking station. The vehicle is yellow and white, with the word "SABERTOOTH" printed on its side. It is positioned in front of a large, yellow, rectangular structure that appears to be the docking station. The background is a deep blue, suggesting an underwater environment.

Sabertooth with underwater docking station. (Credit: Saab Seaeye)

By adapting the latest in low-power microelectronics technology and production methods such as 3D-printed titanium hull components Riptide developed an array of scalable vehicles, which have a nominal depth rating of 300 m. To prove that micro-UUVs can be used for full-ocean-depth missions, they delivered a 6,000-m-rated vehicle, without payload, to the U.S. Navy for \$100,000.

Riptide's vehicles range from diameters of 4.9 to 12.8 in., with associated price ranges that are well below the norm, thus supporting the young company's sale of over 150 vehicles.

As previously mentioned, the government uses the majority of the smaller AUVs that have been developed, in addition to a few of the multimillion-dollar behemoths. But will the high level of government funding for the development of AUVs aid the commercial industry? The capability is there, so successful mission completion comes down to the payload, where industry plays a part. Endurance of vehicles, especially at deep depths, depends on enough onboard energy to complete the missions. Such advanced energy systems are being developed commercially. Electronics, software, camera systems, sonars and other instruments are shrinking dramatically, and these advancements are allowing payloads to match the physical capabilities of AUVs. Government/military/commercial/academic partnerships will support future success, and this will increase the use of AUVs for commercial and academic applications.

L3Harris OceanServer produces its line of small Iver AUVs that has an extensive array of sensors for various missions, are man portable, and range from 5.8 to 9 in. in diameter, with depth ratings from 200 to 300 m. Over 300 of the vehicles have been sold to date.

Bluefin Robotics, now a General Dynamics Mission Systems company, has produced a line of three vehicles that range from approximately 9-, 12- and 21-in. diameters up to 16 ft. long and with depth ratings from 200 to 4,500 m. They have sold more than 100 UUVs that can carry a wide array of sensors for defense, commercial

and scientific missions. In addition, Bluefin is continuing the development of the Knifefish, a 21-in.-diameter, 19-ft.-long UUV for the U.S. Navy. The Knifefish will be a key MCM component of the littoral combat ships, which will each carry two of the AUVs.

Hydroid and its line of REMUS vehicles is now a part of Huntington Ingalls Industries. It has fielded over 500 AUV systems, from small to extra large, for a variety of domestic and international customers.

There are many other companies, labs and academic institutions that are also developing advanced AUVs, but listing all of them is not the intent of this article.

'Inter-Sea-Net'

So, where is this all going? Because of the COVID-19 virus worldwide, the employees of many companies are now working remotely at home, and this may continue for a long time. No one envisioned such a dramatic change. The technology was there, but the mindset wasn't. Things change quickly—it wasn't that long ago that a phone was a phone; now, what we carry with us can do everything except cook our meals.

Can such a change happen offshore? In my co-authored book "The ROV Manual, Second Edition," I project that an "Inter-Sea-Net" type of infrastructure is on its way. Why? Because the technology is there, and we just need to be pushed a little into using it. Not only do we have the technology, but, because of the hazardous offshore environment, there is a strong case to apply it so that things can be done remotely, especially during challenging times such as the coronavirus pandemic.

The elements of this infrastructure for remote operations already exist. There are hybrid AUV/ROV systems that can remain below the surface to conduct maintenance under control of a land-based operator. Underwater charging stations have been developed that can keep an AUV operating for months or years at a time. Resident vehicles, such as Saab Seaeye's Sabertooth AUV, can stay on site for more than six months. The hybrid AUV/



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Naviator AUV. (Credit: Javier Diez, Rutgers University) (Below) Ocean Infinity's ships are each outfitted with five HUGIN AUVs. (Credit: Ocean Infinity)



ROV can be operated directly via a tether or pre-programmed to perform inspection, maintenance and repair (IMR), off-shore surveys, and other tasks. The vehicle can use the docking station to recharge batteries and transfer data via satellite or cable to shore. Autonomous vehicle technology exists for underwater, surface and air vehicles that can allow them to communicate and operate as a team. Swarms of such systems, which could be remotely delivered, are on the horizon. The Aquanaut AUV, being developed by Houston Mechatronics Inc., can reach a remote site and change into a “humanoid” type of system. AUVs are also being developed to surface and become an unmanned aerial vehicle (UAV), such as the Naviator being developed by Rutgers University.

The requirement for mandatory users of surface ships to deploy vehicles is going the way of the rotary phone. The ability (and requirement) to control vehicles and systems from a remote land-based station will extend the Internet into the “Inter-Sea-Net.”

The requirement for mandatory users of surface ships to deploy vehicles is going the way of the rotary phone. The ability (and requirement) to control vehicles and systems from a remote land-based station will extend the Internet into the “Inter-Sea-Net.”

Use It Heavily, Then Lose It

A battle cry I ended many of my past AUV presentations with was: “Now is the time to lose some AUVs.” Why? Once something is used enough that it provides an excellent return on investment (ROI), you will usually replace it.

Therefore, the more you use your vehicles, the better the ROI, and, thus, the more vehicles that will be built,

in turn, likely improving performance and driving down cost of ownership.

The first major AUV lost was Southampton Oceanography Centre’s Autosub 2 that disappeared under the Arctic ice in 2005 after 382 successful missions. Now named the National Oceanography Centre, it figured the ROI was acceptable and has since built Autosub 3 (now retired), Autosub6000 and three Autosub Long Range vehicles, all with 6,000-m depth capability.

More recently, Ocean Infinity took on the job of trying to locate the lost Argentinian Navy submarine San Juan. The unique aspect of Ocean Infinity’s operations is that its ship carries five HUGIN AUVs with a depth capability of 6,000 m that can operate as a team to reduce the search time. The submarine was located in November 2018. Ocean Infinity has lost two HUGIN vehicles, one last year in the Weddell Sea ice pack, and the other on the MH170 search. Two lost vehicles, and they’re not cheap. Such losses are not all negative, though. According to RAdm. (retired) Nick Lambert (see his article on

creating a national maritime security infrastructure in *Sea Technology's* November 2020 issue), who was the project manager on the San Juan search and is co-founder and director of NLA International, which champions the implementation of blue economy solutions: "These are the technologies and systems necessary to understand our planet. If you don't use and operate them, then you don't stress test the technology and you don't push the boundaries."

Ocean Infinity has taken that to heart. It now has three multipurpose support vessels, all with five HUGINs, three USVs and two ROVs. They're also adding a fleet of 15 large Armada robotic ships.

According to Kongsberg, two other HUGINs were lost by other users, but that hasn't slowed Kongsberg, or the users, down any. They have fielded over 85 HUGIN and HUGIN Superior AUVs over the past 20 years. And considering that about two-thirds of Kongsberg's work today is with the defense industry and government, the probability of losing some more vehicles is certainly on the horizon.

Others have indicated a possible 2 to 3 percent loss rate, which seems acceptable because more and more AUVs are being developed.

ROI rules. It's time to lose some more AUVs.

The Law of More: Beyond Theory

According to Douglas Westwood's World AUV Market Forecast 2012 to 2016, the number of active AUVs

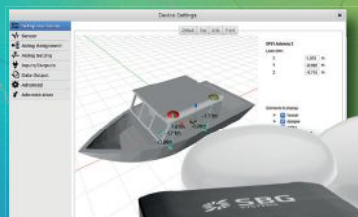
in 2009 was 390, which increased to 560 active vehicles in 2012 and was projected to reach 930 by 2016. Other projections have the number around 1,000 vehicles operating by 2020, with about 75 percent on government and defense industry jobs. And this has become fact—just the number of vehicles sold by the companies listed in this article is well over 1,000. The majority of these vehicles are not necessarily small, but the technology is there, their numbers are increasing, and their size is shrinking. Most of the major AUV companies now have 6,000-m versions of their vehicles.

On the academic side, the advancement of technology to develop cost-effective systems continues to support the AUV market. There is no shortage of applications for future AUVs, and the number of vehicles, especially smaller ones, will increase, continue to support the various missions...and occasionally get lost. For proof, see my 2030 *Sea Technology* article, "2020 Hindsight and The Law of More." **ST**

Robert Wernli, Sr., a mechanical engineer, engineering consultant and writer, spent his career developing undersea vehicles and work systems at a U.S. Navy lab in San Diego. His most recent technical book is "The ROV Manual, Second Edition," and he has also published a series of techno-thriller novels (www.wernlibooks.com).



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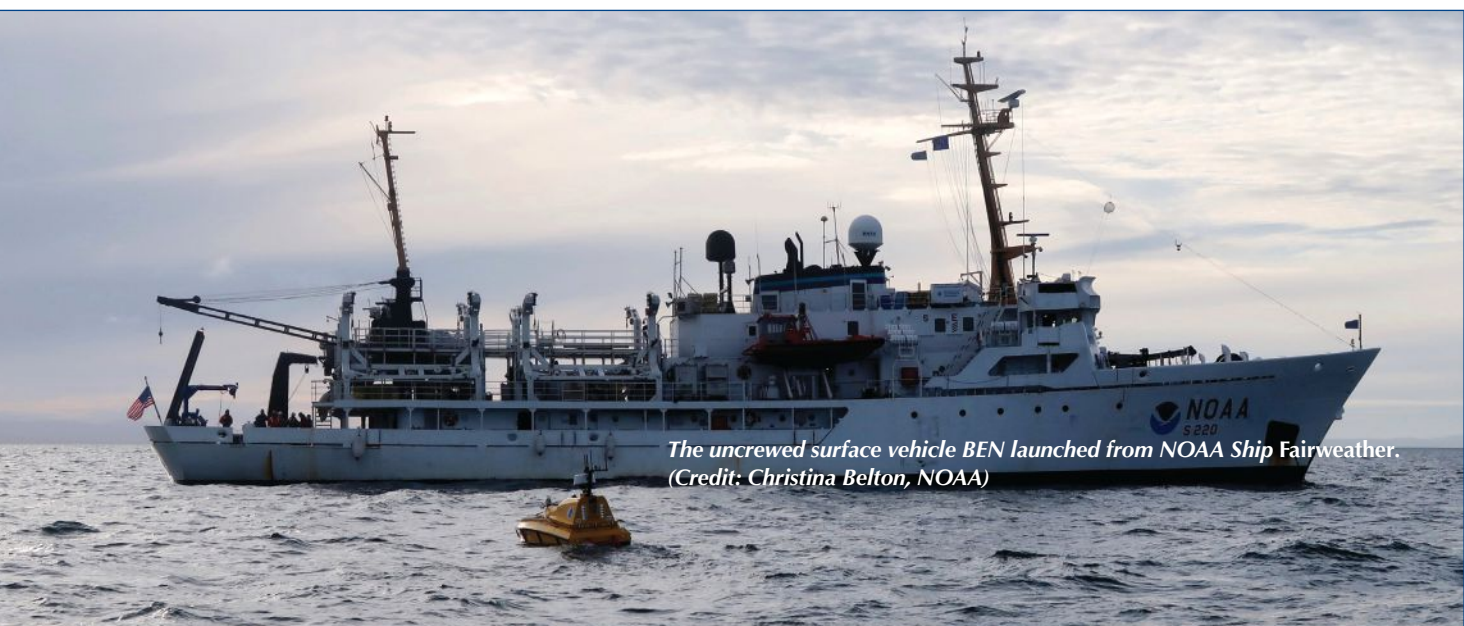
By LCDR Damian Manda

Surveying and charting push the boundaries of marine technology, due to requirements for precise positioning, measurement of ranges through water and large area coverage. With the advent of modern multibeam-sonar-based hydrography, detailed bathymetric data collection is now possible. However, in order to collect full coverage data, more vessel mileage is required in shallow water than previous surveying techniques, and the volume of data increases the load on processing, quality control and other workflow components. In order to maintain and increase production capability under these constraints, hydrographers are increasingly turning to automation for data collection to final product creation.

The Office of Coast Survey (OCS), part of NOAA, and the hydrographic survey contractors who are tasked to complete work for NOAA's charting program have rap-

idly integrated many technological enhancements that greatly affect data collection and production capabilities over the past five years. To increase safety and efficiency of data collection, significant strides have been made toward routine inclusion of USVs and uncrewed aircraft systems (UAS) into data collection operations in both shallow- and deepwater.

NOAA and the U.S. government recognize the transformative nature of uncrewed systems (UxS) and have developed strategies to more widely integrate their use into ocean mapping. In 2018, Congress passed the Commercial Engagement Through Ocean Technology (CENOTE) Act focused on integration of maritime UxS into NOAA operations. In 2020, six NOAA technology strategies were published, including strategies focused on UxS, artificial intelligence and data management.



*The uncrewed surface vehicle BEN launched from NOAA Ship Fairweather.
(Credit: Christina Belton, NOAA)*

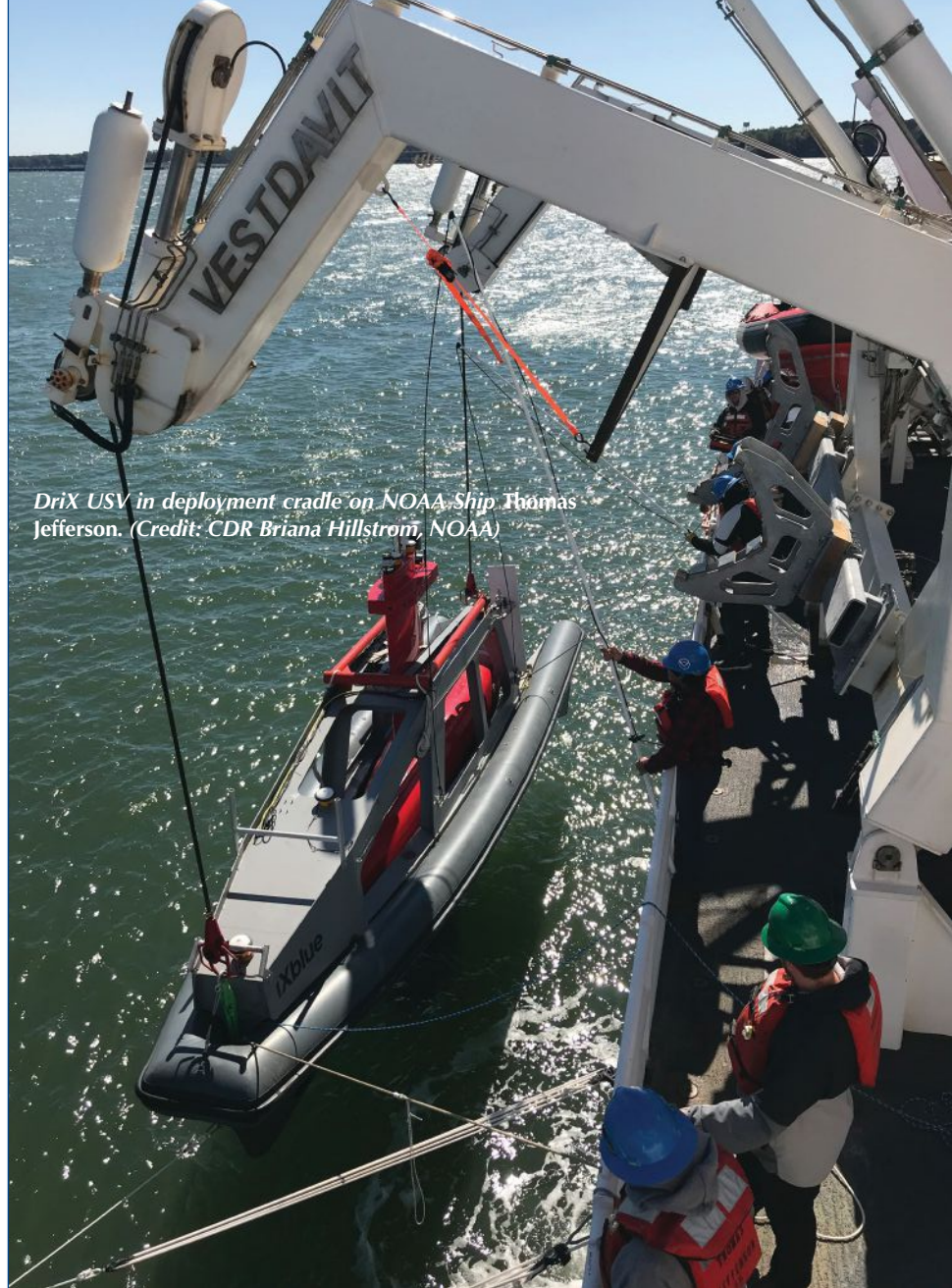
The recently published interagency National Strategy for Mapping, Exploring, and Characterizing the U.S. Exclusive Economic Zone (EEZ) emphasizes that UxS will be critical to achieve full EEZ coverage within a reasonable time frame. OCS released a supporting strategy in 2020, Mapping U.S. Marine and Great Lakes Waters: Office of Coast Survey Contributions to a National Ocean Mapping Strategy, which includes objectives to promote, encourage and ultimately leverage leading-edge survey technology to force-multiply data acquisitions through automated data collection and processing.

Uncrewed Surface Vessel Use in OCS

OCS began acquisition of USVs in 2015 with the addition of two small systems to support missions in shallow water. Previous use of uncrewed vessels focused on underwater vehicles, which were found less suitable for large-scale production hydrography due to endurance and communication flexibility. These vessels were supplemented by the addition of two multibeam-echosounder-equipped Seafloor Systems EchoBoats. The NOAA navigation response team (NRT) stationed in Stennis, Mississippi, assumed responsibility for management and deployment of these UxS. Since they are targeted toward disaster response applications, flexible, low overhead mapping can be completed quickly in a range of coastal environments, allowing ports to be reopened after storms.

For longer duration acquisition in less sheltered environments, OCS turned to partnerships with academic institutions and the Office of Marine and Aviation Operations within NOAA for expertise and operational support. In 2016, NOAA chartered an L3Harris C-Worker 5 for testing applications to bathymetric mapping, which showed the potential of USVs. The first OCS project acquisition took place near Point Hope, Alaska, in 2018 when a C-Worker 4 owned by the NOAA/University of New Hampshire Joint Hydrographic Center (JHC) was deployed from NOAA Ship *Fairweather*. This demonstrated the viability of USV data collection in this type of low-traffic environment, including independent operation, tandem coordination with the ship, and overnight operations. The *Fairweather* testing also provided valuable experience with deployment and recovery of UxS and watch staffing.

A multi-week operational trial of the 8-m iXblue DriX



DriX USV in deployment cradle on NOAA Ship Thomas Jefferson. (Credit: CDR Briana Hillstrom, NOAA)

vessel was conducted in 2019 on NOAA Ship *Thomas Jefferson* in conjunction with the JHC. This included retrofits to davits for a deployment system that cradled the DriX directly into the shipboard systems, simplifying launch and recovery. In addition to supplementing standard data collection, the DriX is capable of acquiring quality data in high sea states due to narrow hull design and a sonar pod keel, a design that would be difficult to replicate in a similar-sized crewed boat.

OCS also retrofits existing crewed survey launches with autonomy hardware, with three of the 28-ft. vessels targeted for conversion. These optionally crewed launches began field testing and protocol development in 2019 and saw initial success in automated control and data acquisition, but continued work is postponed by COVID-19 safety restrictions. The implementation of these vessels utilizes existing expertise in maintenance and crewed operation while introducing the option to automate data collection and train personnel on technologies without



reducing shipboard storage space. The benefits of these uncrewed system improvements are not fully realized, since current platforms were not designed to handle them and crew need to be trained in effective use and maintenance. These aspects are incorporated into the NOAA UxS Strategy Plan and an accompanying implementation plan. Implementation includes creation of a new UxS Operations Center within NOAA to promote and coordinate these activities, as well as provisions for training the workforce and collaboration with partners that will accelerate successful transition to routine usage. Additionally, the design of next-generation survey ships for the NOAA fleet is underway, which will incorporate the lessons learned from test and evaluation of diverse USVs to inform small vessel handling and storage systems for maximum effectiveness.

Uncrewed Aerial System Applications within OCS

Starting in 2018, OCS developed procedures to fly small UAS from vessels, which culminated in an initial test project on NOAA Ship *Thomas Jefferson* in Puerto Rico. The data collected from these flights proved the feasibility of using Structure From Motion (SfM) processing of aerial imagery into digital terrain models that could be used for charting of shoreline features such as rocks, reefs and ledges, as well as constructed objects. The discovery and positioning of these features was traditionally conducted via open skiff and required a close approach in the surf zone, so remov-



ing people from this environment reduces risk of injury. A follow-on project in 2019 created a comprehensive shoreline map of a project area assigned to an NRT in Lake Huron, and also provided images to update harbor approach views in the Coast Pilot, providing a perspective not previously available to aid the mariner.

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field platforms, and in line with the NOAA UxS Strategy goal to promote workforce proficiency, OCS also originated a training program for pilots and is distributing small UAS to applicable platforms to build experience and support ground-control-based surveys. Seventeen people have been trained so far, covering all ships and some NRTs, which enabled NOAA Ship *Rainier* to conduct flights in Alaska this year.

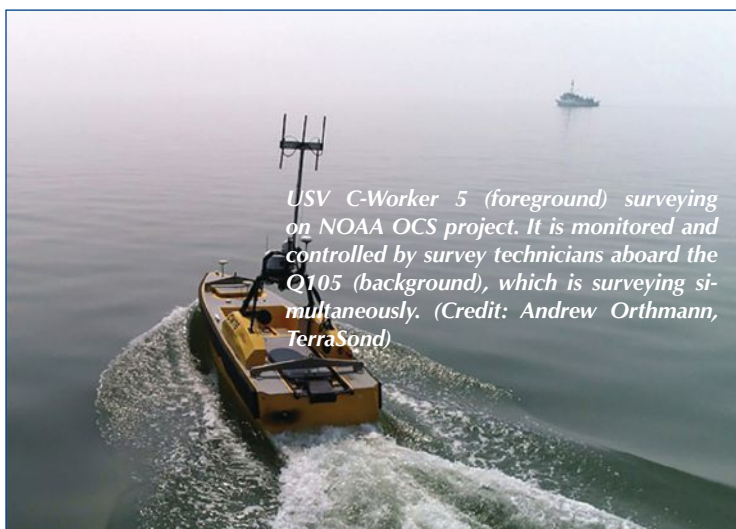
Automated Processing

To reduce the lag between field data collection and application to charts, OCS has implemented automation tools into key portions of the processing workflow. A key component of daily processing is the OCS-developed “Charlene” multiprogram interface. Charlene uses standard folder structures to automatically recognize, transfer and process data from multibeam and side scan sonar systems, apply correctors such as sound speed profiles and datum separation models, and compute and integrate post-processed navigation trajectories. To accomplish this, Charlene interfaces with multiple commercial software programs, existing NOAA and JHC tools within the OCS distributed Pydro ecosystem, and custom checks on file contents and structure. The result is a previously multi-step, error-prone process reduced to a single setup so that hydrographers can dedicate their time to reviewing data, planning operations and monitoring additional acquisition.

When the initial processing completes, there are still manual review checks to ensure quality and consistency. Many of these checks are now aided by an OCS and JHC collaboratively developed utility known as QCTools. Using QCTools, the hydrographer can assess uncertainty metrics, coverage gaps, erroneous spike “flyer” data points and other common pitfalls. The outputs can be visualized in a GIS alongside the original products for rapid analysis of issues. Additional automation has been added to the final report compilation, with a tool that automatically fills out survey statistics and generates standardized diagrams and charts for the descriptive report that is written for each survey area.

Building upon successes with processing and quality control automation, OCS has experimented with application of machine learning (ML) to processing of hydrographic data. Multibeam sonar noise cleaning was pursued with positive results, and the methodology informed commercial efforts to integrate similar characterization. Side scan sonar processing has also been targeted, where the tedious task of identifying relevant target objects from sonar imagery is automated through a custom trained program with an interface for human verification of questionable results. OCS expects to expand applications of AI and ML throughout the quality control pipeline to further enhance productivity and better target human review time.

The combined effect of Charlene, QCTools and streamlining of the survey delivery process is that the average time for delivery of surveys from the field has



USV C-Worker 5 (foreground) surveying on NOAA OCS project. It is monitored and controlled by survey technicians aboard the Q105 (background), which is surveying simultaneously. (Credit: Andrew Orthmann, TerraSond)

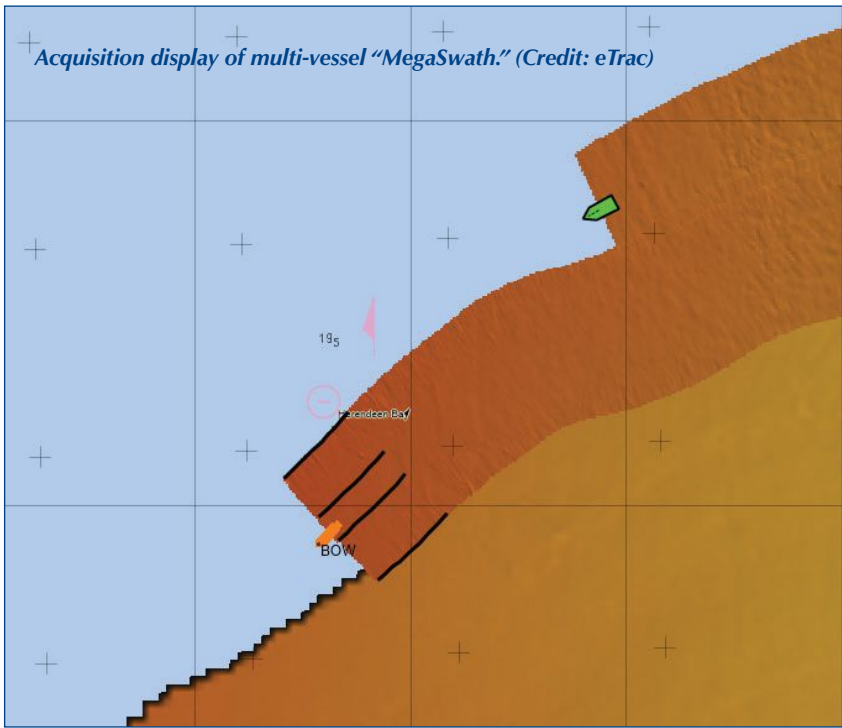
decreased while the number of surveys has increased. Enhancements continue, but the tools to facilitate a transition to increased data collection from truly force-multiplying UxS are in hand.

OCS Tasked Contractor Advancements

A significant portion of the data collected for nautical charting is contracted by OCS to hydrographic surveying companies. Many of these contractors have also implemented UxS into their acquisition paradigm and automation into data-processing workflows.

Contractors have added capacity to projects through the use of USVs and employ them with varying tasking and control scenarios. TerraSond employs a C-Worker 5 to acquire data in nearshore regions in conjunction with a 105-ft. vessel hosting crew who monitor the remote acquisition while also performing ship-based acquisition. The C-Worker 5 can be deployed for up to five days at a time, reducing the need for time-consuming recoveries and deployments and increasing the ability to work through rough seas. Every year since 2017, the USV has collected more linear miles of data than the paired vessel, including 57 percent of the data in 2020, where it surveyed in depths as shallow as 2 m.

While TerraSond has concentrated the USV survey in shallow waters, both Fugro and Leidos have employed custom-designed solutions for offshore survey. Leidos built on experience from defense projects, which required capabilities for COLREGS-based avoidance and response to standard navigational aids. In 2018, a survey vessel outfitted with their control software acquired 519 LNM of data over 62.5 hr. without any human intervention. This included automatically filling gaps that were created in the bottom coverage during maneuvers to avoid other vessels. Fugro launched its custom L3Harris ASV FAS-900 USVs in 2020 and used the vessel as a force-multiplier on a project off the coast of Florida. This 8.8-m vessel features a wave-piercing hull that allows it to operate in offshore conditions with multiple-day endurance. Onboard processing permits ease of monitoring progress and data quality over the long-duration missions.



Whereas the previous examples used a USV in independent data collection areas, eTrac took a different approach during its 2019 survey in the Straits of Mackinac, a fairly shallow, high-traffic region. In addition to a crewed vessel, they employed two 16-ft. Marine Advanced Robotics WAM-V vessels, which were configured to be able to act as “ducklings” offset behind the main vessel. As the depths changed, the operator adjusted the offset so that coverage was maintained across a “MegaSwath” from all three vessels.

The duckling configuration permitted better situational awareness by the operators and efficiency gains through application of sound speed profile casts to all sonars.

David Evans and Associates (DEA) plans to convert an existing RHIB to optionally uncrewed use in similar circumstances where it will follow a host vessel at an offset.

While these systems require local support from a companion ship, OCS worked with TerraSond in 2020 to field four completely independent uncrewed vessels known as Saildrones for an Alaskan Arctic survey. The Saildrones were launched from the company's facility in California and transited through the Aleutians and Bering Strait before commencing survey operations north of Kotzebue Sound. Equipped with single-beam echosounders, they were tasked with locating and following the 20- and 50-m depth contours to better define them for charting and inform future survey plans in the high Arctic. Despite some equipment malfunctions, two Saildrones completed mapping to the Canadian border on the eastern side of the North Slope. Upon return to California, the Saildrones will have traveled over 7,500 nm each without any in-situ human intervention.

In addition to USVs, TerraSond employs UAS for shoreline investigation to obtain similar benefits to the OCS application. Besides the safety benefits, TerraSond

noted a five-times faster workflow for feature processing when aided by the SfM terrain models and accompanying orthoimagery.

Some OCS-funded contractors have also introduced innovations in processing and data management.

Fugro developed a remote data transfer and processing system that allows near-real-time data review from shore-based locations, decreasing personnel needs on ships and allowing hydrographers to work from home during the COVID-19 pandemic.

Geodynamics introduced a web-based Survey Information Management System (SIMS) that enhances situational awareness of projects across the company and feeds automated reporting.

Multiple companies have automated the creation of acquisition reporting logs through ingestion of sensor data combined with real-time user input.

Looking Forward

Both OCS and its contractors continue to further integrate automation of processing and data collection into their hydrographic survey workflows. As manufacturers more tightly integrate acquisition systems with planning and autonomy software, truly independent operation becomes possible.

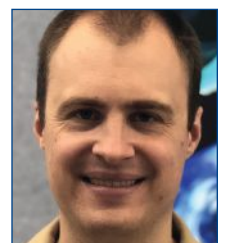
The necessity for expert human monitoring and review will remain for the near term, but when one person can manage multiple high-endurance systems simultaneously, the rate at which the seafloor can be mapped and characterized is greatly increased and costs are reduced.

The National Ocean Mapping, Exploration, and Characterization strategy sets a goal of mapping all U.S. EEZ waters deeper than 40 m by 2030, and OCS commits to 20,000 sq. nm of gap mapping with partners each year. With 54 percent of U.S. waters currently unmapped by modern standards, automation of data collection and processing is the only way to achieve these goals.

References

For a list of references, contact Damian Manda: dami.an.manda@noaa.gov. **ST**

LCDR Damian Manda is chief of the Hydrographic Systems and Technologies Branch within NOAA's Office of Coast Survey, where he is responsible for advancing efficiency and accuracy of hydrographic data collection and processing. He holds a master's in ocean engineering from the University of New Hampshire and an IHO Cat-A hydrographer certification.



ROV Assist

Mako Supports Commercial Diving Project off Vancouver Island

By Dr. Chris Parker • Chris Sundstrom • Simon Douthwaite

The Canadian city of Victoria, the capital of beautiful British Columbia and a city of 370,000, sits at the southern tip of Vancouver Island and was founded as a trading post and fort by the Hudson's Bay Company in 1843. The Lekwungen people named the location of the fort "Camosack," meaning "rush of water."

Victoria's stormwater system helps to manage rain

and runoff; reduces flooding by moving excess stormwater away from properties; and separates some of the oil, metals, sand and soil that would otherwise flow into local environmentally sensitive waterways and the Pacific Ocean. It also harnesses rainwater as a resource, capturing it for reuse in landscaping, or slowing and cleaning it, releasing it back into the natural water table. This in-



CanPac's LARS for its Mako ROV.



CanPac's Mako at a mountain lake.

creases Victoria's ability to deal with a changing climate and rainfall patterns.

The stormwater system is complex and consists of 5,700 catchment basins and 15,013 service pipes that serve as connections to the 253 km of underground storm drains. There are four stormwater rehabilitation units offering filtration and reducing contaminants, and the system ends with 73 stormwater outlets that release the flows into waterways and the ocean.

Stormwater diffusers allow water to be discharged and diluted over a wider area when it reaches the ocean. This critical process reduces the concentration of dirty water and allows it to be broken down faster and distributed more efficiently. The diffusers also slow the flow to reduce local erosion and aquatic habitat destruction.

These waters need protecting—legendary underwater explorer Jacques Cousteau and experts at *National Geographic* magazine identified the coastal region of Vancouver Island as one of the finest cold-water scuba diving destinations in the world due to the species-rich abundant marine life in the area, from the most humble sponge to jaw-dropping pods of resident Orca. Indeed, the University of Victoria's Ocean Networks Canada (ONC) Observatory—made up of the NEPTUNE Canada regional network and the VENUS coastal network—is the world's largest and most advanced cabled ocean observatory and is located in the same area.

Replacing Damaged Diffusers

Reports of damaged stormwater diffusers reached authorities in July 2020, and commercial diving contractor

CanPac Marine Services was called upon to replace the damaged diffusers with the critical assistance of its SEAMOR Marine Mako ROV. Since purchasing a Mako ROV in 2019, CanPac Marine Services has had the vehicle in the water for over 300 days of heavy commercial work, with no time lost for repairs.

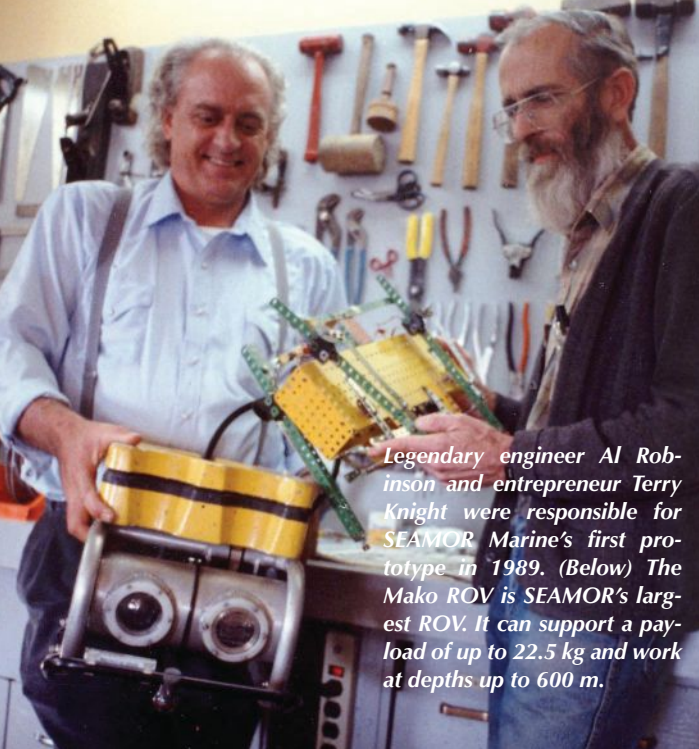
The Mako ROV was used to monitor conditions and assist CanPac's dive team as it replaced the diffusers on a stormwater outfall in a high-current area offshore of Victoria at a depth of 60 m (200 ft.).

"The depth and current created challenging conditions for the CanPac team, but the Mako ROV allowed the diving supervisor to survey the site beforehand, then closely monitor the divers during the repair operation," said Robin Li, president of SEAMOR Marine. "The Mako can cover lots of ground, ascending and descending without issue even in current, to observe from many different angles."

CanPac's diving supervisor used the Mako to check the condition of the work site and scan for any potential hazards before deploying the dive team. The Mako also helped identify areas to focus on ahead of time so that divers could address them more directly.

During the operation, the Mako served as a second set of eyes, enabling the supervisor to monitor the divers and the work site in real time to safely manage any developing hazardous situations. In the event of an emergency, the supervisor could have used the Mako to oversee and control the rescue of a diver.

"Our Mako ROV once again proved to be an extremely valuable asset enhancing our productivity and safety



Legendary engineer Al Robinson and entrepreneur Terry Knight were responsible for SEAMOR Marine's first prototype in 1989. (Below) The Mako ROV is SEAMOR's largest ROV. It can support a payload of up to 22.5 kg and work at depths up to 600 m.

during this project," said Ryan Anderson, director of operations at CanPac Marine Services. "We chose the Mako for this project mainly because of its proven efficiency in high current."

High current can jeopardize safety in a commercial diving situation, but the Mako ROV was designed to mitigate the risk. CanPac, with a spotless safety record over its 40+ years of operations, has used its Mako ROV for dozens of inspections over the last 18 months. It has operated the vehicle primarily in support of its commercial dive teams in roles ranging from fish farm inspection and anchor recovery to structural and cable inspections.

CanPac has effectively used its Mako to supplement its work-class ROV on larger jobs, with the Mako handling initial inspections and acting as a standby vehicle in case the work-class vehicle requires assistance.

"It's a versatile, reliable workhorse that can handle a heavy payload and operate in challenging conditions," said Anderson. "It does the job that we've had to use much larger work-class ROVs for in the past, and it has resulted in a considerable cost savings for us and our clients."

SEAMOR Designs

Based in Nanaimo, British Columbia, on Vancouver Island on Canada's West Coast, SEAMOR Marine Ltd. designs and manufactures underwater observation- and inspection-class ROVs and modular accessories. SEAMOR

sells worldwide and has ROVs operating on every continent and in every major body of water around the globe. The company's ROVs have been used in a variety of fields, including aquaculture, search and rescue, underwater archaeology, Antarctic geology, and pipeline/dam inspection. SEAMOR has collaborated on research projects with NASA, Defense Research and Development Canada, and the Department of Fisheries and Oceans.

The history of SEAMOR Marine began with the very first SEAMOR prototype in 1989. Legendary engineer Al Robinson and entrepreneur Terry Knight were responsible for bringing the initial designs to life. Mark Micire, NASA Robotics Group lead and research scientist recently described Al Robinson as "one of the greatest engineers to walk the planet. Humble, thoughtful and wonderful."

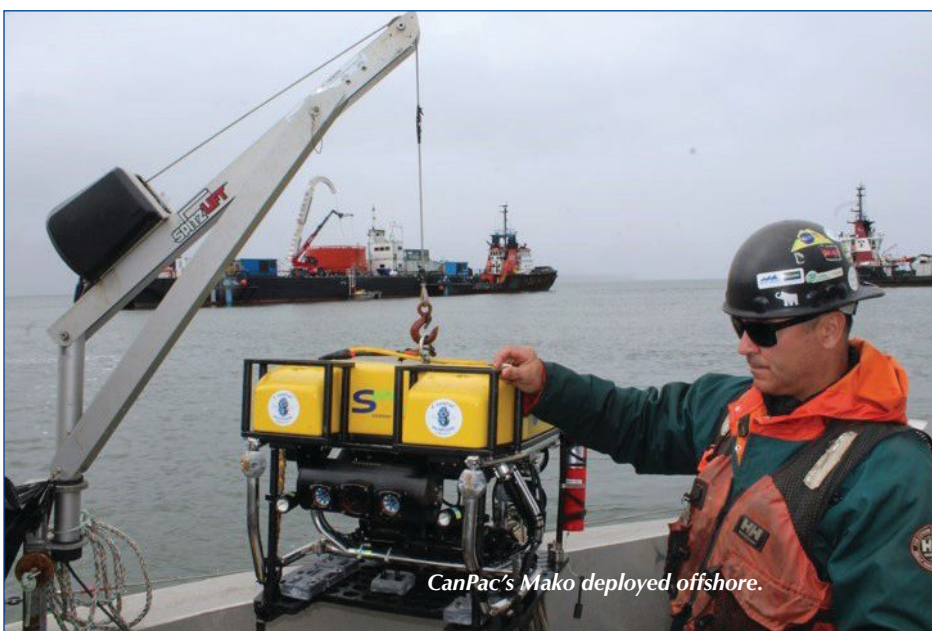
In 2006, Robin Li and Inja Ma, a husband-and-wife entrepreneurial team, co-founded SEAMOR Marine Ltd. and over the last 14 years have taken the company and its ROVs to a new, world-class level while continuing the traditions of excellence and innovation with which

SEAMOR was formed. The Mako is the culmination of all this hard work in a period spanning over 30 years.

SEAMOR Marine took the same approach when developing the Mako as it does with all of its ROVs and accessories. A core pair of goals with SEAMOR systems is modularity and serviceability, and these go hand in hand. The focus on modularity leads to robust reusable interfaces between components; mechanically, electrically and computationally.

This greatly simplifies the integration of a wide range of third-party accessories to meet every customer's needs. User-accessible powered RS-485 ports are a standard feature, and Ethernet (either by fiber-optic bridge or DSL over twisted pair) ports and switches are optional upgrades. Along with the modular mechanical design, these standardized interfaces enable many custom integrations to be completed without having to send a system having back to SEAMOR for work to be carried out. This saves time and money. Furthermore, modularity allows for dock-side system reconfigurability. A single SEAMOR ROV can be set up in minutes at the job site to carry whatever sonar, instruments, manipulator arms, or any other payloads required by the task at hand, all carried out without specialized tools. Customers can choose from a wide range of tried-and-proven payloads, or inquire about custom third-party integrations. This modularity even extends to the tether system, with a single ROV being plug-and-play compatible with both fiber-optic and all-copper tethers. A SEAMOR ROV is a system that can grow with a customer's needs.





CanPac's Mako deployed offshore.

SEAMOR's approach to design leads to products that are inherently serviceable. Printed circuit boards feature a wide range of indicators that customers or service centers can observe to diagnose any problems that may arise. Electrical systems are connectorized, allowing rapid replacement of components to get systems back in the water as fast as possible. This feature is invaluable, especially to operations in remote areas where a quick return to base is not an option.

Furthermore, all of the ROVs' onboard software systems can be calibrated with the standard operator console, without additional computer systems or custom cables. Simply power up and follow the on-screen instructions.

The subsea environment is a harsh one. Although SEAMOR systems are incredibly robust, by planning for service up front, when service does need to happen, it will be quick and easy and at a reasonable cost. It is the proven track record of SEAMOR products that allows the company to offer a two-year warranty on ROV systems.

SEAMOR Marine designs and manufactures a variety of small ROV systems for clients around the world. The Mako ROV is the company's largest ROV and can support a payload of up to 22.5 kg (50 lb.), working at depths up to 600 m (2,000 ft.). In addition to observation and inspection duties, it can carry sophisticated instrumentation packages.

The Chinook is the mid-size vehicle in SEAMOR's line of ROVs, able to dive to 600 m and up to 3,000 m in distance while carrying smaller instruments such as 2D imaging sonars or miniaturized water property sensors.

The Steelhead ROV, SEAMOR's smallest vehicle, is more compact and suited for work in confined spaces at depths of up to 300 m (1,000 ft.). It is often used by hydroelectric or potable water authorities within tanks or pipelines, or for inspection of sluice gates and other dam structures.

The future looks bright as the SEAMOR team is hard at work on the next generation of ROVs. **ST**

Dr. Chris Parker studied electrical engineering at McMaster University in Hamilton, Ontario, Canada. He went on to study computing science at the University of Alberta in Edmonton, where he earned his master's and doctoral degrees. Following a post-doctoral fellowship in mechanical engineering at the University of British Columbia in Vancouver, he joined SEAMOR Marine in 2012 to pursue underwater robotics—a lifelong interest. He is the lead engineer at SEAMOR, carrying out R&D work and leading the company's engineering staff.

Chris Sundstrom studied mechanical engineering at the University of Victoria in Victoria, British Columbia, Canada. He is certified as a small commercial vessel operator and has served in many ROV support and scientific roles in the offshore industry. He has been certified as a pilot on several models of Class I and Class II ROV systems and as a glider AUV pilot, and has worked in support of Class III ROV systems. He started working in the underwater industry in 1998 and has since gained design experience in marine winches, pressure housings, underwater structures, ROV systems and scientific sensors. In 2017 he joined SEAMOR Marine in his childhood home of Nanaimo, British Columbia, where he serves as SEAMOR's senior mechanical engineer.

Simon Douthwaite gained a bachelor of arts in geography (major in economics) from the University of London, U.K. He worked in finance in London (stocks) and in Hong Kong (derivatives) at major institutions such as HSBC. He taught recreational scuba diving in Thailand for two years and has considerable experience in deep technical diving with normoxic trimix, mainly in the Philippines. He has lived and worked in Europe, Asia, Africa and North America. He is the sales and marketing manager at SEAMOR Marine.

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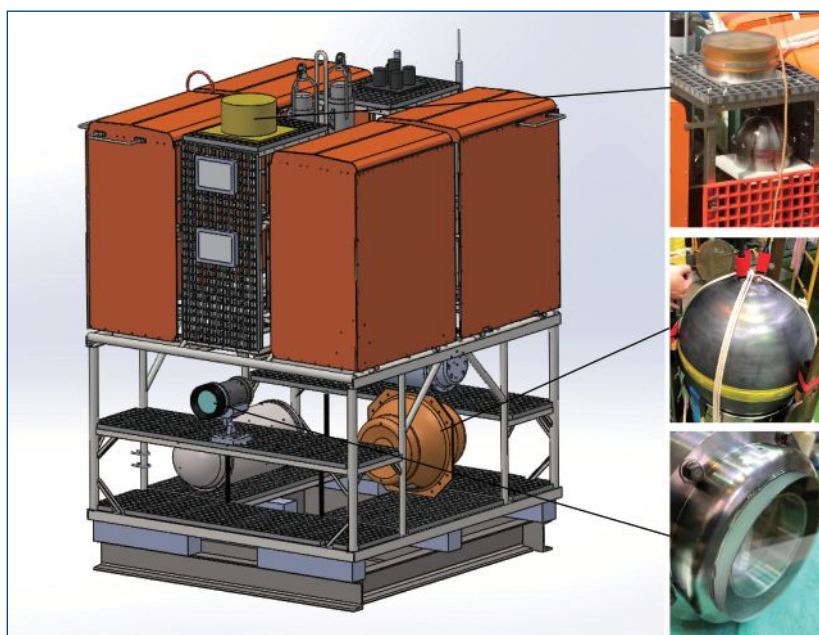



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Hadal Free-Fall Camera Lander

Transmitting Hadal Images via High-Rate Acoustic Communication

By Yosaku Maeda • Yukihiro Kida • Mitsuyasu Deguchi



FFC11K is a full-ocean-depth lander that includes: (top right) a video transmission system with acoustic communication (VT-SAC), (middle right) a silicon-nitride ceramic sphere, and (bottom right) a planar glass viewport for the camera housing.

A free-fall, self-pop-up lander system can descend and ascend between the sea surface and seafloor using its own weight and buoyancy. It needs no winch system for suspension. This feature is especially effective in the hadal zone because the system obviates bulky and expensive handling systems using high strength-to-weight-ratio rope.

Lander systems have been used often for hadal zone observations, including at Challenger Deep. However, lander-to-ship communications are generally poor because few acoustic modems can operate at hadal depths. The data accumulated by the lander are confirmed on board after recovering the lander a few days to months later.

Underlying technologies for vehicles and observation systems have been developed that are applicable to full

ocean depths, such as high-rate acoustic communications and lightweight, high-strength pressure housings. Applying these technologies to a lander system not only enables demonstration of new technologies in the field but also improves lander-to-ship communications in the hadal zone.

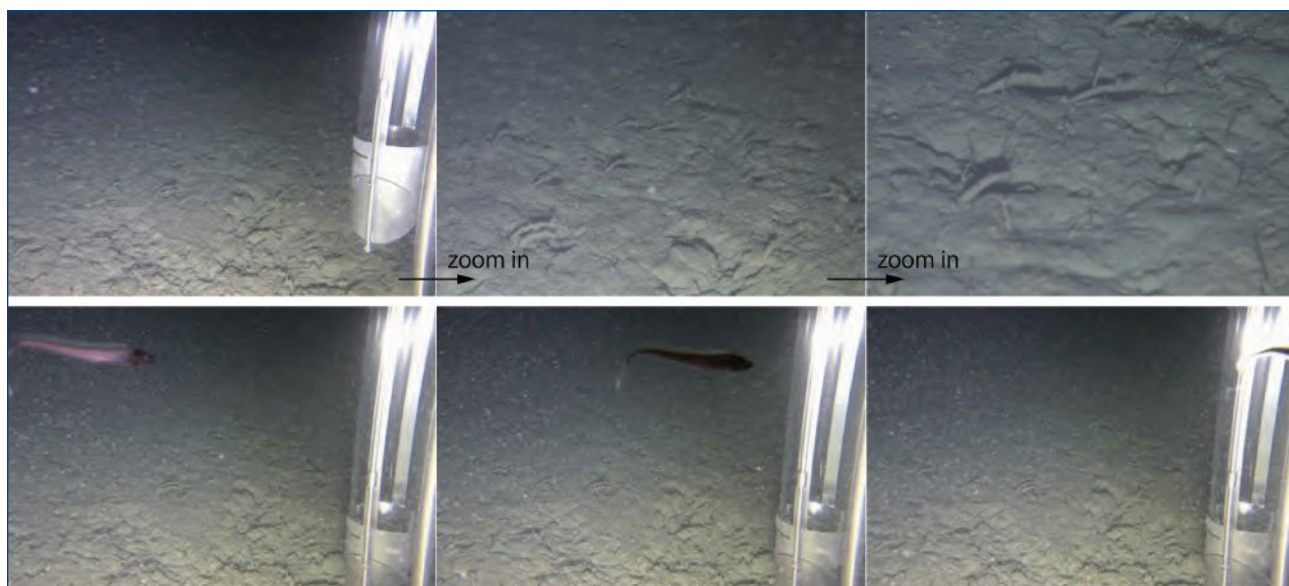
We developed a free-fall camera lander system at JAMSTEC capable of operating to 11-km water depth. FFC11K was developed as both a demonstration platform for technologies and a lander system for scientific observation with enhanced

communication in the hadal zone.

In September 2019, we conducted a demonstration of seafloor video transmission by high-rate acoustic communication and scientific observations, including collecting a core and amphipods using FFC11K, at 9,230-m depth in the plate triple junction of the Izu-Ogasawara Trench.

Design

The size of the lander is 1.6 by 1.7 by 2.2 m. The weight of the standard equipment is 1.6 tons without anchor. The net buoyancy is greater than 170 kg, with sufficient extensibility to accommodate a core sampler, which requires pulling force, and optional devices, which tend to be heavy because of the full-ocean depth rating.



The frame comprises the upper part—with flotation devices, acoustic devices, LED lights, an Iridium beacon and a flusher—and a lower part, with control devices, batteries, a camera, a CTD sensor and other auxiliary sensors and devices. A pure grade of titanium is used for weight reduction and corrosion resistance. An anchor weight release uses two standalone acoustic releasers in parallel for redundancy.

A silicon-nitride ceramic pressure-tight sphere developed by JAMSTEC and Kyocera Corp. in Japan is used to house the main control units. Its net buoyancy is greater than 26 kg, which is equal to that of the 17-in. glass housings.

The main camera is a 4K camera (DS-8230-J, Totsu Sangyo Co. Ltd.) in a Ti-6Al-4V titanium alloy housing with a planar glass viewport. The glass viewport, developed by JAMSTEC and Okamoto Glass Co. Ltd., provides lower distortion and higher transmittance because, by virtue of the high compressive strength of the glass, its thickness can be lower than that obtained using polymethyl methacrylate.

Video Transmission System with High-Rate Acoustic Communication

FFC11K has a video transmission system with acoustic communication (VTSAC), which is a high-rate uplink communication system developed at JAMSTEC based on our study of high-data-rate digital underwater acoustic communication. It has a decision feedback equalizer for signal processing. Through the acoustic source, VTSAC can transmit a 480-by-320 or 360-by-240 pixel capture image of the main camera to a surface ship at 2.5-sec. intervals. The image can be monitored on a surface ship in real time, receiving the signal at the receiver array on the bottom of the ship and demodulating the signal by modem.

VTSAC comprises a video and signal-processing unit, a signal amplifier installed in a Ti-6Al-4V titanium alloy pressure-tight housing, and a high-power transducer for the acoustic source. The frequency band of the source is

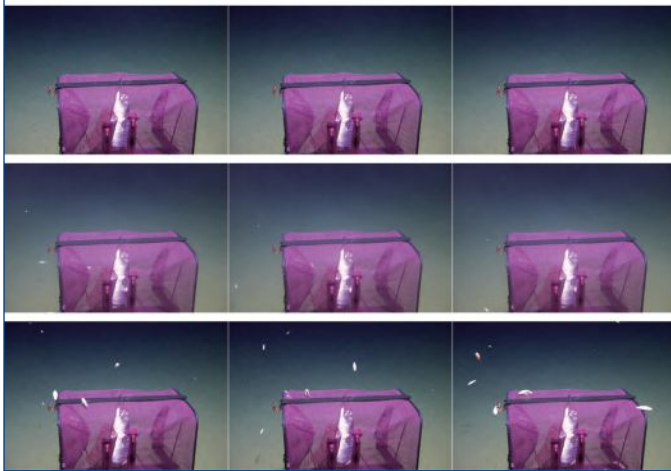
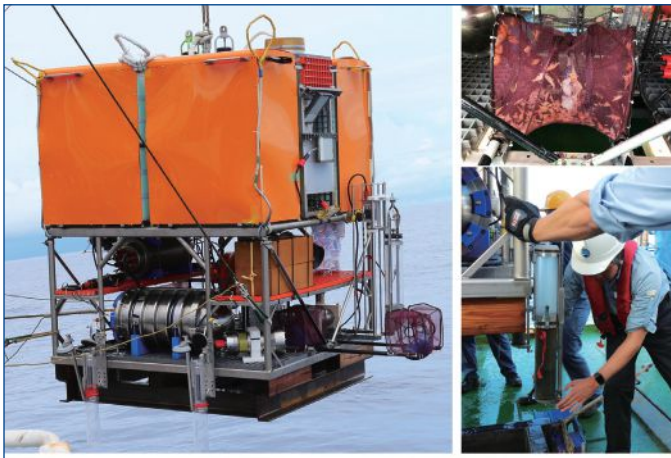
Images from VTSAC at Sagami Bay. (Top) Images obtained when the main camera zoomed in, controlled through the acoustic modem. (Bottom) Consecutive images obtained when a fish passed in front of the camera.

15 to 25 kHz, and the maximum source level is 199 dB re μPa within the directivity of $\pm 20^\circ$. The depth rating is 11,000 m.

Sea Trials and Scientific Missions

Functional tests were first conducted using RV *Yokosuka* in March 2019. FFC11K was deployed to 1,428-m depth in Sagami Bay in Japan. As an additional standard device, a telecommunicable acoustic modem developed in another project was installed to verify the status of FFC11K and to test wireless control of the main camera setting, monitoring a series of images from VTSAC on the vessel. To avoid acoustic interference between the modem and VTSAC, VTSAC was set to stop transmitting signals for 1 min. every 5 min. The size of the transmitted images from VTSAC was 360-by-240 pixels. During the tests, zoom and focus of the main camera on FFC11K were controlled through the acoustic modem. Moreover, change of the zoom and focus was confirmed on the ship in near real time through images from VTSAC. All FFC11K functions as designed were confirmed.

In September 2019, FFC11K was deployed to land on the seafloor at two sites at 9,218 m and 9,230 m depths in the plate triple junction in Izu-Ogasawara Trench for a total of 48 hr. There were two purposes. One was to conduct the engineering test of FFC11K in the hadal zone, including demonstration of the high-data-rate digital underwater acoustic communication using VTSAC, the silicon-nitride ceramic pressure-tight sphere, and the glass viewport with the camera housing. The other was to conduct scientific sampling of seafloor surface sediments and benthic organisms. Scientific sampling devices such as sediment core samplers and baited traps were installed on FFC11K for this purpose.



(Top panels) FFC11K just before release from the vessel on a mission to collect biological and sediment samples at 9,230-m depth. (Bottom panels) Consecutive images from VTSAC after landing on the seafloor: (upper) 0.5 hr. after landing, (middle) 1.5 hr. after landing, (lower) 2.5 hr. after landing.

Continuous clear images of the seafloor at 9,230-m depth from VTSAC were obtained in near real time (9-sec. delay) on RV *Yokosuka*, located directly above FFC11K, with no missing images. Additional experimental signals were also transmitted, which revealed achievement of the data rate of 69.2 kbps. No damages were found on the silicon-nitride ceramic sphere or the glass viewport. Using the sediment core samplers, FFC11K also collected three undisturbed sediment cores in each deployment. In total, six cores were recovered, with a maximum length of 380 mm. A large number of amphipods were also captured in the baited trap.

Conclusion

The full-ocean-depth lander system FFC11K has been developed to demonstrate JAMSTEC's fundamental technologies applicable to ultradeepwater and to execute environmental monitoring and sampling on the seafloor in the hadal zone efficiently.

One key feature of FFC11K is the video transmission system mounted on the seafloor, developed based on the study of high-data-rate digital acoustic communication in deepwater. We succeeded in a series of transmissions

of hadal seafloor images with high-rate acoustic communication and in conducting scientific observations at the maximum depth of 9,230 m by using FFC11K.

Through these sea trials and observations, FFC11K showed that by using the same acoustic communication system, wireless underwater vehicles and observation systems in the hadal zone can transmit larger amounts of information than conventional systems. Moreover, control via surface ship could improve observation efficiency in the hadal zone.

Future studies should address the addition of downlinking communication to VTSAC, as well as installation of a small vehicle by developing small electric actuators on FFC11K to produce a cost-effective compact observatory station for the hadal zone.

Acknowledgments

We thank everyone who supported us in FFC11K development: for trials and logistics, Tsuyoshi Yoshiume and Takuya Shimura are especially appreciated for advice and support on the concept design and technical specifications; Yoshitaka Watanabe and Koji Meguro supported the interface design and operation of the acoustic modems; Ayumi Kobayashi, Masanobu Yanagitani and marine technicians are particularly thanked for assembly and operating support. We also thank Kazumasa Oguri, Akinori Yabuki, Masashi Tsuchiya, crews, scientific parties and the Shinkai 6500 operation team of RV *Yokosuka* cruise YK19-11.

References

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UI Standard for Navigation Systems

Challenges of Implementing New User Interface Guideline

By Dr. Min Jung • Dr. Seojeong Lee

A guideline for standardization of user interface design for navigation systems (the Guideline) was endorsed in 2019 by the International Maritime Organization (IMO) and will be applied from 2024. The Guideline aims to support the decision-making process of maritime officers and ensure navigation safety through a user-friendly interface in core navigation systems such as radar, ECDIS and integrated navigational systems (INS).

The Guideline standardizes icons and terminologies for using navigational functions in the equipment. However, can we be sure users will benefit after the Guideline

is implemented? When users see newly introduced icons, will they recognize them? How should the icons and menus be organized to enhance users' decision making?

Manufacturers now have to solve the problem of developing and/or improving systems in which the Guideline is applied. In this article, we discuss the potential hardships in applying the Guideline from the perspective of the manufacturers and propose things to consider.

Motivation for the Guideline

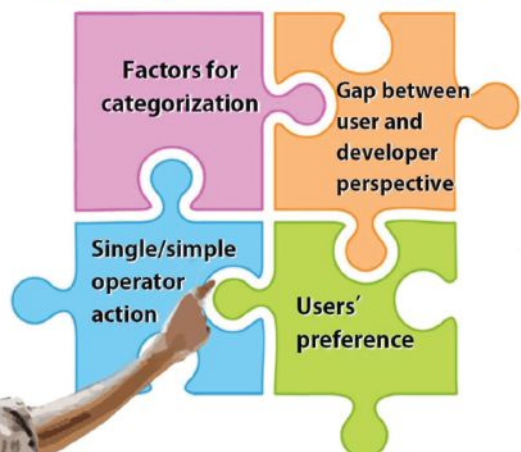
The functions of navigation systems have been harmonized to date due to requirements in the relevant IMO performance standards. However, each manufacturer tends to use different labels for functions and different display arrangements. Therefore, it has been the responsibility of a captain, a maritime officer or a pilot to adjust to the new interfaces of navigation systems. This leads

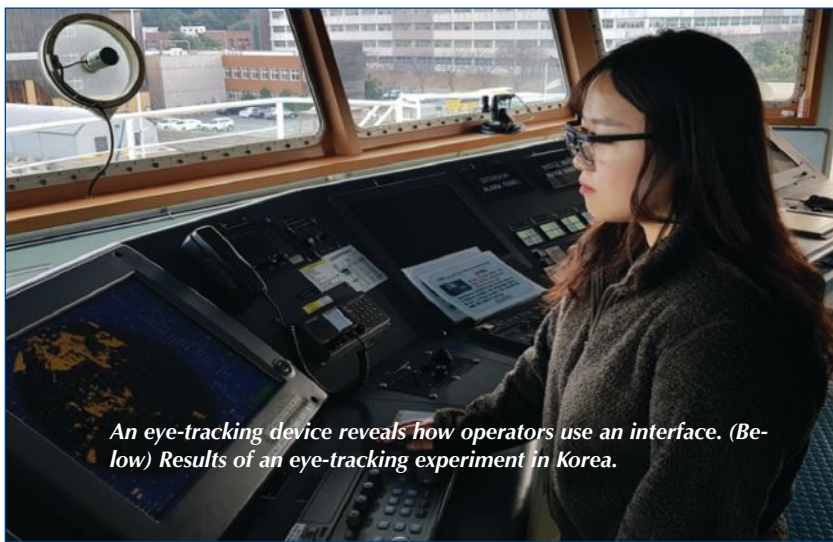
Challenges

- Over 60 types of icons
- Arrangement issues for icons
- Color of functional icons
- Categorization and prioritization of icons
- Size of the monitor and icons



Getting solutions with...





An eye-tracking device reveals how operators use an interface. (Below) Results of an eye-tracking experiment in Korea.

Critical Points for Manufacturers

The Guideline includes standardized icons, terminologies for functions and provisions on representing information. Manufacturers will face several challenges.

Over 60 Types of Icons. The Guideline suggests over 60 icons, and it can be too much to display all at once on the screen. No specific direction has been provided to prioritize which icons should be used.

Arrangement of Icons. Developing a user-friendly hierarchy to arrange icons should be considered. For example, should all icons be displayed on the top of a navigation system, in pull-down or pop-up menus, on a two-dimensional

toolbar, etc.?

Icon Colors. Most icons regulated in Appendix Two of the Guideline only stipulate the symbols and shapes of icons but not the colors. The color scheme is only briefly mentioned in Table Two of Appendix Two. It is up to the manufacturer to select an appropriate color scheme to ensure the best visibility during day and night use.

Categorization and Prioritization of Icons. It is challenging for manufacturers to arrange icons presented in Appendix Two. They could solve by grouping and categorizing icons for users to recognize icons faster, but how will they categorize and to what standards? Consistency of the user interface is required in any standard used for categorizing.

Size of the Monitor and Icons. If the Guideline is implemented in land-based vessel traffic service (VTS) centers, it needs to be considered that they generally use larger displays than on vessels. If more or larger icons can be displayed, what size or number will be best? Similar consideration should be given to portable pilot units (PPUs). Moreover, who should take responsibility for deciding the size of the icons and/or the number of icons displayed on the screen?

Approaches to Resolving Challenges

Identifying Factors for Categorization. The most commonly used features may vary depending on the type of ship, e.g., a generic freighter, an offshore vessel with a dynamic positioning system or a fishing boat. Therefore, careful categorization of menus and icons should be considered depending on frequently used functions in different vessel types.

In-depth consideration should be given to accommodate different circumstances while maintaining standardization. Users may require different functions depending on environments, e.g., whether the vessel is passing

crews to undergo intensive familiarization to be able to properly use an ECDIS, for example. As a result, the need to standardize the user interface of navigation equipment was suggested back in the early 1990s, along with a strong call to mitigate such burdens.

IMO decided to develop the Guideline as one of the significant e-navigation outputs. The Guideline was completed by IMO member states in cooperation with a variety of organizations, such as the International Association for Marine Electronics Companies (CIRM), International Federation of Shipmasters' Associations (IFSMA) and Nautical Institute (NI).

The Guideline was introduced to integrate standardized functional terminology and icons so that captains, maritime officers and pilots can use a standardized interface to support their decision-making processes and to promote improved navigation safety.

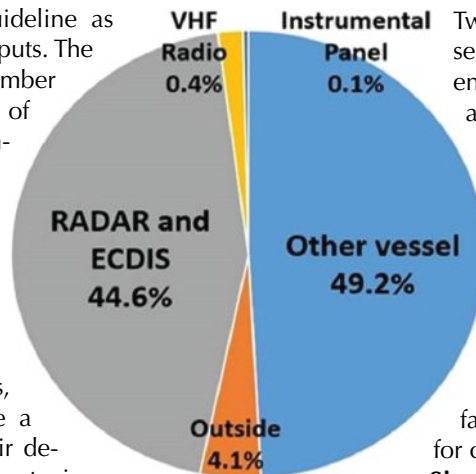
The Guideline may also alleviate other burdens, such as fatigue.

The Guideline has a firm grounding in human factors on standard design principles, icons related to standard navigation terminologies, grouping of navigation information, requirements related to single and simple operator actions, and default and user configurations through five appendices.

The Guideline was published as IMO MSC.1/Circ.1609, and parts of it refer to other IMO documents. For example, Appendix Two (menu terminology and functional icons) and Appendix Three (information grouping) were referenced by IMO Resolution MSC 466(101).

These terms will become mandatory for radar, ECDIS and INS first, beginning January 1, 2024.

Starting July 1, 2025, these requirements will extend to all navigational displays within the bridge. Therefore, manufacturers should undergo prototyping, type approval and production phases before 2025.



“Manufacturers now have to solve the problem of developing and/or improving systems in which the Guideline is applied.”

through a heavily congested narrow channel or sailing through the open ocean. Moreover, a different set of functions may be required based on weather or time of day.

The age and level of experience of users also vary. The system can be handled by officers, captains or pilots, and as the level of experience differs, the frequency and variety of functions used may also differ. Also, icon size and font on the interface may affect older users.

Reconciling Objectives. Developing new systems raises the challenge of limited time and costs. Some developers may be tempted to present a large variety of functions and information on their equipment user interfaces to minimize time and money spent on design. However, operators tend to prefer user interfaces that simplify the presentation of the information and functions they need.

Surveying User Behavior. It is essential to understand users’ needs to make high-quality equipment, which will also help improve market share after the introduction of the Guideline. User preference surveys using eye tracking are useful. For example, research was conducted in Korea involving a survey performed in the process of developing the Guideline to help inform it. Testing was performed on maritime officers in standing duties on board a Korean passenger ferry traveling between Korea and Japan. Three types of ship-handling simulation stations were used to test navigation systems by different manufacturers. Twenty-seven maritime officers and captains participated in the testing. The officer on duty was requested to attend to ordinary duties while wearing an eye-tracking device. Through the testing process, we were able to gather which functions and information they used during decision-making processes. After visually observing a target ahead of the vessel, officers on duty confirmed information they required through the navigation system. We conducted eye tracking during a series of routine actions, such as confirming automatic radar plotting aids (ARPA) information, e.g., course and speed of a target ship, and obtaining solutions from ECDIS. As a result, area of interest (AOI) could be obtained for a set of essential navigation systems such as radar and ECDIS.

Thanks to the eye-tracking device, we identified where users unconsciously gazed into the screen, as well as when users attentively looked at the screen.

The list of navigation information and functions preferred by standing officers is described in detail in IMO document NCSR 6/INF.13.

Considering Essential Functions. Equipment designers may think it is only necessary to arrange menus with functional icons based on frequency of usage. However, there are essential functions for navigation safety that are not frequently used but should be easy to access. For example, among single operation actions for ECDIS, CAT-ZOC (category zones of confidence) should be provided as a hot key to show accuracy-related symbols in an electronic navigational chart (ENC).

The Guideline stipulates that a single/simple operator action should be implemented in essential functions (Appendix Four), which includes existing IMO performance standards of ECDIS, radar and INS.

Conclusion

Navigation equipment manufacturers are required to improve user interfaces to implement the new Guideline. This article suggests some challenges manufacturers may face and how to approach them. Implementation of the Guideline will be successful when these challenges are solved and standardized items are optimized.

References

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Dr. Seojeong Lee is a professor at Korea Maritime and Ocean University (KMOU). Her academic background is in software design. Since 2009, she has been attending the IMO NCSR Subcommittee (formerly NAV) meetings and IALA e-NAV Committee meetings. During this period, she led the SQA part of IMO MSC Circ.1512 “Guideline on SQA/HCD for e-navigation.” Since 2018, she has been working on quality-in-use, software functional safety and security in maritime industries.



international

Contracts for iXblue in South Pacific

iXblue has been awarded two hydrographic charting projects by Australia and New Zealand under their respective annual survey and charting programs. Both projects will take advantage of iXblue's DriX USV and its Australian-based cloud-computing infrastructure for data processing and reporting.

ClassNK's New Survey Offices

ClassNK has opened new exclusive survey offices in Kandla, India, and Valencia, Spain. Both offices are located in one of the most well-known port cities in each country. In recent years, the number of surveys and audits required in the northwest part of India and southern part of Spain has been increasing. Through the opening of its newest offices, ClassNK will improve the efficiency of its ship surveys and audits in these areas.

Slocum G3s for Research

Teledyne Webb Research has sold and delivered Slocum G3 gliders to the University of Bergen: two deep, rechargeable gliders and three deep, endurance gliders.

The Slocum G3 gliders, procured by the University of Bergen's Geophysical Institute, are depth rated to 1,000 m and feature the new G3 processor. The University of Bergen Slocums are configured with oceanographic sensors, including CTDs.

Norway Fuel Cell Project

Shipping is faced with the need to meet the IMO's ambition to drastically cut greenhouse gas emissions by 2050. A project is underway in Norway to further develop fuel cell technology to enable the use of different fuels. Wärtsilä is supporting the project, along with the main partners Odfjell, a major shipping operator, Prototech, a specialist company in fuel cell technology, and Lundin, an offshore oil and gas company.

Preliminary testing indicates that CO₂ reductions of as much as 40 to 45 percent are possible when using LNG as fuel, and emissions can potentially be reduced even further with other fuels, such as ammonia.

Proposed Low-Carbon Cluster in UK

Equinor, with 11 other companies and organizations, has submitted a joint proposal to create a low-carbon cluster in the Humber, the U.K.'s largest and most carbon-intensive industrial region. The application by the Zero Carbon Humber (ZCH) Partnership is a first step to creating the world's first net-zero industrial cluster by 2040 and will support clean growth in the northeast of England. The bid for Phase Two funding from the U.K. government's Industrial Strategy Challenge Fund builds on a successful application for Phase One funding.

Pumps for Powership

In designing a new powership for its global fleet of floating power plants, Turkish company Karpowership

needed an extensive shipset of 72 pumps, capable of withstanding harsh marine conditions and continuous uptime. The company has selected the CIRCOR family of brands to source the pumps.

Once launched, the powership will supply continuous power production for remote, underserved areas of the world.

Hydrographic Survey Educational Support

The Port of London (PLA) Hydrographic department recently teamed up with Unmanned Survey Solutions (USS) to provide educational support to University College London's (UCL) IHO CAT A course in hydrographic surveying. Due to COVID-19 restrictions, the final element of this year's support had to be conducted virtually. PLA, in conjunction with USS and UCL, devised a two-week schedule that incorporated a combination of manned and unmanned survey tasks to bring the very latest industry solutions to M.S. students.

EBS off Ivory Coast

TDI-Brooks International Inc. teamed up with the French environmental firm Créocéan and Benthic Solutions to complete environmental baseline studies (EBS) for TOTAL E&P Côte d'Ivoire (Ivory Coast). TDI-Brooks deployed the RV *Proteus* to blocks CI-705 and CI-706 to conduct seawater sampling and profiling (CTD rosette), as well as plankton sampling (bongo net) at seven stations, sediment sampling (mega box core) at 45 stations, and live-feed benthic video sled at 24 transects.

The two blocks cover an area of about 3,200 sq. km and present multi-target hydrocarbon prospects in water depths ranging from 1,000 to 2,000 m.

USCG Tests Autonomous Vessel Tech

Sea Machines Robotics has partnered with Metal Shark Boats to supply the U.S. Coast Guard (USCG)'s Research and Development Center (RDC) with a new Sharktech 29 *Defiant* vessel for the purposes of testing and evaluating the capabilities of available autonomous vessel technology.

The 29-ft., welded-aluminum monohull pilothouse vessel comes equipped with the Sea Machines SM300 autonomous-command and remote-helm control technology, offering transit autonomy, collaborative autonomy, collision avoidance and remote vessel monitoring.

High-Horsepower Ventilation

The new Seastreak 45-m-class passenger ferry *Courageous* will boast 7,274 bhp of raw power from its four MTU engines, which demands massive airflow. Midship Marine of Harvey, Louisiana, is installing a Delta "T" Systems engineered ventilation package to allow for this. It will assist in achieving expected service speed of 32 kt. The anticipated launch date is May 2021.

AUVSI Award for HUGIN AUV

Kongsberg Maritime's HUGIN AUV has scored a prize in the 2020 AUVSI XCELLENCE awards, which recognize "innovators committed to advancing autonomy, leading

and promoting safe adoption of unmanned systems, and developing programs [using] these technologies to save lives and improve the human condition.” The HUGIN AUV came in third in the Hardware – Platform group award in the Technology & Innovation category.

Chevron Completes Acquisition

Chevron Corp.’s acquisition of Noble Energy Inc. has been completed following approval by Noble Energy shareholders. Noble Energy’s employees and shareholders are now part of Chevron.

RBR’s New HQ

RBR Ltd., named as one of Canada’s fastest-growing companies, has a new office headquarters in Ottawa that covers about 22,500 sq. ft. This two-story space is nearly double the size of the previous office.

Pilot to Partner with GAC on LNG

Texas-based Pilot LNG LLC has executed a heads of agreement, outlining the terms of a partnership, with GAC Bunker Fuels for the supply of LNG as a marine fuel from its proposed Galveston LNG Bunker Port terminal project, which will be the first dedicated LNG bunker terminal in the region.

Wave Gliders for Monitoring

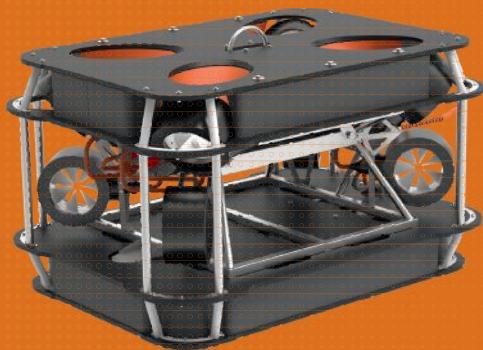
ROMOR Ocean Solutions has announced the arrival of two new Liquid Robotics Wave Gliders for Dalhousie

University in Nova Scotia, Canada. The two gliders are an addition to the suite of ocean monitoring tools used by Dalhousie-based Ocean Tracking Network (OTN), the Ocean Frontier Institute (OFI) and the Marine Environmental Observation Prediction and Response (MEOPAR) network. These two new vehicles will be used to support critical marine research in the northwest Atlantic and will be housed at the Centre for Ocean Ventures and Entrepreneurship (COVE) in Dartmouth, Nova Scotia.

Dalhousie, under the auspices of the Coastal Environmental Observation Technology and Research (CEOTR) group, operates the largest glider monitoring program in Canada.

Proposal to Expand FRC Program In American Samoa

U.S. National Security Advisor Robert O’Brien recently announced plans to conduct a feasibility study on whether to base U.S. Coast Guard *Sentinel*-class fast response cutters (FRCs) in American Samoa to counter “destabilizing and malign actions” by China in the Indo-Pacific region. Together with the FRCs currently based in Apra Harbor, Guam, these cutters will help the U.S. challenge Chinese aggression, maintain U.S. commitment to peace and prosperity, and ensure that the U.S. remains the partner of choice in the region. The new FRCs will conduct maritime security missions, enhance maritime domain awareness and enforcement efforts with regional partners, and ensure freedom of navigation. **ST**



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Shallow-Water Sonar



iDX-PRO is the new model of the 3DSS sonar, featuring a fully integrated SBG Navsight Ekinox INS and Septentrio GNSS in a compact form factor. The combination of the 3DSS and Ekinox excels in shallow-water survey applications with high motion dynamics, such as exposed coastal areas, and in GNSS-denied environments, such as under bridges. Ping DSP Inc.

New Laser Wavelengths

For Model SB10 and SB20 Sea Beam laser scalars, the new laser colors are red for minimum biologic awareness, green for greater brightness in turbid water, and blue for long-distance penetration in clear water. Sea Beam can scale unusual objects, fish, reefs, artificial structures and mechanical fixtures at depths where divers can't explore or the cost is too great. Laser Tools Co. Inc.

Shipping Software, Services Suite

s-Suite includes voyage planning, onboard route optimization, route advisory services and fleet performance management, now combined in one solution. s-Suite delivers a common operational platform for ship and shore. StormGeo AS.

Subsea Wireless Modem

LUMA X can beam data at up to 10 Mbit/s with a 120° cone, enabling real-time streaming of HD-quality video and 4K images wirelessly through water. This allows operators of AUVs to monitor interventions from control rooms onshore. Hydromea SA.

Onboard Work Platform System

The LOBO System combines the

flexibility and strength of traditional scaffolding with the simplicity and mobility of aluminum tower systems. It can be made safely into any shape or size, without the need for any tools, and fits into hard-to-access areas. LOBO Systems Ltd.

Marine Hook

Cranston-Eagle Marine Off-Load Hooks are reliable for deploying rescue and life craft, and distributor Delta "T" Systems offers the global logistics to get the hook tested, re-certified and back into service. SOLAS certified and USCG approved, the hooks are available in davit, crane-fall, boat-roof and open-boat configurations. Eagle Products Ky.

Pipe Pressing Systems



Three marine pipe pressing systems are being introduced to the North American market: Raxofix (16 to 63 mm), commonly used for potable water; Sanpress INOX (15 to 54 mm), available with EPDM or FKM sealing elements; and Profipress (15 to 54 mm), copper and bronze fittings with optional EPDM or FKM sealing elements. Viega LLC.

Wi-Fi Receiver

Wave WiFi Tidal Wave is a professional series dual-band, AC speed Wi-Fi receiver with a built-in SIM-activated cellular system and MIMO (multiple input multiple output) antennas. It allows wireless connection to internet sources farther from shore. When out of range of wireless hot spots, the cellular system provides an alternative path to internet connectivity. Wave WiFi Inc.

Compact Ethernet Switch Modules

The EPSM-10GX4 managed switch offers 24 10/100/1,000-Mbps copper ports, four 10-Gbps SFI ports, Layer 2+ switching and Layer 3 routing/switching software in the ultracompact size of 55 x 84 mm. The module is intended to be used on a carrier board for a complete Ethernet switching solution. Diamond Systems Corp.

Wave Energy Software



Wave Power Verification (WPV) can speed up efficiency verification of the different subsystems of wave energy generation technologies and detect failures in wave modules instantly. It can provide a complete and fast live report of the current efficiency status of production of each wave energy module in a wave energy power plant. EWPG Holding AB.

Hull Monitoring Software

XSHIP Performance is a tool that has been added to the KP Analysis fuel-saving system. The XSHIP methodology is ISO 19030 compliant. Nippon Paint Marine Coatings Co. Ltd.

Electronic Log Book

LogCentral is a secure digital tool to collect and share vessel data. In addition to monitoring fleet activity in real time, shore-side management teams can compare and analyze trends in depth. Insights are available through the online portal. OneOcean.

Risk Awareness

Hosted on the MyGlobeView digital platform, Route Risk Advice evaluates and demonstrates the potential hazards of a voyage, from port of origin to destination. MyGlobeView provides North members and correspondents with ex-

clusive access to over 40 alerting and reporting features, including industry news, port details and weather. North P&I Club.

Reliability Data

Offshore and onshore reliability data (OREDA), gathered by several oil and gas operators for nearly four decades, is now available online through Veracity. Data are included from over 18,000 equipment units, with 43,000 failure and 80,000 maintenance records, and subsea fields with more than 2,000 collective years of operating experience. DNV GL.

Bathymetric Software

Multispectral bathymetric tool for Esri ArcPro processes satellite-derived bathymetry data, assesses accuracy and outputs as .BAG files. ICESat data extraction software leverages artificial intelligence algorithms to automatically extract seafloor depth measurements from ICESat-2 laser data. TCarta Marine LLC.

Compliance Management

NS eLogs is a digital solution that replaces traditional paper logbooks and brings a new dimension to compliance management through a browser-based experience. The launch follows the International Maritime Organization's (IMO) nonmandatory adoption of electronic record books in October 2020. ABS Nautical Systems LLC.

Diver-Assisting Sensors

The Diver Mounted Display system (DMD) offers divers vision in zero-visibility water with the Gemini multibeam sonar mounted on the diver's mask or helmet. A monacle is installed over one eye, projecting a real-time sonar image to the diver. Tritech International Ltd.

Digital Sextant

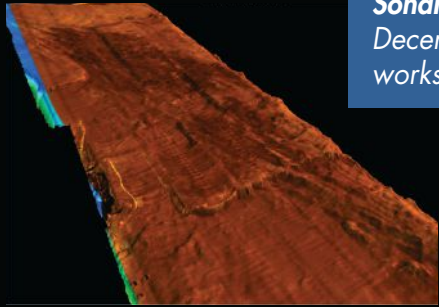
This innovation calculates and fixes a ship's position easily and quickly, with a user-friendly GUI. It serves as a navigational backup that can provide a printable log. LEEYOUNG SND Co. Ltd. **ST**



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Global Cooperation Needed For Ocean Sustainability

Countries need to work together to defend the ocean from a steady rise in temperature, pollution and over-fishing that threatens its ability to continue supporting marine life and providing food and income to billions of people, according to a new OECD report. "Sustainable Ocean for All: Harnessing the benefits of sustainable ocean economies for developing countries" says that with ocean-related economic sectors forecast to grow rapidly over the next decade, ensuring this development takes place in a sustainable way is critical.

While the COVID-19 crisis is hurting key ocean-based sectors, such as tourism and shipping, demands on marine resources for food, energy, minerals, transport, tourism and leisure will persist as the global population grows toward an expected 9 billion by 2050. If managed sustainably, the ocean could have the capacity to regenerate, be more productive, and support more prosperous societies. This will require governments to support those sectors less equipped to foster sustainable ocean economies by facilitating their access to finance and policy evidence.

Noting that the poorest countries tend to be both the most exposed to the effects of ocean degradation and the least equipped to respond, the report calls for coordinated action and more effective international development cooperation to improve sustainability of the ocean economy. The United Nations Decade of Ocean Science for Sustainable Development, starting in 2021, should foster greater use of science and innovation to develop sustainable practices in a post-COVID world.

The report calls on all countries to phase out government support for environmentally harmful economic activities and use instruments like fees, charges, taxes and tradable permits to discourage over-exploitation, pollution and greenhouse emissions and encourage conservation and sustainable development of ocean activities. Such instruments can also generate much-needed financing for ocean sustainability. Taxes relevant to ocean sustainability, in particular, taxes on ocean-related pollution, transport and energy, generated at least \$4 billion globally in 2018.

Scanning Sonar Improves Shrimp Aquaculture

Aquaculture has increased to meet seafood demand and now accounts for over half of all shrimp production. However, the shrimp aquaculture industry operates with little understanding of how much shrimp is in a pond. Farmers must take a "best guess" approach that ultimately results in incomplete and inaccurate information.

JW Fishers SCAN-650 sector scanning sonar produces a detailed image of the underwater environment regardless of the water visibility. It does this by sending out a sound wave that reflects off objects on the bottom or in the water column. The reflected wave returns to the sonar head where it is received and sent to the sur-

face for display. Minnowtech LLC provides a software imaging platform to enable shrimp farmers to estimate shrimp abundance noninvasively with precision. Using a JW Fishers SCAN-650A, Dr. Suzan Shahrestani of Minnowtech is investigating ways of quantifying shrimp in aquaculture. Using the high-resolution data output from the sector scan, Shahrestani provides shrimp farmers with meaningful information on biomass and behavior to help maximize efforts and increase production. Shrimp biomass analysis empowers farms to make critical and timely decisions for their business.

Tool to Reduce Lethal Endangered Whale Collisions

Whale-ship collisions are one of the leading worldwide causes of endangered whale deaths. It is estimated that more than 80 endangered whales—including blue, humpback and fin whales—are killed every year from ships off the U.S. West Coast alone, with many more occurring in other parts of the U.S. and the world. This summer, 30 blue whales were spotted feeding amid ships in the Los Angeles-Long Beach shipping lanes, one of the world's busiest shipping routes, raising concerns about the whales' fates.

Whale Safe is an online tool that has been developed by the Benioff Ocean Initiative at UC Santa Barbara and its partners—the Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, Texas A&M University at Galveston, UC Santa Cruz, University of Washing-

ton and NOAA's Southwest Fisheries Science Center—to detect in near real time whales inhabiting the Santa Barbara Channel to help ship operators avoid hitting them.

Echosounder to Map Seagrass In Marine Protected Areas

Cornwall Inshore Fisheries and Conservation Authority has taken delivery of a BioSonics MX scientific fisheries echosounder, supplied by Swathe Services, to map the extent and density of seagrass in four marine protected areas in Cornwall to ensure management is appropriate and effective. The new echosounder will enable 3D capability to see the canopy height and density and estimate the seabed substrate type.

Seagrass is vital for climate change and is an essential marine habitat. It has a considerable part to play in absorbing carbon dioxide from the atmosphere.

DNV GL Expands Remote Services Delivery

A new state-of-the-art Operational Centre to support the delivery of remote services to maritime customers has been launched in Hamburg, Germany, by DNV GL – Maritime.

The launch also marks the two-year anniversary of DNV GL's fleet-wide roll-out of remote surveys and the milestone of 20,000 remote surveys delivered.

This is DNV GL's second Operational Centre dedicated to the delivery of remote services. The first was launched in Oslo in 2019. **ST**



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Research Explains Saanich Inlet As Natural Carbon Sink

Coastal fjords are known hot spots for organic carbon burial, storing 11 percent of the carbon buried in the oceans—an estimated 18 million metric tons a year. New research using Ocean Networks Canada's (ONC) Saanich Inlet cabled ocean observing infrastructure provides further evidence as to why this deep Vancouver Island fjord is a natural place that stores carbon, also known as a carbon sink.

Ocean sediment health depends on oxygen mixing downward through the bottom boundary layer of the ocean into the sediment. In coastal fjords such as Saanich Inlet, a major limitation on the health of the benthic organisms and the turnover of organic matter raining to the seafloor is the rate at which dissolved oxygen reaches the sea bottom. To quantify the downward flux

of dissolved oxygen continuously over several months, researchers from Oregon State University, ONC and Victoria-based Rockland Scientific used eddy covariance. The researchers deployed sensors for measuring small variations of oxygen and temperature in close proximity to an instrument measuring small changes in water velocity on ONC's Saanich Inlet cabled observatory.

Designed to measure both the smallest scales and the fastest variations, the sophisticated sensors generate a great amount of high-resolution data to determine the rate of gas exchange in a natural ocean ecosystem. The eddy covariance technique is well-suited for a cabled observatory's high-speed real-time continuous Internet connectivity, where data rates are virtually unlimited.

The research results suggest that Saanich Inlet's slow currents and weak turbulence contribute to a

relatively small flux of oxygen. The small amount of oxygen that does reach the bottom sediments is due to the Inlet's annual deepwater renewal events and periodic turbulence. This research also highlights the uniqueness of near-bottom conditions in coastal fjords, explaining why Saanich Inlet is a natural carbon sink.

The complex ocean carbon cycle involves two different forms of carbon: inorganic carbon is a result of the anthropogenic CO₂ emissions being dissolved into saltwater, while biologically "fixed" carbon is stored in marine organisms and sediments. The amount of biological carbon in the ocean varies spatially and over time, variously representing either a net sink or a net source of carbon. Research is continuing to help us fully understand the processes that drive these changes.

Discovery of How Microscopic Algae Reproduce

There are hundreds of different species of microscopic algae in the

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seas and oceans. They are responsible for the production of approximately 50 percent off all the oxygen that is generated through photosynthesis on this planet. Little is known about their life and survival strategies, for example, nutritional habits and reproduction.

The tiny single-celled algae are traditionally thought to reproduce simply by asexual cell division and produce clones, which restricts their genetic diversity and capacity for adaptation in changing environmental conditions.

Now, for the first time, marine scientists found that sexual reproduction (change from diploid DNA to haploid) happens in single-celled algae when their growth becomes limited by resources, in this case, availability of nitrogen. This survival strategy may be much more common among the unicellular algae than previously thought.

This discovery happened by accident in 2017, when Lumi Haraguchi, then a Ph.D. student at Aarhus university in Denmark, looked at her cultures of algae that were left unattended for some time and was surprised to see that the cells were alive but had apparently changed from one species to another.

She speculated that the two different types of algae cells were the same species at different life cycle stages. The hypothesis was later confirmed by analyzing the DNA of the two common Cryptophyte species, *Teleaulax amphioxeia* and *Plagioselmis prolonga*.

Study Links Salinity of Arctic And North Atlantic

New research provides the first clear observational evidence of how salinity is linked between the Arctic and the North Atlantic. U.K. "Ocean salinity plays an important role in regional climate by influencing the ocean currents that drive heat around the planet. Therefore, by enhancing understanding of the source and variability of North Atlantic salinity, this finding may help improve forecasts of the climate in Europe," National Oceanography Centre (NOC) scientist and lead author Dr. Cristian Florindo-Lopez

said. Published in the *Journal of Climate*, this research was led by NOC and includes collaborators from the Bolin Centre for Climate Change in Sweden and the Department for Fisheries and Oceans in Canada.

The authors analyzed many years of ocean measurements taken right in the path of Arctic freshwater currents on the Labrador Shelf, east Canada. The results of this study link the decadal changes of Arctic

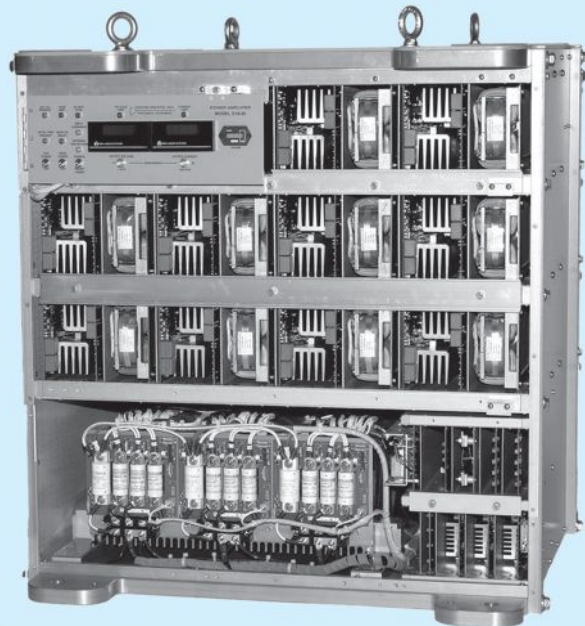
freshwater currents with the salinity of the Arctic and North Atlantic oceans.

In periods when more water was leaving the Arctic, the authors observe a coherent increase in Arctic salinity, and a corresponding salinity decrease in the North Atlantic.

This study shows how changes in the climate system can be coordinated over vast regions of the planet. **ST**

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Pushing European Leadership On Ocean Energy

The new EU Strategy on Offshore Renewable Energy must include a target of 100 MW of ocean energy installed in Europe by 2025, according to Ocean Energy Europe. This would be enough to power 100,000 European homes a year and would pave the way for installing 3 GW by 2030 and 100 GW by 2050. This target would provide the political impetus and incentives needed to maintain Europe's position as the global leader in ocean energy and create a new industry for Europe.

Ocean Energy Europe believes four priority actions are needed to achieve this: the formation of a pan-European alliance of EU decision makers, national governments and industry representatives; investing €300 million in ocean energy at EU level to leverage about €335 million in private investments; launch of a European Insurance and Guarantee Fund; and launch of an offshore renewables export strategy.

Floating Wind Progress In Asia-Pacific

Total and Macquarie are partnering to develop a 2-GW floating offshore wind portfolio in South Korea. This move represents accelerated momentum in the floating wind segment.

Quest Floating Wind Energy's Q Vision illustrates a \$35 billion total addressable market in capex for the Asia-Pacific region, with South Korea leading with 12 projects following the Total announcement.

There are now 26 floating wind projects in Asia, with varying project statuses as defined by Q Vision, and 16 of these are rated at 400 MW or more.

Total now represents about 23 percent of the Asia-Pacific region's projects, followed by Shell (EOLFI) at 18 percent and Equinor with over 8 percent.

Japan Offshore Wind Joint Bid

Equinor, Jera and J-Power have entered a joint bid agreement pri-

or to Japan's upcoming Round One offshore wind auction.

Establishing this consortium is in line with Equinor's renewable strategy of building scale in core regions and developing growth options in selected markets to become a global offshore wind major.

The Japanese government has dedicated Yurihonjo and Noshiro, two areas offshore the northern Japanese prefecture of Akita, as promotional zones for offshore wind, each representing an area for bottom-fixed offshore wind farms of approximately 400 and 700 MW, respectively.

The upcoming auction is anticipated to start within the next several months, with bid submission taking place six months after the auction opens. Once the auction is closed, the results are expected to be announced toward the end of 2021. Potential wind farms would then tentatively be operative post-2025.

Japan aims to increase its renewable energy sources from today's 15 to 16 percent to 22 to 24 percent by 2030, with a target of 10-GW wind capacity to meet its climate change commitments and become more energy independent.

Long-term opportunities are within both bottom-fixed and floating offshore wind, as waters in Japan are deeper than in other parts of the world on average.

Platform for Floating Offshore Wind Construction

A platform designed to aid in the building and launching of floating wind turbines is being researched and tested with support from Marine-i. Partly funded by the European Regional Development Fund, Marine-i is designed to help the marine tech sector in Cornwall and the Isles of Scilly grow through harnessing the full potential of research and innovation.

The innovative design has been created by TUGDOCK Ltd., based in Falmouth, Cornwall. The company has patented and produced a novel floating solution to lift struc-

tures for various uses. The next step is to carry out rigorous testing of a scale model of the platform.

Supply Chain Consultation for Massachusetts Offshore Wind

Xodus Group and BW Research Partnership will conduct a research project to assess the local and regional supply chain in support of the growing offshore wind industry in and around Massachusetts.

Working on behalf of the Massachusetts Clean Energy Center (MassCEC), Xodus and BW Research, in coordination with Greentree Consulting and the Massachusetts Manufacturing Extension Partnership, will deliver a comprehensive offshore wind supply chain assessment and gap analysis. This will be based on the requirements of both developers and tier-one companies, and the capabilities, qualifications and interest of Massachusetts companies and neighboring states.

With most offshore wind facilities currently manufactured and produced overseas, MassCEC is supporting efforts to develop a robust local supply chain in Massachusetts and throughout the region that can manufacture and produce turbine components and associated equipment at a scale necessary to serve planned and anticipated offshore wind projects.

Partnership to Grow UK Tidal Market

The European Marine Energy Centre (EMEC) in Scotland has joined forces with Perpetuus Tidal Energy Centre (PTEC) to develop a large-scale tidal energy site off the Isle of Wight, England. This site will be eligible to bid for future U.K. Contracts for Difference (CfD) allocation rounds, enabling tidal energy technologies developed in the U.K. to deliver predictable low-carbon energy.

PTEC is a 30-MW tidal energy demonstration facility 2.5 km south of the Isle of Wight, with potential expansion capacity up to 300 MW. EMEC is already working on site development and optimization activities, building on work by PTEC to get the site consented in 2016. **ST**

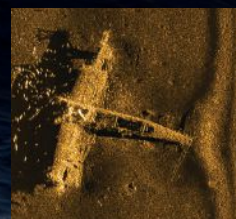
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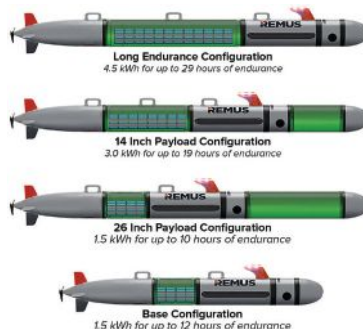
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REMUS 300: One Vehicle, Many Missions

Balancing flexibility with portability for maximum mission efficiency

The REMUS 300 is the newest Unmanned Underwater Vehicle (UUV) built on the REMUS Technology Platform. Open architecture is the platform's backbone, allowing for rapid integration of new payload modules and software while decreasing risk with development, schedule and cost. Combined with advanced core electronics, modularity, and flexible energy options, the REMUS Technology Platform allows REMUS UUVs to keep up with the speed of innovation through rapid spiral integration. This platform is scalable across all UUVs, from small class to extra-large class.

The REMUS 300 represents a generational leap in technology and is the culmination of 20 years of UUV development and feedback from customers worldwide. Building on the trusted, portable design of the small class REMUS 100, the REMUS 300 maintains the



7.5-inch diameter, increases modularity, can go to depths of 305 meters, and offers flexible payload and energy options. The REMUS 300 can be reconfigured for different missions, from an 80-pound base configuration to a 130-pound long-endurance configuration. Balancing flexibility with portability, users can choose payload and energy modules that maximize mission efficiency with improved lithium-ion batteries and battery management software for up to 29 hours of endurance. Blind-mate module end caps allow for easy swapping in the field, adhering to IPX4 water resistance

standards and allowing for quick vehicle turnaround. The REMUS 300 software is built on DDS middleware and is designed to be Unmanned Maritime Autonomy Architecture (UMAA) compliant, while maximizing Modular Open Systems Architecture (MOSA) principles.

Today, over 500 REMUS UUVs are in operation in 22 countries worldwide. Living up to a legacy that includes the REMUS 100 (aka MK18 Mod 1 Swordfish UUV), REMUS 600 (aka MK18 Mod 2 Kingfish UUV and LBS-AUV), and the deep-diving REMUS 6000, the REMUS 300 marks a new era in UUV design with the scalable REMUS Technology Platform that will allow for continuous evolution. To learn more, visit:

tsd.huntingtoningalls.com



Connectivity Trials for SAILOR 600 VSAT

Cobham SATCOM and Kepler Communications have completed connectivity trials on Kepler's low-Earth orbit (LEO) network with the SAILOR 600 VSAT Ku antenna system. The companies demonstrated downlink rates of 150 Mbps and uplink rates of 130 Mbps on a 65-cm antenna with a 6-W BUC over the Kepler LEO network. These data rates are the fastest achieved in an antenna of this class. Typically these speeds are only achieved on much larger antennas with bigger amplifiers and using much larger satellites.

The successful completion of the test will pave the way for the commercial rollout of the SAILOR 600 VSAT Ku on the Kepler LEO network. It will enable vessels to manage and offload large quantities of data in near real time and enable much faster progress on studies pertaining to critical global issues, such as climate change. The two companies are working on live customer trials using the SAILOR 600 platform for both maritime and fixed-site applications.

Cloud Simulation to Train Shipping Crews

Wärtsilä Voyage Cloud Simulation Solution has been selected by ship manager Anglo-Eastern to provide online capacity for the company's training centers in India, the Philippines and Ukraine. The cloud-based simulators will be used for navigation, engineering and liquid cargo handling simulator-based training.

Anglo-Eastern has over 600 ships under management and a crew pool of more than 29,000 seafarers worldwide. It is the first global ship management company to implement the Wärtsilä Cloud Simulation Solution, based on the same platform as the company's physical simulators. It provides online training services when physical attendance at training centers may not be advisable or possible, such as during the COVID-19 pandemic.

Asset Management Digital Partnership

A new digital partnership aims to create one of the most innovative and advanced asset management systems in the maritime and offshore sectors. The collaboration by James Fisher Asset Information Services (AIS) and SRO Solutions, which represents IBM's Maximo software in the marine industry, will offer four proven technologies as one package supported by experienced marine and offshore teams from AIS and SRO Solutions.

The four technologies are: IBM's Maximo asset management software, SRO's Data Replication Solution, AIS's digital twin platform R2S and AIS's Mimic Condition Monitoring (CM).

This partnership will drive massive digital innovation in the efficient management of thousands of pieces of equipment between on-shore and offshore oil rigs and fleets of ships.

Industry-First Type Approval

NAPA has been awarded type approval by DNV GL for its latest loading computer, the NAPA Loading Computer Type 4 and Loading Computer System Damage Control, LCS(DC). The type approval, which is the first of its kind to be awarded by DNV GL, is significant in enabling further adoption of a new generation of loading computers, which assess damage in real time with increased accuracy, allowing crew to make essential decisions on ship stability.

The Type 4 Loading Computer marks a significant shift in operational safety, most notably for passenger vessels. Since the start of 2020, under new IMO requirements, all passenger-carrying new-build vessels will be compliant if a Type 4 Loading Computer is installed. Likewise, passenger ships constructed before January 1, 2014 must also comply with this requirement no later than the first renewal survey after January 1, 2025. To ensure the highest industry safety

standards are reached, and to future-proof vessels in line with regulation, NAPA will also now only deliver Type 4-compliant software.

LCS(DC) provides additional functionalities, including automatic flooding detection by sensors, that assist the master as a decision aid when the ship has been subjected to damage and flooding.

OPENSEA Supports Aquanaut Development

Houston Mechatronics Inc. (HMI) has selected OPENSEA as the development platform for the Aquanaut. Greensea is the creator of OPENSEA, the universal open software architecture for the marine industry. OPENSEA enabled HMI to quickly integrate an executive control and mission planning solution onto Aquanaut, a transforming AUV/ROV. The open and modular architecture of Greensea's software allowed HMI to pick and choose tools that covered software gaps.

Vessel Insight Qualification

KONGSBERG's ship-to-cloud data infrastructure service, Vessel Insight, has been qualified by DNV GL. Safety and cybersecurity were the critical parameters in the recently completed Technical Qualification. Vessel Insight is a subscription-based, cost-efficient service for operators to begin standardizing their data collection and contextualization.

Successful Trials of LD-AUV

Dive Technologies Inc. has completed successful sea trials of a Large Displacement Autonomous Underwater Vehicle (LD-AUV) powered by Kraken Robotics Inc.'s pressure-tolerant batteries. Kraken expects further contracts with Dive for additional batteries in 2020 and beyond.

Kraken has a license to build two Dive LD-AUVs for use in Kraken's growing Robotics-as-a-Service (RaaS) business. Production of Kraken's first Dive LD-AUV is currently underway, with the first unit being manufactured in the U.S., to be delivered for sea trials in the spring of 2021. **ST**

people

The International Foundation for Aids to Navigation (IFAN) has appointed **Louise Evans** to its board of directors. Evans is currently a non-executive director and audit committee chair of AB Dynamics plc and Gooch & Housego PLC and a board adviser to the SCB Group. She previously held group finance director roles at Braemar Shipping Services plc and Williams Grand Prix Holdings plc, as well as senior positions at RPS Group plc and Reynard Motorsport.



The Port of Cork Co. has appointed **Eoin McGettigan** as chief executive, replacing **Brendan Keating**, who retired recently after 18 years of service as CEO. Keating oversaw the commencement of construction of the €86 million Cork Container Terminal in Ringaskiddy, which will future-proof the port. McGettigan

has 30 years of experience as a senior executive in retail, wholesale and property businesses. He and his family have lived in Cork for over 30 years.

Saildrone has added **Barak Ben-Gal** as its first chief financial officer. Ben-Gal's experience in finance, strategy and operational management will be key enablers during the strong growth Saildrone anticipates over the coming years.

AIRMAR Technology Corp. has welcomed **Brian Vlad** to the company as marine product line manager. Vlad joins with over 20 years of marine electronics experience, primarily in product development and line management.

Aqueos Corp. has appointed **Jack Lounsbury** as senior account manager. He has over 39 years of industry experience.

TechnipFMC has named **Arnaud Pieton** as president and CEO-elect, Technip Energies. **Jonathan Landes** has been named president, Subsea, replacing Pieton in the position. Pieton has been with the company since 2004.

J+S Subsea has appointed **Phil Reid** as its first managing director and broadened its leadership team with **Doug Sedge** joining its board as a nonexecutive director. Reid has worked in the oil and gas sector for more than 25 years. Sedge has been involved in the oil and gas sector for 45 years.

RTSYS has welcomed **Pierre-Alexandre Caux** as its new business director. Caux has 11 years of previous experience at ECA Group and knows the unmanned systems market well. **ST**

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contracts

Innovez One, Singapore, has signed a contract with a growing Indonesian port located in a rapidly developing region, to digitize its towage and pilotage operations. Port of Banten.

Wärtsilä, Helsinki, Finland, will supply and construct a plant for production of CO₂-neutral liquid transport fuels (LNG). It will have a capacity of approximately 100,000 tons per year and will be located in Cologne, Germany. Undisclosed.

Høglund Marine Solutions, Tønsberg, Norway, has signed a collaboration agreement to explore how the combination of Høglund's onboard integration and data capture capabilities and Veracity's platform architecture and ecosystem can help shipowners accelerate their digital initiatives. DNV GL.

HGH, Paris, France, recently won contracts from shipyards in the Middle East and Europe to equip new warships with SPYNEL panoramic thermal cameras and its new IRST solution. Undisclosed.

SES Networks', Luxembourg, life-saving connectivity solutions will help provide better healthcare services on the world's largest civilian hospital ship, delivering vital healthcare and medical training in economically deprived regions. Mercy Ships.

C-Innovation, Mandeville, Louisiana, has ordered SPRINT INS, Lodestar attitude and heading reference system, Syrinx DVLs, SPRINT-Nav, Compatt 6+ transponders and Wideband Sub-Mini 6+ transponder/responders for tracking structures and vehicles to support operations offshore Brazil. Sonardyne.

Oceaneering International Inc. Houston, Texas, has been awarded a BOP tethering services contract offshore Brazil. The scope of work includes data acquisition and real-time riser analysis for dynamic

positioning rig operations for up to seven wells in water depths between 150 and 700 m. Petrobras.

OSIL, Havant, U.K., has been awarded a contract for the international supply of a network of dredge-monitoring buoys. The data can be fed from the buoy, using the client's existing sensors, directly into the client's servers via Iridium short-burst data. Undisclosed.

Inmarsat, London, U.K., and Cobham SATCOM, Lyngby, Denmark, have been awarded a new contract to connect 732 fishing vessels active in the Maldives Economic Exclusion Zone to Inmarsat's Fleet One maritime broadband services. Ooredoo and the Maldives Ministry of Fisheries and Agriculture. **ST**

meetings

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

JANUARY

January 5-9—NCSE & Drawdown: Research to Action Conference, Virtual. <https://tinyurl.com/yygpo6o8>.

January 19-20—Floating Wind Solutions Conference & Exhibition, Houston, Texas. 832-862-3390 or <https://floatingwindsolutions.com>.

January 19-21—The Coastal Futures – REACH 2021: Ocean Recovery, Virtual. bob.earl@coastms.co.uk.

FEBRUARY

February 2-5—SMM (Shipbuilding, Machinery & Marine Technology), Virtual. +49 40 3569 2445, nora.hirschfeld@hamburg-messe.de or www.smm-hamburg.com.

February 25-26—Floating Wind Solutions, Houston, Texas. <https://floatingwindsolutions.com>.

MARCH

March 2-4—World Ocean Summit & Expo, Lisbon, Portugal. <https://events.economist.com/events-conferences/emea/world-ocean-summit>.

APRIL

April 28-30—Waterpower Week (WPW) 2021 and the International Conference on Ocean Energy (ICOE) 2021, Virtual. <https://waterpowerweek.com> and <https://icoe2021.org>.

MAY

May 18-20—Aquaculture UK, Aviemore, Scotland. +44 (0)1453 836363, www.aquacultureuk.com or carvonio@divcom.co.uk.

May 25-27—Subsea Expo, Aberdeen, Scotland. www.subseaexpo.com.

JUNE

June 1-4—Nor-Shipping, Oslo, Norway. www.nor-shipping.com.

June 15-17—Seawork and Marine & Coastal Civil Engineering Expo, Southampton, England. www.seawork.com and www.mcceexpo.com.

JULY

July 6-8—Ocean Business, Southampton, U.K. www.oceanbusiness.com.

AUGUST

August 23-27—World Water Week, Virtual. www.worldwaterweek.org.

SEPTEMBER

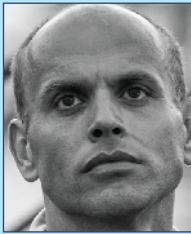
September 7-10—SPE Offshore Europe, Aberdeen, Scotland. +44 (0) 1224 253807, gillian.george@bigpartnership.co.uk or www.offshore-europe.co.uk.

September 13-17—London International Shipping Week, London, England. +44 1296 682104, ljacobs@elabor8.co.uk or <https://londoninternationalshippingweek.com>.

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

One Ocean Expedition: Tradition and New Tech Promote Sustainability — Haakon Vatle

Haakon Vatle works as the general manager for the Statsraad Lehmkuhl Foundation. He is also project manager for the One Ocean Expedition.



Vatle started his career as an apprentice on board ship, and he sailed on deck every season from 1996 to 2005. He has worked ashore since then, and he has been a passionate and enthusiastic manager for Statsraad Lehmkuhl since 2016.

We live in a time when remedial and regenerative action to secure the welfare of our oceans is urgently required. And while it may sometimes appear that many of the individuals and organizations best placed to make a difference prefer a state of ignorance, or even denial, people across the world are doing incredible things to help raise awareness and secure a positive future for our marine environment.

It is this spirit that the United Nations' Decade of Ocean Science for Sustainable Development (2021 to 2030) aims to promote, through its support for a host of initiatives dedicated to raising ocean awareness on a local and international level, educating future leaders and inspiring others to make proactive changes.

One example is the One Ocean Expedition sustainability project to source, exchange and combine the most forward-thinking ocean science and technology developments from around the world. Unveiled in Bergen in August 2020, the project has at its heart an 19-month circumnavigation by the historic tall ship *Statsraad Lehmkuhl*.

Due to depart Arendal on August 20, 2021, the vessel will spend 447 days at sea and visit 35 ports. Traveling at an environmentally friendly 4.9-kt. average speed and following a sustainable route planned to take advantage of favorable winds and maximize the time spent under sail,

any necessary engine hours will be made as efficient as possible by optimizing fuel use through industry partner Kongsberg Maritime's (KM) new Vessel Performance application. *Statsraad Lehmkuhl*, currently the greenest sailing ship in its class, will have covered approximately 52,452 nautical miles by the time it returns to its home port in April 2023.

This momentous voyage is a determined call to action, highlighting four of the UN's 17 Sustainable Development Goals (SDGs): SDG 4 (Quality Education), SDG 13 (Climate Action), SDG 14 (Life Below Water) and SDG 17 (Partnerships for the Goals). Leading by example, the *Statsraad Lehmkuhl* will act as a high-profile showcase for the viability of sustainable operations at sea.

Its presence in global ports en route will stimulate dialogue. These port visits will seek to engage, educate and inspire global youth, community leaders and prospective commercial partners. Operating with collaborative input from the Institute of Marine Research, scientists and university students, the project will work toward establishing a "One Ocean Outcome," a lasting legacy that will develop and normalize sustainable practices in the marine environment.

Statsraad Lehmkuhl's history goes back to 1914, when it was being built in Germany. It started sailing as a Norwegian-flagged vessel in 1923. Managed and operated by the *Statsraad Lehmkuhl* Foundation, the vessel has become a much-loved sight in Bergen, accommodating around 2,000 visitors every year over the course of 15 to 20 cruise excursions.

With its 22 sails, a permanent crew of 25 and space for a further 135 sailors, the 84.6-m *Statsraad Lehmkuhl* makes an impressive and beautiful sight, its main mast towering 48 m above the waterline. Despite its traditional appearance, the

vessel runs with cutting-edge propulsion, engine management, navigation and communications equipment, much of which is on board through the support of KM.

KM's involvement with this emblematic vessel began nearly 40 years ago, when one of the company's Bergen KRM-6 engines was installed. Since then, KM has supplied the ship's main switchboard, bow thruster, hybrid shaft generator, power management system and integrated alarm system. KM has also implemented upgrades and modifications to enhance functionality, and its latest deliveries exemplify sustainable operations. A SAVE Energy 370-kWh battery bank, for example, provides storage for emissions-free energy.

Digitalization has enabled unprecedented efficiencies, and *Statsraad Lehmkuhl* uses KM's Vessel Insight vessel-to-cloud data infrastructure, enabling access to the Kognifai digital ecosystem and deploying the Vessel Performance monitoring and benchmarking application to minimize fuel consumption. The ship also has a full suite of K-Nav navigation products, including radar, ECDIS, AIS and chart plotter systems. KM has supplied a K-Nav Planning Station and most of the research and meteorological equipment on board as well.

In addition to providing tech, KM will work with the *Statsraad Lehmkuhl* Foundation to implement a program for onboard leadership development while also setting up meetings with customers, investors and authorities in new and established markets around the world.

Statsraad Lehmkuhl's voyage will exhibit old-school sail craft with the greenest modern technologies to promote the safeguarding of our seas. Collaboration is key, and with political and industry support, this voyage will aid ocean research and promote conservation around the world. **ST**

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MARCH - digital only

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APRIL

Offshore Technology/Alternative Energy & Ocean Engineering

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***OCEANS 2021 Porto*, May 17-21, Porto, Portugal

MAY

Communications, Telemetry, Data Processing

***CLEAN PACIFIC*, June 28-30, Seattle, WA

***UDT*, June 29-July 11, Rostock, Germany

JUNE

Seafloor Mapping/Sonar Systems/Vessels

JULY - digital only

Deck Gear, Cable, Connectors, Power Systems & Salvage

AUGUST

Ocean Resources Development

***OCEANS 2021 San Diego*, September 20-23, San Diego, CA

***SEG 2021*, September 26-October 1, Houston, TX

SEPTEMBER

Geophysical Exploration

***Offshore Energy, 2021* dates TBD, Amsterdam, The Netherlands

OCTOBER

Environmental Monitoring, Remote Sensing & Pollution Control

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