Hydro
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Seabed 2030: The Final Sprint

Machine Learning as a Tool
Detecting Boulders in a
Multibeam Point Cloud

Exploring New Horizons for Ocean Observation

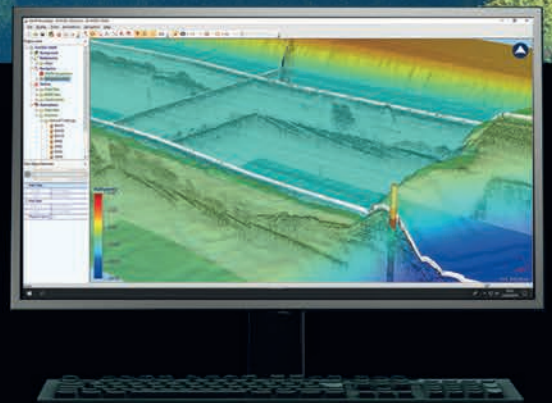### Exploiting Unmanned Surface Vehicles to Collect Ocean Data

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Side scan sonar mosaic and interferometric bathymetry, Plymouth, UK.

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P. 11 Multispectral Multibeam Echosounder Backscatter Data

Backscatter options in MBES have grown from monospectral using a single frequency to multispectral MBES backscatter data, but what are the benefits of this? This article describes the results obtained during a Bachelor's research project at the Maritime Institute Willem Barentsz in partnership with Deep BV – Hydrography & Geophysics, both in the Netherlands.
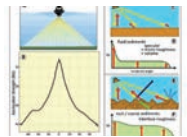
P. 14 Data Quality Factors for Marine UXO Surveys

The detection of unexploded ordnance (UXO) in the sea is a demanding task. UXO survey data are acquired using a set of different sensors in different configurations and can span large areas. To make sure that the resulting highly complex dataset is fit for purpose, a well-defined workflow is crucial. Researchers of the BASTA project are therefore developing quantitative data quality factors to indicate how survey data should be acquired for the detection of a specified reference object.

P. 19 Machine Learning as a Tool

Machine learning is currently experiencing a surge of interest. Of course, what first come to mind are self-driving cars, face recognition and internet algorithms. However, while these are great examples of machine learning in action, artificial intelligence can also be applied for hydrographic purposes. A Bachelor's research project was carried out at QPS B.V. into the detection of boulders in multibeam point cloud data using machine learning.
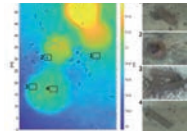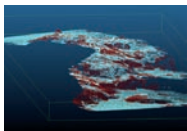
P. 27 Exploring New Horizons for Ocean Observation

As the informed readership of Hydro International knows, the oceans sustain the planet. And, while there are many drivers of the changes to the Earth's climate that now pose an existential threat to humanity, the health of the oceans is arguably the most important factor for ensuring a healthy climate. There is mounting evidence that the world's oceans are under increasing stress and that we must find a sustainable way to protect them. An essential element of doing so is making data-driven decisions as to what steps to take to sustain the 70% of the planet covered by water.

P. 32 The Challenges of Surveying the Faroe Islands

Remotely situated in the northern Atlantic Ocean, roughly equidistant from Scotland, Iceland and Norway, the Faroe Islands form a rugged and rocky archipelago. The cool and cloudy weather, with strong winds and heavy rain possible all year round, means that this is a challenging survey environment. In its search for the best method to capture this stunning environment, the mapping authority has turned to UAVs. This article tells the story of mapping and surveying a truly breathtaking spot on Earth.

Cover Story

Clouds trace out the islands of the Caribbean Sea in this photo taken by an astronaut from the International Space Station. Beyond the solar arrays and the docked Progress resupply vehicle, the multitoned waters of the Caribbean and the Atlantic Ocean frame the Bahamas, Cuba, Jamaica and southern Florida. (Image courtesy: ISS Crew Earth Observations Facility and the Earth Science and Remote Sensing Unit, Johnson Space Center; NASA)
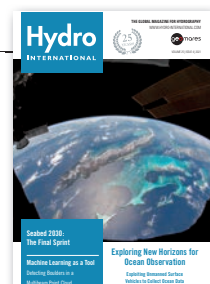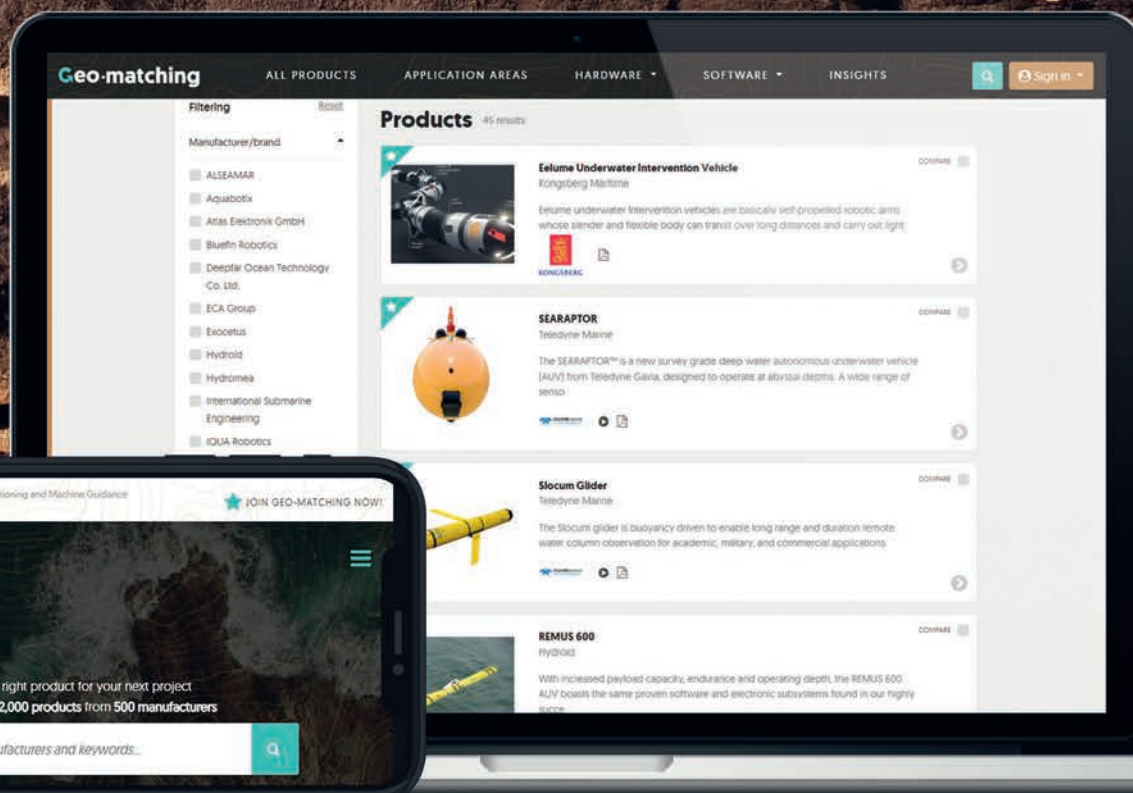
Data Is Here to Stay

Competencies and training seem to take up most of my time lately. As you may be aware, besides being a technical editor and author for this magazine, I spend a lot of time teaching professionals on Skilltrade's Cat B course and 'youngsters' on the NHL Stenden / MIWB Cat A course in the Netherlands. I am also involved in the IFHS Hydrographic Professional Accreditation Scheme (HPAS) as one of the two Hydrographic Society Benelux members on the assessment panel.

Anyway, competencies. As both courses are up for re-accreditation next year, I am spending a lot of time going through the S5 (A and B) standards of competence. As always, I am amazed at how many technical competencies we expect from our hydrographic surveyors. While some in the industry proclaim that surveying is becoming easier, this cannot be seen in the standards of competence.

For example, I recently had a discussion with members of the hydrographic industry about the Cat A course. At some point, the conversation turned to data science, and the point was made that modern surveyors cannot function without learning more about data science. However, looking at S5, roughly 10% is about data processing and charting, and the other 90% about data acquisition and validation.

If we look at the IHO standards of competence for cartographers (S8), there is not much more about data science here either. The focus of S8 is mainly on creating navigation products, which may be digital or paper, but there is little on the data science aspect. However, techniques such as machine learning and AI are the up-and-coming methods in my opinion and, combined with GIS algorithms and elaborate databases, will probably feed the need for information in the future. Hydrographic data will be a small aspect of these future information systems.

The industry recognizes this, hence the request to spend more time on 'data' in the courses, which brings me to a second set of competencies: soft skills. The IHO does not spend many words on soft skills in their standards of competence, and neither does the new IFHS HPAS. However, if you have ever been offshore, you know that technical competencies are not all that matters. You can have the best and brightest onboard, but if they are not team players or cannot handle the stress of a sensor not cooperating, they can be a burden rather than an asset.

What, then, does this have to do with data science? Well, I find that professional students with some years of experience in the field never discuss the importance of data science. Rather, they always want more than the standards require. With the 'youngsters' fresh out of secondary school, however, it is the other way around, especially after they return from their traineeship. The Cat A students are required to carry out a 100-day traineeship at a hydrographic organization, and many of them spend most of this on a ship or construction project. Most are not fanatical about databases, programming and GIS before they go on their traineeship, but when they come back after their 100 days, matters get worse and their interest is only in online surveying.

However, they are not alone. A quick look at the HPAS standard shows that online surveying is also one of the main professional competencies, and we still distinguish hydrographic surveyors from cartographers, even though the divide between them is fading. I therefore think that we have a contradiction that we as a survey community need to recognize and probably address, and I am not alone: a Canadian initiative was recently started on hydrospatial as an extension of hydrography.

To make this work, everybody in hydrography first needs to not only recognize this fact, but also accept it and start to work with it. My plea to the community is therefore to pay more attention to spatial data, in word and deed. This means making sure that surveyors not only spend time online but also become aware of how the data is used. One place to start is with the youngsters during their traineeship. Getting them hooked on data science is a soft skill that we, as their mentors, need to exercise, so that they want to become proficient in this important technical skill.

The good news is that the message is getting through to a few students each year. Of the 20 to 30 Cat A students each year, 2 or 3 are really interested in data science and do their Bachelor's thesis on a related subject. In fact, there is an article in this magazine on the research of one of these students on AI. And, to compensate, an article by another student on MBES backscatter data acquisition. After all, you will never hear me say that online data acquisition is not important to our business, there is just more to it than that.

Huibert-Jan Lekkerkerk, technical editor

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▲ *Huibert-Jan Lekkerkerk.*

XOCEAN Secures Financial Boost to Accelerate Growth

Irish-based international ocean data company, XOCEAN, has received an 8 million investment to accelerate its growth and deliver its ambitions. Valued in excess of €100 million, carbon-neutral XOCEAN is driving down emissions in the offshore industry and is delivering on its sustainability goal of displacing the emission of 1 million tons of carbon. The multi-million-euro investment led by VentureWave Capital, who launched their Impact Ireland fund in June 2020, perfectly aligns with XOCEAN's mission. The fund works with high-growth companies to invest and build global 'technology for good' that will deliver real societal benefits.

Having tripled its revenue growth for two consecutive years, XOCEAN is no longer regarded as just an industry disrupter but as a serious contender within the market. The new funding is set to accelerate their growth, seeing XOCEAN continue to scale up operations. With ambitious plans to increase headcount from over 100 staff to 350 in the next 24 months, while tripling the size of their fleet to over 60 uncrewed surface vessels (USVs), the business will displace the emission of 1 million tons of carbon within the next 5 years alone, while simultaneously improving safety by avoiding over 5 million seafarer exposure hours.

▲ *XOCEAN uses marine robotic technology to collect ocean data sustainably.*

Seabed 2030 Project Enters Partnership with EOMAP

Shallow waters represent the most crucial aquatic zones on Earth and are difficult to survey. Therefore, The Nippon Foundation-GEBCO Seabed 2030 Project has reached a cooperation agreement with EOMAP, a leading provider of shallow water bathymetry from satellite data. The common target is a freely available Ocean Map.

The Nippon Foundation-GEBCO Seabed 2030 Project and EOMAP have signed a Memorandum of Understanding in support of the global initiative to produce the complete map of the ocean floor. The two parties will work together to further the understanding of ocean bathymetry. The effort complements the goals of the United Nations Decade of Ocean Science for Sustainable Development.

Seabed 2030 is a collaborative project between The Nippon Foundation and GEBCO to inspire the complete mapping of the world's ocean by 2030, and to compile all bathymetric data into the freely available GEBCO Ocean Map. GEBCO is a joint project of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC), and is the only organization with a mandate to map the entire ocean floor.

▲ *Satellite-derived bathymetry imagery, Tonga. (Courtesy: EOMAP)*

French Minister for the Sea Visits the IHO

▲ Minister Annick Girardin learned about the benefits of the digital data transition and autonomous surface navigation. (Image courtesy: IHO Secretariat)

Mrs Annick Girardin, French Minister for the Sea, visited the offices of the IHO during an official visit to the Principality of Monaco on Friday 10 September. The Minister was accompanied by H.E. Mr Laurent Stéfanini, ambassador of France to Monaco as well as other government representatives.

They were welcomed by IHO directors Abri Kampfer and Luigi Sinapi. In addition to the IHO programme of activities, organization and strategic plan, the Minister was interested in the benefits brought by the digital transition with the IHO Universal Data Model S-100.

Yves Guillam, assistant to the directors, also presented subjects of particular interest, including autonomous surface navigation, IHO relations with the European Commission, the IHO as a technical and advisory organization, and issues related to knowledge. He highlighted the need to develop countries' abilities to address important challenges, as capacity and technical means are not the same everywhere in the world.

Royal Navy Starts Mapping Uncharted Waters More Efficiently
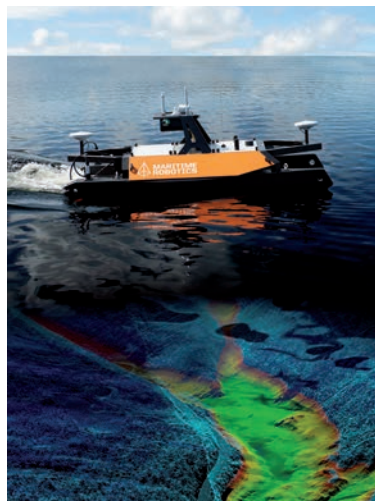
▲ The Otter USV can be fitted with additional hydrographic and bathymetric sensors for any project.

The Royal Navy has recently started trials with the Otter USV and is impressed by the results. Uncrewed and autonomous vessels have begun proving themselves to be superior in many operations at sea. Although water covers about 71% of the Earth's surface, only a few percent of the global ocean have been sufficiently mapped to provide detailed information about the seabed.

However, a new era of cost-effective ocean survey operations is emerging. The shift is made possible by uncrewed and autonomous vessels that can cover far larger areas in a fraction of the time compared to traditional methods. "Uncrewed surface vessels are optimized for specific operations and applications. A single USV can, in most operations, replace larger crewed vessels. They are also far easier to transport and operate," says Kristoffer Fortun, chief sales officer at the Norway-based systems provider Maritime Robotics.

Exploring Seamounts in the Deep North Atlantic Ocean
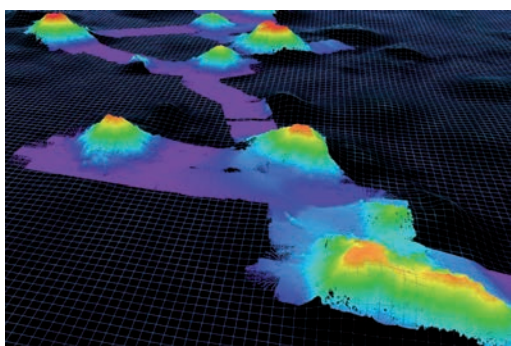
▲ New bathymetry data of the New England Seamounts. (Credit: NOAA Ocean Exploration)

Between 20 June and 29 July 2021, NOAA Ocean Exploration, in partnership with USGS, the U.S. Fish and Wildlife Service (USFWS) and other organizations and universities, conducted a telepresence-enabled ocean exploration to collect baseline information about unknown and poorly understood deepwater areas off the eastern U.S. coast and high seas.

This expedition, called '2021 North Atlantic Stepping Stones: New England and Corner Rise Seamounts', focused on the ecosystems of the Northeast Canyons and Seamounts Marine National Monument and other unexplored areas in the New England and Corner Rise Seamounts chain, which extend from near the Mid-Atlantic Ridge to the eastern continental margin of the United States. USGS scientists Jason Chaytor and Kira Mizell served as the geology science co-leads for the expedition. From land, they worked with multidisciplinary ship- and shore-based scientists to develop the remotely operated vehicle (ROV) underwater machines that can be used to explore ocean depths while being operated by someone at the water surface. They developed dive plans, led and narrated 'Live Dive' events for a worldwide audience, and coordinated science outcomes. Between 2 and 28 July, the team mapped about 40 seamounts, 20 of which had little to no pre-existing data, since many of them had yet to be explored until now. Also, because many of these areas had never been seen before, the team had to conduct 14 'map and dives', meaning they conducted preliminary mapping to determine the optimal location for ROV dives.

Several short video interviews with USGS scientists help to capture the science that guided the expedition's activities and highlight their roles and the collaboration between USGS and NOAA as they explore the largely unmapped seafloor.
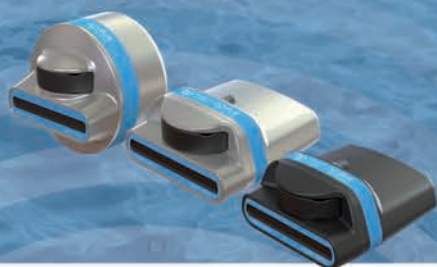
Making Oceanographic Data Accessible to a Wider Audience

▲ *The Nortek ADCP's small form and low profile enabled Alseamar to fit it to the SeaExplorer with little impact on the glider's hydrodynamic properties. (Photo: Alseamar)*

Alseamar, a producer of glider UUVs, has been able to produce highly accurate data plots of current profiles from large swathes of the water column. A combination of tailor-made algorithms, underwater gliders and a high-performing Acoustic Doppler Current Profiler (ADCP) from Nortek has helped to break new ground for the oceanographic community, making high-quality data more accessible for a multitude of stakeholders.

ADCPs have revolutionized our ability to record ocean current movements. However, they can only measure what they can 'see', and that is largely determined by what they are attached to, which may be a surface buoy or a frame on the seabed.

This is perfect for many uses, but if you are interested in the movements of currents across a large swathe of ocean, then moving ADCPs on frames from location to location is a time-consuming business and does not provide a complete picture of the currents in the whole area. Mounting an ADCP on a moving surface vessel is a good option for many, but some users are put off by the work and cost involved in hiring and crewing a vessel.

Rapid advances in underwater glider technology are however providing an exciting new alternative. Slimline battery-powered gliders are capable of cruising through the oceans for months at a time, carrying a multitude of instruments and measuring many facets of the underwater world close up.

IFHS Introduces Hydrographic Professional Accreditation Scheme

The International Federation of Hydrographic Societies (IFHS) has developed the Hydrographic Professional Accreditation Scheme (HPAS) to provide international recognition for hydrographic professionals in demonstrating their competency, educational background and career development.

The HPAS initiative has reached an important milestone by completing its pilot phase, which was initiated in March. This phase, run by a panel of international experts, aimed to benchmark the HPAS procedures and processes. Over 40 hydrographic professionals volunteered to be the first professionals assessed under the HPAS framework. Of these, 18 were selected for the pilot phase from across the countries and regions represented by the IFHS Member Societies: Belgium, France and the francophone countries, Germany, The Netherlands, South Africa and the United Kingdom. The HPAS Panel of Experts awarded HPAS accreditation to 15 of these candidates.

Divers Map Condition of One of England's Most Important 17th-century Shipwrecks

▲ The archaeologists and licensed diving team heading back to shore after working on the wreck site. (Photo: Mark Beattie-Edwards)

A team of divers has been investigating the remains of one of England's most important 17th-century shipwrecks – the London, which accidentally blew up in 1665 in the Thames Estuary near Southend Pier in Essex. The diving project (16–20 August 2021) is funded by Historic England, working with MSDS Marine and Licensee Steve Ellis from the London Shipwreck Trust. It aims to accurately map the layout of the wreck, which has been lying in two parts on the seabed.

The London was one of only three completed wooden Second Rate 'Large Ships' that were built between 1600 and 1642, and is the only one whose wreck still survives. Built in Chatham in Kent, it played a significant role in British history, serving in both the Cromwellian and Restoration navies. It formed part of the fleet that brought Charles II back from the Netherlands in 1660 to restore him to the throne, to end the anarchy that followed the death of Oliver Cromwell in 1658 and his son Richard Cromwell taking power. It blew up when gunpowder on board caught fire as the ship was on its way to collect supplies after being mobilized to take part in the Second Anglo-Dutch War of 1665–1667.

Bedrock Launches Ocean Exploration and Survey Platform

▲ The company's fully electric AUVs allow Bedrock to improve the speed and efficiency of seafloor acquisition and mapping.

Bedrock, a vertically-integrated seafloor data platform and service, has announced the launch of its full-service offering: autonomous ocean surveys powered by the company's proprietary, 100% electric autonomous underwater vehicle (AUV) and Mosaic, a universal cloud-based survey data platform for managing, accessing and sharing any marine survey data from any ongoing or historical survey, which is now open for beta sign-ups.

Currently, the turnaround time of ocean floor maps is up to 12 months per survey to provide customers with usable commercial seafloor data. Bedrock's two modern technologically-enabled services work together to accelerate commercial wind development cycles, providing survey status and data immediately – up to ten times faster than the current solution, the company claims.

With extreme weather incidents becoming increasingly common due to climate change, countries worldwide are looking for solutions to mitigate their devastating effects. Initiatives range from imposing carbon taxes and emissions limits to ambitious green energy transition plans, such as President Biden's 2,000 wind turbine goal by 2030 and multilateral agreements such as the Paris climate accords.

Towards Zero Emission Hydrogen Fuel Cell Technology for USVs

SEA-KIT International, a leading designer and builder of USVs, has won funding to install an innovative PCB-based hydrogen fuel cell, engineered by project partner Bramble Energy, on its 12m uncrewed surface vessel (USV) Maxlimer and to demonstrate zero emission maritime operations.

SEA-KIT secured the grant through the recent Clean Maritime Demonstration Competition (CMDC) – Strand 2. The project, funded by the UK's Department for Transport (DfT) working with InnovateUK, will showcase a successful diesel to hydrogen conversion of SEA-KIT's proven USV design and demonstrate a route to fulfilling the UK's Clean Maritime Plan Strategy commitment of reducing greenhouse gas emissions from shipping by at least 50% by 2050.

"Our USVs have a dual diesel-electric hybrid drive, with propulsion coming from an electric motor powered by battery banks that are charged by in situ diesel generators," said Ben Simpson, SEA-KIT CEO. "This project will replace one of the diesel generators with new hydrogen fuel cell technology from Bramble Energy and demonstrate an offshore operation with zero carbon emissions."
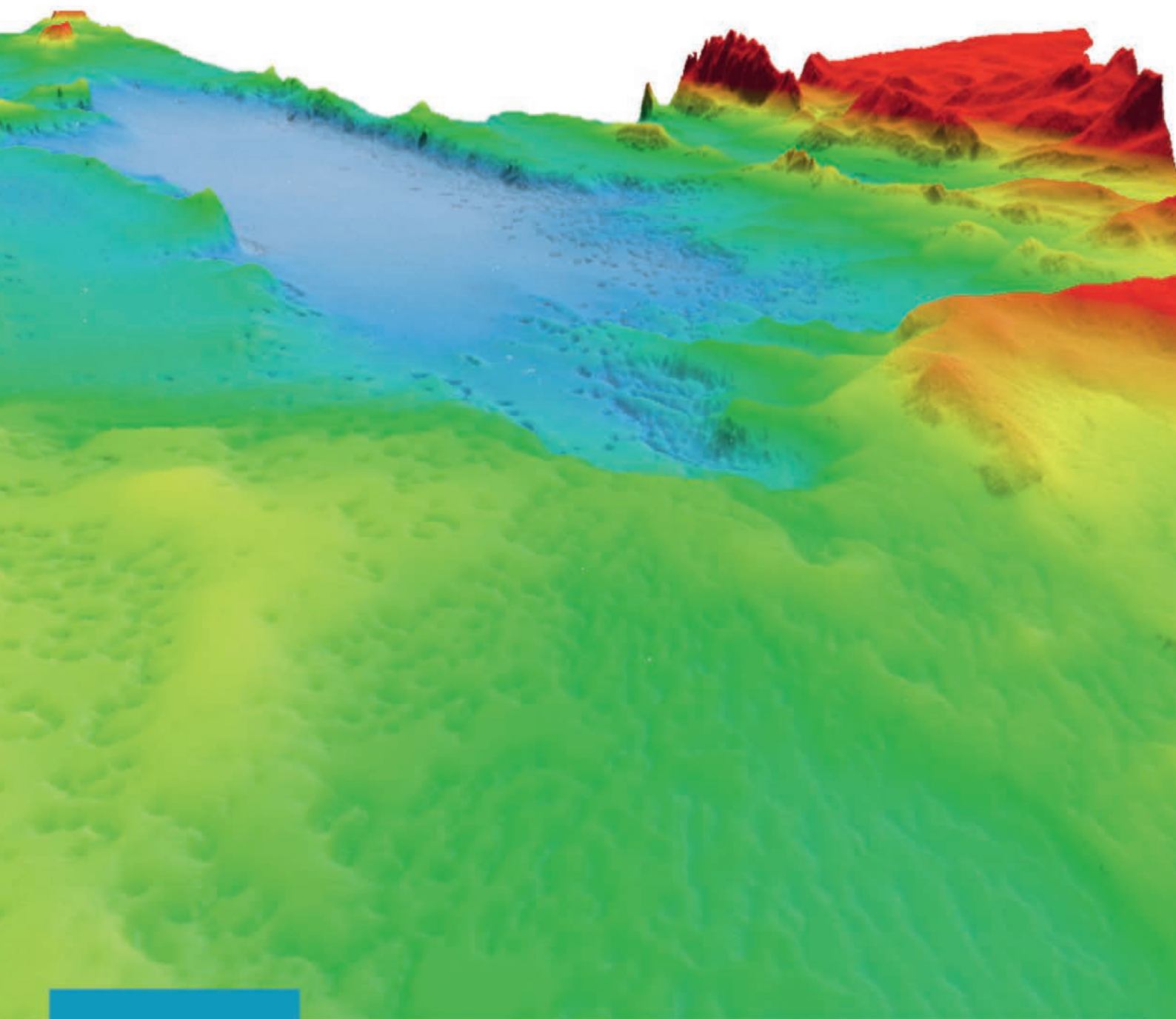

▲ SEA-KIT USV Maxlimer on recent capability demonstrations.

Multispectral Backscatter Data to Improve Seafloor Characterization

Multispectral Multibeam Echosounder Backscatter Data

The Multibeam Echosounder (MBES) is used for various purposes, and MBES systems have become the standard instrument for bathymetric determination. However, new developments mean that MBES systems are no longer limited to depth readings alone. One innovation is the possibility to record the backscatter data of the acoustic beams. MBES backscatter recordings can be used for seafloor classification and object detection. Backscatter options in MBES have grown from monospectral using a single frequency to multispectral MBES backscatter data, but what are the benefits of this? This article describes the results obtained during a Bachelor's research project at the Maritime Institute Willem Barentsz in partnership with Deep BV – Hydrography & Geophysics, both in the Netherlands.

MBES BACKSCATTER IMAGING

Backscatter data provides information about the composition of the seafloor. Data obtained using this collection method can be used to investigate properties of the seafloor, such as hardness, sediment characteristics and even sediment grain size. MBES bathymetry and backscatter data are collected at the same time.

The delay between emission of the pulse and receipt of the returned signal provides a depth measurement (bathymetry), while the strength of the returned signal indicates the reflectivity of the seafloor (backscatter). Multispectral MBES imaging uses two or more frequencies from the same MBES. To do this, the MBES uses a different frequency per consecutive ping. This ability to collect data with multiple frequencies in one pass may allow better distinction between sediment types.

At the same water depth and under the same conditions, higher frequencies and thus shorter wavelengths result in a higher resolution. A higher resolution means that more details can be seen and thus a distinction can be made between small particles, including sediment particles. A longer wavelength (low frequency) has a lower resolution and will, theoretically, distinguish only coarse sediment. High frequencies, on the other hand, are better able to distinguish fine and coarse sediment simultaneously.

MULTISPECTRAL OPERATION

While collecting multispectral data, the frequency changes per ping, and the user can select which frequencies to use in advance. In one single pass over an area, the MBES can therefore record bathymetry and backscatter data using two to five different frequencies. Requirements depend on the project specifications or seabed conditions. If it is known in advance how each frequency responds to a sediment type, this knowledge can be used during specification.

PRACTICAL RESEARCH

The aim of the research was to find out whether the use of multispectral MBES has a definitive
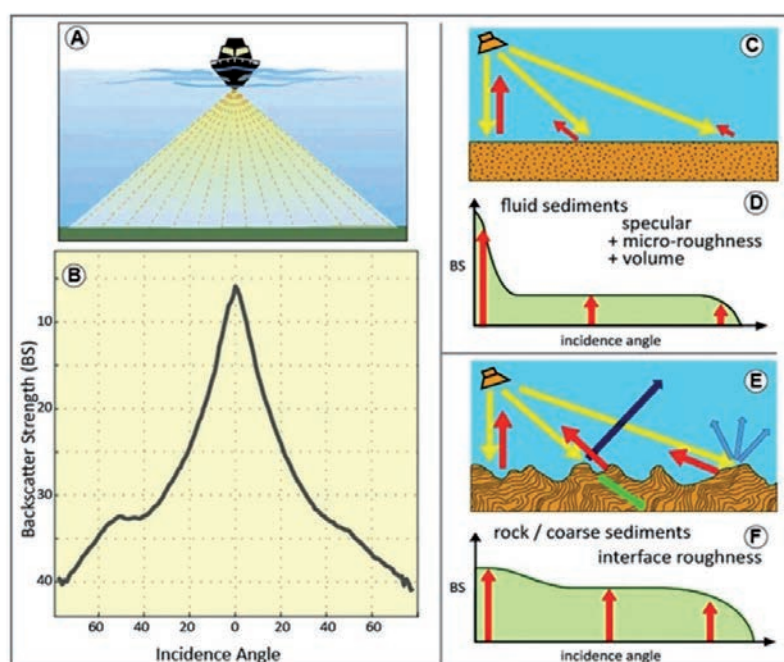
▲ *Figure 1: Backscatter working principle (Lamarche & Lurton, 2018).*

advantage over the use of monospectral MBES for soft sediments. Sand, mud, silt, peat and 'flora and fauna' type bottoms within easy reach of Amsterdam, the Netherlands, were researched.

To verify whether multispectral data improves seafloor characterization, several methods were used to collect the data. To check whether the correct seafloor was identified and to analyse differences, ground truthing measurements were executed using a Van Veen grab sampler. Various checks were carried out to determine the soil type. These steps included the grain density, moisture and stickiness of the sediment. The research was conducted in the Vinkeveense Plassen, the IJ (Amsterdam) and IJmuiden.

Backscatter data was acquired using both MBES and side-scan sonar (SSS) using the following settings:
MBES (R2Sonic 2024):
• Monospectral MBES setting: 400kHz
• Multispectral MBES settings: 200kHz, 400kHz, 700kHz

SSS (Edgetech 4125):
• SSS: 455kHz

Once the multispectral backscatter data had been collected, it had to be separated into different frequencies before it could be used. Software packages such as QPS FMGT can be used to divide the multispectral data into a series of monospectral datasets. Processing and

Figure 3: Peat versus mud mosaics.

data analysis were executed in QPS Qimera, QPS Fledermaus Geocoder Toolbox (FMGT) and SonarWiz, and FMGT Angle Range Analysis (ARA) was performed based on the Jackson model for automatic bottom classification. ARA

recorded in one straight line. Due to the sharp turn of the ship, there is a poorer positioning of the MBES system. In addition, the data density is lower at the outer bend and higher at the inner bend, compared to the mean data density. This
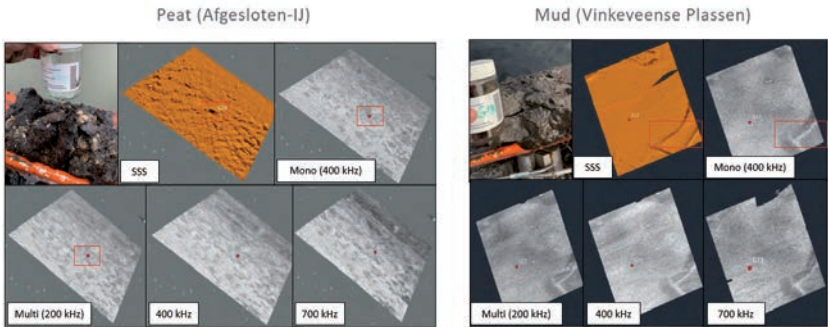
To verify whether multispectral data improves seafloor characterization, several methods were used to collect the data

can be used to determine a sediment characterization based on information such as frequency and grain size using a standardized backscatter response curve.

BACKSCATTER RESULTS
An early result was that data density is something to consider when performing multispectral backscatter analysis. As shown in Figure 2, the data in the curve is different from the data

is because the same number of beams must be distributed over a larger surface (outer bend) or a smaller surface (inner bend). Furthermore, data is more 'stretched' in multispectral datasets due to the lower data density per cell, while data in monospectral datasets has a higher data density (and thus a higher hit count). The lower along-track resolution stems from the ping rate having to be shared by the different frequencies. In other words, at three different frequencies, the ping rate will be at least three times lower than for monospectral MBES.

As expected, the higher the density of the material, such as bivalves or sand, the harder the reflection. With lower density materials, such as mud and silt, the returned signal is much weaker because it partly remains in the soft (smaller grain-sized) material. However, the 700kHz setting quickly produced an oversaturated image that needed to be compensated for, because this signal was scattered in the water column. This created an unreliable picture for every sediment type.

The use of multiple frequencies did not show different sediment layers; hence, it did not seem to add anything when compared to the higher resolution, monospectral mosaics. One disadvantage is that there is currently no method available to display or process multispectral data as actual multispectral data. No further analysis

Soil type	Monospectral data	Multispectral data			Grab samples
	400kHz	200kHz	400kHz	700kHz	Observed
Mud	Silty sand	Silty sand	Silty sand	Gravel	Very fine, organic mud without any sand. No aquatic plants.
Peat	Coarse sand/ gravelly sand	Gravelly coarse sand	Coarse sand/ gravelly sand	Gravel	Firm peat, with some shells on top with sand.

Table 1: FMGT ARA characterization versus determined sediment type.
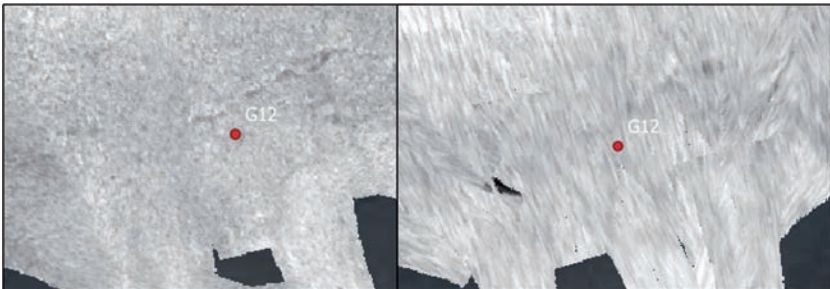
Figure 2: Monospectral 400kHz (left) and multispectral 400kHz dataset (right).

was done on integrating the three derived monospectral sets (from the original multispectral) into a conclusive multispectral image. By examining small variations at the same locations, it may be possible to derive more information. However, current software support for such a method has not been found.

ARA RESULTS

As stated, the various (derived) monospectral backscatter sets were processed using FMGT with the ARA tool. During the fieldwork, different backscatter areas were measured where there was a variation in either depth or salinity. When the grab samples and backscatter ARA results were compared, the backscatter data could not confirm the same material, as can be done with ground truthing. This was however true for all backscatter sets and not just for the multispectral data. Overall, all frequencies were observed to be in error.

For all locations, the ARA classification is incorrect and/or gives similar results across all frequencies, while the sediments differ strongly within the area, as is partially shown in the figures. Therefore, the ARA analysis is considered not fit for purpose for these types of smaller areas but could work for bigger areas where ARA is calibrated with grab samples and the bottom remains constant.

CONCLUSIONS

The original hypothesis that multispectral backscatter data will provide better possibilities when it comes to the automated classification of soft sediments is contradicted by this research. It was expected that the largest differences in backscatter values would be found between the coarsest and the finest bottom sediments. The research reveals that differences can be observed between strongly deviating sediments, but only visually. The SSS and backscatter (monospectral) and multispectral show almost identical mosaics. Software to analyse multispectral data could have benefited this research, but is currently lacking.

Comparing the advantages and disadvantages, it can be concluded that multispectral MBES backscatter data currently does not improve seafloor characterization, looking at the monospectral datasets and soft sediment types.

Furthermore, 700kHz is not suitable due to excessive saturation of the image. Due to data quality issues, it is better to sail in monospectral mode or use an SSS than to use multispectral mode. ◀

Demi van de Vondervoort has just been awarded her Cat A-accredited Bachelor of Science degree in Ocean Technology from the Maritime Institute Willem Barentsz. She carried out her thesis research at DEEP BV and currently works for Van Oord as a hydrographic surveyor.

Huibert-Jan Lekkerkerk is senior lecturer on the Cat A Ocean Technology and the Skilltrade Cat B course at the Maritime Institute Willem Barentsz and is a hydrographic consultant on a variety of projects.

Researchers Involve Stakeholders to Define Unexploded Ordnance Survey Requirements

Data Quality Factors for Marine UXO Surveys

The detection of unexploded ordnance (UXO) in the sea is a demanding task. UXO survey data are acquired using a set of different sensors in different configurations and can span large areas. To make sure that the resulting highly complex dataset is fit for purpose, a well-defined workflow is crucial. Researchers of the BASTA project are therefore developing quantitative data quality factors to indicate how survey data should be acquired for the detection of a specified reference object.
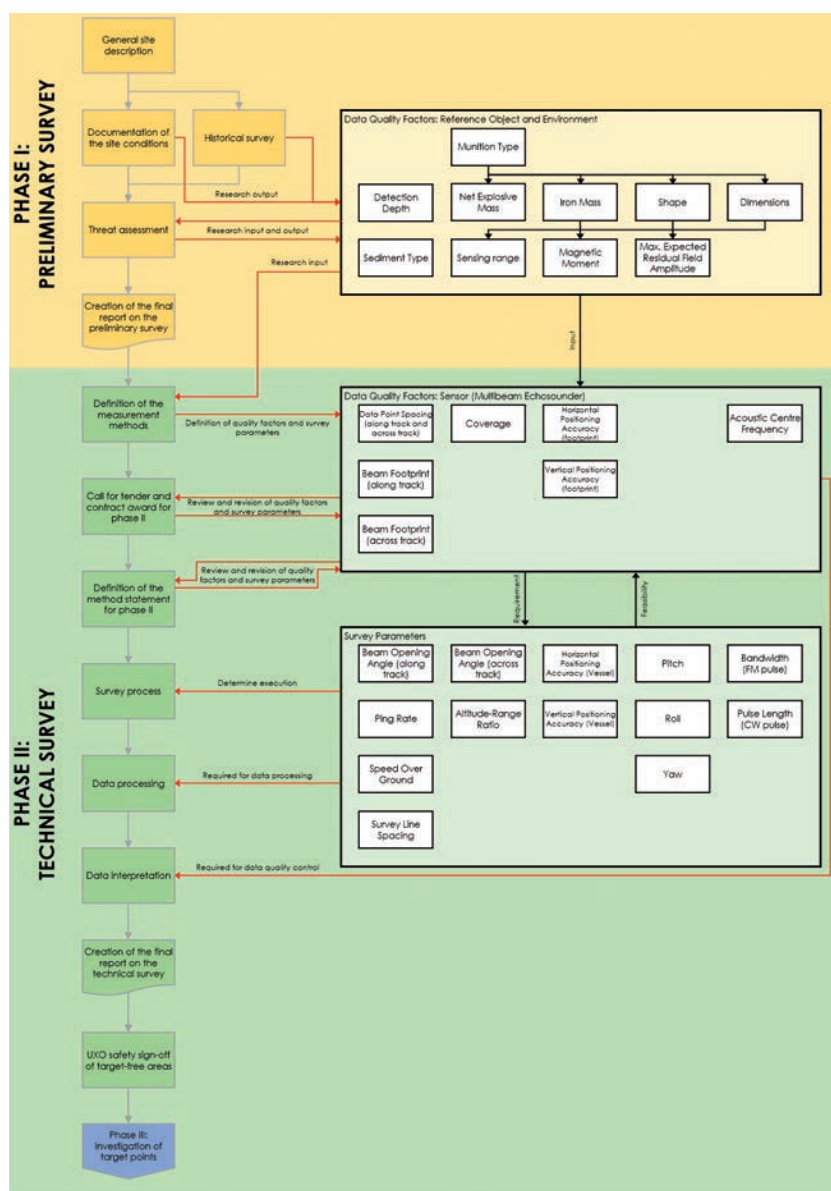
▲ *Figure 1: BASTA UXO survey quality factors flow chart – multibeam echosounder.*

Munition or unexploded ordnance (UXO) in the sea poses a threat during offshore work such as pipeline or platform construction, as well as to the marine environment. If UXO detection and clearance activities are executed erroneously, managed poorly or even omitted, UXO can threaten the lives of construction workers, the construction schedule, the marine fauna, and the public image of the parties involved. In response to these challenges, Frey (2020) developed the Quality Guideline for Offshore Explosive Ordnance Disposal (EOD). The guideline addresses the four phases of EOD: (I) a desk-based preliminary survey of historical data, (II) a technical survey in the field, (III) an investigation of suspected UXO sites, and (IV) UXO clearance and disposal. Other guidelines on marine UXO surveys or on hydroacoustic mapping that are relevant to munition surveys have been published by OWA (2020), IHO (2020), NOAA (2019) and IOGP (2009). All of these documents largely consist of a qualitative description of the workflows for marine geophysical surveys, and to some extent for UXO campaigns. GEOMAR and north.io are now working on a method to quantitatively describe a

Reference Object and Environment				
Parameter	**Variable**	**Unit**	**Example**	**Definition**
Munition Type		[-]	155mm shell BL Mark VII (nation: GB)	The specific type of munition.
Shape		[-]	spheroidal	The geometric shape that best describes the reference object.
Dimensions ($d_1 < d_2 < d_3$)	d_i	[m]	0.15, 0.15, 0.60	The measures of the three dimensions of the munition type in ascending order (e.g. width, height, length).
Detection Depth	z	[m]	1	The depth below the seafloor down to which the reference object shall be searched for.
Sediment Type		[-]	sand, clay	All sediment types that are present within the survey area.
Iron Mass	M	[kg]	34,9	The weight of the amount of iron in the reference object.
Net Explosive Mass	NEM	[kg]	10,5	The weight of explosive material in the reference object.
Magnetic Moment	m	[Am²]	0.4 - 2	The magnetic moment that is estimated/expected for the reference object.
Max. Expected Residual Field Amplitude at 2,3,4,5,6,8,10 m	B	[nT]	41, 12, 5, 2.5, 2, 1, 0.5	The maximum residual field amplitude for the reference object which either was modelled under specified assumptions (modelled shape, orientation, remanent magnetization) or was measured in a field test.
Sensing Range	I	[m]	$I = I'(S/N \geq 3)$	The maximum distance between sensor and reference object at which the signal can still be detected, where S=B and noise N is determined from a field test.

Multibeam Echosounder					
	Quality Factor	**Variable**	**Unit**	**BASTA value/equation for detection**	**Definition**
Detection Parameter	Data Point Spacing (along-track and across-track)	x	[m]	$x \leq d_1/3$	The data point spacing of soundings in across track and along track direction. Threshold relative to Reference Object parameter d1=shortest dimension.
	Beam Footprint (along-track)	F_{al}	[m]	$F_{al} \leq d_1$	The extent of the footprint of the acoustic beam at the seafloor in along track direction. Threshold relative to Reference Object parameter d1=shortest dimension.
	Beam Footprint (across-track)	F_{ac}	[m]	$F_{ac} \leq d_1$	The extent of the footprint of the acoustic beam at the seafloor in across track direction. Threshold relative to Reference Object parameter d1=shortest dimension.
	Coverage	n	[-]	$n \geq 100\%$	The area covered by the measurements relative to the total survey area.
Accuracy Parameter	Horizontal Positioning Accuracy (footprint)	δ_h	[m]	if d1 > 0.5 m then $\delta h < 1$ (according to THU of IHO-S44 Exclusive Order) if $d_1 < 0.5$ m then $\delta h \leq 2*d_1$	The horizontal positioning accuracy of the footprint, accounting for errors of GNSS, offsets, motion and sound velocity. Threshold relative to Reference Object parameter d1=shortest dimension.
	Vertical Position Accuracy (footprint)	δ_v	[m]	if d1 > 0.5 m then $\delta v < \sqrt{(a^2+(b*zw)^2}$ (according to TVU of IHO-S44 Exclusive Order) if d1 < 0.5 m then $\delta v \leq d1/2$	The vertical positioning accuracy of the footprint, accounting for errors of GNSS, offsets, motion and sound velocity (with a=0.15 m, b=0.0075 according to IHO-44S Exclusive Order and zw=water depth). Threshold relative to Reference Object parameter d1=shortest dimension.
Signal Parameter	Acoustic Centre Frequency	f	[kHz]	$f > 300$	The acoustic centre frequency of the signal that is emitted by the sensor.

▲ *Table 1: Example reference object and multibeam sensor quality factors with the threshold values that are partly related to the reference object.*

survey by defining data quality factors. Using such quality factors in the workflow can improve data handling, as more time can be spent on data analysis and interpretation. As multi-sensor datasets become larger and more complex, a well-defined workflow and consistent threshold criteria for data quality will increase project transparency and trust in the results. In addition, clear definitions will improve the communication between all partners involved in the UXO projects, from the project manager to surveyors and data analysts.

METHODOLOGY

The BASTA researchers apply the following steps to define the data quality factors:

1. A literature review of all existing guidelines. Based on this information, an initial table of data quality factors for the reference object and for different relevant sensors (multibeam echosounder, side-scan sonar, sub-bottom profiler, magnetics) could be developed.

2. This initial table of data quality factors was transformed into a questionnaire and sent to 125 experts in the field of marine UXO

surveys. An updated table was then created based on the responses.

3. Digital stakeholder workshops were held to discuss the data quality factors and threshold values that define whether the data are fit for purpose to detect a specified reference object. Two workshops each for magnetic and hydroacoustic sensors were organized, and 29 experts participated in the discussions. The workshops led to the definitive agreement on 57% of the discussed data quality factors, while the remainder is still under discussion. Again, the table of data quality factors was updated.

4. In a final event, that took place during the Kiel Munitions Clearance Week 2021 (www.munitionclearanceweek.org), the remaining, not yet agreed upon, quality factors were discussed furhter. The evaluation is in progress.

DATA QUALITY FACTORS – PRELIMINARY RESULTS

We distinguish between the reference object data quality factors and sensor data quality

factors. In the process described above, these were identified by answering the following questions:

- Reference object: Which reference object data quality factors need to be provided after the preliminary survey and before phase II (the technical survey)?
- Sensors: Which sensor data quality factors are important to determine whether the survey data are fit for the purpose of detecting a specified reference object?

Once these questions had been answered, a standardized UXO survey workflow that is based on transparent data quality factors could be developed. A preliminary version of the workflow for multibeam surveys is illustrated in Figure 1.

The flow chart shows that the historical survey and the documentation of the site conditions are the principal inputs to the definition of a reference object. This is the smallest object that needs to be detectable in the survey data and is commonly defined following a threat or risk assessment. All reference object quality factors

are therefore an output of the preliminary survey (Phase I). Note that not all reference object quality factors are relevant for multibeam systems, as the reference object needs to be defined (and thus its quality factors determined) before the survey planning begins.

The reference object and its properties are the inputs to the technical survey (Phase II), in which measurement methods are defined and subsequently reviewed and revisited by the client and the contractor during the tendering and the definition of the method statement for the survey. In addition, a number of survey parameters define how the survey process itself is executed. The method statement must therefore balance data quality requirements and the survey feasibility requirements. Knowledge of all data quality factors is relevant for the subsequent data processing and data interpretation processes.

Similar workflows were prepared for all sensors that are commonly used in UXO detection surveys, and are available on the BASTA project website (www.basta-munition.eu/events). These include the multibeam echosounder, side-scan sonar, sub-bottom profiler and magnetometer (Frey, 2020). More recent techniques such as electromagnetics, synthetic aperture sonar and possibly chemical sensors will be defined in the future.

For the sensor data quality factors, threshold values need to be defined for the sensor. These act as an objective and theoretical requirement for the detection of the specified reference object. Since reference object data quality factors form the input to the technical survey, they act as controlling variables for many threshold values of sensor data quality factors. Table 1 shows the preliminary data quality factors for an example reference object as well
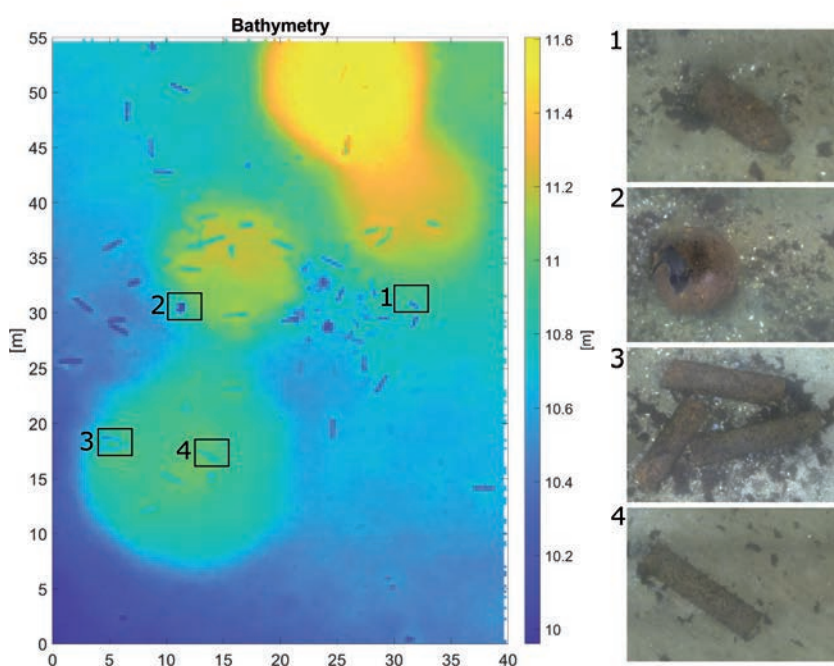
▲ Figure 2: Multibeam data and photographs of munitions objects in the German dump site Kolberger Heide.

▲ Figure 3: A multibeam dataset demonstrating the application of data quality factors. The quality factors are scaled to the thresholds defined in Table 1, where the quality factor exactly meets the threshold for a value of 1.

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as the resulting threshold values for multibeam data quality factors, which need to be defined before a survey can commence. Detailed tables of data quality factors for all sensors considered so far can be found on the BASTA project website.

PRACTICAL APPLICATION

Figure 2 shows an example of a multibeam dataset of the German dump site Kolberger Heide and of a subsequent AUV-based camera survey. Several different UXO objects can be identified in the multibeam data, but how do we know whether all the UXO objects on the seafloor have been detected, or whether some smaller objects have been missed? This question is particularly difficult to answer for datasets that span large areas with varying water depth and seabed conditions. However, the definition of quality factors can help answering this question. Figure 3 illustrates the data quality factors computed on the same real multibeam dataset for two differently sized UXO objects. The quality factors are computed relative to the threshold values defined in Table 1. The dataset

seems to be generally sufficient for the detection of an aerial bomb (left column: GP 550 lb M64). On the other hand, the computed footprints indicate that the smaller object (right column: 155mm shell BL Mark VII) would probably be missed in large parts of the survey area (please note that this working example is meant to illustrate the idea). Similar threshold values can be calculated for the other sensors that are listed in the workflows. Once the data quality factors have been finalized, the calculation presented in this paper will be made available as features via AmuCad.org and TrueOcean.io.

CONCLUSION

A well-defined workflow and commonly agreed data quality factors for geophysical survey data can improve the project transparency for UXO surveys, as illustrated in the example. For complex datasets in particular, which include numerous sensors that need to be understood by multiple parties involved in a project, such guidance can facilitate communication between stakeholders. Since acceptance among industry experts is crucial for the future application of the

data quality factors presented in this article, their definition is supported by stakeholders. ◀

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Detecting Boulders in a Multibeam Point Cloud

Machine Learning as a Tool

Machine learning is currently experiencing a surge of interest. Of course, what first come to mind are self-driving cars, face recognition and internet algorithms. However, while these are great examples of machine learning in action, artificial intelligence can also be applied for hydrographic purposes. A Bachelor's research project was carried out at QPS B.V. into the detection of boulders in multibeam point cloud data using machine learning.

The objective of the research was to develop a working tool that uses machine learning to detect boulders or rocks in multibeam point cloud data. The approach differs from the tools that processors are currently familiar with, such as filter tools that the user can employ to locate boulders. While there is nothing wrong with the current tools, machine learning aims to automate the entire process, mimicking the steps that a human processor would take to detect objects.

REQUIREMENTS OF MACHINE LEARNING

Machine learning requires input data, and lots of it. In fact, the more data, the better. An integral part of any machine learning is the training of the model using real world sample data. Rather than creating fixed algorithms, machine learning adapts the criteria of what is a boulder or rock while learning. The training data needs to be checked and prepared ahead of time by a professional. In this case, a good example of this preparation might be to start with available multibeam point cloud data containing certain objects of interest. These objects would be selected within the data, adding a class to each data point (boulder or

seafloor). The more thoroughly the data is prepared, the better the algorithm functions. Due to the nature of machine learning, the aim of this algorithm is to mimic the input data, thus indirectly learning from processors who prepare the input data. This means that the aim is to achieve the level of accuracy that a human processor produces.

When properly prepared, the machine learning algorithm can produce locations of objects almost as accurately as professional processors are able to do. With more input data and classification of that data by different professionals, the algorithm gains more insight

into the output that it is expected to achieve. Following this cycle, the algorithm can potentially perform better than a single human processor, as it combines the knowledge of various processors and situations. On the other hand, the algorithm will never be able to cope with a situation that is completely unlike one that it has encountered before.

CREATING THE TOOL

The process of creating the tool was undertaken in a simple Jupyter environment, as the tool was developed in Python 3.8. Creating a machine learning algorithm from scratch is time-consuming, so for this research a library, or a
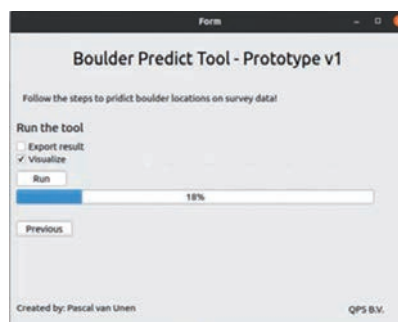
▲ Figure 1: Simple prediction interface for the tool.
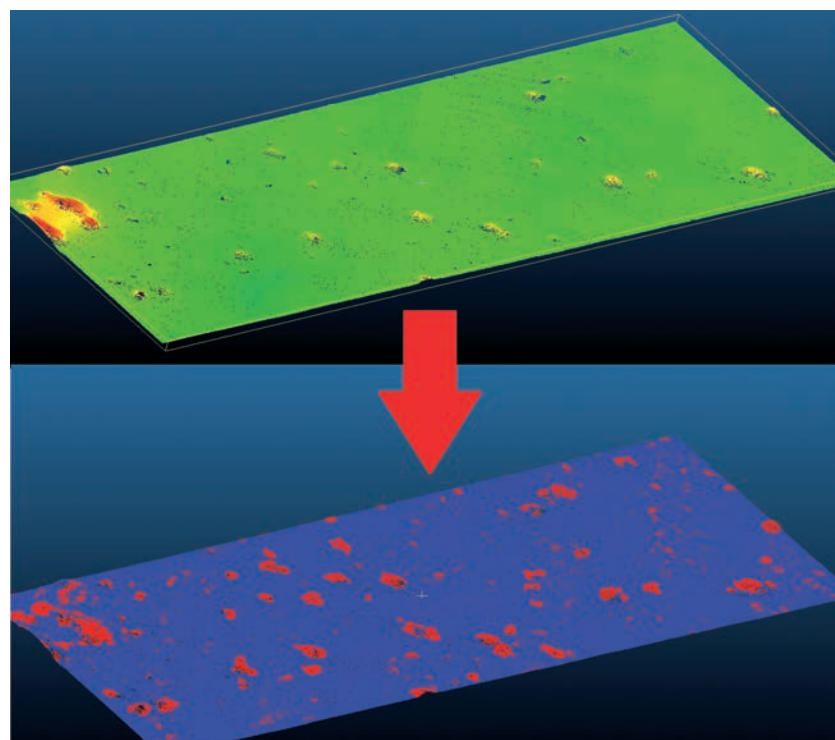
▲ Figure 2: Point cloud data and classification into boulders (red) and seafloor (blue).
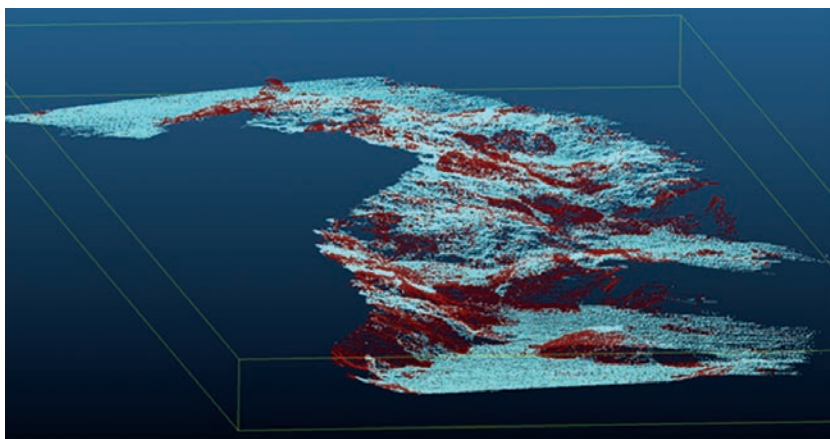
▲ *Figure 3: Untrained boulder shapes detected incorrectly.*

preprogrammed set of usable code, was used. In this case, the library Open3D was used. This allowed the research to follow the basic principles that have been precoded by professional machine learning experts.

The result is a working prototype that is able to import data, run the detection algorithm, and export its predictions on object locations. Training of the algorithm was done using a different set of objects for which boulders needed to be predicted (these pretrained models can be saved for later use). The training process is very computer resource heavy, and this research was executed on a Nvidia GTX 1070, which proved to be a bottleneck. The training process depends heavily on the hardware and the amount of input data, and in this case it took at least 1 hour for 10 million points. With the current setup, the predicted boulders were found while classifying 300,000 data points per 10 minutes. To compare, a modern multibeam produces between 10,000 and 40,000 points per second.

QUALITATIVE RESULTS
The algorithm was trained to produce a list of boulders from the supplied and prepared data. Qualitative results indicated that the algorithm was differentiating between the boulders according to the preprocessed data used to train it.

This conclusion is based on the processing of a small area by several processors, trying to reach the ground truth as much as possible. The actual analysis was therefore based on an assumed ground truth: the accuracy of human processors. It therefore represents the ability of the algorithm to match the accuracy of manually processed data and picked boulder locations.

Several issues remained after visual analysis of the results, mainly concerning the shape of the detected boulders. The algorithm did not completely fill in the boulder locations with the classification 'boulder' and had issues with boulders that it was not familiar with, as expected. This led to the conclusion that more training and more or better data would be required.

Another conclusion related to the size of the found objects. As part of the algorithm, the software smartly scales the boulders to new situations. As a result, the software started to find tiny boulders that, based on their size, should not be classified as such, but as pebbles. A future adaptation to the algorithm could allow for a traditional bandwidth filter that discards objects below a certain threshold.

QUANTITATIVE RESULTS
To verify the quantitative results of the tool, a comparison was made between the results of the tool and those of ten different data processors. For this, seven MIWB students and three QPS data processors were asked to classify boulders in the same dataset using the QPS Qimera Geopicking tool. This resulted in a series of objects in which differences could be seen between manual processors. No further analysis was done on why different processors picked different sets of boulders, but the commonly picked boulders were used as ground truth for the algorithm validation. The resulting list of manually picked boulders was then compared with the output of the tool to gauge the accuracy of the tool.

A statistical analysis of the comparison yielded an overall reliability value of 55%, which means that the results of the tool had a 55% similarity to the manually processed dataset. This is built up from three metrics: accuracy, precision and

recall. Accuracy indicates the percentage of correct predictions, while precision indicates how many of the positive predictions were actually correct. Recall indicates how many of the actual positive values were also predicted as positive. The three parameters each have a weight in the final reliability (Wa, Wr and Wp). As can be seen in the table, accuracy is comparatively higher than precision and recall, the reason being a class imbalance between seafloor (many) and boulder points (few), thus misrepresenting the total reliability.

This means that the algorithm is not yet ready to be trusted. The accuracy consists of both 'false positives', boulders detected by the algorithm but not by the human operator, and 'false negatives', boulders detected by the human operator but not by the algorithm. The number of false positives, or locations where the algorithm thinks a boulder is present where in reality it is not, and false negatives, where the algorithm missed out an existing boulder, represents the error of the algorithm, at first glance already too great to be trustworthy as of now.

Although the algorithm in its current state is far from correct, it might still be of help to the surveyor as a tool that can roughly detect objects. It also became clear that future standards for input 'training' data preparation must be set, which would further increase the reliability of the algorithm. Of interest, but not further studied, is the question why different processors indicate sometimes very different locations as boulders. Using this as further input would allow the algorithm to take these situations into account as well.

MACHINE LEARNING IN HYDROGRAPHY
Although the results of this research are not as reliable as was hoped, this tool in specific, and machine learning in general, can be of great help once made more reliable. Even the rough prototype created during this research could help

Comparison Calculations					
TP	33590	pts		Accuracy	94.16 %
FP	60962	pts		Recall	65.90 %
TN	1229456	pts		Precision	35.53 %
FN	17381	pts			
Wa	0.10				
Wr	0.45			Reliability	55.06 %
Wp	0.45				

▲ *Figure 4: Statistical analysis of the results (TP = true positive, FP = false positive, TN = true negative, FN = false negative).*

the processor to save time by detecting the obvious boulders and smaller, harder to notice objects. Ideally, results will be obtained at just the press of a button, resulting in less manpower required in the processing department, less time to process and, more importantly, more reliable results. Perhaps even more important is that it could also lead to more consistent results across processing datasets as the algorithm provides the same output every time.

The second use for this kind of algorithm is the live detection of boulders. In the case of automated cars, it is possible to display objects that have been detected live to the autonomous system. This can also be achieved for surveying vessels. As the vessel moves and the surveying systems are running, machine learning algorithms can show dangerous or interesting locations to the crew. This could increase safety and awareness of the surroundings. However, the processing time needs to be reduced, as more data is currently accumulated than can be processed in the same time.

Object detection algorithms already exist, and work by trying to figure out a common property of a certain object. Machine learning could add flexibility, human-like processes and applicability. Machine learning cannot only detect objects, but can also predict locations based on its previous experience, in the same way that a processor finds these locations. It can also use any data property to its advantage, as it can use shape, size and other properties that objects share. This forms a reliable algorithm which can, more than existing filters, present the client with a complete picture. A machine learning algorithm can be trained to detect anything that is deemed important. The training cannot however be done in the field yet, and will therefore require specific adaptations to the software package.

CONCLUSION

Machine learning seems to have a lot of potential, as it aims to further automate the process of object detection and even show it live as feedback. Applying it to survey routines may yield great improvements in data processing, as well as having other advantages. Before getting to that stage, however, more research is required. The currently presented research forms a small step in this direction. ◀
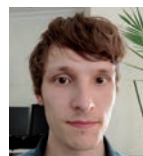
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Phoenix 5: A Versatile, Stable Survey ASV

Aquatic Drones, based in the Netherlands, recently introduced the Phoenix 5 Autonomous Surface Vessel (ASV). The unit, with a length of five metres, provides a stable platform for a range of survey and inspection operations. It can be deployed for bathymetric surveys, sub-bottom profiling, inspection of civil engineering structures, safety and security surveillance, water quality monitoring and other applications. Phoenix 5 is designed for operations on inland waterways, in ports and nearshore.

Maarten Ruyssenaers, founder and CEO of Aquatic Drones, explains the history of the Phoenix: "I worked on marine robotics at the RDM Campus in the Port of Rotterdam, where industry, SMEs, research institutes and government bodies cooperate on innovation projects. I could see great opportunities for autonomous vessels so I set the company up in 2016 to develop these as commercial products. We worked with partners such as the Dutch Ministry of Infrastructure and Water Management, the Port of Rotterdam, Deltares and Boskalis to analyse their requirements and test the pre-production vessels. We learned a lot over a period of five years, surveying ports and large rivers in the Netherlands and supporting dredging operations. And now we are expanding our field of operations towards the sea."

PHOENIX 5 ASV
Although earlier models were catamarans, Aquatic Drones has now adopted an aluminium monohull design. This proved to provide the highest stability at survey speeds of 4 to 5 knots and makes it easier to integrate the propulsion and control systems and survey sensors. The length overall is 5m, the beam 2m and the draught 0.55m, and it can be launched by a single operator. The vessel is powered by lithium-ion batteries and the propulsion system has two ducted propellers driven by electric motors with a combined power of 8 or 20kW, depending on the model. Up to 2kW, at several DC and AC voltages, is available for payloads. Solar panels on deck recharge the batteries during deployment.

PHOENIX 5 MODELS:
- E: standard model with an endurance of up to 20 hours
- EP: higher capacity battery model for operation at higher speeds
- HP: diesel generator hybrid model for surveys lasting several days

AUTONOMY AND SITUATIONAL AWARENESS
Autonomous operation is based on a sophisticated situational awareness system which receives input from radar, Lidar, forward looking sonar, video cameras and an AIS receiver. Positioning relies on GNSS-RTK, providing an accuracy of approximately two centimetres, and an inertial measurement unit. The communications links to the operator station include Marine Broadband Radio, 4G and WiFi, all securely encrypted. The remote operator, onshore or on a nearby vessel, has displays for hydrographic data and for vessel status and control. Aquatic Drones also provide a cloud solution to give personnel at the operator's base immediate access to the data gathered, anywhere in the world.

SAFETY AND RELIABILITY
The vessel has an automatic fire suppression system, bilge pumps and back-up power for essential systems. Redundancy of essential control, propulsion and steering systems ensures safety in the case of component failure. The remote operator can always monitor the health of the systems, intervene and even control the vessel manually. If the communications links are interrupted, the Phoenix will loiter at its current position or return to a predefined home point.
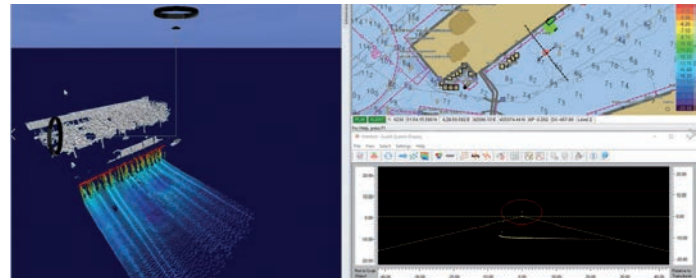

▲ The Phoenix 5 is an Autonomous Survey Vessel for surveying ports, large rivers and nearshore.

▲ *Control Centre showing live camera feed, system health monitoring, water map with line planning, screen alerts and more.*

▲ *Survey screen using Teledyne's PDS – data acquisition software.*

SURVEY OPERATIONS

One of the key applications of the Phoenix is undertaking bathymetric surveys using a multibeam echosounder. The high stability of the vessel and optimized sensor position minimize the impact of waves and the wake of other vessels on the survey operation. Ruyssenaers notes: "During a survey of the IJssel river in the Netherlands, we were still able to obtain valid measurements at gale force 8, which was much higher than we had expected."

The operator defines the survey area, after which the Phoenix control system determines the optimum survey grid and route to the area. During operations, the grid is automatically refined, depending on the water depth and bottom profile. If data acquisition is disturbed by external influences, the vessel automatically goes back and rescans the area.

The ASV can be fitted with a range of sensors, tailored to the application. Examples include single or multibeam sounders, side-scan sonar, turbidity and nutrient sensors, and so on. The onboard winch is used to lower sensors, for example to obtain a vertical temperature and conductivity profile for sounder and sonar calibration.

In addition to bathymetric and environmental surveys, Phoenix ASVs can be used for surveillance operations when fitted with low light and thermal imaging cameras. Lidar can scan above-water structures such as quay walls, to supplement side-scan sonar data.

CASE STUDY: RIVER IJSSEL

(BY JEROEN VAN REENEN, BSC HYDROGRAPHY, HYDROGRAPHX)
The advantages of ASV surveys were demonstrated when the riverbed

morphology of the River IJssel in the Netherlands was repeatedly measured following the construction of temporary breakwaters with a new design. The stable platform provided by the Phoenix ensured excellent repeatability of the measurements. Furthermore, the low noise and vibration of the platform with electric rather than diesel propulsion greatly improved the performance of the multibeam echosounder. The raw data required little post-processing, only the correction of a few outliers associated with steep slopes. This was automated and a clean dataset was available within an hour of the completion of each survey. Weather conditions varied significantly between surveys; however, the stability of the Phoenix meant that this did not affect the results, see graph below.

PARTNERS AND MARKETS

Ruyssenaers concludes: "Undertaking surveys and other operations was essential when developing the product, and we will continue to offer those services in the Netherlands and surrounding countries. We will serve other international markets by supplying Phoenix ASVs to researchers, survey companies, dredging companies, marine contractors and ship leasing operators. Public authorities such as port

operators, river authorities and the police and coastguard are also a key market. Aquatic Drones has a network of agents and dealers in Europe, Asia, North Africa, the Middle East and South America who can support their customers with maintenance and advice. We are currently preparing several international projects.

Our company focuses on listening to customers, building up good relationships and optimizing our products for their applications – we work closely together with them. We are currently also supporting the Netherlands Ministry of Infrastructure and Water Management, which is developing regulations for uncrewed vessels.

Customers are concerned about their environmental impact. A Phoenix has a fully electric propulsion system and operates with zero emissions at the point of use when running on batteries. That avoids the CO_2 emissions of a larger, crewed survey vessel with diesel engines. In the future, we would also like to replace the diesel generator on our HP model with a hydrogen fuel cell."

For more information, please go to www.aquaticdrones.eu ◄
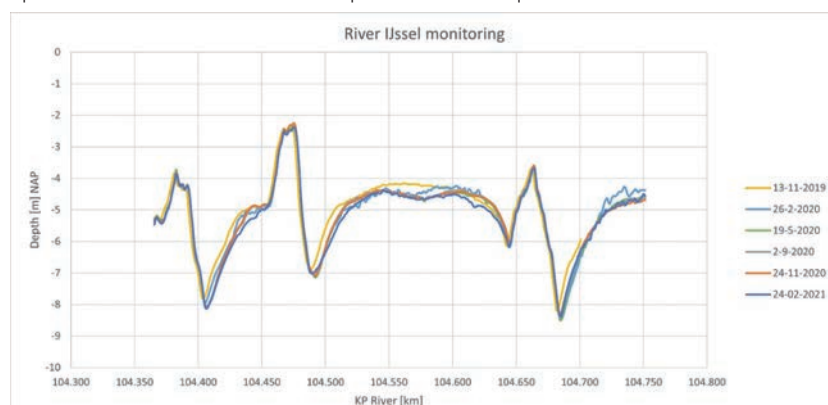
▲ *Periodic surveys of the IJssel riverbed morphology.*

Teledyne Optech and Teledyne CARIS Merge to Form Teledyne Geospatial

Welcome to the New Geospatial

Teledyne Optech and Teledyne CARIS have united to form Teledyne Geospatial in response to the evolving marketplace needs. Under the Teledyne Imaging group, the harmony between the two business units is clear and the two teams were brought together to offer added value to customers through solutions across hardware, software and workflows.

Andy Hoggarth, vice president, Sales and Marketing at Teledyne Geospatial, has been with Teledyne CARIS for almost 20 years. Beginning his geospatial career as a multibeam sonar processor using CARIS software at sea, he transitioned from working on the technical side of the business and is considered an expert in ocean mapping. Hoggarth's role at the helm of sales and marketing is to understand trends and customer needs as they evolve and ensure that these are translated from idea to product. Teledyne CARIS has carved out a solid niche within the marine sector only to become broader via this new collaboration and, for Hoggarth, the synergies were clear: fusing the two companies reflects the natural evolution of the geospatial industry.

WHAT OPPORTUNITIES DOES THIS NEW COMBINED BUSINESS PROVIDE FOR YOUR CUSTOMERS?

"What's new about this model is our ability to streamline and centralize our service provision, offering more to both new and existing customers across the spectrum of needs. Having a single contact point across all requirements means efficiency gains in terms of workflow, saving time and ensuring that our customers get what they need earlier.

"The needs of professionals are evolving to no longer focus solely on land or sea, and both geospatial and maritime enterprises are increasingly expected to offer a more comprehensive suite of services. Bringing Optech and CARIS together enables leveraging the world-leading expertise of both companies, ensuring that customers can take full advantage of their ability to provide targeted solutions for land, air and sea. We see new opportunities to connect existing hydrographic customers to the broader geospatial sector. We can offer solutions to a new spectrum of clients on the topographic mapping side through the latest geospatial workflow software, including tools like AI."

Andy explains that he is most excited about the new possibilities that the merger provides for Teledyne customers to gain a competitive advantage in terms of what they can deliver. For example, processes will be further streamlined: customers can log their high-density, high-resolution Lidar
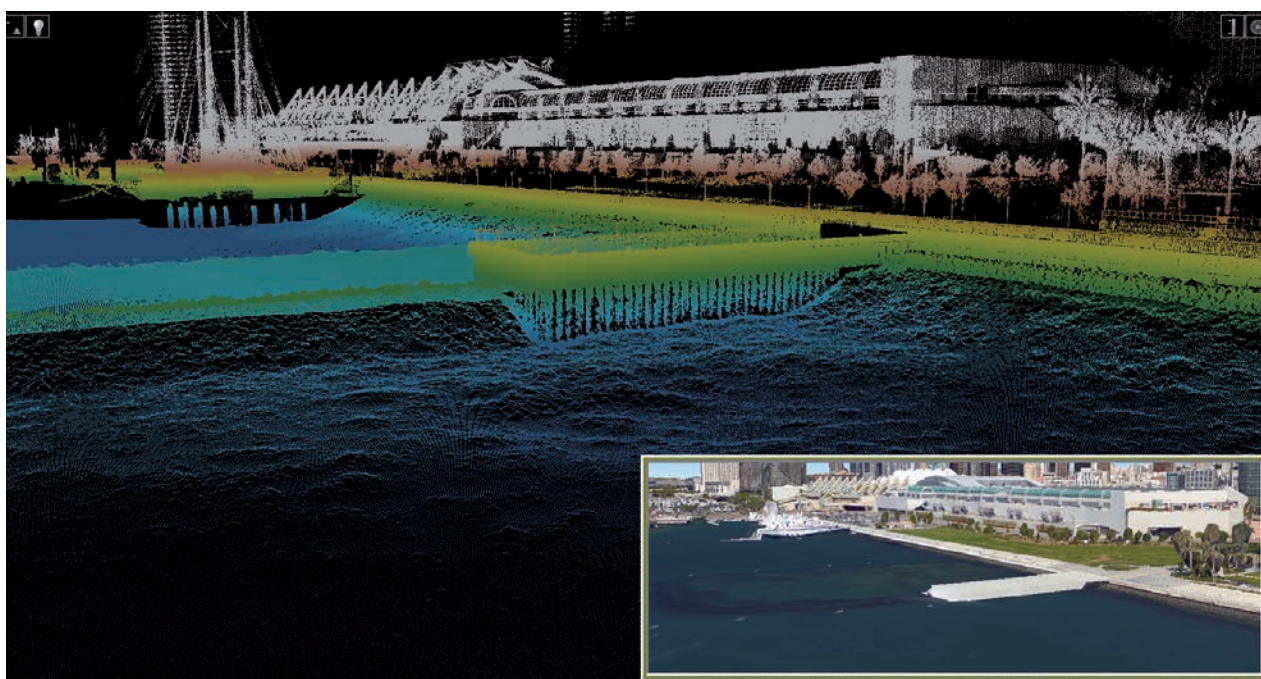
▲ *Teledyne Geospatial provides solutions and workflows for seamlessly mapping land and sea. (Image courtesy: Dave Somers, Ocean Surveys)*

data, store it in the CARIS cloud for immediate processing and analysis, and then move into downstream product creation workflow. This gives a clear operational advantage. This, in turn, enables customers to offer added value to their own clients in terms of the breadth of services they're able to offer.

WHAT DOES THE MERGER MEAN FOR THE CARIS AND OPTECH TEAMS?

"Joining forces means that the teams are gaining new skills across disciplines, and ensuring retention of the field-specific expertise they're known for. The market is familiar with the strong customer service and support model, from engineering to sales, and nothing will change there. Teledyne's arsenal includes hydrographers, physicists, surveyors and GIS professionals, as well as AI specialists, engineers and computer scientists. Going forward, the skills and expertise needed most in the field are at the intersection of traditional domain knowledge and the diverse aspects of computer science, as the market transitions to digital. I would suggest that there is an evolution underway in industry, and enterprises that can recruit highly skilled teams with expertise across the geospatial spectrum will be the ones to engage with. Our teams are industry professionals who understand both hardware and software and we see this as an opportunity to develop holistic solutions for hydrographic and topographic mapping."

HOW DOES TELEDYNE GEOSPATIAL DELIVER A COMPETITIVE ADVANTAGE?

"Geospatial will have access to full range sonar, Lidar and software solutions so customers can get full value from their Teledyne investment with the most advanced sensors in both ocean and land environments. We are unique: while some providers have topographic sensors with integrated software, even bathymetric Lidar, our software workflow goes much further; others are not involved in the final delivery of data, whereas we have end-to-end capability. This is a huge advantage for our customers, who will be able to integrate workflows, create efficiencies and reduce silos. We will reduce the need for separate infrastructure for land and sea since we can support our customers on both. This is
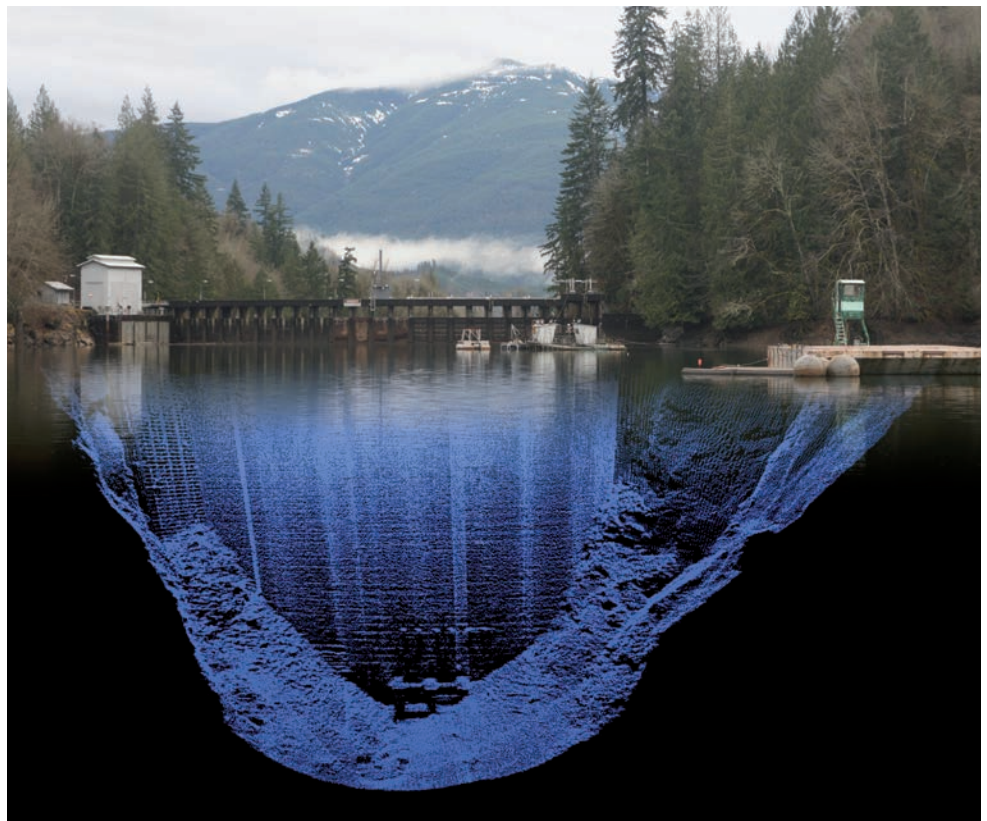
▲ *Ease of data collection through to final products is enhanced with efficiency-driving AI algorithms and real-time quality control. (Image courtesy: Mike Stecher)*

strategic for our customers at the business level, but also makes life easier in certain environments, for example in challenging and extreme settings such as the Arctic. This industry acumen means that Teledyne Geospatial is the ideal partner for a full range of projects."

WHAT HAVE BEEN SOME OF THE KEY CHALLENGES FACED BY THE MARINE SECTOR IN THE PAST YEAR?

"No industry has survived the COVID-19 pandemic unscathed, including the marine sector. Operational challenges have been immense, with businesses forced to pivot their operations from the field or office-based work to dealing with the need to complete projects while necessarily working from home. Limitations like lower-power computers in home offices combined with the inability to travel to worksites to install and maintain hardware systems have only increased this complexity. Despite the roadblocks posed by COVID-19 restrictions, Teledyne has taken the opportunity to explore how to adjust operations and retain the highest level of service provision. A key priority has been to support our customers

to transition their software to the cloud, enabling data processing and cartographic production. Digital and virtual interaction is a key part of our strategy, and we are now conducting much of our teaching and training virtually. On the upside, the pandemic has enabled us to reduce our carbon footprint from travel during this period, which also means less travel burden for our teams. As such, Teledyne is evolving with the industry and has managed to transition through the pandemic period into an even stronger position, having identified ways to make remote operations work successfully."

An example of Teledyne's recent innovation in terms of remote and autonomous operations involves hydrographic data scientists based in Canada, who would normally be on location in Brazil to perform a survey. Due to the COVID-19 pandemic, they worked remotely with colleagues in Brazil to operate survey equipment including AUVs through software workflows to command and control. As just one of many examples, Teledyne Geospatial will continue to apply this remote operations

methodology where possible during the pandemic and its aftermath. In terms of the benefits for customers, some project costs are reduced and the reduced environmental burden is obvious, although companies may need to accelerate their investment in digital to make such remote operations successful.

WHICH TECHNOLOGICAL DEVELOPMENTS SHOULD WE BE ON THE LOOKOUT FOR IN THE COMING YEARS?

"Adaptive capabilities, whereby enterprises can use the same systems for a multitude of purposes and adapt solutions to different survey tasks, will be imperative. With Teledyne Geospatial, customers will be able to use the same setup for ocean mapping and corridor mapping for powerlines, delivering a wider range of services. Lidar for both topographic and bathymetric purposes is a pertinent example of how one powerful tool can be applied across sectors. Going forward, UAVs and USVs will be critical, and our software can process the data from these drones, supporting automation."

What has worked well in the past in shallow water has since demonstrated success in deeper water due to better capabilities, thanks to advances in Teledyne's portfolio of solutions. For example, Teledyne recently began a partnership with the UK Hydrographic Office on The Nippon Foundation-GEBCO Seabed 2030 Project. This project aims to map the entirety of the world's ocean floor by 2030, contributing to supporting maritime trade and protecting oceans, a critical weapon in the fight against climate change. Teledyne's AI capability is used to process incoming multibeam bathymetry datasets more rapidly and accurately than previously possible, overcoming major bottlenecks created by the backlog of data. Enterprises should similarly consider next-generation tools and technologies, and AI will continue to gain momentum, for its capacity to enable accurate, fast data classification and data extraction.

WHAT CAN WE EXPECT FROM TELEDYNE GEOSPATIAL IN THE YEARS TO COME?

"At the heart of Teledyne Geospatial lies integrated solutions. The offering will include turnkey systems, Lidar, sonar,
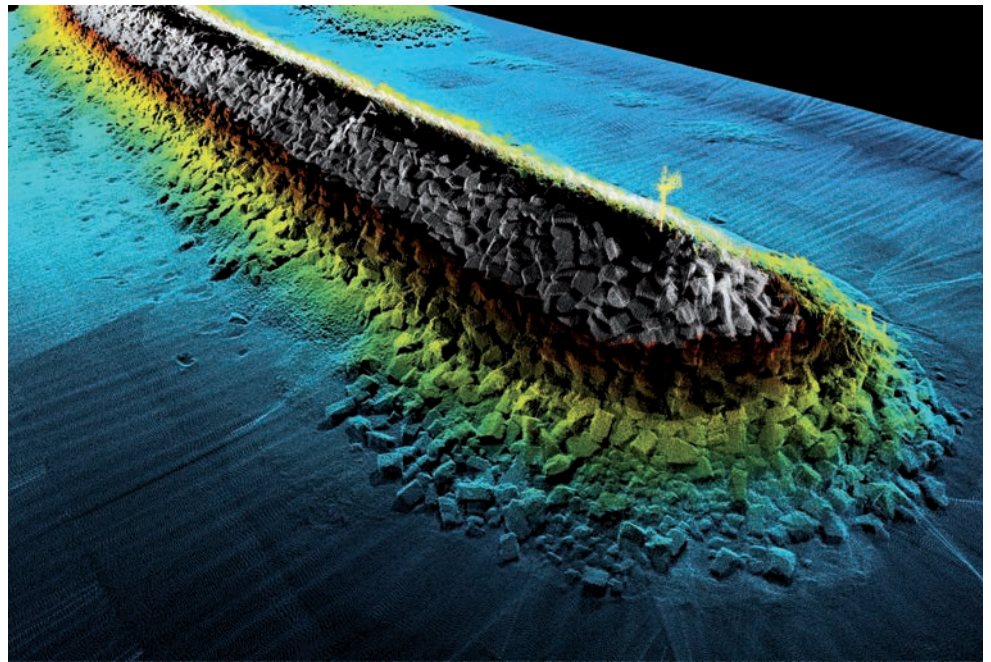
▲ Customers benefit from a competitive edge, mapping and delivering data products inside of one workflow. (Image courtesy: Chris Esposito)

integrated workflows and a range of systems and solutions that support full, precise data collection. Geospatial will also work closely with Teledyne Marine, in particular concerning sonar systems, and both sonar and Lidar can be logged in CARIS's recently launched Onboard360 acquisition software. With Onboard360, a near real-time and autonomous data acquisition and processing solution, it will become possible to create a common workflow using AI and cloud-native technology. For example, customers will be able to log data to the cloud with their hardware, streamlining their product timeline. A streamlined workflow for customers is a central, underpinning goal of Teledyne Geospatial."

WHAT NEW PRODUCT DEVELOPMENTS CAN WE EXPECT TO SEE IN THE COMING MONTHS?

Andy regards software as a differentiator, enabling customers to get the most out of their hardware: "We will be releasing new software products in the coming months, which will allow users to get the most out of their sensors. An example of this is the recently launched CZMIL SuperNova, which combines Optech's powerful bathymetric Lidar with CARIS' comprehensive processing software." Terratec AS, a leading Norwegian mapping company, has purchased and

flown CZMIL SuperNova for airborne survey projects, collecting and processing marine coastal zone base maps and mapping Arctic lakes. Working with the CZMIL SuperNova sensor and AI techniques, they conducted automatic discrimination and noise classification, capitalizing on the system's advanced capabilities and software workflow integration.

To get a first look at CZMIL SuperNova and to hear more about Teledyne's other upcoming combined solutions, customers are invited to join the conversation under the new banner Teledyne Geospatial at its booths at key industry events in the coming months. Teledyne Geospatial will be at Ocean Business in October and GEO Business in November, both in the UK. In the meantime, readers should reach out to Andy Hoggarth or Jennifer Parham for anything related to current or future Lidar, software and sonar needs. ◀

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Exploring New Horizons for Ocean Observation

Exploiting Unmanned Surface Vehicles to Collect Ocean Data

As the informed readership of *Hydro International* knows, the oceans sustain the planet. And, while there are many drivers of the changes to the Earth's climate that now pose an existential threat to humanity, the health of the oceans is arguably the most important factor for ensuring a healthy climate. There is mounting evidence that the world's oceans are under increasing stress and that we must find a sustainable way to protect them. An essential element of doing so is making data-driven decisions as to what steps to take to sustain the 70% of the planet covered by water.

BACKGROUND

Data-driven decisions cannot inform those with stewardship of the world's oceans unless we collect the right data, at the right places and at the right times. However, where those with stewardship of various aspects of ocean sustainment cannot find an affordable way to collect this data, it will very likely not be obtained and, unfortunately, large gaps in the data will lead to an incomplete picture. Clearly, this is a situation that degrades the chances of achieving long-term ocean health.

In the recent past, the failure to accurately assess temperature, current, wind, salinity, bathymetric, hydrographic and other oceanic conditions could be forgiven, as there simply were no affordable ways to do so on a repeatable basis. Today, however, unmanned maritime vehicles of various types can be used; in particular unmanned surface vessels, or USVs. While there have been some tentative attempts in the past to employ USVs to collect such data, there have been few – until now – comprehensive evaluations of this capability.

A UNITED STATES BEST-PRACTICES EXAMPLE OF A UNIFIED EFFORT TO COLLECT OCEANIC DATA

The U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Navy have formed a partnership to obtain and utilize unmanned maritime systems for a variety of missions, most notably to assess the health of littoral and oceanic waters. These two major

oceans stakeholders recently signed an agreement to jointly expand the development, acquisition, fielding and operations of unmanned maritime systems in the nation's coastal waters as well as in the world's ocean waters. This will enable NOAA to leverage the Navy's expertise, infrastructure and training to accelerate its science, service and stewardship mission.

The new arrangement corresponds with rapid expansion and innovation in the use of unmanned systems across the government, academia and private enterprise. The new pact formalizes the U.S. Commercial Engagement through Ocean Technology Act of 2018 that directs NOAA to coordinate with the U.S. Navy on a wide range of functions, including research in emerging unmanned technologies.

FROM ASPIRATIONAL IDEALS TO PROGRESS ON OCEAN OBSERVATION

This NOAA-U.S. Navy partnership is an important initiative that underscores the vital nature of robust data collection and why this is critical to ensuring the health and vitality of the world's oceans. For both the U.S. Navy and NOAA, a major appeal of unmanned systems is to provide a persistent sensor picture to ascertain various aspects of the ocean's health.

Given the importance of ocean observation as a critical ingredient in ensuring the long-term and sustainable health of the oceans, unmanned systems have a strong appeal. Due to the prohibitive costs of using manned aircraft or seacraft to conduct these observations, as well as the dangers of using these vessels in bad

▲ *Mantas T12 USV.*

weather, in turbulent waters or at night, the only effective solution may be to invest in affordable USVs to conduct these observations.

In support of NOAA and U.S. Navy objectives for ocean observation, one U.S. company, Maritime Tactical Systems Inc. (MARTAC), was invited to demonstrate the use of commercial off-the-shelf USVs to conduct a comprehensive environmental monitoring evaluation. This month-long endeavour was conducted under the auspices of the Naval Meteorology and Oceanography Command (CNMOC). Under CNMOC's stewardship, an advanced naval training exercise (ANTX) was conducted in the Gulf of Mexico, south of Gulfport, Mississippi.

EQUIPPING UNMANNED SURFACE VESSELS FOR EFFECTIVE OCEAN OBSERVATION
Having a capable USV is only one part of conducting a comprehensive ocean observation
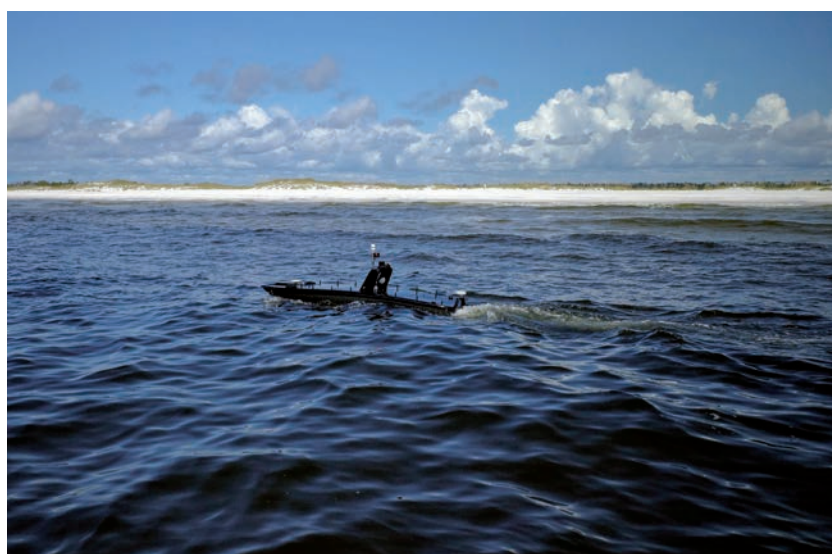
exercise. CNMOC scientists outfitted a MANTAS USV with a CNMOC Environmental Monitoring System. These systems and sensors were designed to provide a one-vehicle solution to environmental sensing that was, in the past,
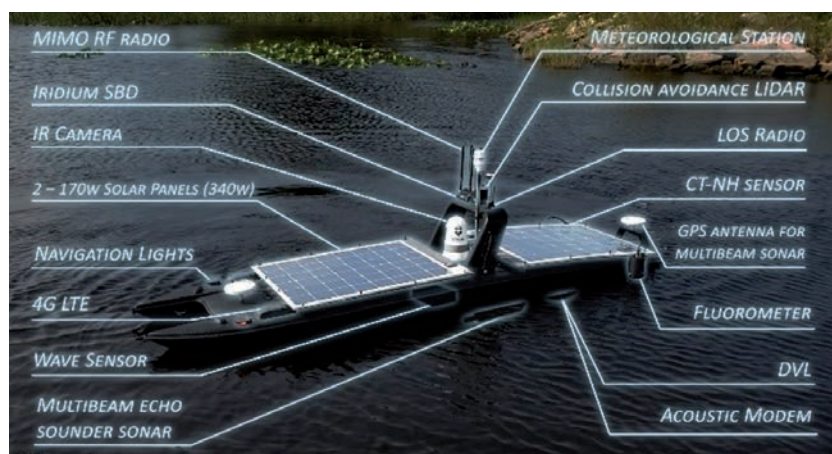
conducted by multiple platforms. Key to the success of this ANTX was the fact that the catamaran-hulled, compartmented MANTAS USV was outfitted with solar panels which enabled it to remain at sea for 30 continuous days.

In order to have this single USV conduct comprehensive environmental monitoring of the Gulf of Mexico, CNMOC equipped it with nine sensors: (1) a Teledyne Benthos ATM603 underwater modem, (2) a FLIR M232 camera,

Beyond the collection of vital ocean data, another area in which USVs can make an important contribution to monitoring ocean health is in response to real-world challenges

(3) a Teledyne Citadel CTD-NH conductivity temperature depth monitor, (4) a Teledyne DVL with ADCP Doppler Velocity Log, (5) a Norbit iWBMSh-STX echosounder, (6) a Turner C3 fluorometer, (7) a Quanergy M8-1 Plus Lidar, (8) an Airmar WX220 MET meteorological sensor and (9) a SeaView SVS-603 wave height sensor.

In order for CNMOC officials to have real-time information on ocean conditions, four different communication systems were utilized: line of sight (LoS), 4GLTE, Silvus radios and Iridium Short Burst Data. The use of multiple communication paths was important to the ability of CNMOC scientists and engineers to change the paths of the USVs as different sets of data were collected and new search patterns were needed.

CONDUCT OF THE ADVANCED NAVAL TRAINING EXERCISE
CNOMC conducted the testing described above, and it was so successful that the command employed a second USV (another MANTAS USV) equipped with a different suite of ocean monitoring systems and sensors. These included a Norbit iWBMSh-STX echosounder coupled with a Klein UUV 3500 side-scan sonar. As testing continued with both USVs, CNMOC scientists and engineers provided vital feedback and suggested several enhancements to these vessels.

An important aspect of demonstrating the cost-effectiveness of employing commercial off-the-shelf USVs during this CNMOC ANTX was the ability of one operator to control both USVs simultaneously as they conducted surveys along specific paths, even with high sea states and currents of up to five knots. The ability to conduct surveys in higher sea states and in the presence of strong currents had thwarted other

▲ Mantas T12 USV on a nearshore scanning mission.

MIMO RF RADIO
IRIDIUM SBD
IR CAMERA
2 – 170W SOLAR PANELS (340W)
NAVIGATION LIGHTS
4G LTE
WAVE SENSOR
MULTIBEAM ECHO SOUNDER SONAR
METEOROLOGICAL STATION
COLLISION AVOIDANCE LIDAR
LOS RADIO
CT-NH SENSOR
GPS ANTENNA FOR MULTIBEAM SONAR
FLUOROMETER
DVL
ACOUSTIC MODEM

▲ Nomenclature of the Manta T12 USV.

USVs in the past, and was one of the highlights of this month-long event.

OTHER USES OF UNMANNED SURFACE VESSELS – DEALING WITH EPISODIC OCEAN EVENTS

Beyond the collection of vital ocean data, another area in which USVs can make an important contribution to monitoring ocean health is in response to real-world challenges. The testing described above occurred in the littorals of the Gulf of Mexico, an area that has more than its share of environmental challenges. USVs are an ideal asset for evaluating the extent of damage as a first step in triaging the problem.

Again, this is a specific U.S. example, but USVs can be used to measure fresh water run-off from rivers which can kill a great deal of marine life, as well as to identify green tides and red tides that harm tourism in local regions. Using a solar-powered USV that can remain at sea and the environment for up to 30 days

at a time can alert communities to the extent of these green and red tides. This enables officials to be more exact in determining which beaches should close and which ones can remain open.

MOVING FORWARD WITH EFFECTIVE, AFFORDABLE OCEAN OBSERVATION ASSETS

The use of the commercial off-the-shelf USVs successfully employed during this demonstration can be readily scaled-up in oceans, seas, bays, rivers and other waterways and can lead the way to enhanced data collection and transmission and the evaluation of water conditions. The results will help to sustain a healthier ocean.

As a major step forward in this effort, U.S. Navy officials encouraged the MANTAS USV manufacturer, MARTAC Inc., to scale up the 12-foot MANTAS used for this effort and produce larger vehicles. This was accomplished this year and a larger, 38-foot MANTAS USV

was deployed during the U.S. Navy exercise Trident Warrior with positive results. These larger vessels will be ideal USVs for conducting ocean observation due to their ability to carry considerably more sensors and remain at sea for longer periods.

CONCLUSION

During a recent webinar, NOAA's deputy administrator indicated that two of the primary priorities this year for NOAA are ocean mapping and ocean health. Leveraging USVs to accomplish these priorities will go a long way to protecting the oceans. We envision a tremendously increased demand for unmanned systems prototyping and experimentation to support robust and continuous ocean observation. The vast array of technologies emerging with today's unmanned maritime systems provides a tremendous opportunity to move forward with an effective and affordable ocean observation taxonomy. ◀

▲ The Mantas T38 Devil Ray USV is designed for speed, stability and manoeuvrability.

George Galdorisi is Director of Strategic Assessments and Technical Futures for Naval Information Warfare Center Pacific. Prior to joining NIWC Pacific, he completed a 30-year career as a naval aviator, culminating in 14 years of consecutive experience as executive officer, commanding officer, commodore, and chief of staff. In his spare time, he enjoys writing, especially speculative fiction about the future of warfare. He is the author of 15 books, including 4 consecutive New York Times bestsellers.

Gas Detection and Quantification Using iXblue's Sonar Systems

In collaboration with four French, Belgian and German geoscience laboratories, iXblue's sonar systems division recently mobilized its SeapiX 3D multibeam echosounder and Echoes 10,000 sub-bottom profiler to image the Laacher See. Located in the Eifel region of Germany, the Laacher See is a caldera volcanic lake measuring two kilometres across, formed by an eruption 12,900 years ago. The main goal of this scientific mission was to detect gas bubbles that would help to better understand the current activity of the volcano.

Gas can trigger volcanic and limnic eruptions and can be easily detected using hydroacoustic methods. However, its quantification has until now remained complex due to the 3D structure of clouds and the acoustic interactions between bubbles. The different bubble clouds need to be accurately mapped, to monitor their evolution and to dissociate different gas origins to evaluate the volcanic risk, which is considerable in aquatic environments.

The use of two hydroacoustic instruments designed and built by iXblue, the SeapiX

multibeam echosounder (150kHz) and the Echoes 10,000 (10kHz) sub-bottom profiler, proved to be of great help during this scientific expedition on the Laacher See. Remotely controlled at several hundreds of metres, the SeapiX sonar recorded the lake's bathymetry and different backscatter signatures of elements in the water column. The target strength backscatter signature of the elements makes it possible to distinguish fish, macrophytes and gas bubbles. Statistics were conducted on the acoustic signatures at different locations. Several

concentrated colocations of gas flares were thus identified and suggested that the bubbles were very small (~35µm). This could explain why the geoscientists had not observed gas bubbles using a camera mounted on an ROV at these locations. It also raises new perspectives for improving CO_2 budget modelling from volcanic bubble releases.

4D MONITORING OF GAS FLARE DYNAMICS USING STATIC SEAPIX MEASUREMENTS
Caudron et al. (2012) recently showed that degassing underwater is one of the earliest precursors to volcanic eruptions, as observed in a caldera in the Philippines (Bernard et al., 2021). Almost ten years ago, they derived a first empirical law to estimate CO_2 fluxes in volcanic lakes using single-beam echosounders (Caudron et al., 2012). However, robust methods taking advantage of high-resolution equipment, such as multibeam sonars or distributed acoustic sensing (DAS) systems, are required to provide reliable quantification. In this study, SeapiX was able to record gas diffusion in the water column as a bubbling dynamic through time. With its 120° per swath scanning and target strength gas bubble identification, this study introduces new perspectives to anticipate gas-driven volcanic eruptions.

GEOHAZARD HISTORY AND GAS DIFFUSION IN SEDIMENTS USING ECHOES 10,000
The Echoes 10,000 provided high-resolution images of the architecture of the

▲ Figure 1: Laacher See (Image courtesy: Shutterstock).

lake deposits, which could be visualized in real time using the Delph Geo Software (iXblue software suite for the acquisition, processing and interpretation of geophysical data). Derived from 30 years of expertise in low distortion and high efficiency power amplifiers, Echoes technology ensures that the acoustic signal transmitted is very close to the theoretical CHIRP waveform. The resulting seismic profiles more accurately reflect changes in the nature and texture of sediment layers. More than 40 metres of sediment penetration provided high-resolution images of the sediment architecture (with a theoretical 8cm resolution), suggesting great potential for paleoenvironmental and paleoclimatic reconstruction. Indeed, combined with sedimentological analyses of sediment cores, 3D modelling of the main reflectors allows reconstruction of the past remobilization of materials derived

from extreme events and potentially linked to past volcanic and/or earthquake activities. Finally, the quality of the signal revealed the presence of gas diffusion in the sediment, which was compared to the SeapiX dataset (Figure 2). Using this scientific approach, it was possible to ensure that vertical structures were indeed gas flares (and not macrophytes), and to provide the best accuracy of target strength measurements.

CONCLUSIONS

Thanks to the SeapiX selectivity function, different target strength signatures will help researchers to identify different categories of elements and to best understand the physics of gas bubbles, their generation, origins and dynamics. Since SeapiX was used together with a gas probe installed on the lake for long-term monitoring, it has great

potential for better understanding the life cycle of gas generation by combining the acoustic data from the two different systems. It also introduces new insights for developing an automatic gas detection module using the SeapiX software.

Real-time and multiproxy hydroacoustic data contribute to ongoing and global scientific efforts to increase the predictability of volcanic and limnic eruptions. Intrinsic and spatial dynamics of volcanic gas bubbles are thus the cornerstone for developing the new generation of early warning systems that is needed for future risk assessment. Echoes 10,000 and SeapiX have a part to play in this. ◀
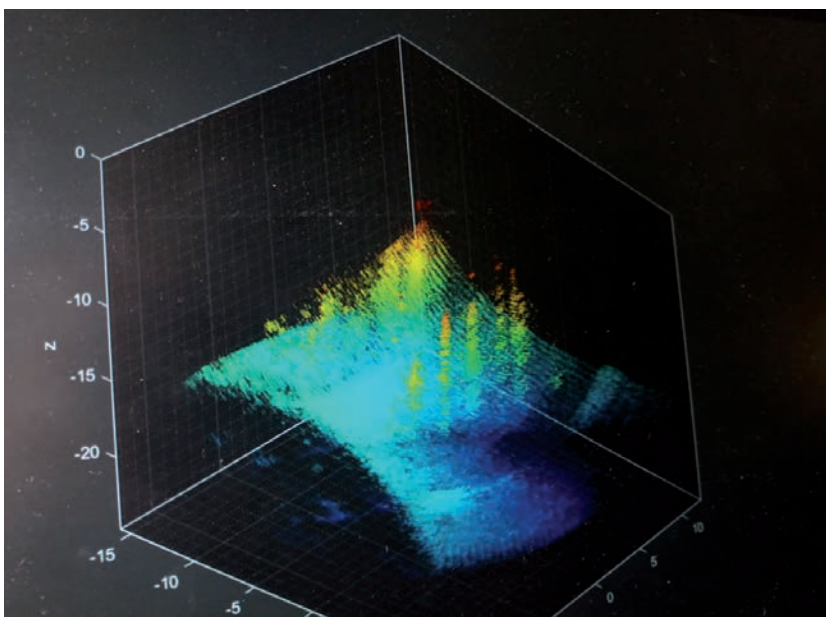
▲ Figure 2: Gas bubbles in 4D.
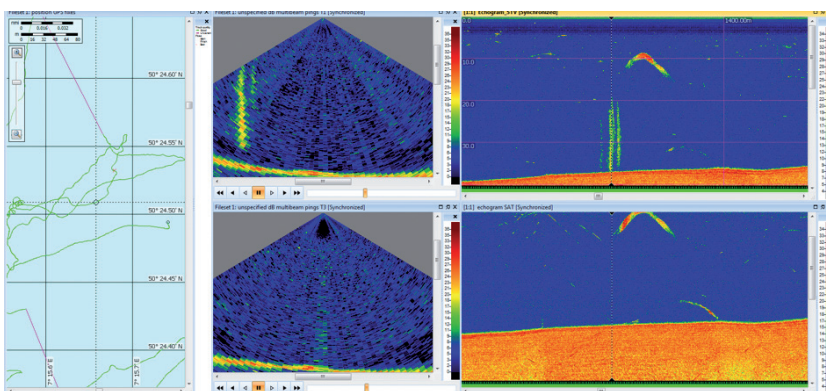
▲ Figure 3: Fish and gas bubble detection using SeapiX.
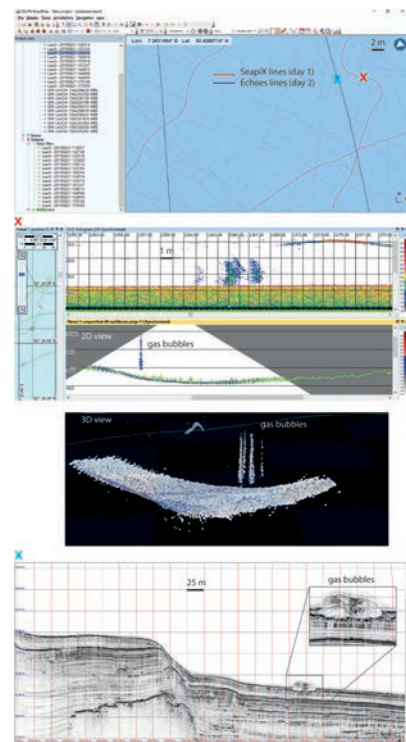
▲ Figure 4: From top to bottom: Delph Roadmap visualization of SeapiX (red, first day) and Echoes (blue, second day) survey lines. Crosses indicate the position of profiles visible below. Red cross (SeapiX data): 2D and 3D views of backscattered signatures of elements showing the vertical release of gas in the water column. Note that the maximum distance between gas chimneys is about seven metres. Blue cross (Echoes data): Seismic reflection profiles with a roughly 30-metre gas release from the sediment (zoom area), suggesting a potential link between a main gas conduit and the four chimneys diffused in the water column.

The Versatility of UAVs in a Remote and Rugged Archipelago

The Challenges of Surveying the Faroe Islands

Remotely situated in the northern Atlantic Ocean, roughly equidistant from Scotland, Iceland and Norway, the Faroe Islands form a rugged and rocky archipelago. The cool and cloudy weather, with strong winds and heavy rain possible all year round, means that this is a challenging survey environment. In its search for the best method to capture this stunning environment, the mapping authority has turned to UAVs. This article tells the story of mapping and surveying a truly breathtaking spot on Earth.

▲ *A hiker admiring the Drangarnir rocks – the iconic sea-stack with a hole in it – on the Faroe Islands.*

The weather is always a factor on and around the 18 islands that make up the Faroe Islands. Too much wind or rain is bad news for surveyors, among others. In the past, Umhvørvisstovan (the Faroese Environment Agency, which is the authority in charge of mapping and monitoring progress across the islands, including coastline mapping) used aeroplanes to capture the imagery needed for mapping and surveying. However, this was not without limitations because the aircraft had to be booked a few days in advance from photogrammetric companies in Denmark or Iceland. That often proved difficult in view of the changeable weather in the region – especially in periods when most of the companies were busy capturing images elsewhere.

TURNING TO CREWLESS AERIAL MAPPING

In 2015, Umhvørvisstovan therefore decided to work with unmanned aerial vehicles (UAVs or 'drones') instead of aeroplanes. The local survey team researched the strengths of drone photogrammetry and learned that the UAV-captured geospatial data could generate orthophotos with less work and effort than aeroplane-based photogrammetry. The labour-saving benefit was regarded as an important advantage, since there are only six employees to carry out all the mapping responsibilities at Umhvørvisstovan. Three of them work on surveying and mapping on land, whilst the other three work on nautical charts for ships and ferries (see box).

Another benefit is that clear skies are not essential when using drones. In fact, the result is sometimes better with some cloud cover, as long as the drone can operate under the clouds. Having said that, however, poor weather earlier this year meant that Umhvørvisstovan was unable to collect any data using drones until the second half of May 2021. Even in calmer conditions, fog sometimes posed an issue – especially when it was hanging low at around the flying height of the drone. Fog can trigger the ground sensor, thus setting off the drone's safety system, not to mention the fact that images collected while flying in fog are unusable.

So in 2015, the Danish company COWI, who already had wide experience with drone mapping, sent a drone pilot to the Faroe islands tasked with collecting images of the capital (Tórshavn) and the second largest city (Klaksvík). This project successfully convinced the Faroese of the capabilities of UAVs for mapping applications, and less than a year later the team started looking to acquire drones for themselves. After some research, they ended up buying two FX-61 fixed-wing drones with Pixhawk installed, from the Danish company Nordic Drone. Later, in 2020, an eBee X was purchased to supplement the fleet.

FLEXIBILITY AND OTHER BENEFITS

For Umhvørvisstovan, the key benefit of drones is their flexibility. Another major benefit for the Faroese surveyors is the fact that UAV mapping entails a relatively short workflow, from collecting the data to the finished products. This means that the images are rapidly available, plus the surveyors appreciate being in control of every step of the process. Now, in the case of any errors or unreliable data, the surveyors can either correct the errors or quickly collect new data themselves, without being dependent on others.

EASE OF USE AND HIGH-QUALITY RESULTS

In a place as unique as the Faroe Islands, situated in the middle of the Atlantic, aerial mapping of the islands is far from a run-of-the-mill survey project and it involves a lot of pioneering. In order to complete challenging missions effectively and safely, it is important to know the capabilities and also limitations of the drone and how it will react in different circumstances. Umhvørvisstovan's use of drones has not been without mistakes, but they have ultimately enabled the team to gain a lot of valuable experience.

The main objective is to map all urban areas on the islands, and the maps that are created from the captured images are used mainly for land planning and for the national register. The municipality of Tórshavn even has its own drone to enable it to map the town at a higher rate than the agency is capable of. Since 2017, Umhvørvisstovan has collected 117,130 high-resolution images, which is an average of approximately 30,000 per year. The UAV-based maps have an average ground sampling distance of 3cm, which is considerably higher than before.

Both drones in the Umhvørvisstovan fleet – the Phantom FX-61 fixed-wing drone fitted with a Pixhawk camera, and the senseFly eBee X with an Aerial X camera – have worked really well for the various projects. There are pros and cons to the two systems, the team noticed; the senseFly ecosystem is very robust and user-friendly, whereas the Pixhawk and Mission Planner set-up has the advantage of quick repairs and maintenance, such as in the case of a hard landing or when changing a servo. Both drones have also demonstrated that they are capable of coping very well with the often windy and turbulent conditions above the Faroe Islands.

For processing, the team have used Pix4D ever since they started working with drones. They have found it to be very effective and robust photogrammetry/mapping software which delivers high-quality results combined with ease of use. ◀

Read the full story here. ▶

Hydrography of the Faroe Islands

As the Faroe Islands are situated in the Atlantic Ocean, coastal and hydrographic mapping is also an important pillar for the authorities. The responsibility for the hydrography and charting was devolved to the Faroese authorities from the Danish authorities in January 2020. The Faroese seabed covers 300,000km^2, and can reach depths of up to 3.6km in the north. Being a small country can sometimes be an advantage, however. The Hydrographic Office and the Land and Surveying Office in the Faroe Islands are actually in the same department at Umhvørvisstovan. This means that land and sea are right next door to each other, which presents some great collaborative opportunities.

The Hydrographic Office within Umhvørvisstovan comprises just three members of staff who focus on hydrography, charting and administration. The responsibility covers eight nautical paper charts and 21 electronic navigation charts. Furthermore, Havstovan (the Faroese Marine Research Institute) recently launched a new 54m-long research ship, which houses a Kongsberg EM712 multibeam system. Umhvørvisstovan is responsible for the operation of this and gathers medium-to-deep water data. Landsverk (the Faroese Roads Authority) is responsible for gathering both surface data and bathymetry data to monitor changes in the ports and harbours.

▲ A detailed and clear point cloud output of a UAV survey of the Faroe Islands.

Wim van Wegen is head of content at *GIM International* and *Hydro International*. In his role, he is responsible for the print and online publications of these worldwide leading geomatics and hydrographic trade media brands. He is also a contributor of columns and feature articles, and often interviews renowned experts in the industry.

Seabed 2030: The Final Sprint

The Nippon Foundation-GEBCO Seabed 2030 Project has just over nine years left to achieve its indispensable goal of the definitive, freely available, map of the entire world ocean floor. The Project's timeline is ambitious but vital – in 2019, we were warned that we only have 11 years left to prevent irreversible damage from climate change. The upcoming United Nations Climate Change Conference (COP26) will undoubtedly act as a poignant reminder of the commitments that must be made on a global scale if we are to safeguard the future of our planet; and certainly Seabed 2030 is operating on that global scale.

ENVIRONMENTAL IMPACT

Our oceans drive global systems that make the Earth habitable for humankind, with the UN even describing the oceans as 'our planet's life support'. Our rainwater, drinking water, weather, climate, much of our food, and even the oxygen we breathe, are all ultimately provided and regulated by the sea. But despite this critical dependence on the oceans, we still know so little about them, and the threats to our ocean environment continue to grow – much of which are caused directly by humankind. Heading the list are plastic pollution and the collapse of fisheries, acidification and ocean warming.
Having a complete map of the ocean floor will equip us with the information and knowledge we need to provide many of the solutions to these pressing challenges. When Seabed 2030 was launched in 2017, only 6% of the seabed had been mapped to a modern standard. Our dependency on the ocean hasn't changed since then, but the need to ensure its sustainable management has become ever more apparent. Today, there's been a notable increase in the amount of bathymetric data logged, with over one fifth of the entire seabed now mapped in the latest GEBCO grid. Since its launch, Seabed 2030 has supported the UN's Sustainable Development Goal 14: 'to conserve and sustainably use the oceans, seas and marine resources for sustainable development.'

OCEAN DECADE

The time remaining for Seabed 2030 to achieve its goal also coincides with the UN Decade of Ocean Science for Sustainable Development (2021-2030), which launched earlier this year with the aim to strengthen cooperation needed for the sustainable management of our oceans. Seabed 2030 was one of the first Actions to be officially endorsed as part of the Decade.
Seabed 2030 is aware of the monumental task ahead, but the Project is also certain that with global cooperation, a complete map of the ocean floor by the end of the Decade is achievable. With the ocean covering over 70% of Planet Earth, a complete map of the ocean floor can aptly be referred to as an international necessity – demanding international collaboration.

COLLABORATIVE WORK

A complete map of the seabed is a vital tool which will enable us to make informed decisions – decisions that affect the entire human population. To this end, Seabed 2030 continues to enter into partnerships with various institutions and individuals in pursuit of its goal. This year also marked the first ever agreement between the Project and a government.
Working collaboratively towards a goal which is ultimately for the benefit of humanity is central to Seabed 2030 – every time a research vessel adds bathymetry data gathering to its mission, every time a ship takes a slightly altered course while in transit to survey an uncharted area, they are helping to fill in the gaps in the grid.
This year, Seabed 2030 will also be participating in the fourth Paris Peace Forum. The Project intends to use this platform to continue to raise awareness and inspire new partnerships to bring about impactful changes to the way in which the world is governed – and its resources managed. Over three billion people depend on the oceans for their livelihood, but less than 2% of national resource budgets are currently allocated for ocean science. COP26 and the Paris Peace Forum may act as catalysts for the changes that we need to make on a global scale and Seabed 2030's progress, but it is the international community that can take it over the finish line. ◀

▲ *Jamie McMichael-Phillips, Project Director, The Nippon Foundation-GEBCO Seabed 2030 Project*

About GEBCO
The General Bathymetric Chart of the Oceans (GEBCO) partners with The Nippon Foundation in the Seabed 2030 Project. GEBCO is a joint project of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO – the United Nations Educational Scientific and Cultural Organization. It is the only intergovernmental organization with a mandate to map the entire ocean floor.

About the author
A chartered surveyor, hydrographer and former Royal Navy officer, Jamie McMichael-Phillips has worked in a range of leadership roles from running his own marine data gathering missions to directing defence geospatial strategy and plans for the UK. Prior to joining Seabed 2030, he chaired the International Hydrographic Organization's Worldwide ENC Database 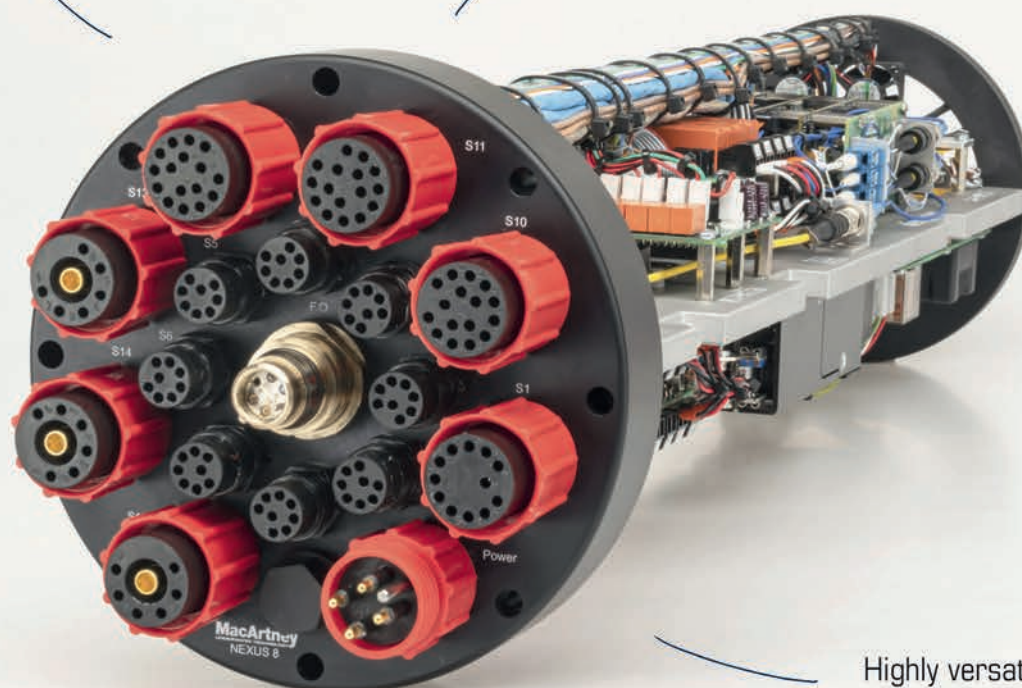Working Group for over nine years.