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An Oceanbotics SRV-8 captures an image of a second SRV-8 as it heads to the surface after exploring the depths off the coast of Catalina Island, California, in March 2019. (Credit: RJE Oceanbotics)

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Subsea Supercharger delivers large-scale energy down to 600 m … Armored cable assembly for renewable power system in Alaska … Commercial derelict vessel removal … AUV launch and recovery system for small craft … Synthetic mooring helps conserve marine habitats.

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***Sui Chian Phang**, Secretary, Centre for Blue Governance*

Governance for Sustainable Ocean Development

Aquatic environments cover more than 70 percent of our planet's surface, and the value of the global oceans is estimated to be $24 trillion. Robust governance is needed to ensure the sustainability of services provided by the world's aquatic environments. Development must align with the principles of social inclusion, environmental sustainability, and innovative and dynamic business models.

There are large gaps in how best to govern aquatic environments for the common good. Decision making at all levels must be evidence-based, inclusive, transparent, accountable and equitable. To help meet this need, the University of Portsmouth, U.K., has created the cross-faculty Centre for Blue Governance (CBG).

Blue governance is an emerging concept. Governance refers to structures and processes designed to ensure accountability, transparency, responsiveness, rule of law, stability, equity and inclusiveness, empowerment, and broad-based participation. Blue governance relates to the public and private institutional mechanisms (coordination, private-public partnerships, etc.) required to implement blue economy and blue growth initiatives, strategies and policies. Ultimately, blue governance integrates blue economic growth with good governance principles.

Over 40 university researchers will collaborate with national and international partners to address transdisciplinary needs for holistic governance of aquatic ecosystems. The Centre will develop theoretical and practical elements of blue governance under four main themes: blue policies, planning and security; blue energy, technologies and transport solutions; biodiversity, blue carbon and climate change; and aquatic resources management. It will address challenges in freshwater and marine systems and approach the socioecological systems of rivers, lakes, wetlands, coasts, seas and oceans as "development spaces."

CBG tackles current and new research areas. Ongoing research projects include investigating pollutant impacts on the behavior and physiology of marine organisms, the role of nature-based solutions to address societal challenges, and bio-prospecting for new enzymes to breakdown plastics and wood. Technological advancements in these areas will be critical in creating new markets and driving more sustainable and efficient blue growth. In addition, the Centre contributes toward blue economy development strategies, including leading the Blue Economy Strategies for Africa, Intergovernmental Authority on Development Countries and the Indian Ocean Commission. The Centre will also empower countries and practitioners to drive their marine and freshwater strategies. By the end of the year, it will create a framework for developing countries to design national policies and research strategies and make available online learning material on blue economy and blue governance principles for capacity development globally. The Centre will also feed into high-level initiatives and needs surrounding the blue economy. It has contributed to regional and global workshops and policy development for the UN Decade of Ocean Sciences for Sustainable Development (2021-2030).

Ultimately, greater cooperation and partnerships among aquatic system stakeholders are needed. The Centre adds to global efforts and looks forward to collaborating with the community to better use and better protect these environments, their biodiversity and their resources that are critical to the world's economy and the health of the planet. **ST**

)) UK's Subsea Industry Helps Coronavirus Response. The U.K.'s underwater engineering industry is exploring ways to transfer its expertise to support the national effort to tackle the coronavirus pandemic. Industry body Subsea UK says that underwater engineering companies have the relevant products and manufacturing expertise, particularly in breathing apparatus and life-support equipment, valves and control systems, to answer the call for help from government. Subsea UK member JFD Global has already stepped up to develop and bring to market a revolutionary respiratory ventilator. Other companies are exploring how standard diving equipment could be adapted to meet current medical needs and providing drive systems for medical equipment. Viewport3 is using its 3D print design expertise to create a template for adaptors to connect equipment from the diving or C-PAP (continuous positive airway pressure) industries to be used as a moderate form of ventilation or respiration. Maxon's products are already used in medical devices such as ventilators, respirators, protection masks and lab automation. Subsea UK represents the U.K.'s £7.8 billion subsea industry and is gathering intelligence on how other firms could assist in the fight against COVID-19 and on the impact of the pandemic and the collapse in oil price on its 300 member companies.

)) Global Wind Turbine Materials Market to Double. The increasing demand for energy worldwide and traditional energy independence due to volatile oil prices is encouraging governments throughout the world to harness the potential of renewable energy, driving the global market for wind turbine materials. Expanding at a compound annual growth rate (CAGR) of 8.9 percent, the wind turbine materials market is likely to almost double, reaching $19.57 billion by 2026 from $10.76 billion in 2019, according to Frost & Sullivan's Global Wind Turbine Materials Market, Forecast to 2026. Further, as greenhouse gas emissions increase, government authorities worldwide are expected to focus on offshore wind energy installations, which are still at a nascent stage in most parts of the world. This is expected to strengthen the demand for high-performance specialized materials. Uncertain government policies and inconsistent incentives and tariff rates, along with the scarcity of infrastructure for wind energy transmission, are likely to restrain the growth of the wind turbine materials market. However, original equipment manufacturers' focus on innovation and product enhancement within existing material chemistries is expected to unlock tremendous growth opportunities.

)) Project Hygiea Seeks to Limit Coronavirus on Passenger Ships. Foreship has devised an initiative to limit the presence and spread of coronavirus and other pathogens on passenger ships and get the cruise sector back up and running. Project Hygiea comprises a four-step approach of interception, prevention, mitigation and evacuation. Stage one aims to keep the biohazard off the ship. Ports will be designed for efficient interception, with technology installed for testing and measuring body temperature, for example. In the event that a vaccine becomes widely available, passengers will be screened for vaccination before being allowed to board. Stage two is about preventing the virus from spreading, which means employing stringent hygiene measures and optimizing spaces and routes to maintain a safe distance between individuals. Stage three is a matter of isolating the pathogen through quarantining and decontamination. Technology such as air treatment systems and medical facilities will be provided to support these efforts. Stage four focuses on preparation for the worst-case scenario: critical incidents on board. Evacuation procedures will be put in place, with routes through the ship designed for speedy extraction, while emergency suits, capsules and craft will be made available.

)) New Contributor to *Mayflower Autonomous Ship* Project. exactEarth Ltd. has joined an international effort to build an unmanned, fully autonomous transatlantic research vessel that is set to launch on the fourth centenary of the original *Mayflower* voyage (newsroom.ibm.com/then-and-now). exactEarth joins an illustrious international project team led by ProMare and its technology partner, IBM. The *Mayflower Autonomous Ship* (MAS) mission will commemorate the original *Mayflower* crossing and advance technologies that could transform the shipping industry and help gather critical data about the ocean. exactEarth will contribute two of its services to the MAS project: exactAIS (the supply of live satellite AIS data into the mission's operations center) and exactSeNS (the use of exactEarth's VHF-based M2M satellite communications service to upload sensor data in real time from the ship's onboard weather station).

)) Long-Time *Sea Technology* Editor Passes. David Monroe Graham has passed at 84. He was born in Lansing, Michigan, July 25, 1935, to the late Albert Douglas Graham and Mariam Moore. Graham had a colorful career as a journalist, including an almost 20-year stint as the editor-in-chief of this magazine, which took him to cities around the world and deep underwater in the Alvin submersible, and allowed him to meet legends of the industry, such as marine biologists Sylvia Earle and Jacques Cousteau. He maintained life-long friendships he made over the years at *Sea Technology*. He is survived by his wife of 18 years, Rebecca Graham; daughter, Catherine; two sons, Robert Graham and Jaimie Graham; three grandchildren; and sister Pat Grasser. To honor his memory, in lieu of flowers, the family requests a donation to the American Humane Society or another animal welfare charity in his name. **ST**

Going It Alone

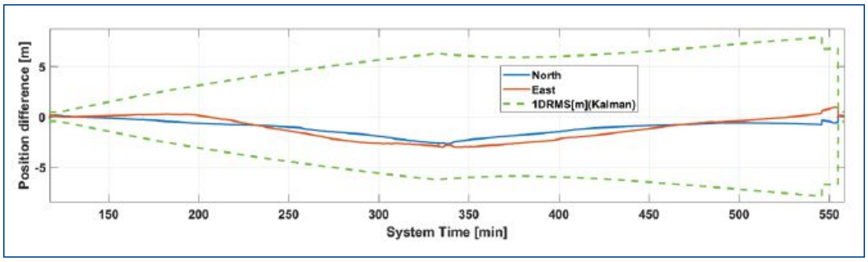
Enhancing Independent AUV Navigation

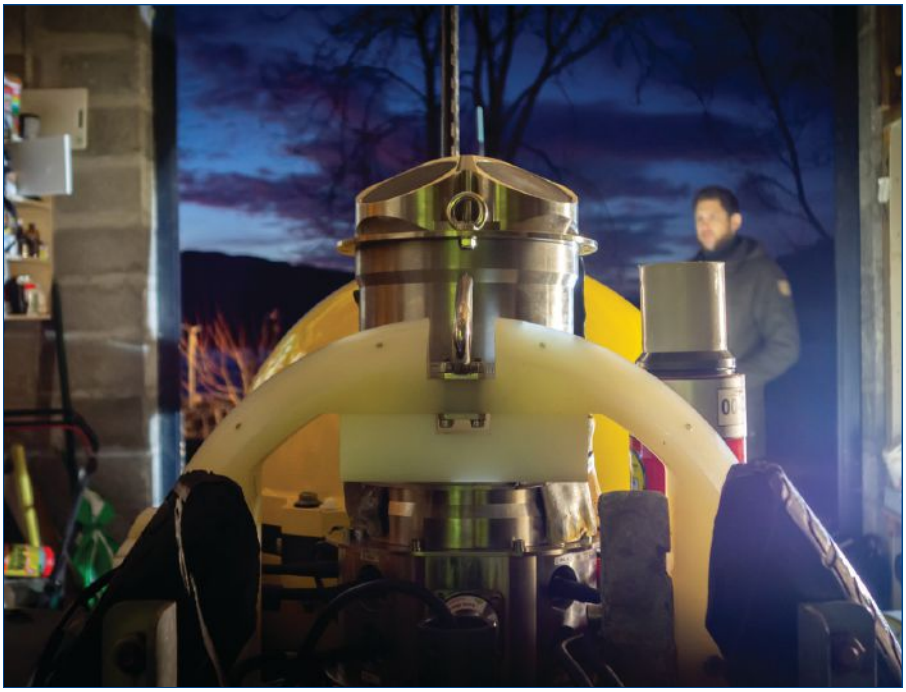
By John Houlder • Matt Kingsland • Geraint West

Recent years have seen significant increases in the endurance and capability of AUVs and UUVs. However, the capability to operate such vehicles independently on long-duration, long-distance missions has been limited by their reliance on external navigational aiding to meet positional accuracy requirements.

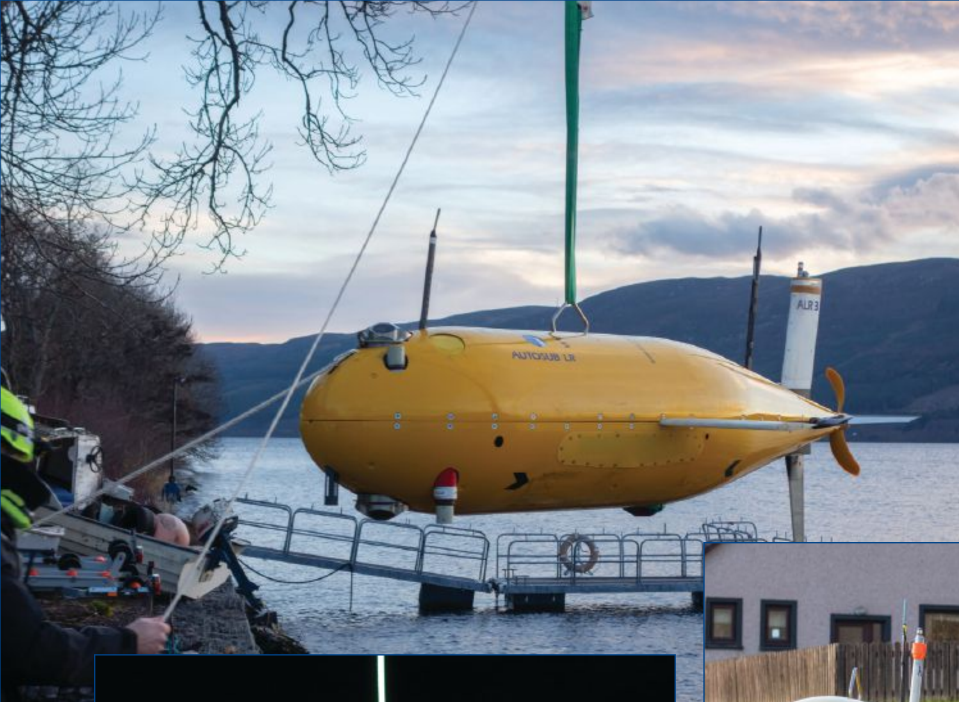
These accuracy requirements range widely, depending on the application, from mapping at sub-meter levels to several hundreds of meters. This in turn affects how long an AUV or UUV may be able to position itself unaided and still meet mission-specific specifications. Because of this, the full potential of many AUVs and UUVs remains untapped.

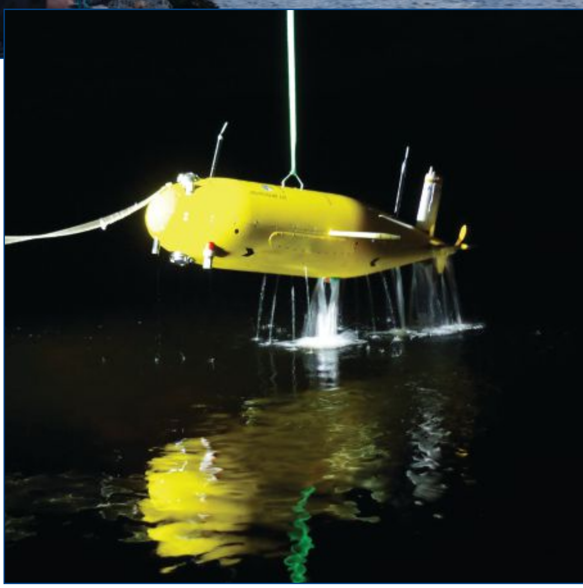
This was the motivation that led to the initiation of an ambitious two-year, £1.4 million project led by Sonardyne International Ltd. in partnership with the U.K.'s





(Top) The plot shows the difference in position between the Janus post-processed LBL data and the real-time SPRINT-Nav output during the 10-km run, which starts at 130 min., with the return leg starting at 340 min. The position difference peaks at less than 4 m at the end of the outward leg before returning to start position, where it drops to less than 1 m. The green line shows the real-time position error estimate provided by the SPRINT-Nav. At all times, the SPRINT-Nav's given position remains well within this estimate, providing an example of the trustworthy metrics given to AUV integrators. (Bottom) An upward-facing Syrinx DVL with ADCP capability, alongside the SPRINT-Nav with its downward-facing DVL, was installed in the NOC's ALR to aid positioning accuracy during descent/ascent.





(Counterclockwise from top) Each day during the trials at Loch Ness, the ALR was lifted and lowered into the loch. Trials were also undertaken during night-time hours, thanks to the short winter days in Scotland. In total, during the trials, the NOC had five of its underwater vehicles at Loch Ness, which enabled it to demonstrate initial multi-vehicle over-the-horizon operations via remote satellite communication.

National Oceanography Centre (NOC) and unmanned surface vessel developer ASV Ltd. (now L3 Harris). The project, called Precise Positioning for Persistent Autonomous Underwater Vehicles, or P3AUV for short, started in early 2018 and was partly supported by public funding from Innovate UK's research and development competition for robotics and artificial intelligence in extreme and challenging environments.

Precise, Persistent, Autonomous

P3AUV set out to integrate existing and emerging technologies to deliver a step-change in unmanned platform endurance and navigational precision. The benefits of this would be to deliver substantial increases in the efficiency of AUV/UUV survey operations. Overall, the aim was to develop solutions that deliver navigation for long basin-scale science transects over several weeks and thousands of kilometers and, in so doing, also deliver significant improvement in the ability of AUVs/UUVs to conduct seabed surveys with minimal reliance on external references.

The project comprised developments in three key and complementary areas: improved lower power navigational accuracy over long distances for AUVs/UUVs; improved positioning accuracy during vehicle descent/ascent in the water column; and autonomous transponder box-in with an unmanned surface vessel.

Improving Navigation over Long Distances

The first of these areas was heavily driven by the NOC's motivation to ensure that it can adequately navigate AUVs on missions that are now lasting for days and even months, often over long linear transects. A long-linear-transect survey style is highly challenging, as errors can accumulate, whereas a conventional seabed survey, often described as a "mowing the lawn" survey style, or reciprocal running, reduces this effect.

Understanding navigation performance in these two quite different scenarios is therefore critical and resulted in Sonardyne introducing new performance terms to better describe each scenario: the first is "distance from origin" (DFO), which is the expected accuracy after following a trajectory in a single linear direction, and the second is "typical survey," which is the expected accuracy in a more typical bounded area when doing a survey. These specifications vary across Sonardyne's growing range of market-leading SPRINT-Nav hybrid navigation instrument variants. As an example, the DFO accuracy for Sonardyne's SPRINT-Nav 700 system is 0.05 percent of the distance traveled, whereas the typical survey accuracy is 0.01 percent of distance traveled.

For these reasons, it was critical that the trials area enabled long straight runs as well as sufficient depth to test performance during the AUV dive and surfacing phases. In addition, stable environmental conditions without large variations in sound velocity and minimal surface traffic noise were also desirable. Benign acoustic conditions were also preferred in order to deploy a long baseline (LBL) acoustic array to act as a reference positioning data set.

Loch Ness Test Range

It was for these reasons that Loch Ness, in Scotland, was chosen as a trials site during November to December of 2018 and 2019. With an average depth of 132 m (maximum 227 m), low volumes of powered traffic and a linear orientation running for 37 km from northeast to southwest, the loch provided an almost perfect environment. In particular, its configuration enabled selection of a 10-km-long "test range" with an average depth of 200 m for the demanding linear DFO trials. For the trials, this test range was instrumented with a sparse LBL array consisting of four Sonardyne Compatt 6 transponders, spaced roughly 2.5 km apart, with a number of additional Compatts deployed for other elements of the trials.

The trials environment was complemented by a unique installation of equipment on the NOC's Autosub Long Range (ALR) AUV (a.k.a. "Boaty McBoatface"). For the initial trials in 2018, one of the original three 6,000-m-rated ALRs was used. However, the final trials were conducted with one of the more recent 1,500-m-rated vehicles, which can travel distances of up to 6,000 km. LBL positioning to +/- 1 cm level as well as positioning and telemetry from a support vessel fitted with a gyro USBL (ultrashort baseline) system were supported with Sonardyne's AvTrak 6 acoustic navigation and communications instrument mounted in the nose of the AUV, while a SPRINT-Nav was installed as the platform for navigation instrument development.

SPRINT-Nav is an all-in-one navigation instrument, comprising a SPRINT inertial navigation system (INS), Syrinx 600-kHz Doppler velocity log (DVL) and high-accuracy intelligent pressure sensor all tightly coupled in a single housing to achieve unprecedented levels of accuracy and reliability. Tight integration means that individual beam level measurements from the Syrinx DVL are used in the hybrid positioning solution, rather than just DVL output velocities.

For this project, however, a specially built SPRINT-Nav was created, comprising of a SPRINT-Nav 700 variant, together with an upward-looking Syrinx DVL, as well as the standard downward-facing DVL. It also had interfaces for a number of trial inertial measurement units (IMUs).

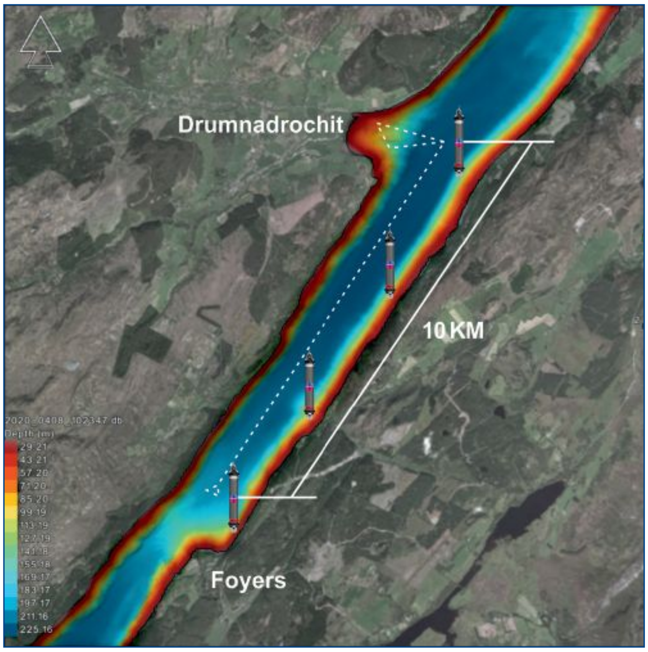
A Layered Experimental Approach

This layered approach, with experimental systems able to be benchmarked against the SPRINT-Nav and with LBL "ground-truthing," enabled the collection of a unique data set. It also provided valuable data on Sonardyne's new SPRINT-Nav Mini hybrid acoustic-inertial navigation instrument, which was also mounted in the ALR for the final trials. Four sets of trials were run, each with a specific pattern, in order to gather a comprehensive AUV data set for future analysis.

One trial set involved a straight-line 10-km dead reckoning from Drumnadrochit to Foyers and back to test the hybrid acoustic-inertial DFO performance and return-to-origin performance of the SPRINT-Nav 700.

The second was a straight-line 10-km DFO test from Drumnadrochit to Foyers and back, with figure-eight turns on the return leg. The figure-eight turns on the return leg enabled an assessment of this kind of dynamic behavior on dead-reckoning performance.

The third was a series of different diving behaviors that were trialed using the ALR to see how position



A 10-km-long straight-line test range was set up in Loch Ness with a sparse array of Compatts to enable LBL "ground-truthing" during the trials.

error acquired during a free inertial dive can be limited without adding any external aiding sources, such as propeller speed, water track, LBL or USBL. The dynamics trialed for this included: a straight-line descent from surface to survey altitude of 20 m; figure-eight from surface to survey altitude of 20 m; and descending from surface to survey altitude of 20 m in box patterns.

The fourth set of trials was a site survey at 10-m altitude, with 180-m line spacing, designed to prove dead-reckoning navigation performance of SPRINT-Nav 700 during a typical AUV-based multi-aperture sonar campaign.

During the 10-km runs, SPRINT-Nav 700 performed well within specification, with less than 4 m (0.04 percent) of positioning error versus the reference LBL position after 10 km from origin, and less than 1 m (0.005 percent) after return to origin, representing a total mission endurance of 20 km over nearly 10 hr.

Overall, the trial confirmed the world-leading capability of the SPRINT-Nav system to support the most demanding of tasks, including seabed mapping. This was in addition to providing some exciting insights into new technologies, including SPRINT-Nav Mini, which has since been launched into the marketplace.

Vehicle Descent/Ascent Accuracy

The second aim of the P3AUV was to improve positioning accuracy during vehicle descent/ascent in the water column. This was driven by the fact that, without DVL bottom-lock, and the INS working in a free-inertial mode, significant errors can build up during descent/ascent, especially when AUVs are deployed from the surface to significant depths. This was the reason that an upward-looking DVL, as well as the SPRINT-Nav's downward-looking DVL, was mounted in the ALR for the trials. This configuration enabled the gathering of comparative upward- and downward-looking data from the acoustic Doppler current profiling (ADCP) capability now available in the Syrinx DVL. This functionality interleaves DVL and ADCP pings so that ADCP data can be collected without compromising navigation or the ADCP data quality.

In addition, this capability enables Syrinx to ingest inertial velocities from the SPRINT-Nav's INS to compensate water profiles for vessel motion when bottom tracking is compromised. This allows absolute water velocities to be measured even under challenging conditions, such as high altitude or a moving seabed. This is mandatory for many offshore energy projects and can be valuable for ocean research.

Autonomous Transponder Box-In

The final output of P3AUV was proving the ability to perform an autonomous "box-in" of a seabed-deployed Compatt LBL transponder using a USV. This originally also included deployment of the Compatt from a USV, but it quickly became clear that payload and deployment constraints limited the number of transponders that could be deployed from most current USVs, and, consequently, the focus became integration of a fully optimized over-the-horizon system for boxing-in.

In simple terms, boxing-in refers to a process of maneuvering a surface vessel around a prescribed sail pattern, while simultaneously acoustically ranging to the seabed transponder in order to accurately position it in a world reference framework. Although simple in concept, in this case it meant the integration of the software for Sonardyne's Ranger 2 USBL system into the USV's control software, using Sonardyne's remote control interface. The L3 ASV C-Worker, owned by the NOC, was already fitted with the Ranger 2 system, including a high-performance transceiver (HPT). This enabled control of the Ranger 2 system remotely, from shore, which meant these capabilities are now available for the NOC's operations.

It's also further proof that autonomous transponder box-in is viable. Sonardyne has been supporting USV-based box-ins with its technology since 2014, when an oilfield service company in the U.S. Gulf of Mexico trialed this technique using an ASV C-Worker. Further USV-based box-ins have been done since, and they don't have to use an HPT; a Sonardyne Dunker transceiver can also be used.

Moving Toward Swarm Operations

The trials were also used by the NOC to demonstrate initial multi-vehicle over-the-horizon operations via remote satellite communication with a network of five vehicles. This network involved two additional ALRs, a glider and the C-Worker, which provided surface tracking and gateway communications. Although the NOC and others have been performing autonomous over-the-horizon operations for many years, they are at present mostly achieved by simple waypoint-following algorithms. The next major hurdle is operating vehicles on multi-month missions over the horizon and in cooperation, ideally with the vehicles reacting to their environments so that they gather the most useful data sets.

No one vehicle or sensor package is suitable to all tasks; for example, a single propeller-driven AUV is most efficient at taking measurements at a set depth, gliders are better when profiling and multi-thruster vehicles are best at inspection activities. Thus, one solution to an AUV "swarm" is a variety of vehicles each optimized for a specific task.

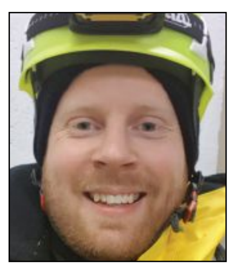
During the P3AUV trial, the NOC demonstrated a small swarm operating over the horizon to measure the conditions of the Loch. The logical consequence of this is the prospect of using high-accuracy positioning data from a SPRINT-Nav-enabled AUV to provide comparable accuracy of positioning to other smaller vehicles deployed with it. The implications for enabling a multi-vehicle survey mapping capability without the need for each AUV/UUV to be fitted with a high-end instrument are potentially game-changing.

Conclusion

The Loch Ness environment proved an invaluable setup for development and evaluation of hybrid autonomous navigation technologies, and the results of this project will underpin both technology and enhanced autonomy product development for some time. In summary, the outcomes of P3AUV were the delivery of new capabilities that significantly enhance the ability of AUVs to operate independently for extended periods. Although this was primarily focused on automated over-the-horizon operations, the implications are equally applicable to more local detailed mapping operations, which also have the potential to benefit from more efficient AUV operations. **ST**

John Houlder is a product manager at Sonardyne, focused on shallow-water navigation systems. With a hydrographic survey background, he has a keen interest in hybrid navigation systems and how they can be used by robotic platforms to improve ocean mapping.

Matthew Kingsland is a senior robotics systems engineer specializing in subsea systems at the National Oceanography Centre, Southampton, U.K. He is currently leading the design of the NOC's new 6-m-long under-ice vehicle, along with research into the operation of AUV swarms.



Geraint West has managed Sonardyne's ocean science business activity since 2016. Previously a director at the National Oceanography Centre, he set up its Marine Autonomous and Robotic Systems facility. He is currently chair of the U.K.'s Society for Maritime Industries' Marine Autonomous Systems Council.

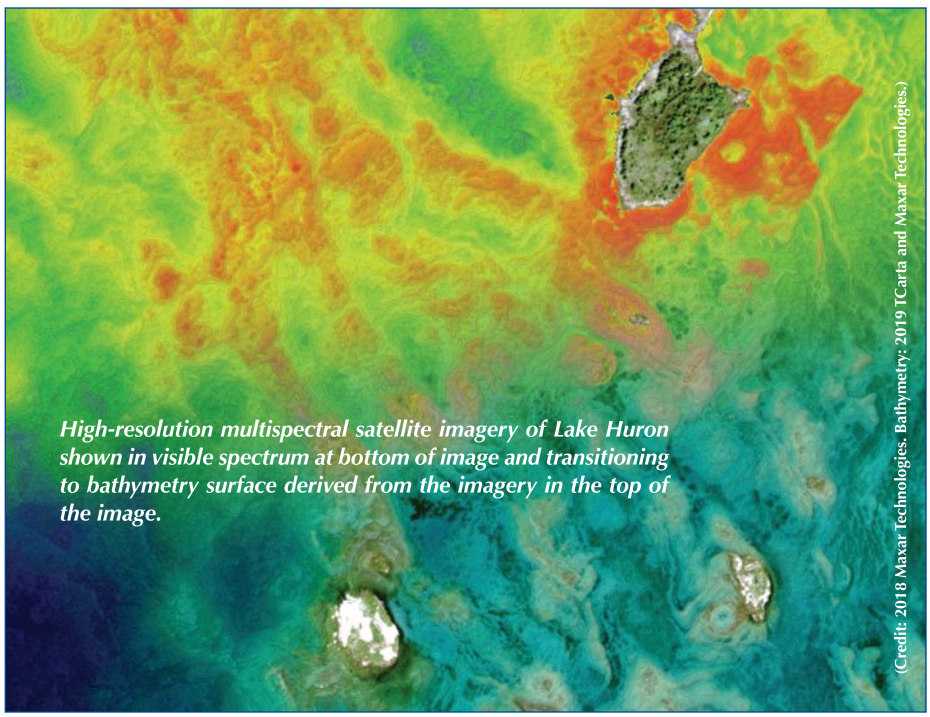
ICESat-2 Space-Based Laser

Validation for Satellite-Derived Bathymetry in NSF-Funded Research

By Kyle Goodrich • Ross Smith

The value of nearshore bathymetric measurements has always been directly proportional to the difficulty of collecting them.

Charting water depths in the shallow coastal zones has been critical to navigation for centuries—because that is where so much ship traffic occurs as freight and fishing vessels move in and out of ports. The need for mapping in nearshore areas has only intensified in recent decades as leisure craft use and other marine recreation activities have multiplied.



High-resolution multispectral satellite imagery of Lake Huron shown in visible spectrum at bottom of image and transitioning to bathymetry surface derived from the imagery in the top of the image.

(Credit: 2018 Maxar Technologies. Bathymetry: 2019 TCarta and Maxar Technologies.)

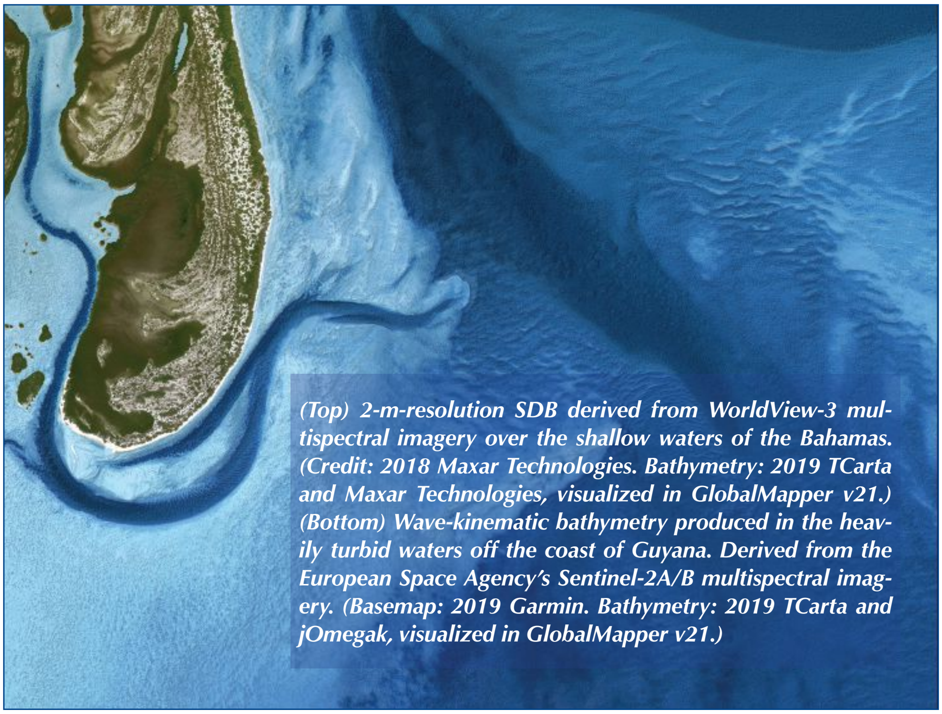
The application of precise seafloor depth measurements isn't only limited to ship navigation, however. Construction of resorts, energy facilities and other infrastructure along shorelines requires detailed information about what lies beneath the surface of the water. And protecting the sea life and natural habitat in these areas in the face of development and climate change has turned the coastline into the front line in the battle for environmental preservation.

In the 20th century, lead-line surveys and other manual methods of capturing water depth data were replaced primarily with automated ship-borne technologies, such as single- and multibeam sonar.

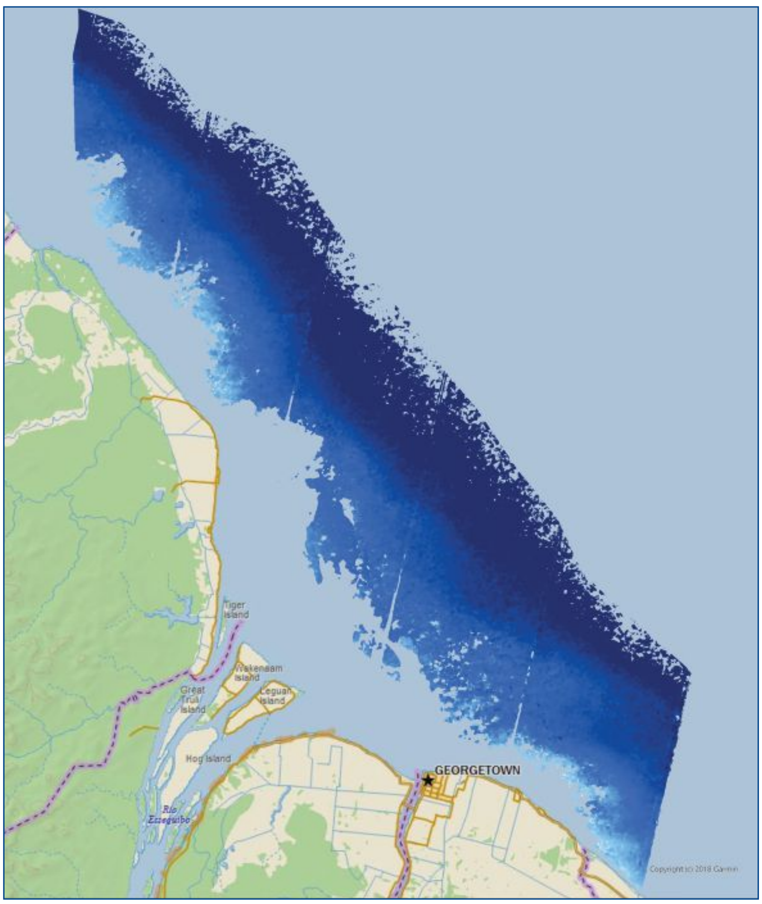
While extremely accurate and cost-effective in deeper waters, these techniques become challenging to deploy closer to shore. Operating large marine survey vessels poses danger to the ship, crew and instruments in the shallow, dynamic coastal zone. In addition, these shallow-water mapping efforts can be impractically time consuming.

Airborne laser scanners, also known as LiDAR (light detection and ranging) devices, have provided a solution for coastal bathymetry in the past 10 to 15 years as the affordability of the technology has improved. While deployments of LiDAR systems has increased significantly for terrestrial mapping, proliferation of airborne lasers for marine environments has been less rapid. These airborne systems remain extremely expensive to deploy to remote locations, and their use in some areas is prohibited due to airspace restrictions and ITAR limitations.

This growing demand for up-to-date water depth measurements in the littoral zone combined with the chal-



(Top) 2-m-resolution SDB derived from WorldView-3 multispectral imagery over the shallow waters of the Bahamas. (Credit: 2018 Maxar Technologies. Bathymetry: 2019 TCarta and Maxar Technologies, visualized in GlobalMapper v21.) (Bottom) Wave-kinematic bathymetry produced in the heavily turbid waters off the coast of Guyana. Derived from the European Space Agency's Sentinel-2A/B multispectral imagery. (Basemap: 2019 Garmin. Bathymetry: 2019 TCarta and jOmegak, visualized in GlobalMapper v21.)



lenges of nearshore data collection opened the door to commercialization of a space-based method called satellite-derived bathymetry, or SDB. The Earth observation satellites collecting the digital imagery that serves as the raw material for SDB measurements can capture images everywhere and anywhere, without the limitations of airspace or political boundaries, as often as once a day.

Deriving Depth from Multispectral Imagery

The key to SDB is high-precision multispectral imagery. This means the sensor, or digital camera, aboard the satellite measures energy reflecting off the Earth's surface in multiple discrete wavelengths or "bands." The most common multispectral bands are red, green and blue in the visible portion of the electromagnetic spectrum, as well as various slices of the near-infrared (NIR) spectra. For SDB, all bands are processed, but the blue band is critical. Visible light in this wavelength penetrates water most effectively, reflecting off the seafloor in shallow areas and returning data values to the sensor in space.

Development of the first SDB algorithms for civilian applications dates to the launch of the U.S. Landsat program in the 1970s. The decades since have witnessed remarkable advances in both the creation of new SDB algorithms and development of commercially available multispectral satellite systems. Today, there are many sources of satellite image data for SDB extraction.

TCarta, a global provider of marine geospatial products based in Denver, was among the first to offer SDB data sets as commercial products starting in 2012. This is when the private-sector market for SDB became viable thanks primarily to the launches of commercial imaging satellites capable of capturing data with spatial resolution, or ground detail, of 1 m or better.

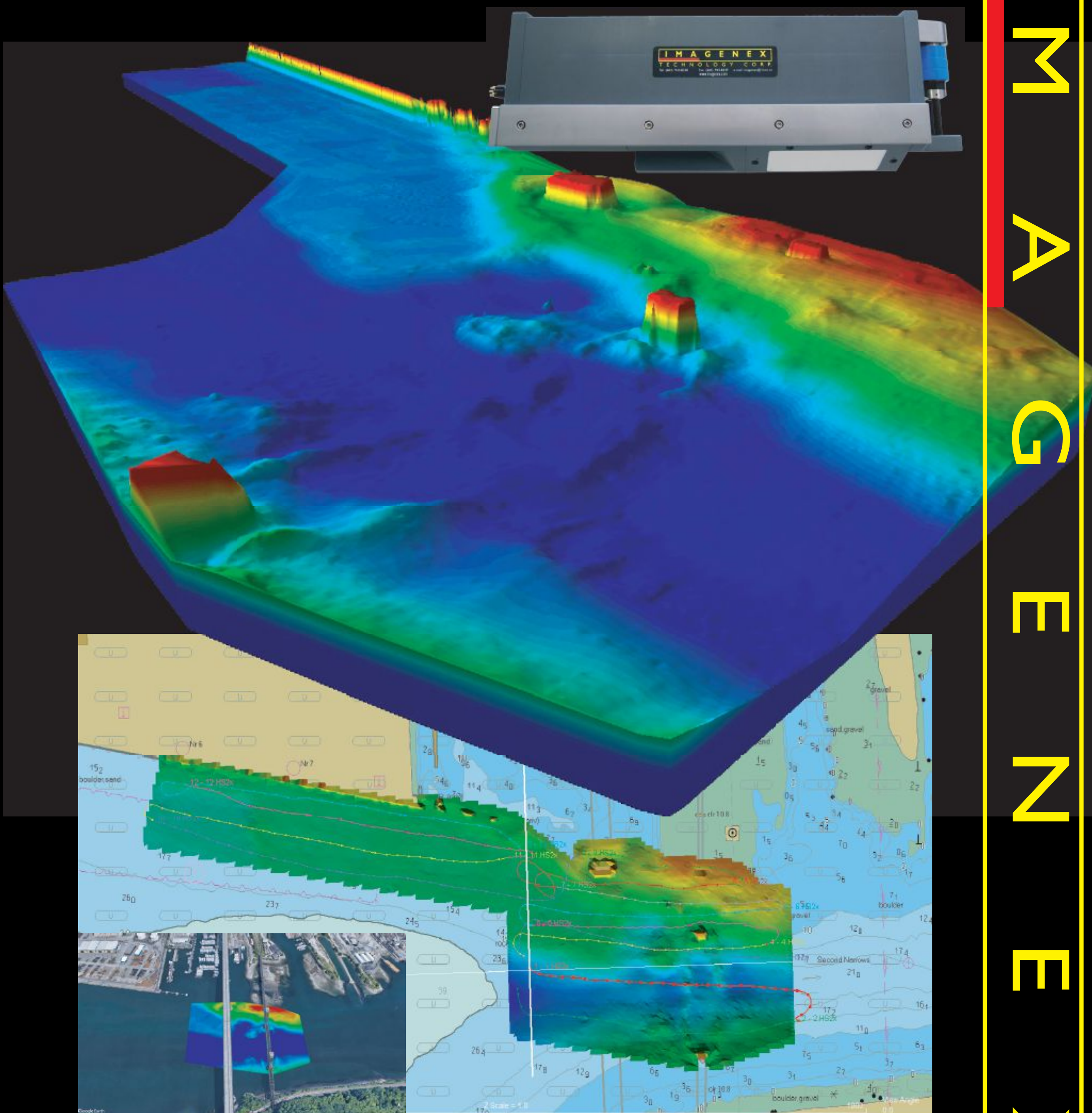
The overall quality of SDB measurements—quantified by their depth limit and accuracy—is a direct function of the spatial resolution of the source imagery. In other words, higher resolution imagery yields higher quality SDB.

Today, the workhorse satellites for SDB applications are the high-resolution WorldView-2 and -3 missions launched by DigitalGlobe (now Maxar Technologies) of Westminster, Colorado. Not only do these satellites boast resolutions of about 0.5 m, they also capture multispectral data in numerous wavelengths, including a small slice of the visible blue spectrum called Coastal Blue. This band provides remarkable penetration of the water column for SDB calculations.

Applying proprietary and adaptable extraction algorithms on the WorldView data, TCarta routinely generates SDB products for the littoral zone to a depth of 20 m, depending on water clarity and turbidity. In extremely

DT102Xi Multibeam

Survey of Second Narrows in Vancouver Harbour, including bridge footings and rock covered cables



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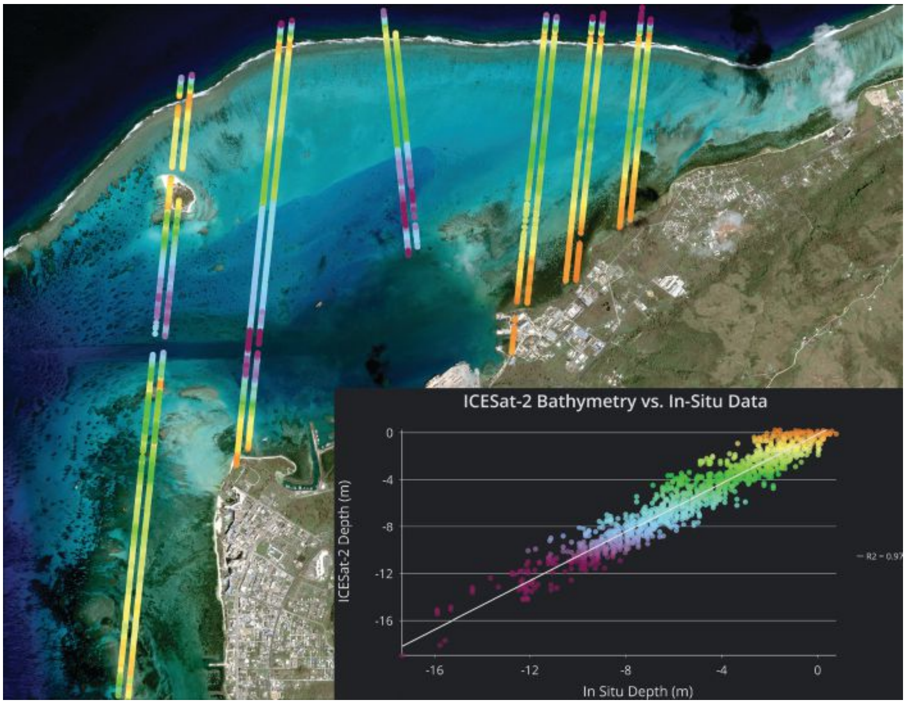
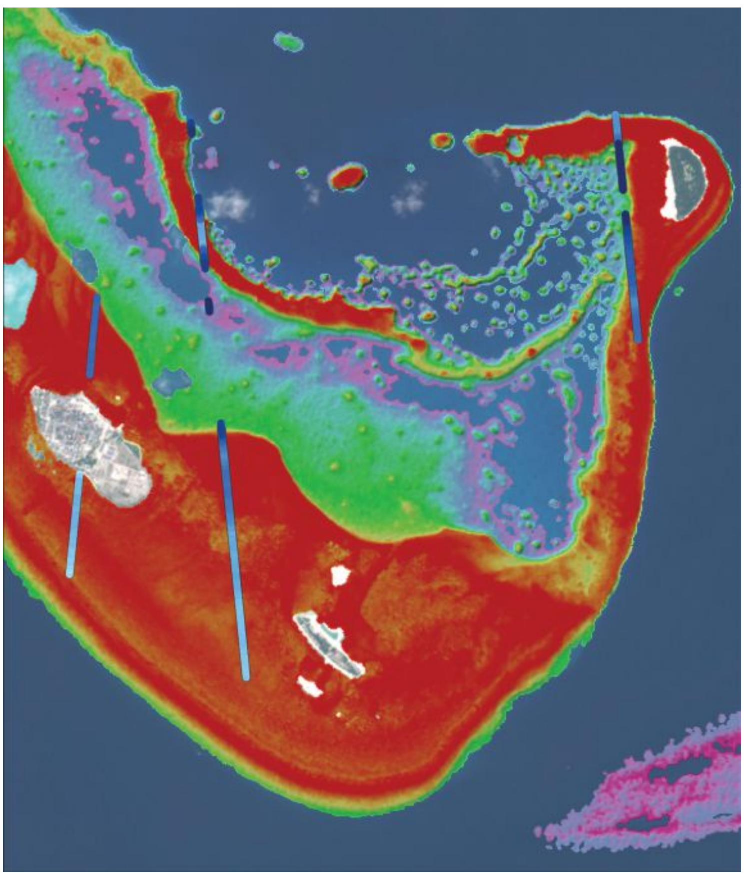


(Top) Space-based laser depth retrieval transects derived from ICESat-2 laser altimeter data collected November 2018 to May 2019 offshore Saipan, Marianas. (Credit: 2018 Maxar Technologies. Bathymetry: 2020 TCarta, NSIDC data, visualized in Esri ArcGIS Pro 2.5.) (Bottom) 10-m-resolution, satellite-derived bathymetry data and space-based laser bathymetry data produced by the Trident mapping system for Thulhaadhoo Atoll, Maldives. Data produced from Sentinel 2 A/B imagery collected April 17, 2017 and ICESat-2 data collected October 18, 2018 and May 5, 2019. SBL tracks shown in blue. (Credit: European Space Agency, ESA. Bathymetry: 2020 TCarta, NSIDC data, visualized in Esri ArcGIS Pro 2.5.)



clear water, such as the Caribbean, SDB measurements of 30 m are reliably produced. The accuracy of these bathymetric data sets is typically 10 to 20 percent of water depth.

These SDB products have been purchased extensively for use in a variety of nearshore marine applications related to oil and gas exploration and production, coastal infrastructure engineering, environmental monitoring, and geospatial intelligence (GEOINT) activities.

Not all marine operations require the measurement accuracy of SDB data extracted from high-resolution imagery, however. For those, there are coarser resolution images collected by the U.S. Landsat program, now operating Landsat 8, and the European Sentinel-2 mission. While the spatial resolutions of these governmental programs are 30 and 10 m, respectively, these programs collect data globally on a continuous basis, available at no charge.

From these data sets, SDB products can be produced that are lower resolution but at attractive price points and covering broad areas. For many applications, such as storm surge modeling, the lower resolution is preferred, and the high temporal frequency of collection from these programs provides capability to detect changes in the seafloor over time.

Whether derived from high- or coarse-resolution data sets, SDB products have been extremely well received in the marine market. One challenge to the SDB workflow, however, is the need for in-situ data to validate derived seafloor measurements, which are often challenging to acquire and important to properly communicate to end-users on the quality of the SDB. In some areas, high-quality sonar track lines can be found, but for the vast majority of the world's littoral zones, less accurate data sets, including paper charts dating to the 19th century, have been the only option. Poor validation information limits the ability to report on data accuracy and can diminish end-user confidence in SDB quality.

TCarta set out to eliminate this weakness in the SDB workflow and improve the overall quality of derived bathymetric products. Among the goals was to expand the geographical capabilities of SDB and work on development of two independent validation methods: stereophotogrammetry and space-based laser (SBL) techniques. This is where ICESat-2 and artificial intelligence (AI) entered the SDB picture.

NSF Funds Project Trident

In August 2018, a research team led by TCarta launched Project Trident with funding from the National Science Foundation's (NSF) Small Business Innovation Research Program. The team includes jOmegak, a marine remote-sensing consultancy based in San Carlos, California, and DigitalGlobe/Maxar Technologies, the WorldView satellite operator headquartered in Colorado.

Now in its second phase of NSF funding, the project, as its name implies, focuses on enhancing SDB technology with a three-prong approach: expand SDB use into waters with poor clarity; improve the accuracy of SDB measurements with higher quality validation; and automate and integrate SDB production from multiple methods.

Expand Use into Turbid Waters by Applying Wave Kinematics. Turbid waters carrying lots of sediment prevent light from penetrating the water column, which in turn yields little or no seafloor reflection in visible wavelengths back to imaging satellites overhead. Project Trident has focused on supplementing the traditional SDB workflow with wave kinematics calculations in these dynamic coastal zones.

jOmegak has pioneered development of a process that derives seafloor depth by measuring the horizontal distance between wave peaks seen in Sentinel-2 A/B satellite imagery. The two European Space Agency satellites in this constellation capture multispectral data with fraction-of-a-second time delays between each spectral band. These delays are long enough to gauge wave movement over time, and the method leverages the vast and ongoing imagery and determines water depth using well-known equations. Integration of this technique into the Trident workflow is underway now and could be part of the commercial TCarta product offering as early as summer of 2020.

The second and third prongs of Project Trident heavily leverage machine learning and computer vision to develop new validation data sets through the automation of existing image-processing techniques that have traditionally been too manually intensive for practical use in SDB.

Derive High-Confidence SDB Measurements from Dozens of Images. While the governmental Landsat and Sentinel satellites capture coarse resolution data, these data sets are plentiful and free. Unlike the commercial missions, these satellites collect data continuously, resulting in hundreds of images available for nearly every spot on the Earth, including coastlines, in publicly accessible archives.

Applied to high-resolution imagery, SDB typically involves data extraction from one or two images, due to the cost. TCarta researchers have developed AI methods to quickly and inexpensively apply SDB algorithms to dozens of the free Landsat and Sentinel data sets acquired over the same geographic locations. This yields highly accurate "average" water depth measurements that can be used to validate the SDB results extracted from one or two high-resolution WorldView images. Performed manually, this iterative process applied to dozens of images would be impossible without AI.

Automate Digital Stereo Photogrammetry with AI. TCarta researchers have automated a traditional terrestrial 3D elevation extraction technique called stereo photogrammetry and extended the technique into the marine domain. In this process, a subsurface feature such as a rock or reef tip is identified and measured from different angles in multiple overlapping WorldView images to calculate 3D location values.

The addition of computer vision to this traditional process has greatly accelerated the overall workflow. Initial results for AI-assisted stereo photogrammetry are promising, and research continues.

As research has continued on these three methods, TCarta image-processing technicians have also spent considerable time fine-tuning the traditional SDB extraction algorithms. Already, the team has enhanced these algorithms to perform multiple linear or polynomial regressions on the ratio of blue and green bands from multispectral imagery, resulting in a more customizable data extraction and higher quality SDB measurements.

ICESat-2 Data: The Fourth Prong

NASA launched the ICESat-2 (Ice Cloud & land Elevation) satellite in September 2018 with an onboard laser altimeter, or LiDAR, designed mainly to measure the thickness of sea ice, terrestrial glaciers and tree canopies. As ICESat-2 data became available to participating researchers in 2019, it became evident that the data were quite useful for deriving coastal bathymetry measurements.

The Project Trident team saw an opportunity to add a fourth prong to its research and applied for participation in the NASA Applied User program for ICESat-2 to test the laser measurements as an SDB validation source. The data appealed for many reasons, especially its free price tag, global availability and continuous updating with new collections.

The onboard Advanced Topographic Laser Altimeter System (ATLAS) actively emits beams of light that strike the Earth's surface, or objects on it, and return to the device. The time lag between the emission and return is used to calculate the elevation of the surface points. The ATLAS sensor operates similarly to airborne LiDAR, with one difference. Whereas aerial sensors capture wide swaths of laser measurements to generate large-area surface models of tightly spaced elevation points, the space-based device captures point measurements along multiple parallel narrow lines, or ground tracks.

ICESat-2 collects data in three pairs of lines. Each pair is separated by approximately 3 km on the Earth's surface, while individual scan lines within each pair are spaced approximately 90 m apart. The spacing of elevation point collection within a single scan line, however, is an impressive 0.7 m. While impractical for broad-area bathymetric mapping due to the line gaps, the tightly spaced points are ideal for calibrating other seafloor-depth data sets.

While NASA makes several ICESat-2 products easily available to end-users, accessing full-resolution bathymetry data necessitates processing of the raw photon data and requires highly specialized software and skills. TCarta has developed a software that streamlines ICESat-2 data access and employs a proprietary algorithm to derive seafloor depths from the laser data for use in Project Trident. This routinely extracts 100,000s of measurements to depths of 30 m, accurate to within centimeters.

Trident Continues

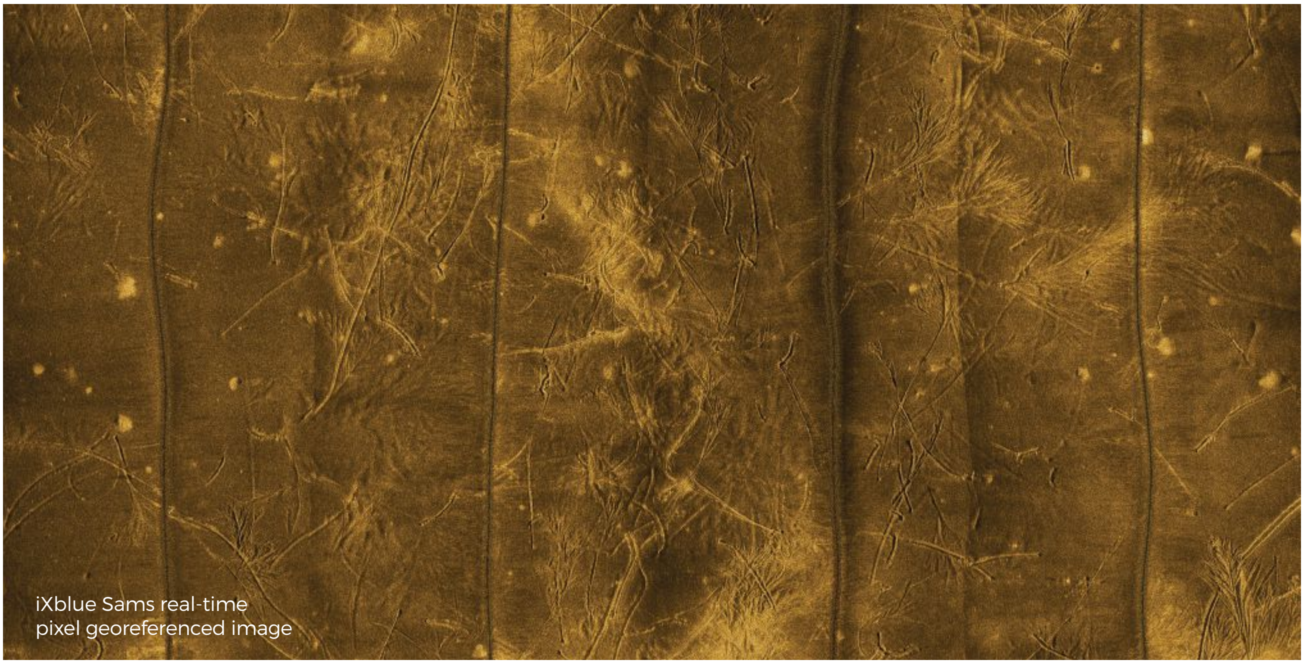
The better-than-anticipated quality and coverage of ICESat-2 data make them a valuable data source for SDB validation and has expanded the scope of Project Trident as research continues in wave kinematics, multi-image processing and automated stereo photogrammetry. Results indicate the space-based laser data will not replace any of these but become a complementary validation tool. Each of the four techniques will be applicable in specific water conditions and provide complementary capabilities.

Through the NSF funding, TCarta has made the ICESat-2 bathymetric extraction application available as a stand-alone commercial product. In addition, the initial enhanced SDB processing workflow is now offered as a tool in the Esri ArcGIS Pro software. Over the coming months, TCarta will add wave kinematics, multi-image processing and automated stereo applications to this toolbox. Negotiations are under way with developers of hydrographic software products to add the Project Trident toolbox to their packages as well. **ST**

Kyle Goodrich is the president of TCarta Marine in Denver, Colorado. He has a 19-year career in remote sensing and geospatial services and a degree in geosciences from Williams College. Since founding TCarta Marine in 2008, Goodrich has led numerous geospatial product commercialization plans, including satellite-derived bathymetry, shoreline classification and global bathymetric products. He has extensive experience serving the oil and gas industry, NGOs, foreign and U.S. government agencies, and the geospatial intelligence sector with successful delivery of hundreds of projects worldwide to various industries and applications. As principal investigator, Goodrich leads the business development and commercialization plan for Project Trident.

Ross Smith is the technical project manager of TCarta Marine. He began his GEOINT career in 2011 as an infantry sergeant, leading Company Intelligence Support Team operations during Operation Enduring Freedom. After joining TCarta in 2017, Smith now leads technical research and development of new marine geoprocessing and remote-sensing technologies under TCarta's National Science Foundation Small Business Innovation Research program. Smith is currently a Certified Geospatial Intelligence Professional in GIS & Analysis Tools (CGP-G) and a USGIF Individual Member & Young Professionals member.

Ifremer new 6,000m AUV will feature iXblue SAS sonar and sub-bottom profiling solutions.



iXblue Sams real-time
pixel georeferenced image

Ifremer, the French National Institute for Ocean Science, has chosen iXblue to develop a cutting-edge Synthetic Aperture Mapping Sonar Sams-150 for AUV-borne investigation and mapping of the deep-sea environment in the frame of the CORAL project. The "Constructive Offshore Robotics ALliance" CORAL project aims at developing, in an industrial alliance led by Ifremer, a deep sea AUV - Autonomous Underwater Vehicle- for seabed exploration down to 6,000m depth.

iXblue Sonar Systems Division (based in La Ciotat, France) has a long history in the design, development and manufacturing of sonar transducers, systems and software. With worldwide track records, iXblue has been equipping Ifremer's oceanographic fleet for more than 25 years.

Sams 150: optimal imaging performance for ROV and AUV

With extended expertise in combining sonar, inertial navigation and acoustic positioning technologies, iXblue has developed one of the most advanced and accurate solutions for seabed mapping. Available as an AUV payload, Sams-150 expands the capabilities of conventional side-scan sonar for shallow- to deep-sea applications. The Sams 150's interferometric sonar delivers co-registered full-swath backscatter and bathymetry data, increasing the achievable resolution and coverage rate from AUV surveys.

Mastering the integration of subsea positioning and inertial navigation together with advanced sonar techniques and data processing, iXblue brings turn-key SAS technology to all scientific and hydrographic surveyors. Sams delivers optimal imaging performance with respect to environmental conditions in terms of swath, resolution, image quality, coverage rate and absolute pixel positioning accuracy. At a speed of 3 knots, Sams-150 delivers a true sonar resolution of up to 2.5cm x 7cm and interferometric bathymetry over a 500m full swath. Thus the Sams system ensures a complete natural insonification of the seabed; a SAS processing gain of 6 is guaranteed with motion and acceleration tolerance that are 10 times better than other existing solutions on the market.

Delph SAS software to streamline SAS processing with workflow

iXblue's original processing – Delph-SAS – adds SAS processing capability to its industry-proven Delph software suite with a seamless integration to the workflow and interpretation features. The accurate coupling of SAS beam-forming and micro-navigation with the inertial navigation data results in optimal resolution and image quality in every environmental condition. Coherent and non-coherent SAS processing for sonar and interferometric bathymetry allow users to maximize the resolution or imaging quality depending on the navigation stability and survey requirements. Additionally, Delph-SAS integrates the co-registered AUV's multi-beam echosounder data, delivering full-swath bathymetry and sonar imaging. As the need for overlapping survey lines is reduced, AUV coverage rate and autonomy are maximized, thus saving time and mission costs.

Real-time absolutely positioned imagery

Sonar mosaics at a grid resolution of up to 5x5cm are fully corrected from geometric and radiometric distortions and accurately positioned in real-time. The highest pixel's relative positioning precision is achieved through the high level of coupling with the INS while the absolute submetric precision is given by the acoustic positioning system solution (USBL, Sparse-LBL, etc.). iXblue's inertial navigation post-processing software Delph-INS enables the fusion of surface USBL positioning and the AUV's INS in post-survey. Near-perfect line matching immediately improves map consistency, data interpretation and targeting accuracy.

An innovative AUV to meet scientific deep-water exploration challenges

The hosting AUV is a newly developed system with a dual navigation capability allowing to combine acoustical imagery and bathymetry survey at 3-4 knots for up to 36h duration, with low velocity close-to-seafloor optical mapping and inspection down to 6,000m depth. Standard payload includes the Sams 150, a bathymetric plus water column multi-beam echo-sounder, a still photo camera, a magnetometer, a CTD, and a current-profiler. A modular payload section hosts in addition a set of scientific sensors for physical or chemical parameters, and either one of the Sams 150, iXblue Chirp sub-bottom profiler Echoes 5000, a spectrometer or an event-triggered water sampler.

In order to make optimal use of the large number of payload devices, and the AUVs navigation capabilities, a novel mission management concept will allow the graphical definition of a logical mission plan from basic proven behaviors, allowing to implement reactive exploration strategies adapted to the current scientific objectives.

As a national tool within the French Oceanographic Fleet, the AUV will provide scientists with a wide set of co-referenced high-resolution data for multi-disciplinary exploration of the deep-sea. ■

Ifremer new 6,000 m AUV

Sams 150 AUV kit

MORE INFORMATION ABOUT:

iXblue:
https://www.ixblue.com/

Coral project details:
https://www.flotteoceanographique.fr/en/Technology/Ongoing-Major-Projects/Coral

Coral project video:
https://wwz.ifremer.fr/webtv/Conferences/Projet-Coral

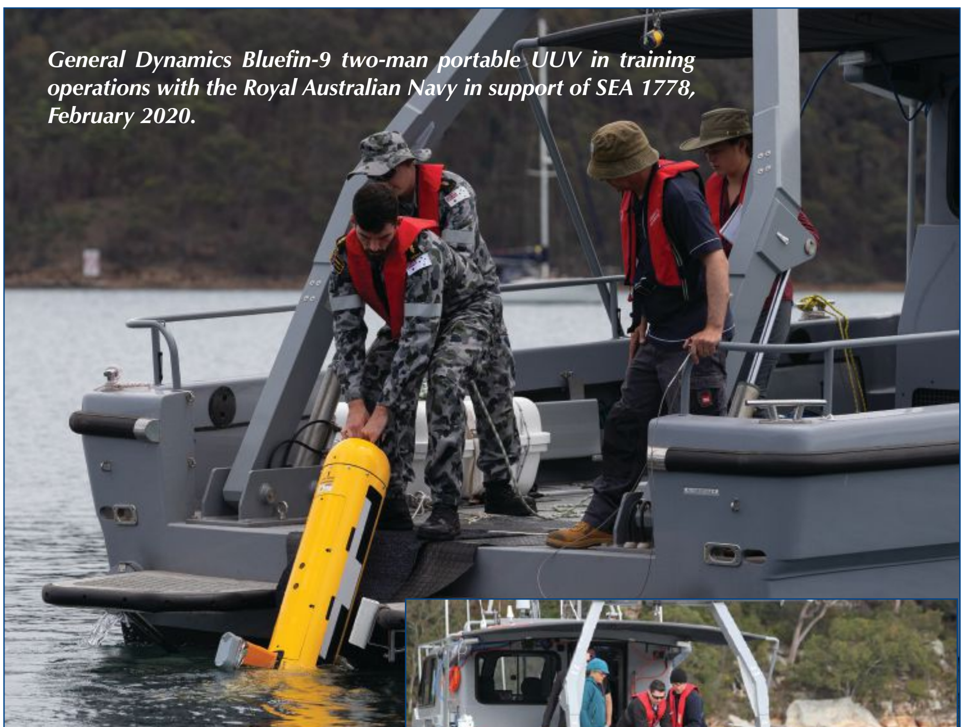
iXblue

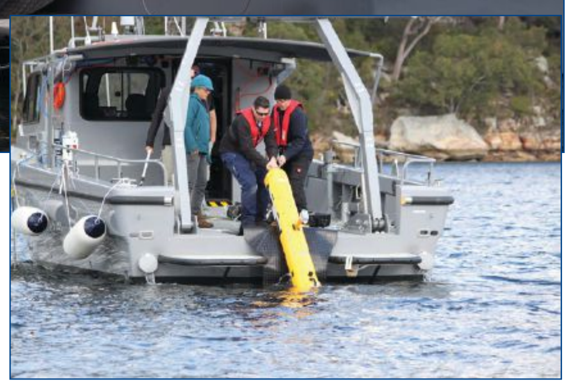
UUVs on the Frontier

Augmenting Naval Operations in the New Decade

By Michael Guay • Gordon Clark

Unmanned Underwater Vehicles (UUVs) are an increasingly important component of naval operations, supporting core missions such as mine countermeasures (MCM), intelligence preparation of the operational environment (IPOE), and search and recovery (SAR). The next decade will see significant steps forward in the use of UUVs and other unmanned maritime systems to augment the impact of naval platforms, integrate vital mission data into the common operational picture and reduce human operator's exposure to hazardous conditions. Indeed, the proliferation of unmanned systems like UUVs is central to much of the forward-looking defense doctrine that is shaping future naval requirements. General Dynamics Mission Systems works closely with customers to design and develop these mission-critical technologies, spearheaded by its Bluefin Robotics line of UUVs and application-specific derivatives.



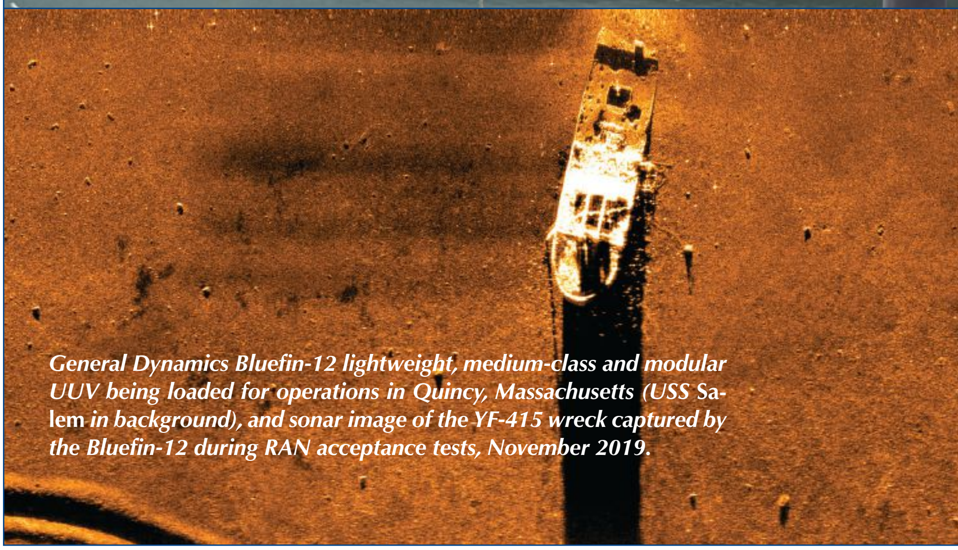


General Dynamics Bluefin-9 two-man portable UUV in training operations with the Royal Australian Navy in support of SEA 1778, February 2020.

Enhancing Littoral-Zone Expeditionary MCM

Worldwide, existing MCM forces are aging. Asset obsolescence and the resulting loss of MCM capability is a pressing concern. The United Kingdom's Royal Navy is slated to lose much of its mine-hunting capability in the early 2030s, according to the U.K. Comptroller and Auditor General, while the U.S. Navy has reported that some of its *Avenger*-class MCM ships—developed in the early 1980s—have already been decommissioned.

UUVs are now fundamental to modern naval MCM missions. In an MCM context, where operators are searching for mines and other explosive devices, time to action is invaluable. For example, UUVs like the two-



General Dynamics Bluefin-12 lightweight, medium-class and modular UUV being loaded for operations in Quincy, Massachusetts (USS Salem *in background), and sonar image of the YF-415 wreck captured by the Bluefin-12 during RAN acceptance tests, November 2019.*

man portable Bluefin-9 are greatly increasing the speed at which actionable data are delivered to decision makers.

Advancements in sensor technology, such as the Sonardyne Solstice multi-aperture side scan sonar, have given integrators new avenues to provide high-resolution data collection capabilities on smaller platforms. When combined with marked improvements in power consumption and processing speed in commercial-off-the-shelf CPUs and GPUs, operators now have the capability to process a full range of sonar imagery, bathymetry, still images and full-motion video in situ. Actionable data are then simply offloaded via a removable data storage module (RDSM) upon recovery without the need for additional processing time.

Leveraging machine-learning algorithms via onboard automated target recognition (ATR) software, UUVs can now autonomously iterate on processed data sets and flag contacts of interest throughout the mission, increasing the efficiency of operations. Contact details and image snippets are sent back to the operator workstation acoustically while submerged, or via satellite communication when on the surface.

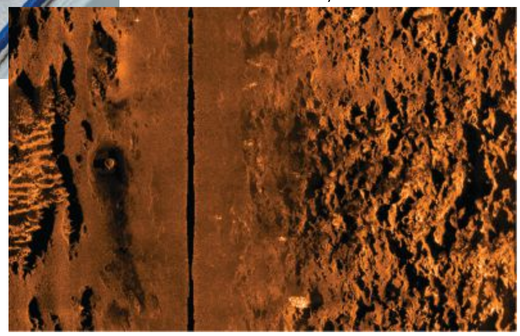
With such capabilities, navies around the world are now leveraging UUVs as an MCM force multiplier. For instance, the Royal Australian Navy (RAN) is modernizing its MCM capability via the ongoing SEA 1778 program, which includes employing the General Dynamics' Bluefin-9 and Bluefin-12 UUVs alongside a suite of new maritime platforms.

Safer Waters at Home

UUVs are also becoming vital for port and harbor security. Maintaining safe and open access to ports is essential to global commerce. As such, ports and harbors must be defended against a variety of real-world threats and hazards. Here, UUVs will allow leaders to quickly assess their operational environment and make better decisions. With the help of high-resolution sonar and advanced change-detection algorithms, a fleet of UUVs can survey waterways with greater regularity and quickly flag anomalies that require investigation. For example, an improvised explosive device (IED) could be detected before it causes potentially catastrophic harm to personnel and equipment. Coastal-based critical infrastructure like power plants could have a team of UUVs working in concert to patrol and stand watch over the adjacent waterways. Subsea cables and pipelines could be more routinely inspected for damage or tampering.

In 2019, General Dynamics supported an evaluation of the Bluefin-9 UUV in the English Channel to better understand this mission focus. Alongside members of the United Kingdom Ministry of Defence's Defence Science and Technology Laboratory (Dstl) and the Maritime Autonomous Systems Trials Team (MASTT), the group performed numerous trials in an area known as the Solent, set between the Isle of Wight and the city of Portsmouth, England. Strong currents have long plagued unmanned systems in this area of operations, but recent advances in propulsion and dynamic control capabilities have overcome some of these challenges. The Bluefin-9 was able to successfully identify the test's inert mine-like objects

General Dynamics Bluefin-9 performing operations in the Solent with MASTT and sample of resulting data, November 2019.



with high locational accuracy despite the unique challenges of the operational environment.

Mission-Based Modularity

As the nature of UUV missions evolves and expands, UUVs of all sizes will need to be able to adapt to and perform multiple missions. Certainly there will always be a role for purpose-built UUV solutions, but in many applications the concept of a UUV as a common platform is much more desirable. In this way, the UUV is akin to a truck, transporting payloads that are tailored to accomplish specific missions and objectives. As the mission changes, so too does the payload.

Many of the sensors and underlying computer hardware integrated in UUV payloads are now commodity products with wide commercial availability. This has given rise to a host of new foundational components for expert integrators to build upon and bring more immediate focus to installation of more advanced capabilities.

As a UUV designer and manufacturer, General Dynamics—with the Bluefin-9, Bluefin-12 and Bluefin-21 UUV platforms—has put tremendous focus on making UUVs user-friendly and adaptable for mission-specific sensors and payloads.

The U.S. Navy's Surface Mine Countermeasures Mission (SMCM) UUV program-of-record, Knifefish, was adapted from a standard and commercially available Bluefin-21 UUV platform, bringing a host of custom payload capabilities that enable its users to accomplish their mission. Without a modular UUV, this type of technology becomes far more difficult to develop, test and deliver.

Modularity also extends to software, where standardization of data and communication interfaces can greatly streamline integration of payloads into host UUV platforms. General Dynamics publishes its Bluefin UUV Standard Payload Interface (SPI) specification to the public to give researchers, developers and other integrators

"The next decade will undoubtedly see UUVs leading the way in some of the world's dirty, dull and dangerous naval operations."

General Dynamics heavyweight, medium-class Bluefin-21 UUV and the Knifefish SMCM UUV. The Bluefin-21 modular construction and payload capacity provided the foundation for the Knifefish SMCM UUV program of record.

a comprehensive ability to communicate with the host UUV. This includes allowing a full "backseat driver" capability whereby a payload can fully control the vehicle's core navigation and dynamic control functions and essentially pilot the vehicle.

New standards for command and control like the U.S. Navy's Unmanned Maritime Autonomy Architecture (UMAA) will enable disparate unmanned maritime systems to rapidly interface with one another and integrate mission-required sensors across platforms.

These types of standards are geared toward giving naval commanders and unmanned maritime systems operators a new flexibility to utilize unmanned assets in their operations.

With standards in place, concepts like the Defense Advanced Research Projects Agency's (DARPA) Mosaic Warfare could broadly expand the role of UUVs as sensing platforms capable of relaying relevant mission data to other disparate systems and achieving coordinated mission effects.

Accelerating Operational Sense-Making And Increasing Agility

As UUVs take on expanding roles in naval operations, naval commanders will have new data to evaluate and integrate into their decision making. UUVs provide an affordable mechanism for quickly gathering vital situational awareness, i.e., environmental, hydrographic, bathymetric and localization data for objects of interest—all while manned vessels maintain safe standoff. In dynamic and potentially contested environments, increasing the density of UUVs effectively scales the number of subsea sensors available to a naval commander, thus increasing the range, speed and resolution at which they can develop a tactical picture.

Tomorrow's naval commanders will see the benefits of further integrating air and surface assets into the tactical picture alongside UUVs. Self-forming, self-healing, adhoc mobile networks will provide data-range extension, higher bandwidth connections, and synchronization of action between UUVs, unmanned aerial vehicles and USVs. Maritime operations centers will take on an increasingly important role in orchestrating missions using autonomous assets. Many of these capabilities are closer to implementation than may be commonly thought.

During the U.S. Navy's annual Advanced Naval Technology Exercise (ANTX) in 2017, General Dynamics demonstrated the ability to simultaneously deploy a smaller UUV and a UAV from a Bluefin-21 UUV while submerged. The UAV, floating to the surface in a canister, launched itself into the air in a holding pattern over the area of operations. The smaller UUV collected mission data, which it acoustically transmitted to a subsea node, before surfacing and transmitting the data to the UAV overhead. The UAV acted as an additional relay of data back to a mock maritime operations center.

UUVs at the Forefront

The next decade will undoubtedly see UUVs leading the way in some of the world's dirty, dull and dangerous naval operations. Leaders and operators will have unprecedented access to new data sources to better inform decision making. UUVs will continue to expand into new mission domains, with modern, modular designs to speed integration of critical technologies. Industry partners like General Dynamics stand ready to help customers leverage these technologies now and in the future. **ST**

Michael Guay is the product manager for Bluefin Robotics UUVs at General Dynamics Mission Systems.

Gordon Clark is the chief engineer for Bluefin Robotics UUVs at General Dynamics Mission Systems.

Accelerating Ship Design

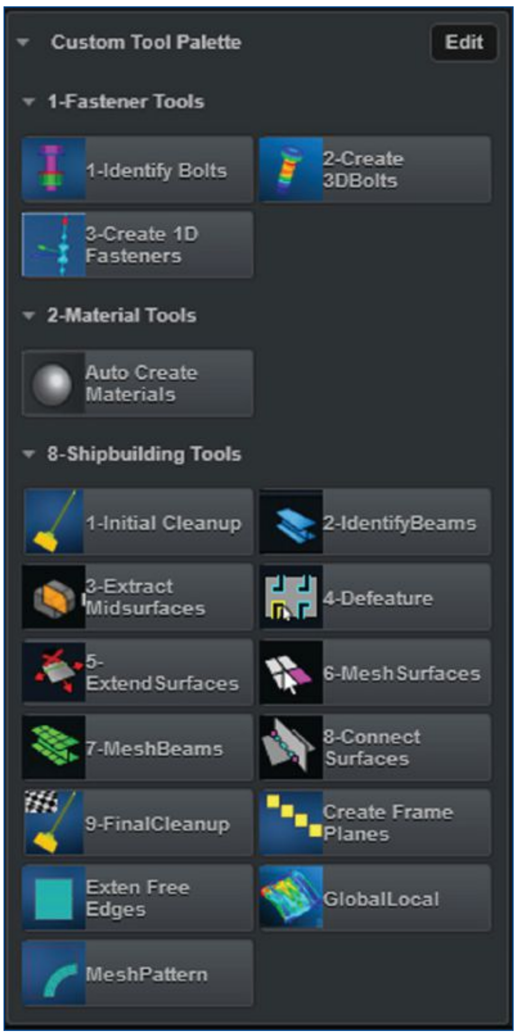
Supporting Sustainable Shipping with Improved Ship Simulation

By Stefan Tynelius • Ole Jan Nekstad

This year has been marked by a step-change in priorities in the maritime sector, with the container shipping industry facing growing pressure to reduce energy use and emissions while increasing capacity in a high fuel-cost environment.

Historically, shipping has accounted for at least 2.4 percent of global emissions, which has attracted the attention of regulatory authorities. As a result, the International Maritime Organization (IMO) has mandated the international shipping sector to reduce emissions by a minimum of 50 percent compared with 2008 levels by 2050, and achieve a 40 percent reduction in emissions by 2030. The low-sulphur fuel mandate has already had a significant impact on shipping and will cost the industry $10 billion to $15 billion a year in fuel costs. Meanwhile, the industry itself shows no sign of slowing down, with the container shipping market set to increase by 4.8 percent by 2021.

These demands combined present a challenge for the tanker and commercial maritime industry. Boosting capacity while simultaneously transitioning to a carbon-neutral shipping environment presents a major engineering conundrum, particularly as shipyards are also under pressure to reduce shipbuilding costs, such as by reducing investment into raw materials. The key is to find ways of creating low-cost, lightweight ships, containers and other parts that can sustain greater loads with the minimum weight and steel, while also reducing other factors in fuel inefficiency such as drag and water resistance.



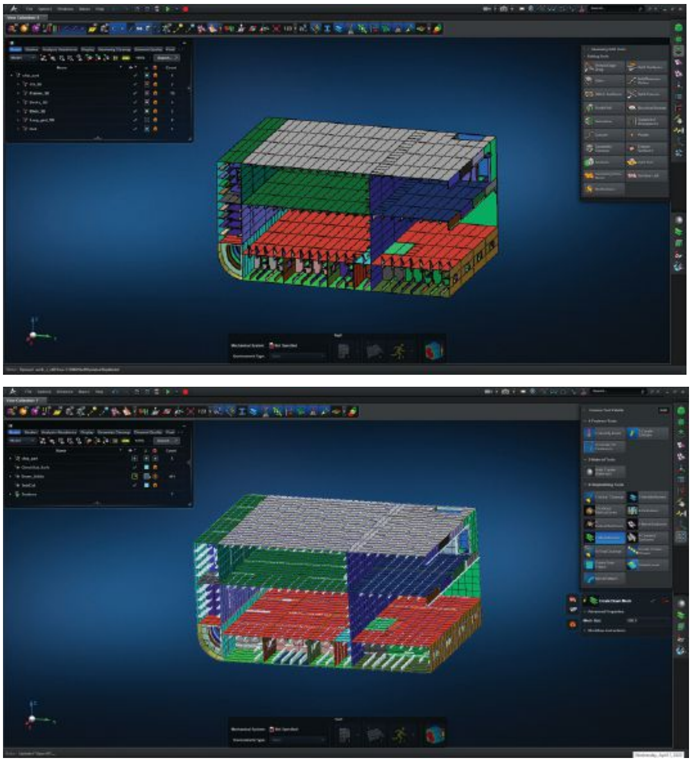
Ship tools menu.

These new classes of lightweight, high-capacity vessels will require many design iterations and the use of novel materials, including composites. But meeting these seemingly disparate demands can provide rewards. Research indicates that just a 20 percent reduction in the weight of empty 40-ft. shipping containers would deliver $28 billion in fuel savings.

However, achieving such drastic weight reductions requires investment in novel engineering solutions, and validating a new design and the design cycle of an entirely new vessel is extremely costly and time-consuming. One of the reasons for this is that the process of designing and engineering ships is entangled in a substantial framework of regulations and guidelines, both for the generation of simulation (computer-aided engineering, or CAE) models and for the analysis and evaluation of them, known as the "code check."

3D Simulation Package

A new partnership between DNV GL and MSC Software is addressing this problem by bringing together the



(Above) Sample 3D simulation of a ship section, from starting model to model with beams added. (Below right) Sample 3D quarter-section simulation, from starting model to model with beams added.

computer-aided design (CAD) and computer-aided engineering of maritime and offshore systems into a single package, reducing the process of validating new designs by weeks.

Typically, CAE models are highly idealized; small parts such as collars and brackets are omitted, geometric features such as fillets and cut-outs are removed, and stringers and stiffeners are often represented as one-dimensional beam elements, thus transferring the stiffening effect on its attached panel. The approach is to capture the load distribution throughout the ship structure, and then evaluate each part of the structure individually using class-specific rules, the so-called code check. The goal is to ensure that the structure can withstand pre-defined load conditions, such as buckling under hydrostatic load, within the safety margin.

Traditionally, the CAE models have been built from scratch based on 2D CAD, or even starting from a stack of blueprint drawings. The new partnership means that the CAE model can now be generated starting from existing 3D CAD models. The challenge is to aid the CAE engineer in the preparation and idealization of the 3D CAD data and to identify slender components such as stringers and stiffeners and convert them into equivalent one-dimensional elements. The idealized model has to conform to the regulations, rules and guidelines surrounding ship design.

MSC Apex features a strong set of geometry tools and supports the most important CAD formats. This, combined with its best-in-class framework for customization, makes it a perfect solution to tackle the challenge of creating an idealized CAE model starting from a detailed 3D CAD.

The easy-to-learn and easy-to-use system merges a graphical user interface with the embedded solver, instructions, explainer videos and searchable documentation, ensuring a very short learning curve to get new users up to speed.

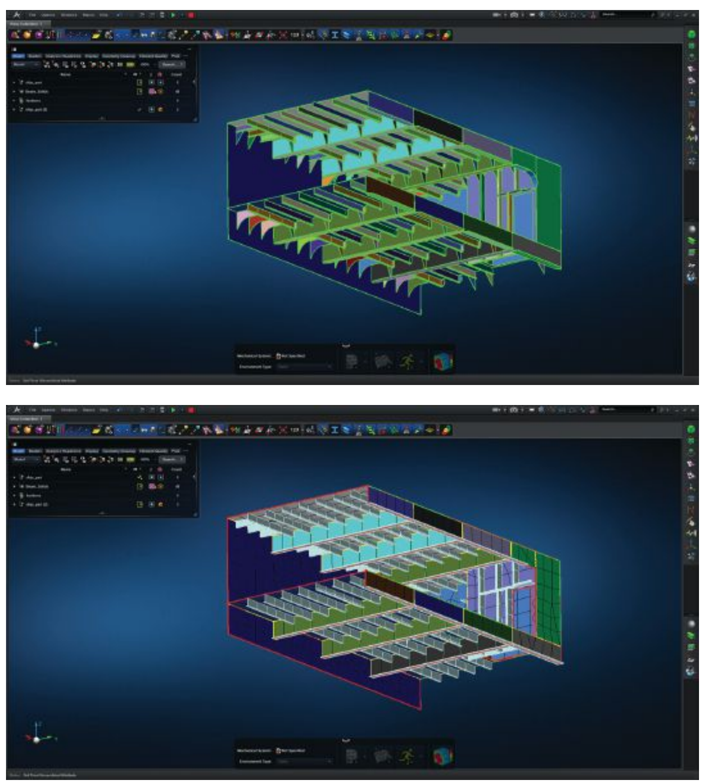
This is in sharp contrast to legacy CAE tools, which often require extensive training before a new user is proficient enough to use them to their full potential and increase productivity.

To further aid the analyst, a set of shipbuilding-specific tools are developed and organized in logical sequence to guide the user through the process of cleaning, idealizing, meshing and, finally, connecting the model.

The new solution is a part- and assembly-based simulated environment. This means the CAD tree structure is preserved from the imported CAD, but it also allows users to build and check out the model quality incrementally.

Here, the MSC Apex built-in solver is a great tool to quickly validate a part or a subassembly before being combined to another part or subassembly.

The incremental approach enables the user to validate the model on the fly, during the modeling process. This is preferable to the previous approach, in which the validation cannot start until the entire model is completed. Debugging and fixing modeling errors can be tedious and time-consuming and can delay the design process, as the amount of time needed for debugging to get to a run-ready model is often unknown.



"The incremental approach allows the user to validate the model on the fly, during the modeling process."

The MSC-DNV GL partnership allows DNV GL users access to MSC Apex in conjunction with the industry-leading DNV GL software suite Sesam. The model generated in MSC Apex is imported to Sesam, where loads are then applied, the model is run with the Sesam Solver and, finally, analyzed through the code check routines. A fully integrated connection between MSC Apex and Sesam ensures that no information is lost in the transfer of data. Sesam has an interface with Nauticus Hull, DNV GL's ship-rule calculation software.

These accelerated ship design process tools are already in use by customers. The dramatically reduced modeling time removes barriers of innovation by enabling more design iterations to be analyzed in less time. The solution therefore allows for a further refined, more optimized design to meet the challenges of low-carbon, fuel-efficient ships and ensures increased profitability can go hand-in-hand with improved sustainability. **ST**

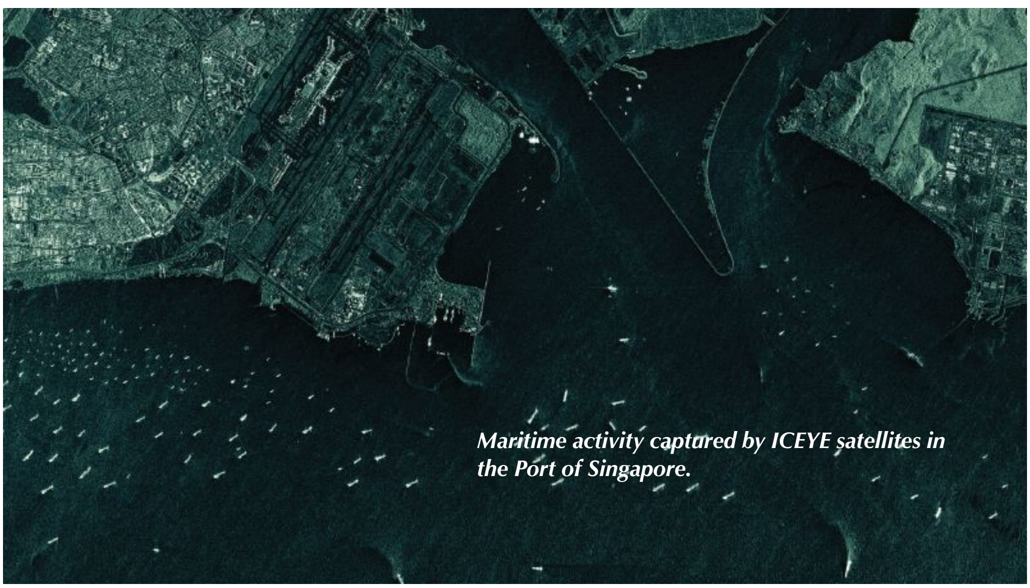
Stefan Tynelius is MSC Software's MSC Apex business developer specialist, EMEA. After graduating from Chalmers University of Technology with an M.S. in mechanical engineering, he joined Volvo Car Corp.'s CAE department, working on advanced engineering method development and body noise, vibration, and harshness (NVH) in vehicles. In 2002, he joined the Ford Motor Co. of Australia, working on Complete Vehicle NVH CAE. He joined MSC Software in 2006.

Ole Jan Nekstad obtained his M.S. in offshore engineering from NTH, Norway, in 1981. Upon graduating, he began his career at DNV GL, working on numerous FE analyses of ships, semisubmersibles, GBS and jackets. In 1989, he joined its software division and has been product director of Sesam since 1994.

Detecting Dark Vessels

Radar Satellite-Based Monitoring of Illegal Activities at Sea

By Dr. Mark Matossian • Pekka Laurila • Charles Blanchet



Maritime activity captured by ICEYE satellites in the Port of Singapore.

Illegal maritime activities at sea cause severe damage to economies worldwide and lower the security of nations. These activities are numerous and diverse, including illegal fishing, unauthorized transshipment, illegal immigration and ocean dumping, as well as smuggling of people, arms and drugs. These are serious risks to legal sea operations, especially in the vicinity of ports and much frequented sea routes. All of the world's coastal countries are facing one or more of these threats.

Considering that maritime traffic is rising year by year, there is a growing demand for effective and comprehensive monitoring of all activities at sea to avoid any illegal activities and ensure safety for the shipping industry.

Vessel detection and monitoring procedures are in place globally and have been for a long time. However, detecting ships that don't want to be visible to authorities is still a challenging task.

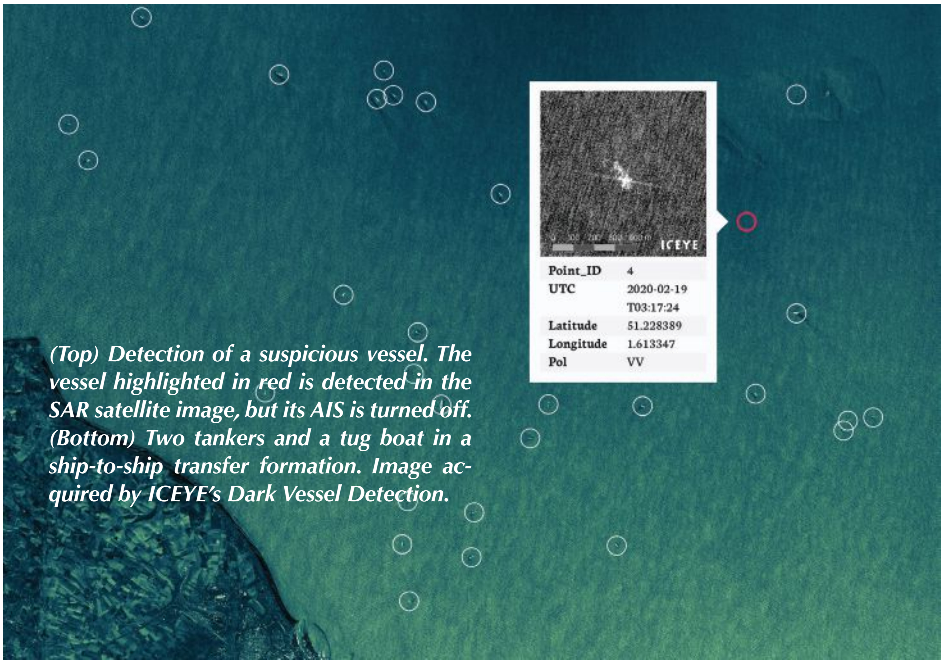
Current Situation of Maritime Monitoring

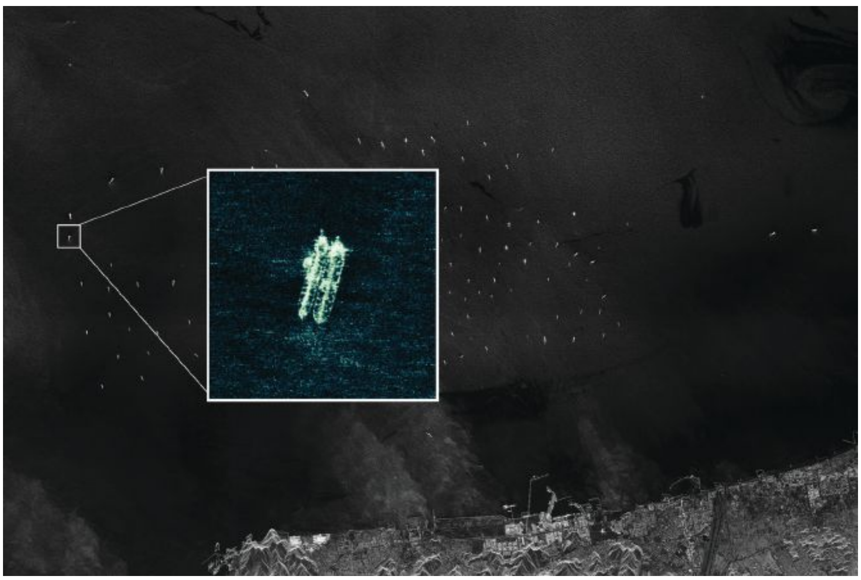
The most common systems for maritime self-identification and tracking are the automatic identification system (AIS) and the vessel monitoring system (VMS). The AIS transponder reports the location of the vessel to the local coast guard and other ships. VMS is mainly used by fishing vessels. It provides information about the location and activity of the vessel to coastal states and regional fisheries management organizations.

Vessels are required—but not enforced—to use AIS or VMS. And even if they are equipped with one of the systems, they can be turned off on purpose to hide vessels' activities and "go dark."

In coastal areas, systems are in place to control vessel volumes and activities: Coastal radar systems are very effective in controlling activities in coastal areas, i.e., the Exclusive Economic Zones (EEZs) stretching out to 200 nautical mi. from national coastlines.

The challenge is more pronounced in open-sea areas. Continuous sea- or airborne-based monitoring is not possible since patrol boats and planes cannot cover large areas at the same time. Additionally, their operations might be quite limited in bad weather conditions, and, especially in the case of using planes, the costs are considerable. Therefore, it happens frequently that vessels





(Top) Detection of a suspicious vessel. The vessel highlighted in red is detected in the SAR satellite image, but its AIS is turned off. (Bottom) Two tankers and a tug boat in a ship-to-ship transfer formation. Image acquired by ICEYE's Dark Vessel Detection.

can evade coast guards and conduct illegal operations.

Satellite SAR Technologies:
A New, Efficient Approach to Detect Suspicious Vessels

The advancement of satellite technologies allows for new opportunities for maritime monitoring. The so-called "New Space" approach entails the operation of an extensive constellation of small satellites in orbit. Operating a large number of satellites is the basis for an efficient, continuous monitoring of large sea areas.

The most reliable solution for maritime monitoring is the usage of SAR (synthetic-aperture radar) satellites. They are able to monitor day and night, during all weather conditions. This is a critical advantage of SAR compared to optical satellites, which can acquire imagery only during daylight and in clear weather conditions since they cannot penetrate clouds.

Thus far, the usage of SAR satellites for monitoring sea activities has been highly limited due to the small number of satellites of the available constellations and associated infrequent revisit rates over the areas of interest. Added to that were the high costs of SAR image acquisitions.

This is no longer the case: ICEYE has successfully developed small satellites by miniaturizing SAR satellites and reducing the entire weight payload of the satellites to below 100 kg, compared to expensive legacy solutions that weigh 1,000 to 2,000 kg. This enables the launch and operation of a high number of satellites in orbit and offers an unprecedented high revisit rate for monitoring broad areas worldwide. Building and operating small satellites also leads to a reduction of the SAR image costs due to the reduced launch costs.

Currently, ICEYE offers data from its commercial constellation of three satellites, and it plans to launch several new SAR satellites in the upcoming months. This will significantly improve the already uniquely high revisit rate—the frequency with which a location on the Earth can be imaged. The company's goal is to operate a satellite constellation that will provide imagery every hour throughout the globe with short delivery lead times. So far, ICEYE has proven image delivery within 15 min. from acquisition, which brings a new approach to monitoring vast sea areas. Obtaining actionable information in such a short time facilitates response actions for a wide range of maritime threats and emergencies.

Methodology

The principle of ICEYE's Dark Vessel Detection combines SAR imagery with AIS location information. All vessels depicted in the SAR imagery covering the surveillance area are detected by automated SAR imagery analysis processes, and their location coordinates are calculated. To identify these vessels, they are synchronized with the AIS data made available by a number of external providers. All vessels located in the SAR imagery that cannot be linked to AIS data are classified as "dark."

ICEYE determines the latitude and longitude for all identified dark vessels and provides the coordinates with a time stamp. For further detailed analysis, the satellite imagery of each vessel will be made available to the user in the form of an image chip. This can be used to obtain more information about the direction, speed, size and type of the vessel. ICEYE's Dark Vessel Detection approach has been successfully tested in several use cases. It is validated to detect vessels as small as 9-by-20 m and targets as small as 3 m, confirmed by AIS. In the future, the algorithm will be able to track even smaller vessels based on wake analysis.

This method also allows the tracking of suspicious vessels over a certain period by taking advantage of the high revisit rate of the ICEYE SAR satellites.

Implementation

The Dark Vessel Detection service can be easily implemented and adjusted to the user's specific requirements due to its flexible architecture. The frequency and the exact dates of image acquisitions and analysis are defined together with the users for their needs.

For all vessels detected in the SAR image and matched to an AIS signal, the information about name, International Maritime Organization (IMO) number, country of registration, type, length, speed and heading of each vessel is delivered.

For the dark vessels, the location in latitude and longitude and the time stamp are provided.

In addition, the deliverables can include a 500-by-500 pixel image chip (PNG) for every vessel for visual analysis. ICEYE guarantees an independent validation and verification check of each analysis result to ensure high-quality standards.

This solution is already in place, delivering reliable service to customers worldwide. As ICEYE steadily grows its satellite constellation, the solution aims to provide near-real-time monitoring from space in the near future.

Illegal Fishing

Illegal fishing is one of the greatest threats to marine ecosystems. It harms fisheries' sustainability, leads to economic loss and hurts biodiversity conservation efforts. According to FAO (Food and Agriculture Organization of the United Nations), up to 26 million tonnes of fish are caught illegally every year worldwide. This amounts to an economic loss of $10 billion to $23 billion annually.

SAR satellite-based Dark Vessel Detection allows for effective monitoring of fishing activities within and outside of an EEZ. This solution empowers reliable tracking of the activity pattern of illegal fishing vessels to better plan response activities. Pre-planned image acquisitions help to achieve shorter lead times and enable the maritime authorities to take immediate response actions. ICEYE's Dark Vessel Solution is already successfully used by customers fighting illegal fishing activities worldwide.

Illegal Transshipment

Transshipment is a regular method of goods transportation at sea, but it can be used for a number of illegal activities, such as the smuggling of drugs, armament, people and illegal goods. Illegal transshipment is hard to detect, as it is usually held far from the coastline and at night.

SAR imagery allows gaining an overview of activities in vast sea areas in one frame. For example, in one case, a user saw an image that showed two tankers in a ship-to-ship (STS) transfer formation, with a supportive tug boat at the side of one vessel. It was possible to detect the vessel's type due to the high resolution of the satellite SAR imagery. In this case, the transshipment was legal, and both ships had their AIS system turned on. The SAR imagery enables users to distinguish legal activity from illegal ones.

Gaining Dark Vessel Detection information allows coastal authorities to react in a timely manner against illegal transshipment activities, or to observe the activity patterns of vessels to tailor a response. An example is the monitoring of illegal oil shipments. A typical behavior of these tankers is to perform STS transfer at sea to conceal the origin of the crude oil. For this, the tankers turn off AIS to avoid being tracked. By observing these STS events, ICEYE's Dark Vessel Detection analysis can be used to regularly investigate if there are any illegal oil transfers in embargo zones.

Supporting Safety, Search and Rescue

Emergency situations are always a challenge for maritime authorities. Especially under bad weather conditions in the open sea, it is very hard to react to emergencies by defining the precise location of the vessel concerned and to organize rescue and intervention activities. Satellite SAR data allow maritime authorities, coast guards and rescue teams to gain timely and actionable information from broad sea areas.

ICEYE's solution has already proven its efficiency in tracking vessels smaller than 10 m, as well as its capability to deliver data in less than 15 min. Future developments could support search and rescue activities at sea with timely and reliable determination of the precise location of a vessel during an emergency.

By providing access to SAR satellite imagery, ICEYE empowers government and commercial users to solve challenges and make better decisions in the maritime, disaster management, insurance and finance sectors. The company is tackling the current critical lack of actionable information with world-leading aerospace capabilities and a New Space approach as it builds its small-satellite constellation. **ST**

Dr. Mark Matossian is the CEO of the U.S. subsidiary of ICEYE, and he works with partners to fully utilize ICEYE's SAR satellite constellation. Before that, Matossian spent 13 years managing global projects at Google. He specializes in scaling up products and services, leading projects across Asia, Europe and South America.

Pekka Laurila is the chief strategy officer and co-founder of ICEYE. He has been establishing and directing the company's strategy, including raising initial funding. Prior to ICEYE, Laurila played a significant role in Finland's Aalto University Nanosatellite Program Aalto-1. He studied engineering and geoinformation systems at Aalto University.

Charles Blanchet is the vice president of commercial solutions at ICEYE, working on various business lines focusing on vessel detection and flood monitoring. Over the past 17 years, Blanchet has developed solutions for early-stage, venture-backed B2B technology start-ups, acquiring huge numbers of early adopters. Before joining ICEYE, he was an operating partner at one of ICEYE's investors.

World's First All-Electric Ship-Handling Tug

Ports of Auckland Ltd. (POAL) in New Zealand has entered into a partnership with the Damen Shipyards Group in the Netherlands to develop a fully electric ship-handling tug, the first of its kind in the world.

The result of this joint initiative will be the RSD-E Tug 2513, a zero-emissions derivation of the IMO Tier III-ready RSD Tug 2513, introduced by Damen in 2018. The radical new tug will be equipped with two Kongsberg US255 L PM FP azimuth thrusters, providing a bollard pull capability of 70 tonnes.

Carbon Capture Evaluation

Houlder Ltd. has commenced work in partnership with PMW Technology on a study to evaluate the potential marine applications of carbon capture technology, specifically, the A3C carbon capture process designed to extract carbon dioxide from marine exhaust gases by freezing, then subliming the carbon dioxide, which is then liquified and stored in dedicated tanks on board, allowing for carbon capture from vessel emissions without radical technical overhauls of marine engines and fuels.

PMW Technology has received funding from the U.K. Department for Transport's Transport-Technology Research Innovation Grant (T-TRIG).

Sustainability Scorecard

Stress Engineering Services Inc. (SES) has developed a sustainability scorecard with RPS to assess the emissions, carbon footprint and environmental impact of systems, subsystems and facilities in the upstream, downstream and midstream sectors, in addition to manufacturing plants, power plants, wastewater systems and processing systems. The sustainability scorecard is built upon SES's competencies and track record in inspection, sensor technology, predictive modeling, system digital twin, data science and asset integrity monitoring.

Closing of Hydroid Acquisition

Huntington Ingalls Industries (HII) has closed on the acquisition of Hydroid Inc. In conjunction with the transaction, HII and Kongsberg Maritime have established a strategic alliance to jointly market naval and maritime products and services to the U.S. government market and, potentially, to global markets.

ChartWorld Group Addition

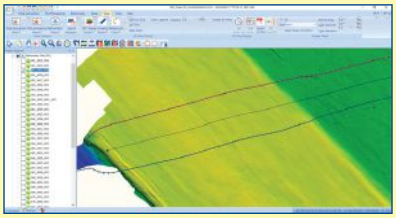
ChartWorld, a digital chart agent and ECDIS manufacturer, has announced the acquisition of Maritime Services Ltd. as the latest addition to the ChartWorld Group.

ChartWorld has solutions on over 8,350 active vessels, with more than 19,000 subscribed services. It says it is the largest company in the world solely focused on the implementation of end-to-end digital navigation solutions for commercial shipping. **ST**

productdevelopment

For more information on any of these products, visit our website at **www.sea-technology.com/products**

Sonar Software Update



SonarWiz 7.6 features forward-looking sonar processing and overlay of FLS with other data sets; multibeam beam performance test to verify full system performance; A–B change detection difference plot to spot changes in repeat side scan surveys; 3D View window using LOD to handle more points and faster drawing; and improved drawing of bathymetry points in 2D View. Chesapeake Technology Inc.

First Flying, Electric Boat

Launched in the U.S., the long-range, high-speed, 25-ft. electric Candela Seven bowrider is the first electric, foiling boat in serial production. With a lightweight carbon-fiber hull and foils, it has longer range and higher speed than any previous electric boat. Flying effortlessly above the sea surface up to 30 kt., the Seven can cruise up to 57 mi. on a single charge. Candela Speed Boat and Denison Yachting.

Hull Form for Autonomy

Pentamaran vessels can be custom configured for military; patrol; intelligence, surveillance and reconnaissance; anti-submarine warfare; and hydrographic survey work. The design reduces drag as much as possible, with a very slender central hull and two smaller hulls (sponsons) on either side. BMT.

Digital Twinning with Smart Data

A digital twinning and smart data asset management tool is capable of saving between 9 and 15 percent on total decommissioning costs. The Veristar AIM3D system provides a true, as is, 4D picture of an asset's condition instantly, everywhere, on any platform or device, at any time. Bureau Veritas and Dassault Systèmes.

Coronavirus Disinfection

Based on UV light technology used to kill invasive species found in ships' ballast water tanks, a 50-cm handheld scanner using UV-C reactor technology emits a ray of UV-C that is passed over a surface. It takes only seconds to disinfect the scanned area. BIO-UV Group.

Digital Platforms for Shipping

An ecosystem of online logistics tools and services covers shipping around the world to enable freight forwarders and any business to book shipments of cargo from and to anywhere, by any combination of sea, land and air. DP World.

Power Safety Alarm

The quality and reliability of marina shore power wiring can vary greatly. When plugging into an unfamiliar 120-V AC pedestal, the Reverse Polarity Alarm sounds an alarm that warns owners of potential electric shock, fire and/or electrolysis damage from an electrical service. Raritan Engineering Co. Inc.

Navigation Tool

ORCA Pilot X software, designed as a primary navigation aid for pilots, is now free to download on the Apple AppStore for iOS tablets. It delivers a unique 3D Head-Up situational awareness mode, rapid installation of official ENCs and chart updates, bathymetric data, route planning, and navigation and docking modes. SevenCs GmbH.

Vibration Data Collection

The USB Digital Accelerometer puts high-quality, low-hassle vibration measurements in the palm of your hand. It allows you to take professional-grade vibration measurements right from a PC, smartphone or tablet, turning any device into a portable, handheld vibration meter spectrum analyzer. PCB Piezotronics Inc.

Shore Power Cord Set

The 50-A, 125-V or 125/250-V Twist-Lock LED Shore Power Cable Set provides many safety and convenience features, including a built-in LED to show when power is flowing and warn of a poor connection. It is available in 25- and 50-ft. lengths. Hubbell Marine Electrical Products.

Reservoir Characterization

All applications across the GeoSoftware portfolio now run on both Azure and AWS platforms, enabling easy access to products from wherever a client is working. The newest releases, Jason 10.1, HampsonRussell 10.5 and PowerLog 10.1, offer advances in machine learning and artificial intelligence and streamlined connections to Python ecosystem notebooks. CGG Software.

Augmented Reality

With more than 20 percent of industrial downtime reportedly due to human error, ABB Ability Augmented Field Procedures for the energy sector will enable consistency in executing manual procedures; standardizing operating procedures and maintenance or repair techniques in the field; tightening field-to-control-room integration; and digitally recording notes. ABB Ltd.

USV Update

Combining a dual GNSS positioning and heading sensor, a stable and reliable hull attitude and an IMU sensor, the APACHE3 USV allows uninterrupted survey while passing under bridges. The 2020 edition includes a GNSS/INS control box; integrated 4G and LAN transmission module; sonic radar for obstacle avoidance; and overspeed engines to allow operation in most water conditions. CHCNAV.

Deep-Tow Side Scan Sonar

The ARC Hunter builds on the ARC Explorer & Scout family of products, providing high-resolution adaptive CHIRP side scan sonar. It leverages a larger, heavier tow body paired with your choice of low-frequency transducers. Operational depth is 200 m. The Hunter is available as single or dual frequency. Marine Sonic Technology.

INS/GNSS PPK Software

Qinertia now covers all surveyors' projects by offering a license dedicated to GNSS post-processing. Qinertia supports all major GNSS receivers and is now open to third-party IMUs. SBG Systems S.A.S.

Commercial Tourism Sub

Triton DeepView 24 conveys 24 passengers to depths of up to 100 m. The 15.4-m-long submersible sits steady on the water surface and has a generous access hatch for passengers with reduced mobility. Triton Submarines LLC.

Payloads for Light, Modular AUVs

The RECON line of products includes: the RECON CS, a 4K stills camera and LED lightbar payload, and the RECON LS, a payload featuring the ULS-500 micro-laser scanner and micro OBSERVER stills camera. They facilitate high-accuracy inspections. 2G Robotics Inc.

Managed Data Services

Skala Global Platform offers next-generation ground system technology, advanced satellite capabilities and service life cycle expertise for commercial shipping companies. SES and De Boer Marine. **ST**

Tech Chosen for Japan's Progress in Offshore Wind

ABB's advanced power systems have been chosen for the first self-elevating wind turbine installation vessel built in Japan to support the nation's fast-expanding offshore wind sector. The 28,000-GT jack-up ship is on order from builder Japan Marine United Corp. Delivery is due to Shimizu Corp. in 2022.

Shimizu Corp.'s 142-m newbuild will feature the highest lifting and carrying capacity ever available on a wind turbine installation vessel. Using a 2,500-ton crane capable of a maximum lift height of 158 m, the ship will be able to transport and install seven 8-MW wind turbines in a single voyage and operate in waters ranging between 10 and 65 m deep.

ABB will deliver a closed ring configuration for the vessel's dynamic positioning operations, enabling safe and predictable performance with high tolerance in the event of a power plant fault.

Fugro Consortium Among Winners of Wind Competition

Fugro, in a consortium with AS Mosley and the PeriDynamics Research Centre at University of Strathclyde, is one of eight winners of the Carbon Trust's Floating Wind Technology Acceleration Competition. The winning innovations will receive a share of GBP 1 million prize fund from the Scottish government and the opportunity to consult on their innovations with the 14 leading offshore wind developers represented on the Floating Wind Joint Industry Project (JIP), which is managed by the Carbon Trust.

The competition addresses four key industry challenge areas: monitoring and inspection, mooring systems, heavy lift maintenance, and tow-to-port maintenance.

Fugro and its consortium partners will develop cost-effective condition monitoring software that characterizes the condition of mooring lines of floating wind turbine assets in respect of wear, corrosion and fatigue. Reducing and/or eliminating the requirement for visual inspection by ROVs and divers will reduce costs and offshore health and safety exposure.

Wave, Tidal Energy Surges

Global wave and tidal stream energy production has risen tenfold over the last decade, according to an annual report by Ocean Energy Systems (OES). Cumulative energy produced from wave and tidal stream sources surged from less than 5 GWh in 2009 to 45 GWh in 2019.

Numerous wave and tidal stream devices have been deployed in open-sea waters for testing, and there are more "push and pull" mechanisms stimulating the ocean energy sector in regions around the world.

Hornsea Two Cable Protection

Trelleborg's applied technologies operation has been awarded a contract by Ørsted to provide four integrated cable protection systems for Hornsea Two, the world's largest offshore wind farm. Trelleborg's NjordGuard cable protection system will protect the inter-array power cables from fatigue, over-bending and abrasion at the entry point of the monopiles.

Hornsea Two comprises 165 turbines and will provide a combined total capacity of 1.4 GW. Located in the North Sea, it is set for completion in 2022.

Vibro Hammer for Monopiles

CAPE Holland has been awarded a contract by Seaway 7 to supply a Vibro Lifting Tool (VLT) for the installation of the monopile foundations for Kaskasi offshore wind farm. After years of development and many successful installations, this will be the first offshore wind project whereby the monopiles will be driven to final penetration with a vibro hammer only.

The Vibro Lifting Tool for this project will have multiple vibro hammers linked together to provide a total of 1,920 kgm, which makes this the most powerful vibro pile driver in the world, CAPE Holland said. A specially developed clamping system will be used to create the interface between the Vibro Lifting Tool and the flanged top of the monopiles.

WaveBoost Project a Success

The three-year, Horizon 2020-funded WaveBoost project has ended with a step-change improvement in the reliability and performance of wave energy technology. Led by CorPower Ocean, the WaveBoost consortium designed and developed an advanced power take off (PTO) system allowing wave energy converters (WECs) to operate safer and more reliably in harsh ocean conditions while increasing annual electricity production by 27 percent.

The system incorporates a revolutionary pneumatic module that has 80 percent less components, thus reducing complexity and CAPEX while improving reliability, compared to previous designs. An energy redistribution system manages fluctuating power input from ocean waves to support grid integration and increase energy production.

The improvements enabled the levelized cost of energy (LCOE) to drop by 18 to 29 percent, with operational expenditure expected to decrease by up to 30 percent.

Life cycle analysis undertaken on a theoretical 50-MW array deployed in Scotland indicated a carbon intensity already as low as 31.4 gCO_2e/kWh based on the first prototype WEC generation design alone.

The learnings from WaveBoost will inform CorPower Ocean's progress toward the manufacturing, dry testing and deployment of its next full-scale C4 WEC. **ST**

people

Sonardyne International Ltd. has named **Graham Brown** managing director. Brown, who takes over the role from **John Ramsden**, has served on Sonardyne International's board from 2008, most recently as sales and marketing director and deputy managing director. Ramsden is now CEO of Sonardyne Group, the new parent company of Sonardyne International and its sister companies: Chelsea Technologies, EIVA, Wavefront and 2G Robotics.

Hiroaki Sakashita was promoted from senior executive vice president to president and CEO as well as a representative director of ClassNK. Sakashita holds a bachelor's degree in naval architecture and ocean engineering from Yokohama National University and started his career at Japan's Ministry of Transport (now Ministry of Land, Infrastructure, Transport and Tourism) in 1980.

Greensea has added to its engineering team in the Plymouth, Massachusetts, office to support its hull robotics program. **James Truman**, senior robotics engineer, is leading the development of Greensea's hull-crawling robot with precise hull-relative navigation and autonomy capabilities. Assisting Truman in the hull robotics program is **Sam Fladung**, robotics engineer. **ST**

contracts

Tugdock, Falmouth, England, has partnered to receive Seaflex brand buoyancy bags for its systems and allow use of its international network for product representation. Tugdock's system can lift vessels and other floating structures clear of the water. Unique Group.

WFS Technologies, Livingston, Scotland, has a new strategic oil and gas partnership to promote and deliver the full range of Seatooth products for asset integrity and flow assurance monitoring to existing and new clients in Nigeria. AeonX Ltd. (Nigeria).

Aquatec, Irvine, California, has chosen a representative for the distribution of its underwater instrumentation for oceanographic research, environmental and coastal applications in the Japanese market. SeaBreath.

Pulse Structural Monitoring, London, England, an Acteon company, signed its first major contract for the provision of digital structural monitoring and insight services and equipment on an offshore wind farm. The contract provides for the design, fabrication, yard installation and commissioning of its monitoring instrumentation on three wind turbine foundations to be installed offshore Taiwan. Ørsted.

Planet Ocean, Bracebridge, England, has teamed up to provide data buoy solutions worldwide. The partnership will see Pharos Marine responsible for manufacturing the buoy hulls and mooring designs, while Planet Ocean will provide the sensors, loggers and telemetry solutions, along with data visualization systems via delivery partner OceanWise. Pharos Marine.

SeaQuest Marine Project Management, Hong, Kong, China, will supervise construction of three zero-emission NB Ro-Ro vessels at China Merchants Group's Nanjing Jinling Shipyard. Finnlines Plc.

Olis Robotics, Seattle, Washington, has a new agreement for the sales, distribution and support of its machine-learning ROV manipulator controllers. The Olis Master Controller applies to the ROV inspection, repair and maintenance (IRM) global market. Aleron Subsea.

Fugro, Leidschendam, Netherlands, has been awarded another hydrographic survey contract as part of the MAREANO seabed mapping program to collect high-resolution, high-density multibeam echosounder and sub-bottom data. The fieldwork will run from June to late October this year. Norwegian Hydrographic Service.

COMSAT Inc., Herndon, Virginia, has added the ABS-3A satellite to the COMSAT Southbury, Connecticut, teleport services, bolstering its reach throughout the Americas, Europe, North Africa and the Middle East to provide more resilient and robust connectivity solutions. ABS.

Berge Bulk, Hamilton, Bermuda, is revamping its fleetwide procurement processes via a long-term partnership with a maritime e-marketplace, seeking to "bring the market to the ship." Moscord.

DNV GL, Oslo, Norway, has signed a memorandum of understanding to work together to contribute to the marine industry's ongoing digital transformation. This will unlock the benefits of new digital technologies and methods and include sharing data collaboratively, and the creation of frameworks and standards to develop new products and services and enhance existing ones. Alpha Ori Technologies.

General Atomics Electromagnetic Systems (GA-EMS), San Diego, California, has been contracted for an 18-module Gulftronic Electrostatic Separator system to be used by an international refinery to produce International Maritime Organization Regulation 2020-compliant clarified slurry oil for use in the shipping industry. Undisclosed. **ST**

meetings

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

JULY

July 1-2—Scottish Fishing Conference 2020: From Innovation to Action, St. Andrews, Scotland. paul@mindfullywired.org or tinyurl.com/thlwnkx.

July 14—Restoring Estuarine and Coastal Habitats in the North East Atlantic, London, England. roger.proudfoot@environment-agency.gov.uk.

July 15-16—American Society of Naval Engineers Multi-Agency Craft Conference, Baltimore, Maryland. 703-836-6727, asnehq@navalengineers.org or www.navalengineers.org/Symposia/MACC-2020.

AUGUST

August 4-6—Technology, Systems & Ships, Arlington, Virginia. www.navalengineers.org/Symposia/Technology-Systems-and-Ships-2020.

August 11-14—Oceans 2020 Singapore, Singapore. info@oceans2020singapore.org or https://singapore20.oceansconference.org.

August 18-21—International Partnering Forum on Offshore Wind, Providence, Rhode Island. www.offshorewindus.org/2020ipf.

August 26-28—INAMARINE (Indonesia International Shipbuilding, Offshore, Marine Equipment, Machinery and Services Exhibition), Jakarta, Indonesia. +62 21 5435 8118, santi@gem-indonesia.com or www.gem-indonesia.net.

SEPTEMBER

September 7-9—Oceanology International Middle East, Abu Dhabi, United Arab Emirates. +971 2 491 7615, firas.abultaif@reedexpo.ae or www.oceanologyinternationalmiddleeast.com/en-gb.html.

September 9-11—Noia Oil & Gas Conference & Exhibition, St. John's, Canada. kmorrissey@noia.ca or www.noia.ca.

September 14-17—Fleet Maintenance and Modernization Symposium, Virginia Beach, Virginia. www.navalengineers.org/Symposia/Fleet-Maintenance-and-Modernization-Symposium-2020.

September 21-25—NMEA/RTCM Conference & Expo, Orlando, Florida. 410-975-9425 or www.nmea.org.

September 23-24—Oil Spill India, Mumbai, India. +91-8287955348, kamna@itenmedia.in or www.oilspillindia.org.

September 23-24—Remote Hydrography Conference, Southampton, England. tinyurl.com/y7v95eeg.

September 28-October 2—SNAME Maritime Convention, Houston, Texas. 703-997-6701 or www.sname.org.

September 29-30—Teledyne Marine Canadian Users Conference, Halifax, Canada. www.teledynemarine.com/events/Teledyne-Marine-Users-Conference-Canada.

OCTOBER

October 5-8—AUVSI XPONENTIAL, Dallas, Texas. meetings@auvsi.org or www.xponential.org.

October 6-8—World Conference on Floating Solutions, Rotterdam, Netherlands. admin@pavingthewaves.blue or www.pavingthewaves.org.

October 11-16—SEG, Houston, Texas. exhibits@seg.org or https://seg.org/AM/2020.

October 12-14—Climate Risk Summit, London, England. +44 (0)20 7576 8118, events@economist.com or https://events.economist.com/events-conferences/emea/climate-risk-summit-2020.

October 14-15—OilComm, Houston, Texas. www.oilcomm.com.

October 14-15—World Ocean Tech and Innovation Summit, Halifax, Canada. oceanspeakers@economist.com.

October 19-22—OCEANS 2020 Gulf Coast, Biloxi, Mississippi. www.oceansconference.org/gulf-coast-2020.

October 20-23—EURONAVAL, Paris Le Bourget, France. www.euronaval.fr.

NOVEMBER

November 2-4—MAST Asia, Tokyo, Japan. https://mastconfex.com/asia2020.

November 3-5—Marine Renewables Canada Conference, Halifax, Canada. amanda@marinerenewables.ca.

November 10-12—Marine Autonomy & Technology Showcase, Southampton, England. https://noc-events.co.uk/mats-showcase-2020.

November 16-20—BlueTech Week, San Diego, California. www.tmabluetech.org/bluetech-week.

DECEMBER

December 1-3—Oceanology International London, London, England. j.riegal@saltwater-stone.com or www.oceanologyinternational.com.

December 2-3—LNG Latin America & the Caribbean, Buenos Aires, Argentina. http://LNGlatinamerica.com.

December 8-10—UDT, Rotterdam, Netherlands. www.udt-global.com.

December 16-17—West Coast Defense Contracting Summit, San Diego, California. marketing@defenseleadershipforum.org.

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

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60th Anniversary of First Descent into Deepest Part of the Ocean—*Scott Hochenberg*

Scott Hochenberg is a corporate strategic communications contractor for the U.S. Office of Naval Research and is the editor of its internal newsletter, Snapshot. *Previously, he was a program analyst for the United States Agency for International Development in the Bureau for Legislative and Public Affairs. He has a master's degree from Bowling Green State University and a bachelor's degree from The Ohio State University.*

We are tied to the ocean. And when we go back to the sea, whether it is to sail or to watch—we are going back from whence we came. — John F. Kennedy

The year was 1960. Plunging into the deep, dark abyss of the Pacific Ocean's Mariana Trench, U.S. Navy Lt. Don Walsh and Swiss engineer Jacques Piccard heard a loud cracking sound in their vessel, the bathyscaphe Trieste, owned by the U.S. Office of Naval Research (ONR).

Already 30,000 ft. down, Walsh and Piccard faced the ultimate decision—risk their lives to become the first people to travel to the deepest part of the ocean, the Challenger Deep, or return to safety?

The crack had scarred one of Trieste's outer plexiglass panels. Walsh and Piccard (whose father designed Trieste) decided to push on. After all, if Trieste had suffered catastrophic damage, both men would inevitably be crushed by the ocean's pressure, so there was really no turning back.

After a nearly 5-hr. descent, the Trieste reached the Challenger Deep, approximately 36,000 ft. below sea level. They didn't see much when they hit bottom; a large cloud of particles from the seafloor engulfed the vessel. Because the journey had to be completed in a single day during daylight, they could only spend 20 min. at Challenger Deep before heading back to the surface.

Exactly 60 years later, on January 23, 2020, the National Museum of the U.S. Navy in Washington, D.C., celebrated the anniversary of Trieste's journey with a program featuring Walsh, the lone remaining pilot of the trip.

Walsh said January 23 "was a lucky day." Ambition, a sense of adventure and good fortune placed him on the path to historic destiny.

Growing up near the San Francisco Bay, Walsh was captivated by the ships entering and exiting the harbor. Inspired, he attended the U.S. Naval Academy and became a submariner.

Not long into his naval career, Walsh heard that the Navy recently acquired the Trieste and needed volunteer pilots to test it, but volunteers were scarce. Volunteer expeditionary missions were not seen as a pathway to career advancement.

Few people wanted to risk their lives sitting in a steel ball the size of a refrigerator while descending thousands of feet. Trieste had to be towed, then sunk to desired depth. To ascend, it simply dropped ballast and rose to the surface. "This was a balloon, plain and simple, except in the water," said Walsh, who retired from the Navy as a captain.

"I had nothing to lose. I was on the 'junior varsity' for the Navy. My class standing at the Naval Academy was not great. I was told, 'You're officially stupid.'"

Adm. Arleigh Burke, then chief of naval operations, told Walsh if he and Piccard were successful, the Navy would publicly celebrate the mission—but if they failed, it would remain silent.

Worried about the potential dangers of the Mariana Trench, a risk-averse commanding officer ordered Trieste's crew to abort the journey on launch day. But a chief petty officer decided on a delayed response to the commanding officer, after Trieste was 10,000 ft. down, knowing it would be too late to stop the trip.

Walsh knew the many potential dangers facing him and Piccard. They could be adrift at sea for days or locked inside the Trieste while it was being towed ashore. As a precaution, Walsh brought Hershey's chocolate bars for emergency rations. Being Swiss, Piccard brought Nestle chocolate.

The anniversary ceremony 60 years later concluded with the distribution of Hershey's bars to guests.

"ONR is underappreciated for this whole enterprise," Walsh said at the ceremony. "All credit is due to ONR—they were the ones that rolled the dice buying the Trieste from the Swiss."

Trieste's descent to the Challenger Deep was a remarkable achievement for the Navy, ONR and oceanography as a scientific discipline. Trieste was designed to go deeper than any previous craft. The historic feat of reaching the deepest part of the ocean ushered in a "golden age" of manned underwater exploration in the 1960s and 1970s, when submersibles helped make extraordinary discoveries in biology, geology, chemistry, oceanography and other fields. Science books were updated as researchers confirmed the ocean floor was not a flat landscape, but rather a diverse set of geological features. The trip to Challenger Deep also laid the foundation for future deep-sea vessels such as the Navy's submersible Alvin.

The Trieste's success is a tribute to the value, and risks, of basic research. "The only limit that humans can face is the limit of the ocean itself," said Capt. Matthew Farr, executive officer of ONR Global, at the 60th anniversary ceremony. "Cuts in basic research deplete our knowledge base. ONR is a guardian looking beyond the immediate needs of science toward the future."

To learn more about Trieste, visit https://tinyurl.com/tq9jo3g. **ST**

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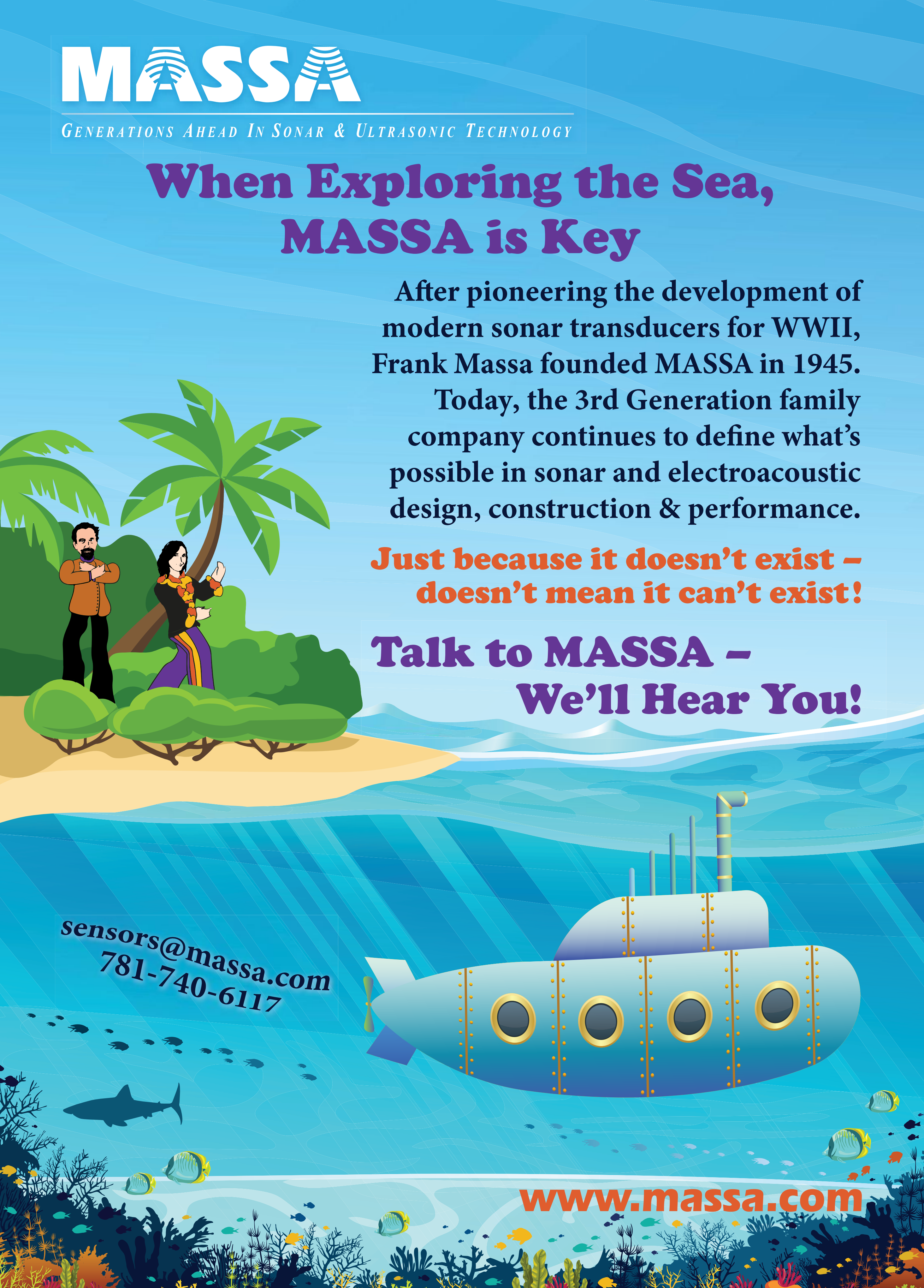
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