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Uncovering the Secrets of German Marine Munitions Dumpsites

Who Is Going to Map the High Seas?

Exploring the Marine Environment in South Africa

Using Machine Learning to Derive Benthic Habitat Maps

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Geomares
P.O. Box 112, 8530 AC Lemmer, The Netherlands
Phone: +31 (0) 514 56 18 54
E-mail: info@geomares.nl
Website: www.geomares-marketing.com

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Cover Story

The image on the front cover shows a harbour in South Africa with the famous Table Mountain in the background. On page 18, you will find a story that takes place in this area. It focuses on a method of mapping using machine learning in combination with marine geophysical and biological data and which has been tested in multiple sites along the South African coastline. (Photo courtesy: Shutterstock)

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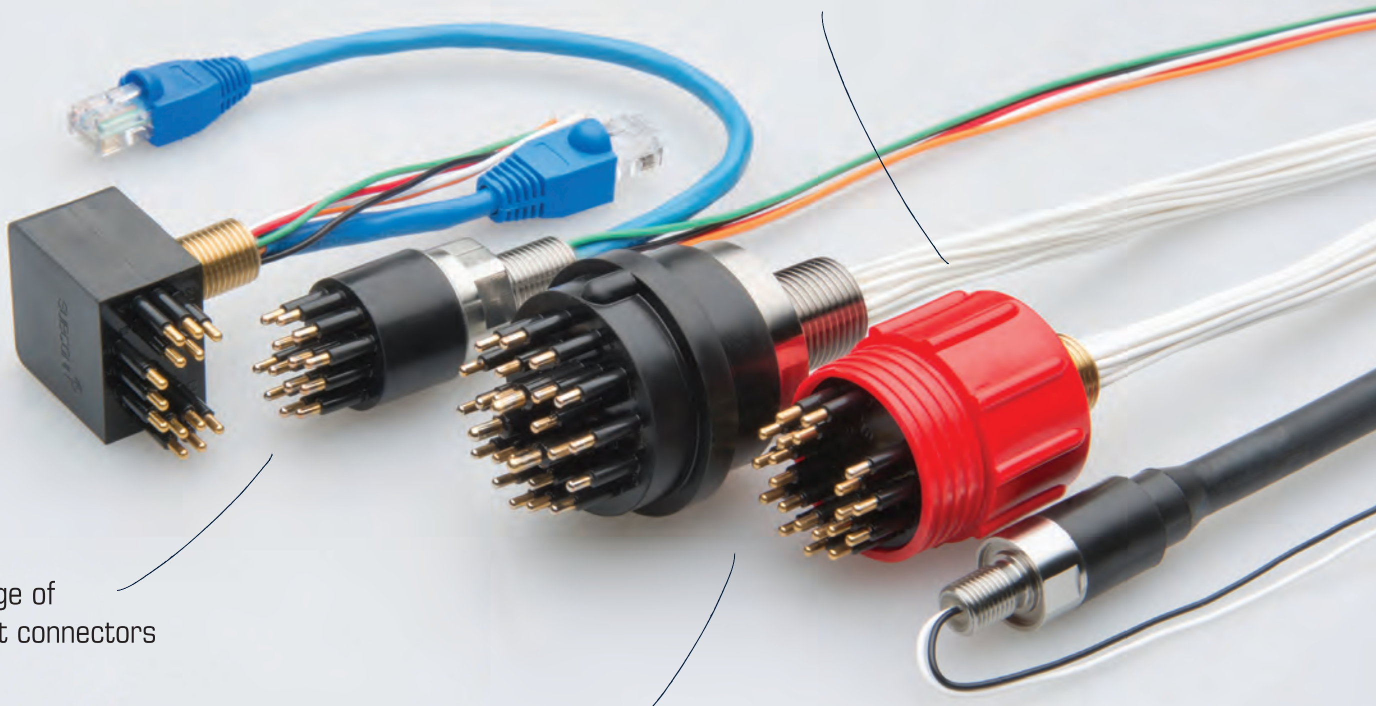

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Prestigious

Summertime is a special time. Even more so for a kid. Who doesn't remember that last day at school before it closes for the holidays, long evenings, swimming in the sea or going to the forests and mountains? And the good thing was, being a kid, summer seemed to last forever. One of the many treats of summer used to be the summer special or holiday book of the magazine you subscribed to, laden with strips, new stories, posters and puzzles. Often thicker than your regular edition and often with that upbeat feeling that belongs to summer. We want to try and bring back that feeling to you with this special Prestigious Projects edition.

We're diving deep into the secrets of German marine munitions dumpsites (see page 14): a team of researchers from GEOMAR and EGEOS embarked on an unusual round trip across the Baltic Sea to try and shed light on the secret legacy of munitions dumpsites and to improve technologies for their detection. In seas around South Africa, an equally ambitious, but completely different team is looking to understand the benthic biodiversity off the shores of the southern tip of the African continent (see page 18). Machine learning techniques are helpful in the process of improving map accuracy and reducing processing time.

This issue of Hydro International should leave you proud of the profession you've chosen, astonish you with the technology that is being used and happy with the contribution that hydrography is making to help this world become a better place. On page 11 of this issue, you will find an article by Brian Connon, Vice President of Ocean Mapping at Saildrone. Before joining that company, he was director of the Hydrographic Science Research Center of the University of Southern Mississippi and he served 28 years in the US Navy in a variety of positions. In his spare time, he is also acting as Editor-in-Chief of the International Hydrographic Review. Brian Connon asks himself and our readers – who is going to map the high seas? For the answer to that question, I refer to the article. All the projects described in this issue – and there are many more than I can point to in this editorial – and the projects that you are involved in on a daily basis are prestigious in every sense of the word. From the smallest survey to those projects that aim to map the complete ocean floor. Every project brings together a prestigious and also precious combination of technology and human brilliance. For once, this summer, wallow in this brilliance for a little while, before returning to work with a clear head and some forward thinking. Enjoy our first Prestigious Projects special!

Durk Haarsma,
director strategy & business development
durk.haarsma@geomares.nl

▲ *Durk Haarsma.*

PS Of course, we realize all too well that it is midwinter in the Southern Hemisphere. Hopefully, this edition of *Hydro International* will give you that feeling of a warm and sunny summer's day! Only a few more months and you'll be there. As you know, seasons fly by; winters - and unfortunately, it goes for summers as well - don't last half as long as they used to when we were kids.

ADVERTISERS

Rovco Launches New Hydrographic Division

▲ *With experience in site investigations and detailed engineering surveys for both floating and fixed-bottom installations, Rovco has already worked at over 50% of the UK's operational wind farms to date.*

Rovco has announced the launch of a new hydrographic services division, Rovco Survey Solutions, building on the company's experience as a leader in asset integrity and ROV projects and now offering a range of hydrographic, geophysical and site survey services across the offshore sector and pledging an investment of £9.5m in the new division, to be spent over the next 24 months. Additionally, the company will expand its survey team, which has already flexed to more than 45 people for recent key projects, by welcoming a further eight new survey staff members this month.

Rovco Survey Solutions will offer a broad range of hydrographic services, from wind farm site and cable route surveys, spanning seabed mapping, geophysical and shallow geotechnical services, to hazard surveys and UXO target identification. This will go alongside broader offerings such as UXO disposal, marine habitat assessment surveys and archaeological investigations. Utilizing Vaarst's SubSLAM 3D vision system, the company also provides a fast method for conducting precision accurate point-to-point measurements for subsea metrology and dimensional control.

Expedition Team Reveals Deepest Points in Indian and Southern Oceans

▲ *The submersible 'DSV Limiting Factor' played a crucial role in mapping the deeps. (Courtesy: Triton Submarines)*

As part of the Five Deeps Expedition team, scientists from the British Geological Survey have surveyed in detail the deepest reaches of the Java and South Sandwich trenches. New seabed surveys show, for the first time, the deepest points of the Indian Ocean and the Southern Ocean.

As part of the Five Deeps Expedition (FDE) team, scientists from Caladan Oceanic LLC and the British Geological Survey (BGS) have surveyed in detail the deepest reaches of the Java and South Sandwich trenches. Data published in Geoscience Data Journal shows the deepest point of the Indian Ocean at 7,187m, within the Java Trench, and the deepest point of the Southern Ocean at 7,432m, within the South Sandwich Trench.

Prior to the FDE, the deepest parts of some oceans were relatively well known, such as Challenger Deep in the Mariana Trench, but others had multiple 'deeps' where several contenders challenged for the deepest point in that particular ocean.

Ocean Infinity Acquires Ambrey

▲ *Ambrey's Athena logistics platform.*

Ocean Infinity, the marine robotics company, has acquired maritime services company Ambrey. Ambrey's team of maritime professionals delivers a range of bespoke offshore services including security, crisis and risk management, intelligence, insurance, fleet operation and vessel design and build.

The acquisition combines Ocean Infinity's robotic vessels, data, cyber, artificial intelligence and low emission operations with one of the leading brands in the maritime security sector. Ocean Infinity's data and software capabilities will revolutionize Ambrey's intelligence and insurance services, while its robotic surface and sub-surface vessels have huge potential for Ambrey's shipping and offshore client base.

Ambrey's vessel manufacturing and fleet management capabilities will bring meaningful operational advantages as Ocean Infinity moves closer to mobilizing its 'Armada' fleet of robotic vessels, set to be the largest fleet of its kind in the world. Ambrey's and Ocean Infinity's highly complementary competencies will enable the enlarged group to expedite its strategy of becoming the world's leading marine robotics company, with technology and sustainability at its core.

Successful Sea Trials with Sonar and Pressure-tolerant Batteries

▲ *The DIVE-LD with Kraken MINSAS120.*

Kraken Robotics has announced that Dive Technologies recently completed successful sea trials of Kraken's Miniature Synthetic Aperture Sonar (MINSAS 120), integrated into Dive's Large Displacement Autonomous Underwater Vehicle (DIVE-LD). The DIVE-LD is also powered by Kraken's pressure-tolerant batteries.

Kraken's MINSAS is a commercially available off-the-shelf configurable Interferometric Synthetic Aperture Sonar (SAS), which replaces high-end side-scan sonar systems while delivering significantly higher resolution, range and area coverage rates (ACR). The increased range and resolution and associated higher ACR of SAS over traditional systems offer a powerful capability when combined with the long range and endurance of the DIVE-LD.

Sea trials were conducted in shallow water and very shallow water environments in and around Buzzards Bay, Massachusetts and Narragansett Bay, Rhode Island. Due to Covid-19 travel restrictions, Kraken personnel provided support remotely throughout the integration and sea trials with the DIVE-LD. Immediately following successful sea trials, Dive was also able to conduct a number of customer demonstrations for commercial and defence customers.

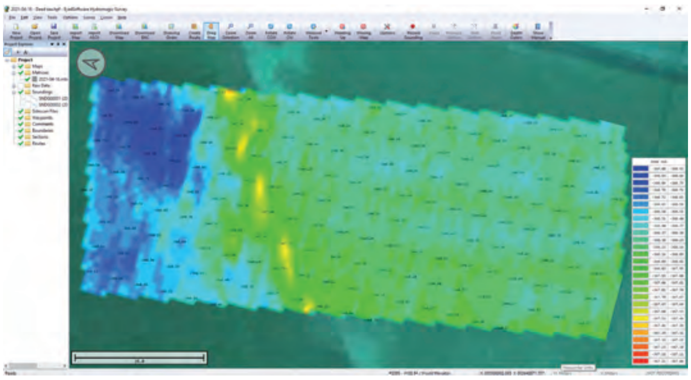
Bathymetric Surveying with UAV and Echosounder in Dead Sea

Israeli drone service provider ERELIS recently conducted a number of pilot projects using a drone equipped with a singlebeam echosounder in the Mediterranean and Dead Sea. The reference bathymetric data was collected using a manned boat and multibeam and single-beam echosounders and demonstrated a good match between the results of new drone-based and traditional methods.

The data was validated by authorized local surveyors and reports from previous surveys of the same areas by Michmoret Campus – Faculty of Marine Sciences, which is part of the Ruppin Academic Center.

The bathymetric system consisted of a standard commercial DJI drone (UgCS SkyHub onboard computer and terrain-following system with radar altimeter) and Echologger ECT400 single-beam echosounder provided by SPH Engineering, Latvia. For data processing, the Eye4Software Hydromagic software package was employed.

“I was surprised by the manoeuvrability of the system and how easy it is to conduct bathymetric surveys using a UAV equipped with an echosounder. Some of our survey areas were 400–500m away from take-off/landing positions and that means that the term remote sensing comes to the world of hydrography and becomes available to any drone service companies,” Roman Kirsanov, CEO of ERELIS, commented.



▲ *Survey data of the Dead Sea bathymetry project.*

iXblue Demonstrates Future Hydrographic Capabilities at IHO Centenary

Invited by the International Hydrographic Organization (IHO) to demonstrate the most modern hydro-oceanographic technologies during the celebrations marking the 100th anniversary of the international organization, iXblue demonstrated its DriX Unmanned Surface Vessel, in the presence of Prince Albert II of Monaco, Dr Mathias Jonas, IHO secretary-general, Laurent Kerléguer, director general of the French Hydrographic and Oceanographic Service (SHOM), and Ambassador Peter Thomson, the UN Secretary-General’s Special Envoy for the Ocean.

Identified by the IHO as a pioneer in the transition of the hydrographic industry towards more efficient and environmentally friendly unmanned maritime operations, iXblue presented the new methods and strategies deployed for seabed mapping, as well as how autonomous vehicles can collect data in support of the hydro-oceanographic industry.

“We are proud to be recognized by the IHO as a key player in the hydrographic industry and to be able to represent, with our DriX Unmanned Surface Vehicle, the future of hydrography,” stated David Vincentelli, director of the Sea Operations division at iXblue. “It was an honour to be a part of this event celebrating 100 years of IHO’s missions to serve our oceans and to be able to contribute, alongside them, to the transformation and promotion of our industry.”

▲ *iXblue demonstrated its DriX Unmanned Surface Vessel in the harbour of Monaco.*

Hydrospatial Technology: Collaboration Expanding Globally to Address Escalating Needs

Hydrospatial could be described as that portion of geospatial knowledge infrastructure that addresses the hydrosphere, and hydrospatial technologies support navigation, economic development, stability, security and defence, resilience and scientific research.

The last few years have been historic for hydrospatial technologies, providing access to high-quality geospatial data that supports the research and analysis of our oceans, seas, coastal areas, lakes and rivers. The growth and diversity of geospatial data in the maritime domain is escalating at an unprecedented pace, as coastal and inland waters impacted by climate change are being mapped and monitored with greater precision and frequency.

I have been working in this domain for the last 6 years, after getting my start 14 years ago as an airborne sensor operator. I focused primarily on U.S. federal civilian projects for Woolpert prior to becoming the operational lead and project manager on a high-flying Lidar sensor development programme for the Army Geospatial Center. In Mississippi, through a joint venture between Woolpert and Optimal Geomatics (WMR-532), our team supports the Joint Airborne Lidar Bathymetry Technical Center of Expertise and its efforts with the U.S. Army Corps of Engineers' National Coastal Mapping Program and the Naval Oceanographic Office's Airborne Lidar Hydrography branch.

Addressing governments' geospatial and hydrographic needs

Working with JALBTCX jump-started my curiosity about all things ocean, shallow water and coastal zone. Since then, working with our team and partners, it has been my great pleasure to execute airborne Lidar bathymetry projects across the globe, testing and evaluating satellite-derived bathymetry, unmanned aircraft systems and other derived bathymetry techniques. By consulting with officials at all levels of government, we are helping craft solutions to address their coastal, riverine and shallow-water geospatial and hydrographic needs.

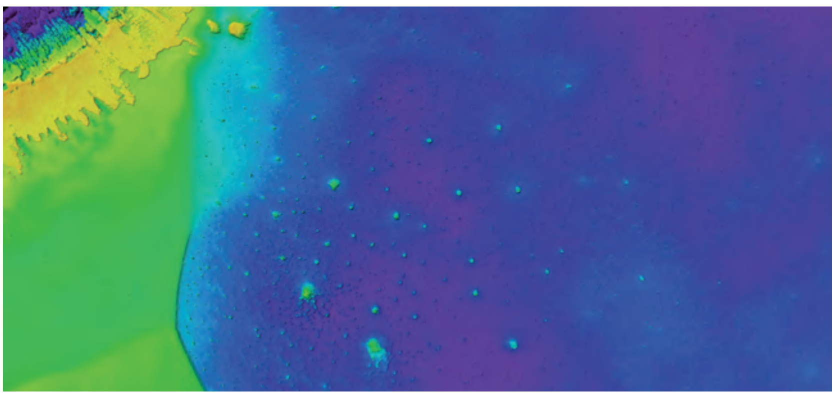
Hydrospatial technologies have had recent challenges, as new capabilities have prompted questions about how we think about data requirements, information needs and decision criteria. Furthermore, also local populations are increasingly engaged in decisions regarding their ability to build, maintain and persevere along coastlines and waterways. We need to help them to answer questions such as: Should we spend to replenish our beaches? Should we harden our infrastructure? Should we invest in other resilience solutions? Do we need to plan for relocating homes, businesses and communities?

Hydrospatial collaboration and innovation

In response to the Covid-19 pandemic, the last year has seen increased health and safety engagement and visibility worldwide. This has also spurred collaboration and innovation as we all endeavour to build a more sustainable, more resilient world. In the U.S., we're seeing better cooperation across states, as coastal engineers and scientists conduct environmental monitoring for independent and combined local, state and federal initiatives. The biggest example of this focused collaboration is the Ocean Decade, designated as 2021–2030 by the United Nations, which has a vision to: "develop scientific knowledge, build infrastructure and foster relationships for a sustainable and healthy ocean."

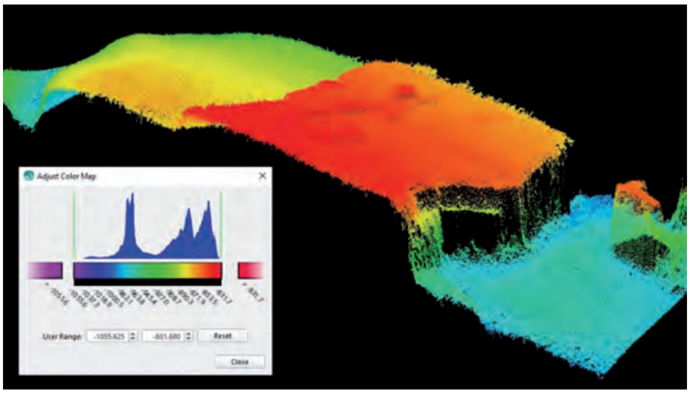
As we move forward, I see hydrospatial needs escalating, exceeded only by the enthusiasm in our industry to address these needs and embrace the Fourth Industrial Revolution and its blending of the physical, digital and biological worlds. More personally, where the water meets the land is always where I want to be. After all, it brought me to Mississippi, where I have started a family, helped open an office, expanded my firm's hydrospatial offerings, and worked alongside clients and colleagues.

The rise of hydrospatial technologies invites the curious and the hard working, the engineers and the sailors, the mechanics and the scientists. It is hard to find an industry that scales globally so easily, and yet involves so many professionals, peoples and solutions. I am honoured to be a part of this effort every day. ◀



▲ *Bathymetric Lidar is one of the solutions to address governments' coastal, riverine and shallow-water geospatial and hydrographic needs.*

NOAA Vessel Completes Successful First Trial for New Echosounder



An EM 304 MKII 0.5°x1° image capture from the NOAA vessel 'Okeanos Explorer'. Depth 1,000m, 5km swath.

Kongsberg Maritime (KM) has reported that its new EM 304 MKII high-resolution deep-water multibeam echosounder system has just successfully completed its first trials on board the NOAA vessel *Okeanos Explorer* in the waters off the coast of Florida.

Okeanos Explorer is the first vessel in the world to be fitted with the EM 304 MKII transmit array – a comprehensive upgrade to the trusted EM 302 deep-water multibeam system which has been deployed daily since the ship was originally launched in 2008. The new EM 304 MKII was put through its paces over the course of a 25-day expedition on board *Okeanos Explorer*, conducted by a team from NOAA Ocean Exploration, the US federal organization devoted to the exploration of deep-ocean environments.

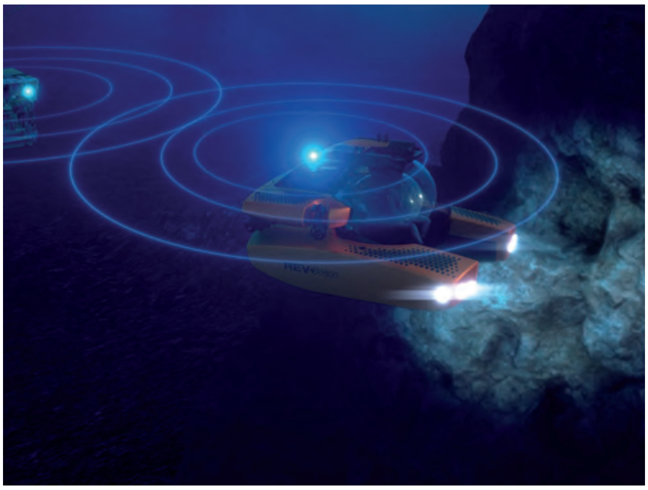
The motive behind the expedition was to assess the functionality and readiness of all mapping-related equipment on the vessel – including an official authorization of the new EM 304 MKII system – before the remainder of the field season commences. Receiving a green light from the NOAA verifies that this equipment is capable of collecting the most accurate, high-quality survey data and of sharing it with hydrographic communities. By enabling the team to optimize the planning and execution of surveys, it will ensure that all forthcoming missions produce definitive results in the most cost-effective manner.

Sonardyne BlueComm to Stream Ocean Exploration Missions Live

The world's deepest diving acrylic-hulled manned submersible is to be equipped with Sonardyne's BlueComm optical communications link to allow live streaming of deep ocean expeditions anywhere in the world. The Triton 7500/3 series submersible will operate from *REV Ocean*, one of the world's most advanced research vessels, currently under construction for the Norwegian non-profit organization of the same name.

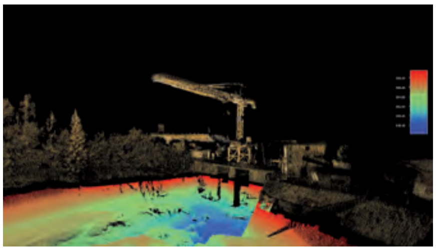
BlueComm will allow the occupants of the Triton submersible to live-stream high-definition video and audio to the surface, including to those on board the vessel's 35-person auditorium and even to website and television audiences worldwide, to share first-hand in their experience.

The Triton 7500/3 is the only acrylic-hulled submersible able to carry up to three people down to a water depth of 2,286m. BlueComm will support its missions by transmitting data using high power, rapidly modulated light emitting diodes (LEDs).



Underwater research re-imagined. Sonardyne's BlueComm will unlock opportunities to share ocean science from onboard the REV Ocean. (Image courtesy: Sonardyne)

Seabed Selects Velodyne Sensors for Mobile Mapping System



▲ *The Seabed Lidar system, equipped with a Velodyne Lidar Puck sensor, conducts hydrographic surveys of inshore, nearshore and inland waterways. It collects 3D data to support sustainable planning that can help protect sensitive environments.*

Seabed BV, which specializes in high-quality equipment for offshore surveying and dredging, has selected Velodyne Lidar's Puck sensors for its Lidar mobile mapping system. The Seabed system is a turnkey mobile Lidar solution for hydrographic surveys and can support sustainable planning, which aims to protect sensitive historic and marine environments. The Seabed Lidar system, equipped with a Puck sensor, provides complete above-water point cloud data and can operate in harsh maritime conditions. The system conducts 3D data capture of intricate measurements of inshore, nearshore and inland waterways from up to 100 metres away. It is designed to be simple to mobilize and easy to use without the need for specialized training or qualifications, delivering rapid results that can save time and money. "We selected Velodyne's Puck because it produces the high-quality, consistent data our customers need," said Elice Collewijn, general manager, Seabed, which is based in Amsterdam, the Netherlands. "The Puck has demonstrated outstanding reliability and power efficiency while operating in severe offshore situations. The sensor allows us to capture vital, high-resolution data to accurately measure and analyse marine environments."

Employing a USV for a Wide-swath Bathymetric River Survey

Storm Geomatics used a combination of the SL40 USV and traditional survey techniques.

In early spring 2021, Storm Geomatics was approached by an existing client to carry out topographic and bathymetric surveys on the River Aire, in the village of Newlay, to the north-west of Leeds, Yorkshire, in the UK. The survey was required to provide information for local asset recovery works. In the extremely shallow river, the system supplied by THURN Group, compromising the OceanAlpha SL40 Unmanned Survey Vessel (USV) equipped with a GeoSwath4 Interferometric Sonar and SBG Ekinox IMU, enabled Storm Geomatics to carry out a full bathymetric survey efficiently and safely in a difficult to access and fast-flowing section of the River Aire. The 250m stretch of the River Aire surveyed included Newlay Weir, the riverbanks, the foreshore and the flood defences, and was surveyed with no issues due to the USV's shallow draught and the interferometric sonar's wide swath, which was able to efficiently survey the river bank-to-bank.

Long Endurance, Low Impact Uncrewed Systems Vital to the Success of Seabed 2030

Who Is Going to Map the High Seas?

To achieve the aggressive goals of Seabed 2030, uncrewed survey systems must be used to augment more traditional ocean mapping efforts, particularly on the high seas. In addition to providing a much-needed force multiplier for surveying, these systems lower environmental impacts by using harvestable energy, eliminating personnel at sea, and reducing ship-generated noise, overboard discharge, and potential for pollution. Saildrone Surveyor, a 22m Unmanned Surface Vehicle (USV), recently completed a mapping mission that traversed approximately 4,200 kilometres and mapped nearly 22,000 square kilometres (see box) of previously unmapped seafloor. Primarily powered by solar and hydro energy and propelled by wind, Saildrone Surveyor ushers in a new era of long endurance, low impact (LELI) USVs for ocean mapping.

SEABED 2030 AND THE HIGH SEAS

Seabed 2030 is a joint project of The Nippon Foundation and GEBCO with a goal of mapping 100% of the world's oceans by the year 2030. As of today, only 21% of the ocean is considered mapped to modern standards. Many coastal nations have instituted programmes to map their waters, focusing primarily on their Exclusive Economic Zones (EEZ). If one were to exclude these EEZs from the calculation of unmapped seafloor, the remaining high seas are less than 15% mapped (approximately 31,874,043 of 212, 881, 389 km^2) , . Generally, the high seas are deep, difficult to reach, and more accurately, expensive to survey with manned vessels, and there is limited incentive to map the seafloor. This will be a significant challenge for the Seabed 2030 project-how to map the deep ocean in areas of low priority to countries with limited budgets. As marine resource exploitation efforts, such as deep-sea mining, become a reality, mapping of the high seas will become a higher priority, but it is unlikely these areas will receive the necessary attention prior to 2030. Industry, government, and philanthropic organizations must be convinced to fund high seas mapping projects to achieve the goal of Seabed 2030. These high seas projects must be efficient, cost-effective, and attractive to potential funding partners by offering something unique and different to traditional survey ships. In other words, mapping of the high seas requires long endurance, low impact (LELI) survey vehicles.

▲ *Figure 1: Saildrone Surveyor arriving in Honolulu after mapping over 4,100km of unmapped seafloor during a mission between San Francisco and Honolulu.*

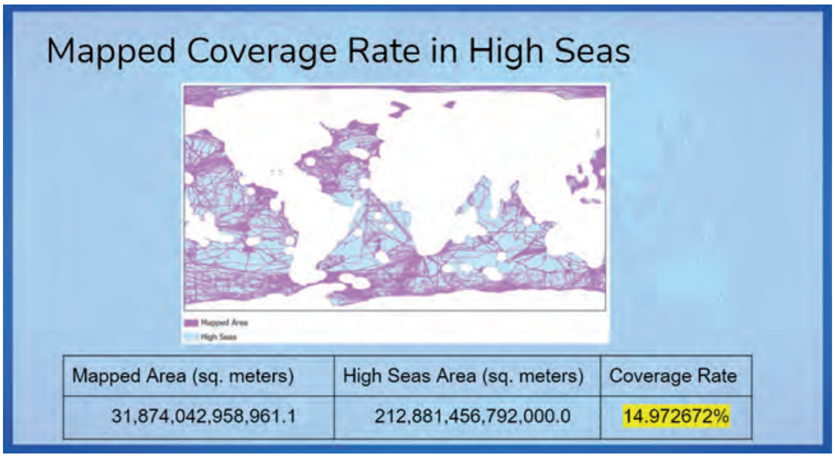
WHAT IS LONG ENDURANCE, LOW IMPACT?

Mission endurance for motorized USVs, whether diesel or electric, typically ranges from hours to less than two weeks. These systems often have limited power available on board, which restricts both endurance and capability of installed sensors. Many advanced USVs are outfitted with high resolution multibeam sonars for use in shallow (less than 300 m) water and may require a mother ship or local team to provide necessary services and support. To address the mapping shortfall of the high seas, without using a mother ship or local support, a USV must have a deep ocean mapping sonar system and be able to transit to a remote area, survey for months at a time, and safely return to port. Saildrone Surveyor was uniquely designed for this exact mission – by sailing to and from a survey area, using solar and hydro power to

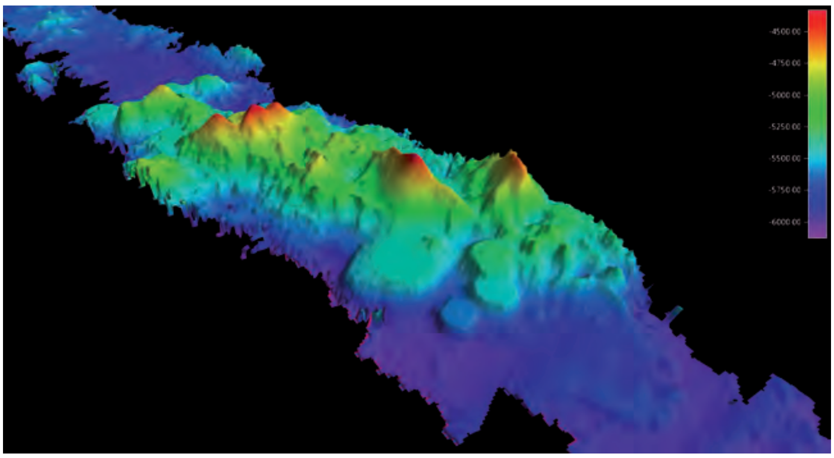
▲ *Figure 2: An example of ocean mapping data collected by Saildrone Surveyor.*

charge batteries, and limiting engine use to battery charging unless absolutely necessary, Surveyor can remain on station for upwards of six months before returning to port. A traditional survey ship would very likely need to return to port multiple times for fuel, replenishment, and crew swap, losing valuable survey days to transit.

In addition, USVs emit very little or zero CO^2 when compared to a survey ship. This makes the overall carbon footprint of Surveyor and other USVs extremely small, hence the "low impact" adjective. This advantage is being recognized and, primarily to reduce the effects of CO^2 on our climate, is often seen as a contract requirement to use carbon friendly methods in survey operations. But low impact is more than just about carbon – USVs significantly reduce impact to the environment by simply being uncrewed and quiet. Crewed vessels not only use tremendous amounts of fuel for propulsion and power generation, but they also must provide hotel services, such as food storage and preparation equipment, bathing facilities, and air conditioning for the people on board. Overboard discharge of pollutants and fuel is always a possibility, especially because of a collision or grounding. While USVs are not excluded from the risk of accidents, there is not a significant amount of fuel or pollutants on board. Finally, ships are very noisy despite efforts to reduce machinery and propeller noise projected into the ocean. Specific impacts of ship-generated noise on ocean inhabitants, especially marine mammals, continues to be the focus of significant research, especially as ships have become the most ubiquitous and pervasive source of anthropogenic noise in the oceans. USVs, especially the Surveyor, are incredibly quiet during operations, which is good for the environment and even better for collecting sonar data.



▲ *Figure 3: High Seas Bathymetric Coverage (Courtesy: Esri).*



▲ *Figure 5: An example of transit ocean mapping data collected by Saildrone Surveyor.*

LELI OPERATIONS WITH SAILDRONE SURVEYOR

The challenges of high seas surveying outlined above have been mitigated by the Saildrone Surveyor, a USV capable of harnessing renewable energy to transit to remote areas of the ocean and survey for months at a time. For any USV, the main components for success are the availability of power, robust communications, and precise, safe navigation. Surveyor uses both solar and hydro generated power to charge the battery banks on board; a small diesel engine is also available for additional power generation and propulsion, if needed. Although much larger than Saildrone's original Explorer (7 m) class USV, Surveyor retains the unique rigid wing design that enables efficient propulsion from the wind with minimal electric power required. However, Surveyor's modern multibeam sonar systems, the Kongsberg EM 304 and EM 2040, require significant, sustained electrical power to operate properly, as does the onboard computer stack, a Kongsberg Seapath positioning system, a winch with attached Sound Velocity Profiler, and a host of other atmospheric and oceanographic sensors.

Captain Brian Connon, US Navy (Ret) is vice president ocean mapping at Saildrone. He is a chartered marine scientist (hydrography) and fellow of the Institute for Marine Engineering, Science and Technology. He also serves as editor for the International Hydrographic Review and is a trustee of The Hydrographic Society of America.

▲ *Figure 4: Saildrone Surveyor departing San Francisco enroute to Honolulu.*

Surveyor is an extremely capable survey platform from nearshore to the deep ocean, but, like all large USVs, it does require satellite communication and navigation systems. The hardware and software for ocean mapping is currently no different from that aboard a ship, which means a surveyor must be on watch to monitor operations, conduct SVP casts, and troubleshoot any problems that might arise. Communication via the Iridium Certus service allows global coverage and sufficient bandwidth for this remote monitoring and limited onboard operations. Survey data is currently not offloaded until return to port; only coverage maps, health and status messages, and quality control information are pushed ashore. Onboard data processing is utilized to prepare the data prior to offload and limit the time required to deliver final products. In the future, higher bandwidth satellite communications combined with direct to cloud services should allow for near real-time offload of survey data. Surveyor's navigation systems, including surface radar, automated identification system (AIS), and a high-resolution camera array add increased power requirements but are necessary components to ensure safe navigation during transit and while on mission. A Surveyor Pilot, operating from Saildrone Headquarters or other remote operations centre, provides vigilant oversight of operations, aided by a virtual bridge and a sophisticated set of alerting algorithms to provide timely images and reports of close contacts, engine performance, and communications status.

LELI USVS PROVIDE A LEAP FORWARD IN CAPABILITY AND CAPACITY FOR OCEAN MAPPING

Seabed 2030 estimates that mapping our deep oceans could take as long as 350 ship years and cost over US$3 billion. As demonstrated by the successful ocean mapping transit of Saildrone Surveyor from San Francisco to Honolulu, LELI USVs offer a substantial and much needed increase in our ability to successfully achieve the goal of Seabed 2030, especially on the high seas. ◂

San Francisco-Honolulu Challenge

In June 2021, the uncrewed, autonomous Saildrone Surveyor arrived in Hawaii after a groundbreaking maiden voyage from San Francisco to Honolulu. While ocean crossings are nothing new for Saildrone's autonomous surface vehicles, the Saildrone Surveyor is a new, much larger class of vehicle that is optimized for deep-ocean mapping. During the 28-day voyage, the Saildrone Surveyor sailed 2,250 nautical miles and mapped 6,400 square nautical miles of seafloor.

Measuring 72 feet long (22m) and weighing 14 tons, the Saildrone Surveyor carries a sophisticated array of acoustic instruments that is normally only carried by large, manned survey ships. The Surveyor's sensors interrogate the water column, looking at underwater ecosystems and mapping the seafloor in high resolution to a depth of 23,000 feet (7,000m).

Multibeam data from the Saildrone Surveyor has been calibrated and assessed by an external team from the University of New Hampshire (UNH), which normally calibrates large government survey vessels. "The data quality from the Surveyor is of very high quality; as good as anything we have seen from a ship," said Larry Mayer, director of the UNH Center for Coastal and Ocean Mapping (CCOM). "Due to the wind-powered nature of the vehicle, it is very quiet, and this enables the very accurate acoustic measurements needed to map to these depths."

"This successful maiden voyage marks a revolution in our ability to understand our planet," said Richard Jenkins, Saildrone founder and CEO. "We have solved the challenge of reliable long-range, large-payload remote maritime operations. Offshore surveying can now be accomplished without a large ship and crew; this completely changes operational economics for our customers. Based on this achievement, I am excited to apply Saildrone Surveyor technology to other markets normally reserved for large ships, such as homeland security and defence applications. The implications of a low-carbon solution to these critical maritime missions are significant."

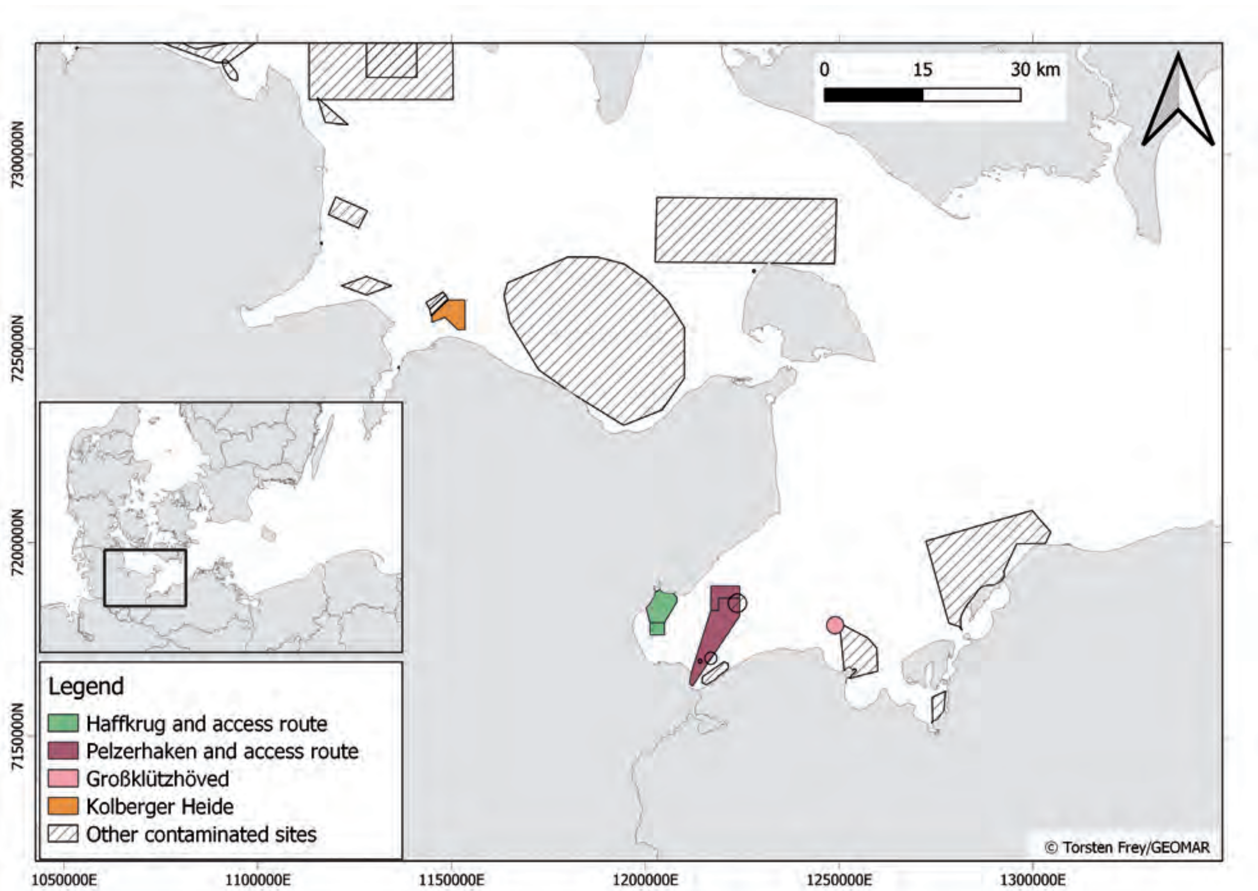
High-performance UXO Detection and Visualization

Uncovering the Secrets of German Marine Munitions Dumpsites

In November 2020, a team of researchers from GEOMAR and EGEOS embarked on an unusual round trip across the German Baltic Sea. Their mission was to shed light on the little-known postwar legacy of munitions dumpsites and to improve technologies for their detection.

On a sunny November morning, the scientific team of GEOMAR Helmholtz Centre for Ocean Research Kiel and EGEOS GmbH boarded the research vessel ALKOR. After five long days in quarantine and upon receiving negative Covid-19 test results, it was finally possible to embark on the trip to munitions dumpsites in the German Baltic Sea. The working schedule was tight, and the dry lab was packed with computers for data acquisition and processing. As the research vessel ALKOR left Kiel harbour, the sea was calm and smooth. With the sun reflecting on the water, not many people were aware of the thousands of tons of dumped munitions from World War II (WWII) rusting below the sparkling surface. Nevertheless, the contamination is very real because around 300,000 tons of munitions are located within the German waters of the Baltic Sea.

Over the years, numerous research projects have focused on chemical munitions dumpsites



▲ *Figure 1: Overview map of the marine munitions dumpsites in the area of Kiel Bay and Lübeck Bay, showing the dumpsites Kolberger Heide, Haffkrug, Pelzerhaken and Großklützhöved.*

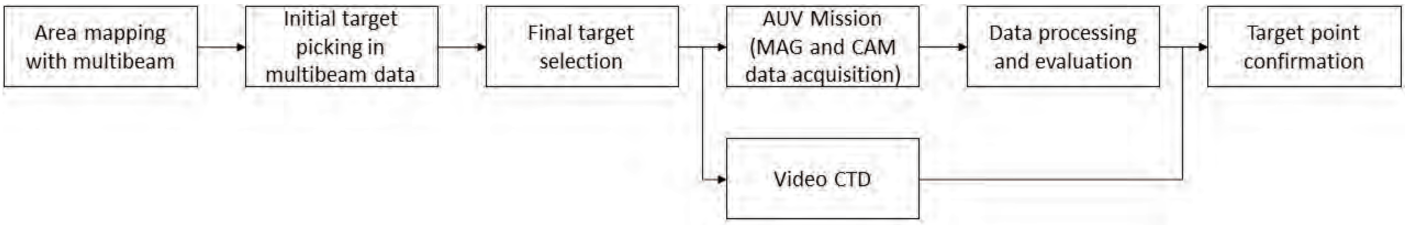


Figure 2: Workflow from initial multibeam mapping to target point confirmation.

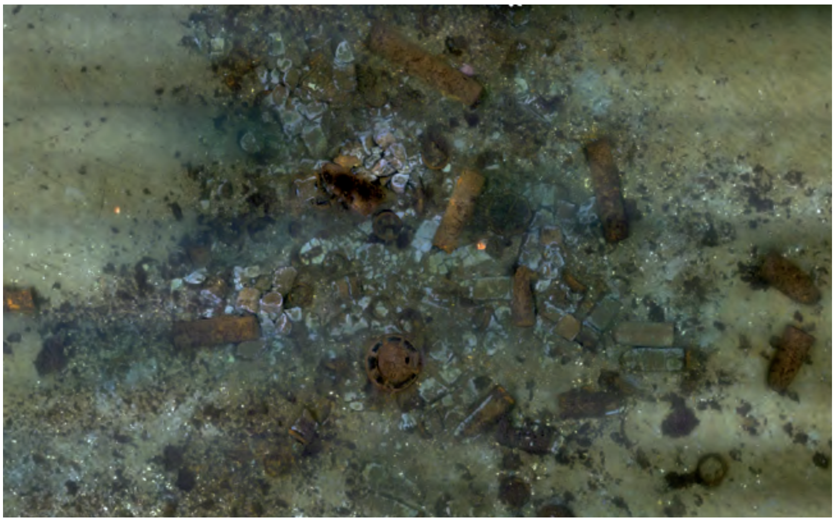


Figure 3: Photomosaic of a munitions pile in dumpsite Kolberger Heide.

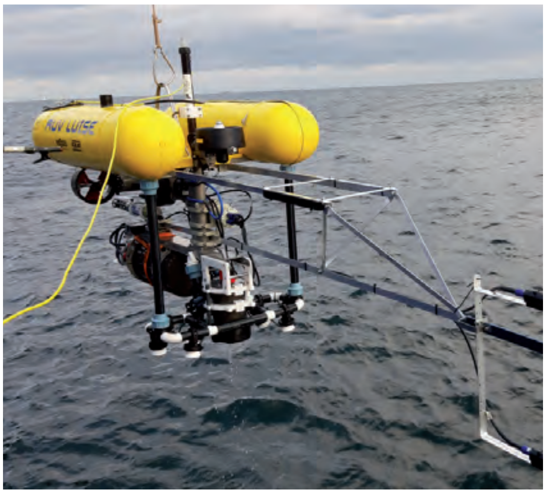


Figure 4: Two fluxgate magnetometers arranged as a vertical gradiometer mounted on GEOMAR's AUV LUISE.

in the Baltic Sea, located in the Bornholm, Gotland and Gdansk Deeps. It is only recently that the much larger conventional (i.e. explosive) munitions dumpsites were identified as a potential area of concern. The MineMoni-II trip was conducted as part of two EU-funded projects – BASTA and ExPloTect - both of which aim to improve detection capabilities. In the case of BASTA, the goal is to make hydrographic and geophysical mapping more efficient by advancing AUV-based data acquisition, applying artificial intelligence and developing data quality factors. The purpose of ExPloTect, on the other hand, is to enable near-real-time detection of dissolved explosive compounds in the water column. During the trip, this toolkit was used in all of the main munitions dumpsites in the German Baltic Sea: Kolberger Heide, Pelzerhaken and Haffkrug (Figure 1).

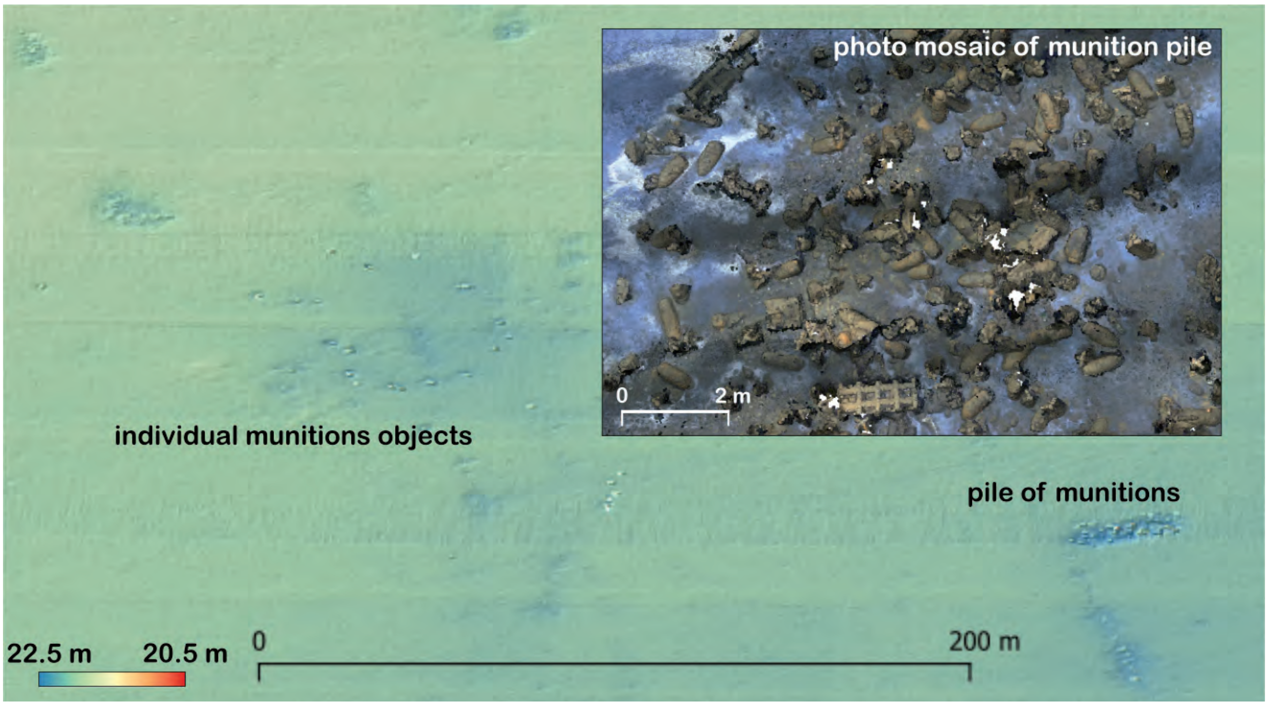
The trip focused on the acquisition of high-resolution multibeam data. Based on this, contact lists, indicating potential munitions objects, were produced immediately on board. Subsequently, the researchers conducted AUV-based surveys to promptly verify whether potential contacts were indeed munitions objects. All of this was supplemented by towed video (TV)-CTD profiles that were used to investigate spectacular hot spots. Figure 2 shows the workflow that led the researchers from an entirely unmapped area to detailed knowledge about individual target points.

THE JOURNEY STARTED IN A KNOWN ENVIRONMENT

The first research area of the trip was reached only 1.5 hours after the departure from Kiel. The Kolberger Heide is a munitions dumpsite in the outer Kiel Bay, located only 2km offshore. Previous multibeam investigations had already revealed more than 1,000 large munitions objects, such as torpedo heads, ground mines, moored mines and depth charges. Historic research suggests that overall roughly 30,000 tons of legacy munitions are located in the area. It is the best-known dumpsite in Europe and there is still much more to explore.

The GIRONA 500 AUVs known as ANTON and LUISE tirelessly mapped and collected magnetic data and underwater images of the seafloor and the munitions objects beneath their tracks. The advantage of these AUVs is their hover-capability, which enables movement at a very slow pace close to the seafloor and allows them to turn almost on the spot. These are necessary requirements for dense photographic investigations and high-resolution magnetic surveys. With each AUV dive, around 10,000 images are produced, which are processed to create photomosaics. It took approximately 20 hours for one mosaic to be generated. For this reason, two PCs, equipped with high-performance GPUs and memory were running non-stop. The effort was worth the waiting and each mosaic revealed a detailed look at the munitions on a millimetre scale (photomosaic resolution: 5mm) (Figure 3).

The hover-capability of the AUVs enables movement at a very slow pace close to the seafloor and allows them to turn almost on the spot



▲ *Figure 5: Multibeam data of the marine dumpsite Pelzerhaken; cell size 0.5m. Several dumped objects and a pile of munitions are visible. The pile extent is around 30m in length and 10m in width and the pile is composed of numerous bombs and other types of munitions, as shown in the photomosaic.*

AUV Luise played an additional role, as it also carried two Sensys 3-components fluxgate magnetometers. The research vessel ALKOR cannot navigate dense profile lines with line spacing of 1m. The AUV, on the other hand, is an ideal platform for precise navigation and high-resolution magnetic mapping. Once deployed, the AUVs can conduct surveys for several hours. To reduce the magnetic noise that originates from the AUV, GEOMAR constructed a modular system of aluminium poles that could be attached to the AUVs. The magnetic sensors were installed at a lateral distance of 2m to the front of the AUV (Figure 4). Each magnetometer sampled three spatial components at a rate of 200Hz. In this way, it was possible to determine whether a target object was ferromagnetic or not – independently of the turbidity of the water or from biofouling, which sometimes impedes distinction between, for example, a moored mine and a spherical rock.

NEXT STOP: LÜBECK BAY

Once the remaining gaps in the multibeam map of Kolberger Heide were filled and selected targets were investigated by AUV missions, the ALKOR was on its way to the next dumpsite. The transits to and between the research sites had been planned along WWII constraint routes. These routes were continuously cleared by German minehunters during the war and were thus the main targets of the British Royal Air Force for remining and bombing. Accordingly, larger numbers of mines and bombs were to be expected along these routes. During transits, water samples were taken with CTD-(conductivity, temperature, depth) rosette-mounted Niskin bottles. Similar sampling had been conducted in 2018, during the MineMoni-I trip. By resampling at the same locations, the scientists started to create a time series, which will help to obtain a comprehensive understanding of the distribution of explosive compounds (inter alia trinitrotoluene (TNT)) across the German Baltic Sea.

Two additional dumpsites are located in Lübeck Bay (Pelzerhaken and Haffkrug) where 65,000 tons of munitions were dumped after WWII. In the nearby harbours of Neustadt and Travemünde, barges were loaded with train loads of all kinds of conventional munitions. Additionally, over the years, 1,000 tons of blast furnace slag from Travemünde was dumped in the Pelzerhaken area. Detailed bathymetric mapping had already been conducted at both sites in 2018 and in 2020, and data resolutions of 25-50cm were achieved in a water depth of around 20 metres.

Now that ALKOR had reached Lübeck Bay, multibeam mapping continued, and the scientists gained a full understanding of the spatial extent of the two dumpsites. The high-resolution data was acquired by using a

Torsten Frey is a researcher at GEOMAR Helmholtz Centre for Ocean Research Kiel. He is the lead author of the Quality Guideline for Offshore Explosive Ordnance Disposal (EOD) and continues to research new opportunities to improve the quality and efficiency of the EOD process. In his current research, he focuses on risk-based decision-making during UXO clearance operations.

Mareike Kampmeier is a geoscientist at GEOMAR Helmholtz Centre for Ocean Research Kiel. Her research focus is on UXO detection via hydroacoustic systems and high-resolution photo mosaics. She is working on establishing a workflow for automated munition detection and making a mass estimation of dumped munitions in German waters.

Marc Seidel is a geophysicist at GEOMAR Helmholtz Centre for Ocean Research Kiel focusing on electric and electromagnetic methods. Within the BASTA project, he is working on the integration of geophysical sensors into GEOMAR's AUVs.

400kHz RESON T50 multibeam and did not only reveal individual munitions items, but also numerous, at first glance, piles of unidentifiable objects. Owing to high beam density (600 beams/120° swath) and small footprints (0.5x1°), even sedimentary features, such as scours around possible targets could be observed. Based on this data, a contact list was created and once again the AUVs were deployed for mapping. After the trip, detailed processing and interpretation of the data revealed that the Pelzerhaken area alone contains at least 1691 individual munitions objects and 127 piles of munitions. The different distribution patterns originate from two very different methods of dumping. One way was to throw the munitions overboard, which led to individual objects sometimes forming lines or other patterns, which now allow the course of a dumping vessel to be retraced. The other method of dumping was to fill barges with munitions and open them once a dedicated site had been reached. This resulted in chaotic piles of both larger objects and boxes containing smaller items. Figure 5 shows both types of patterns in the Pelzerhaken area.

WRECK SEARCH IN AN UNMAPPED AREA

To make best use of the time, multibeam mapping was always conducted at night time. Once the areas in Lübeck Bay had been fully mapped, the researchers spontaneously decided to visit yet another site that is located 6nm to the east. Historic research indicates that the area called Großklützhöved was used to scuttle entire barges that were loaded with munitions. The prospect of investigating a munitions-filled wreck was exciting to everyone on board and when the first wreck was visible in the data, the entire group quickly gathered around the multibeam station. During the course of the night, two additional wrecks (one of which appeared to be a sailing boat) were found. The next day, the two sunken barges were explored using towed TV-CTD with real-time video stream. One of them capsized and lost its hazardous cargo during sinking. In the darkness of the Baltic Sea, a pile of grenade cartridges came into view of the TV-CTD LED spots. The photo and video footage combined with high resolution MBES led to a more qualified estimate of the amount of dumped munitions. For the planning of future UXO remediation, it was essential to gain precise knowledge about the number, location and types of munitions.

During MineMoni-II, there was not enough time to map the entire area of Großklützhöved, so the researchers decided that they would come back in 2021 to finish the job. When ALKOR returned to Kiel harbour, the team were able to look back at two very successful weeks. More than 26km² had been mapped to acquire high-resolution multibeam data. Water samples were taken at 77 locations, which means that over 200 syringes with exchanger resin are stored in the freezer, waiting to be analysed with liquid chromatography-mass spectrometry. The AUVs ANTON and LUISE went on 36 missions to acquire tens of thousands of photographs and finally, 32 TV-CTD profiles were filmed. It will take the researchers a year to evaluate this massive amount of data. By then, they will be ready to embark on MineMoni-III, which is planned for October 2021. ◂

Disclaimer: With the contribution of the European Maritime and Fisheries Fund of the European Union (Grant Agreement No: 863702 (BASTA); 863693 (ExPloTect)

Exploring the Marine Environment in South Africa

Using Machine Learning to Derive Benthic Habitat Maps

The South African Council for Geoscience recently launched an initiative to optimize marine geophysical data collection in South African waters. The main aim of the initiative is to produce marine offshore maps with 100% seafloor coverage in the highest resolution currently possible, according to International Hydrographic Organization (IHO) standards. Scientists set to work and developed a tool to classify seafloor bathymetry and a predictive tool that classifies geological data into substrate maps using machine learning techniques.

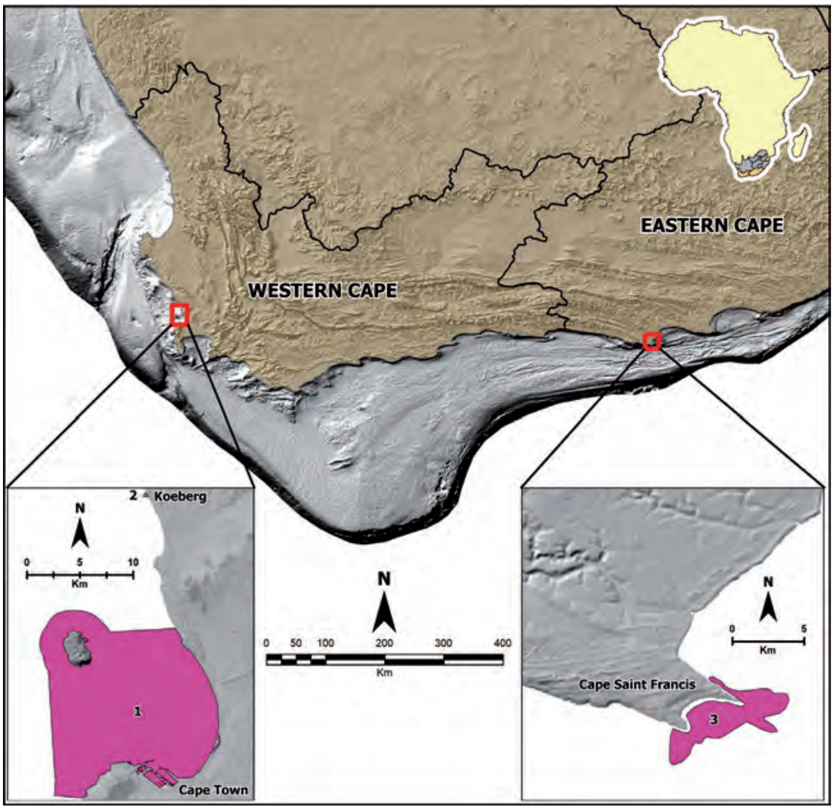
In the recent history of southern Africa, there has not been a large-scale systematic marine geophysical offshore mapping project. This lack of data resulted in the Council for Geoscience initiating its own offshore mapping programme to optimize marine geophysical data collection. The main aim of the initiative is to produce marine offshore maps with 100% seafloor coverage in the highest resolution currently possible, according to International Hydrographic Organization (IHO) standards. One of the main focuses of the strategy has been technology and innovation in mapping, to better inform research projects and build on the collective knowledge in the marine sphere. The programme also plans to advance the public understanding of science exposing the character of the seafloor, which has been underrepresented up to now.

As South Africa collates and acquires new hydrospatial data, it is imperative that these datasets are used for a range of applications. Benthic habitat mapping considers the distribution of biological habitats, as chiefly governed by morphology and geological substrate, and lends itself to applications of machine learning, and the South African seafloor is both vast and variable in composition. This method of mapping using machine learning in combination with marine geophysical and biological data, tested in multiple sites across the South African coastline, will aid in improving our current understanding of the relationships between biota and physical habitats.

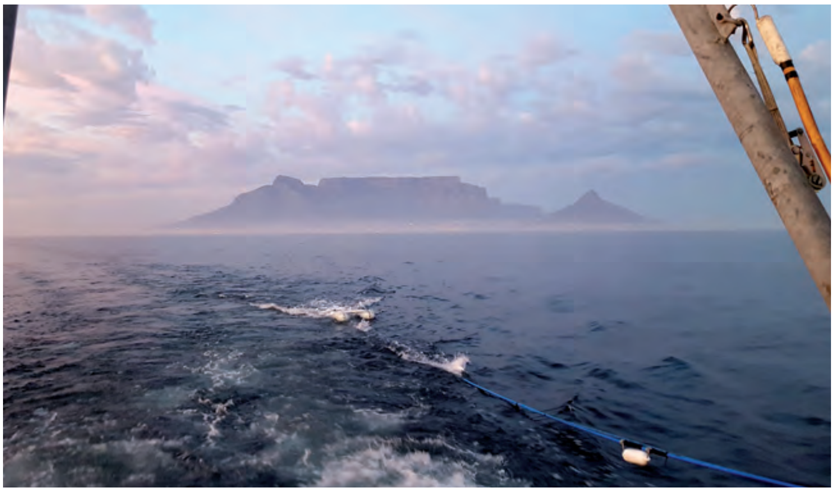
▲ *Figure 1: Combining machine learning and marine geophysical data in an innovative way to enhance benthic habitat mapping techniques.*

TECHNICAL SPECIFICATIONS FOR DATA COLLECTION

The multibeam bathymetry and backscatter data acquired from the investigations undertaken so far were collected using a pole-mounted 400kHz R2Sonic 2024 multibeam echosounder, with motion correction and dynamic positioning for the system provided by an Applanix POS M/V Oceanmaster inertial motion reference unit (IMU). Positioning was derived from a differential correction from a C-Nav 3050 DGPS. Survey line planning facilitated full seafloor coverage. The acquisition of data close to the coastline or in shoaling areas was not possible because of the presence of thick kelp beds and/or dangerous surf conditions. It took approximately 70 days to process and interpret ~5,000 kilometres of data, with all data acquired and processed using QPS Qinsy and Qimera software. The bathymetric data was levelled to Mean Sea Level using an SBET solution relative to the SAGEOID2010 orthometric model. The final bathymetric grid was resolved into 1m (shoalest depth) bins/tiles/pixels.



▲ *Figure 2: Locality map of Koeberg, and Clifton and Table Bay found along the Western Cape, as well as Cape St Francis found along the Eastern Cape of South Africa.*



▲ *Figure 3: Data collection offshore of Table Bay in April 2017.*

Conventional sidescan backscatter data was acquired using a dual-frequency (500/100 kHz) Klein 3000 sidescan sonar, which was towed behind the survey vessel using a CSW-9V winch. Lines were acquired using a scan range of 75m with 15% overlap of adjacent lines and full ensonification of the seafloor. The position of the towfish was determined using the reciprocal-layback method, transmitted in real time to the acquisition software via a radio modem. This data was processed using NavLog proprietary software to produce four sidescan sonar mosaics with a pixel resolution of 10cm. The multibeam derived backscatter data was processed using QPS FMGT™ to generate a final mosaic with a 0.5m resolution.

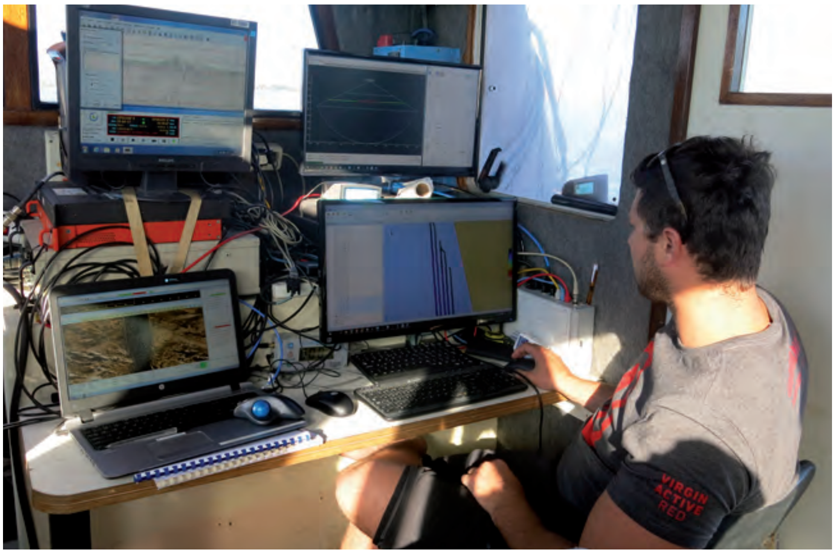
DIFFERENTIATION OF MACHINE LEARNING TECHNIQUES

Over the past two decades, machine learning has become a cornerstone in information technology, as increasing amounts of data are now available to scientists in various fields. This accumulation of data along with the need for efficient data analysis will become a necessary component for technological advancement in the future. Machine learning is based on computer modelling processes and their multiple manifestations; it combines task-orientated studies, cognitive simulations and theoretical analysis to interpret and understand a wide variety of datasets.

In machine learning, there are two main categories of data classification: namely supervised and unsupervised. Supervised classification refers to the use of image processing software that is guided by the user to specify the categories into which the data should be classified. During supervised classification, ground-truthed data is classified and then used to constrain the interpretation of the acoustic data. Unsupervised classification refers to a method where the outcomes (groupings of pixels with common characteristics) are based on the software's analysis of an image without the user providing sample classes. The software then determines which pixels are related and groups them into classes.

In the first phase of an initiative to develop capability to do semi-automated benthic habitat mapping in South Africa, three different machine learning techniques were tested in Table Bay, South Africa to find out which would be the most cost-effective, efficient, easy-to-use algorithm for the multibeam bathymetry, backscatter and sidescan sonar data collected by the Council for Geoscience, as part of a national offshore mapping programme. Initially, an unsupervised method of classification was chosen, with these results being compared to historical data interpreted in the area, to ensure a level of accuracy.

Decision Tree Classifiers, Random Forests and k-means clustering algorithms were used to classify the hydroacoustic data. These unsupervised classification methods were combined with a classification accuracy measure to ensure the validity of the results. The advantages and disadvantages of each algorithm were identified and the k-means clustering method was understood to be the best suited for our multibeam bathymetry and backscatter applications. This algorithm was conceptually simple and easy to implement, versatile, easily updated, efficient and computationally fast, and could store large amounts of data. The Decision Tree Classifier tended to over-fit data, did not work well with



▲ *Figure 4: Above: Data acquisition in Table Bay, including sidescan sonar, multibeam and pinger data. Below: The Council for Geoscience survey vessel R/V Nkosi at sunrise.*

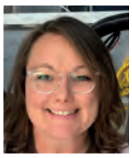
complex data or noisy data, whereas the Random Forest algorithm was slow in the pre-processing stages, and in generating predictions due to the multiple decision trees being output, the model is difficult to interpret.

CREATION OF SUBSTRATE AND BENTHIC HABITAT MAPS USING K-MEANS CLUSTERING

The k-means clustering algorithm was then used to create substrate maps in two contrasting study areas (Clifton and Koeberg, in South Africa), with differing geological settings. Drop camera footage and sediment grab samples were collected from the sites for the purposes of ground-truthing and improving the accuracy of the k-means clustering algorithm. Drop-camera footage was classified using the Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) substrata classification scheme and sediment grab samples were processed using a settling tube. The statistics from the samples were used to define the sediment categories that were input into the clustering algorithm, in order to validate the results and reinforced by determining the measure of classification accuracy. The algorithm results reiterated that if it is supplemented with new data, with differing seafloor characteristics, and a combination of different input datasets, it can create more reliable and accurate final substrate map products.

The k-means clustering algorithm was further refined in an area that has significant variability in geology and terrain, in comparison to the first test sites that were composed mainly of unconsolidated sediment. Multibeam bathymetry, backscatter and ROV footage were collected in Cape St Francis, South Africa, and the hydroacoustic data was processed using machine learning k-means clustering. Eight ROV dives took place along the three transects, ranging from 30-80m in depth and the ROV footage was classified using the CATAMI substrata classification scheme. The most common Phyla ordered from most abundant to least abundant were; Cnidaria, Mollusca, Echinodermata, Chordata (fish species), Arthropoda (Subphylum Crustacea), Bryozoa, Porifera and Chordata (Class Ascidiacea). These species were identified both on rocky substrate and sand. Using this scheme, each species class was assigned a colour and input into the k-means clustering algorithm, which linked each sediment class of the substrate map to a species class. This was done using the k-means clustering algorithm as the intensity of the backscattered waves for species classes could be linked to the intensity of similar seafloor substrates. The algorithm was able to create a map with ten different benthic habitats that combined all the input datasets (multibeam bathymetry, backscatter data and ROV footage). The benthic habitat map of the area was able to

Dr Talicia Pillay. Talicia Pillay is a Scientist within the Marine Geoscience Unit at the Council for Geoscience with a PhD focusing on benthic habitat mapping using machine learning techniques. She has both theoretical and practical experience in a number of marine geophysical datasets, as well as being proficient in Python coding and algorithm writing, with an emphasis on artificial intelligence.



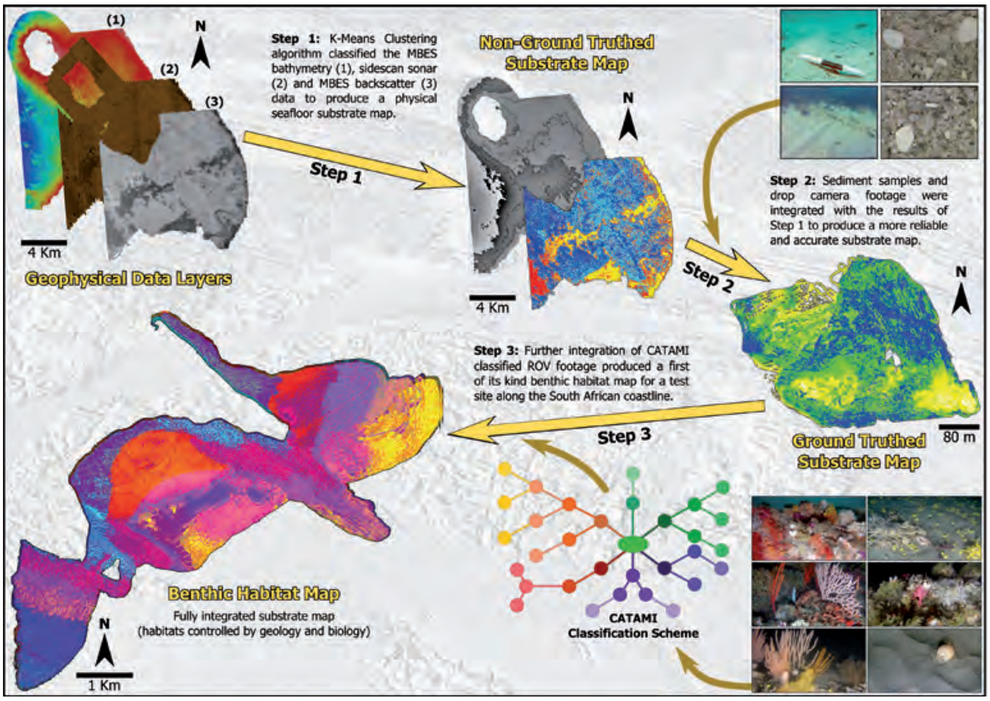
Dr Hayley Cawthra - Pr.Sci.Nat. Hayley Cawthra is a Chief Scientist in marine geoscience at the Council for Geoscience, South Africa, and a Research Associate at the Nelson Mandela University. She has a PhD from the University of Cape Town and specializes in past sea-level change, palaeoscience research from seafloor proxies, and interpreting human use of ancient coasts.

Michael MacHutchon – MSc (Geology), Pr.Sci.Nat. "Mac" is a specialist marine geophysicist with over 17 years of experience in advanced geophysical post-processing and coastal, near- and offshore morphodynamics. He is a specialist in the use of all marine geophysical instrumentation suites and a variety of acquisition and post-processing software. Internationally published, including a substantial amount of commercial scientific reports, he is passionate about marine geoscience and always open to new ideas and techniques to improve our understanding of this dynamic environment.

use machine learning to identify and quantify different habitat types, accounting for geology, topography, sediment cover and species distribution.

CONCLUSION

Like most coastal nations, South Africa is exploring avenues to grow its oceans' economy and better understand the marine environment, yet relatively little is known about the distribution of the country's offshore benthic biodiversity. Given the considerable expense of sampling deep benthic biodiversity, models created from hydroacoustic data can be helpful in creating benthic habitat maps, which can in turn be used as surrogates for unsampled bioregions. With high quality and accurate modern hydroacoustic systems in combination with machine learning techniques, the ability to survey and sample in logistically challenging areas, with small operating budgets, can now be achieved. Furthermore, this study has demonstrated the importance of implementing machine learning techniques to improve map accuracy and reduce processing time. ◂



▲ *Figure 5: An overview of the processes and methods used to classify the multibeam bathymetry and multibeam backscatter data. This image highlights the multiple steps and input datasets required in order for the machine learning algorithm to create a reliable and accurate benthic habitat map.*

Combination of Strengths

Proclaimed in 2017 by the United Nations General Assembly and after yearlong preparations by UNESCO's Intergovernmental Oceanographic Commission (IOC) to coordinate the later implementation, the first week of June saw the official opening of the UN Decade of Ocean Science for Sustainable Development (2021-2030).

The Ocean Decade provides a convening framework for scientists and stakeholders from diverse sectors to develop the scientific knowledge and the partnerships needed to accelerate and harness advances in ocean science. This will lead to a better understanding of the ocean system and deliver science-based solutions to achieve the overarching UN agenda on sustainable development goals to create a better world by 2030.

Being a longstanding partner of IOC, it was clear from the beginning of this programme that IHO would be among the stakeholders to proactively contribute. IHO's official definition of hydrography suggests that our discipline is an "applied science" and it seems to me that this is the best precondition to be part of the Ocean Decade, since the request to undertake ocean science for sustainable development is exactly the call for the productive application of new insights gained.

The known strengths of the IHO´s expertise lie in ocean mapping and standardization. For the latter, IHO´s S-100 universal hydrographic data model framework offers a unique opportunity to merge hydrographic measuring of the ocean´s physics such as seabed topography, sea level, tides, currents, and also elements like temperature and salinity with marine chemistry and marine biology in a new way. Emphasising that "all the physics of the seas" are under the remit of hydrography sheds light on a new balance between the general scopes of hydrography and oceanography. There is no sharp categorization but, to my understanding, hydrography measures the phenomena and oceanography delivers the interpretation of the effects observed. If this is becoming the common understanding, the classic question for hydrographers "What does the seafloor look like?" can be supplemented by "What is in the water?".

The self-concept of hydrographers as being more engineers of the blue than scientific observers of the marine environment delivers an ideal combination of both strengths. I was recently invited to contribute to a broadcast named "Planet beyond". The moderator asked me for practical examples of the outcome I expect from the Ocean Decade in relation to our corporate activities. Here they are:

- I hope to see an all-embracing digital data model in place for all kinds of marine geoinformation based on IHO´s S-100 framework. If, in the future, all sorts of marine data is formatted according to this paradigm, it would be fully interoperable and could be easily combined.
- For our GEBCO ocean mapping programme in collaboration with the Seabed2030 project, I hope we can receive nearly full global coverage in a decent accuracy and resolution. For that we need more and better data. We are hoping for contributions from all actors, including ships of opportunity. For them, we have developed our crowdsourcing bathymetry campaign. Seafarers and shipping companies are very motivated to contribute but, so far, only thirteen coastal states allow this sort of citizen science in their respective waters of national jurisdiction. I hope that by the end of the decade all of the almost one hundred IHO Member States will have given permission for the use of crowdsourced bathymetry.
- For the blue water, I hope that IOC´s ARGO programme can establish a regular routine and that the descending floats report depths and positions back to us. This would be particularly helpful in remote areas such as the Southern Ocean.
- I note that the matter of microplastic monitoring is currently entering the global agenda. I hope that research & development can feed us with smart through-flow measuring sensors to be mounted on autonomous units. The hydrographic offices of the world are champions in repetitive in-situ measurements and the collective processing of the results. If plastic pollution can be monitored, we will be able to contribute.

Mathias Jonas, Secretary-General, IHO.

The collaboration of GEBCO and ARGO and the monitoring of microplastics would be perfect examples of how engineers and scientists could collaborate to find new answers to "What does the seafloor look like?" and "What is in the water?"!

High-density Airborne Lidar Sensor Ideal for Challenging Coastal Survey of Sylt

Arctia-Meritaito has efficiently produced a seamless digital terrain model of land and water along the shallow coastal areas of the German island of Sylt, using a Leica Chiroptera 4X airborne bathymetric sensor.

Bathymetric surveying offers a unique opportunity to capture Lidar point clouds and images of the transitional zone comprising shallow water and coastal land. This information provides valuable insights into environmental conditions, supports research and planning to protect vulnerable locations and aids marine navigation.

Coastal surveys are greatly influenced by the quality of the water, which can be degraded by swirling sand, algae, and seaweed. Difficult conditions in the North Sea compound these issues and increase the importance of fast data collection and reliable operations. Finnish company Arctia-Meritaito Ltd. successfully completed an airborne topographic and bathymetric survey on Sylt, a popular German island known for its vacation resorts and 40-kilometre-long sandy beach, using a Leica Chiroptera 4X as its surveying instrument.

▲ *Sylt Island in northern Germany on the border with Denmark.*

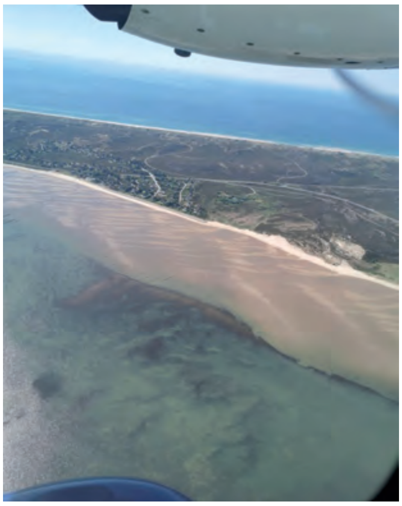
THREATS TO THE ISLAND

The German island of Sylt lies on the outer edge of the Schleswig-Holstein Wadden Sea, between 9–16 km off the mainland. While other islands in the North Sea are surrounded by extensive intertidal sand and mud flats - called wadden - that protect the coastlines, the west coast of Sylt is completely unprotected and exposed to the forces of the water. Harsh weather conditions such as strong currents from tidal ebb and flow, frequent sea storms, and waves up to 10 metres high continuously reshape the island, despite attempts to reduce erosion along its sandy beaches. Since the 1980s, preservation efforts have focused on pumping sand back onto the beaches every year, rather than constructing unnatural concrete structures.

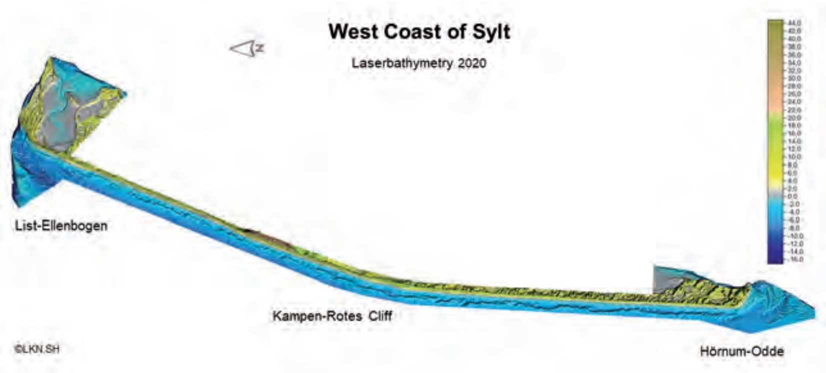
The Landesbetrieb für Küstenschutz, Nationalpark und Meeresschutz Schleswig-Holstein (National Office for Coastal Protection, National Park and Marine Protection Schleswig-Holstein) is responsible for drawing up coastal protection plans and implementing appropriate measures. In recent decades, the organization has experimented with different technologies to identify the most effective methods of maintaining the coastlines.

In the past, surveying vessels carried out the bathymetric mapping of the seabed. For profile lines with a total length of approximately 1,100km, about four weeks was required to allow for the daily varying tide. Mapping was complicated by an underwater reef about 400 – 500m off Sylt's west coast, where the depths rise from about -6m up to 3m. Outside the reef, the depths in the open North Sea fall again to a depth of about -10m. This reef has always been an obstacle to measuring the whole area with a vessel due to potential damage to the ship and equipment.

In 2020, Arctia-Meritaito was selected to survey Sylt with a Leica Chiroptera 4X airborne bathymetric scanner. The Chiroptera 4X can typically penetrate down to 25m and has even reached 30m depth in ideal conditions. The elliptical scan pattern captures a forward and backward view to provide two datasets of the same point, which reduces noise caused by waves and increases depth penetration. In addition, the oblique view of the laser beam captures data of vertical objects. Despite the turbidity and waves around Sylt, the Chiroptera 4X successfully penetrated 10m to reach the seabed, meeting all project requirements.



▲ *Photo of Sylt, taken from the survey aircraft.*



▲ *The west coast of Sylt, captured with the Leica Chiroptera 4X airborne bathymetric system.*

"Bathymetric laser surveying from the air is a more suitable method to capture the coastal area of Sylt," says Lutz Christiansen, head of surveying, topography, and morphology at the National Office for Coastal Protection, National Park and Marine Protection Schleswig-Holstein. "By conducting the survey under favourable weather conditions at low tide, Arctia-Meritaito successfully met the required depth and accuracy with an airplane rather than risking running aground with a ship. Based on these results, the measurements will be performed every three years in the future using airborne bathymetry."

LIMITED WINDOW OF OPPORTUNITY

The most notable challenge of collecting airborne bathymetric data is timing. Perfect timing produces a clean dataset that is fast to process, while bad timing results in a very noisy dataset that does not fulfil the specification, or even no data at all. In the area around Sylt, there are multiple issues. Too much wind causes white water and waves, while algae floating on the surface blocks the laser and fine sand stirred up from the seabed interferes with data collection.

"Being ready at the right time and making the best of the good weather window requires dedication and effort," explains Mikko Ojala, head of airborne Lidar bathymetry, Arctia-Meritaito. "The weather and water conditions can change very rapidly. We cannot perform topographic surveys when it is raining, and airborne bathymetric surveys are impacted by inflows of water from the land that increase turbidity. When conditions are finally right, the equipment needs to be functioning and ready to go."

Spring and autumn, when there is no algae and no ice in the North Sea, typically offer the most favourable conditions. However, seabed material consisting of fine sand is always moving and causing turbidity. As the seabed is frequently changing, overlapping data collected many days apart will not match and will take longer to process. It is crucial to cover the whole project area as quickly as possible to maximize consistency. To capture topographic and bathymetric data of Sylt's west coast and south and north ends, Arctia-Meritaito targeted June 2020. In two days and a total of five flight hours, the team collected 70 square kilometres.

"We flew the whole area with only two flights, with one day between, and still the seabed topography had changed between the flights," says Ojala. "This created a processing challenge because there were two seabeds in some places where the data from the previous flight overlapped."

In addition to Terrasolid for point cloud processing and the QPS hydrographic software suite, Arctia-Meritaito used Leica Lidar Survey Studio (LSS) to process all waveform and position data and incorporate four-band camera data from the Chiroptera 4X. Arctia has a Lidar-specific processing setup based on recommendations from Leica Geosystems.

SURVEY RESULTS SUPPORT ANALYSIS

To ensure high quality results that guide preservation decisions for the future, the surveying contract stipulated that measurements should only be carried out under favourable conditions (easterly winds). Deliverables included point clouds with classifications (1m and 10m grid) and orthophotos. The height accuracy had to be better than 20cm and the positional accuracy better than 50cm. Processing was done completely by Arctia-Meritaito, with results delivered about eight weeks after data collection.

"We achieved a minimum point density of 5 points per square metre in the water, thus demonstrating the Chiroptera 4X fulfils general industry requirements in shallow water," says Ojala. "In addition, simultaneous collection of the bathymetric and topographic point cloud along with aerial imagery is highly efficient and produces a seamless dataset from the land to sea bottom."

The dataset confirms the status of the coastline and allows for further analysis. When compared with previous measurements, the 2020 survey indicates that the sand deposits added to the beach have contributed to the protection of the coast since the 1980s. Lutz Christiansen intends to continue monitoring Sylt with periodic bathymetry measurements.

"I am very satisfied with the results. The Chiroptera 4X reached the necessary depth," says Christiansen. "The data density, accuracy and type of processing met all of our requirements. It was an excellent project that provides an up-to-date status of the west coast and shore area. Now we have a digital terrain model (DTM) from the steep coast of +20m down to -10m water depth."

"Now we collect land and water in one effort, instead of executing a separate survey for the land portion"

DEVELOPMENT OF BATHYMETRIC MAPPING

Arctia-Meritaito specializes in hydrographic mapping, fairway maintenance and maritime navigation, carried out with a fleet of ice-breaking ships and surveying vessels. With its roots reaching back to the Finnish Maritime Administration and its predecessors, the company has highly skilled professionals familiar with the unpredictable waters of the Finnish archipelago and surrounding region.

Traditionally, Arctia-Meritaito surveyed shallower depths with vessels equipped with a single beam echosounder that resulted in depth profiles at defined interval distances rather than complete coverage. This approach left significant data gaps between the survey lines in a single beam dataset.

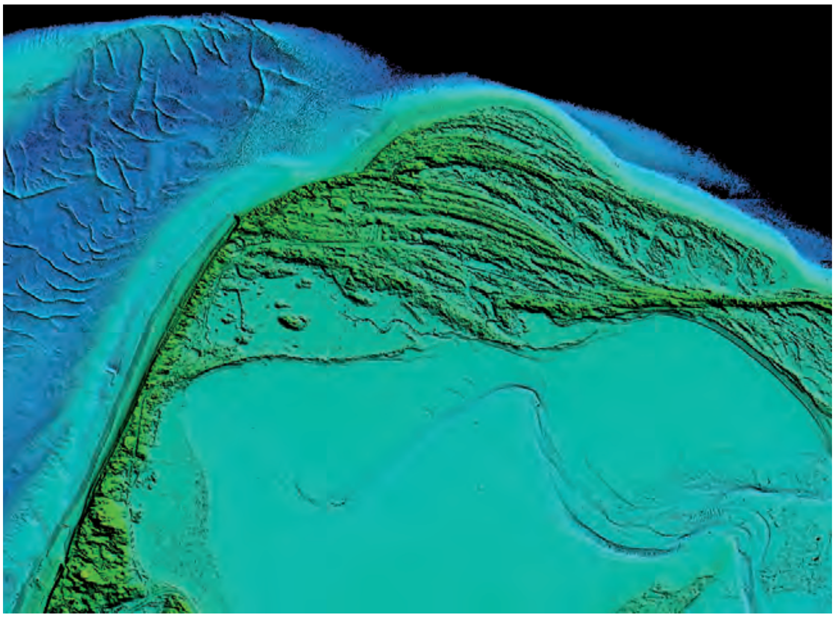
More recently, the multibeam echosounder addressed the data gap issue; however, a multibeam echosounder is not always efficient in shallow waters. The survey swath gets narrower as the seabed rises toward the sensor. Other disadvantages include an increased risk of equipment damage or loss in shallow water if the vessel collides with an uncharted shoal, and the echosounder cannot produce seamless data from water to land.

In 2015, a pilot project was conducted by the Finnish Hydrographic Office that compared the performance of several airborne bathymetric sensors. This project proved that airborne Lidar surveys could meet required mapping standards in shallow water. A subsequent project in 2016 favourably compared airborne Lidar results to single beam and multibeam echosounders. To adapt to changing industry demand and remain technologically up to date, Arctia-Meritaito replaced its single beam echosounder service with airborne bathymetric Lidar.

"There were other sensors in the 2015 pilot project, but we saw that the Leica Chiroptera 4X provided the most promising results," says Ojala. "By replacing single beam vessels with airborne Lidar, we get full coverage in shallow waters with depth penetration down to 25m depending on the conditions, while minimizing the risk of losing sensors. Now we collect land and water in one effort, instead of executing a separate survey for the land portion."

The Schleswig-Holstein national agency for coastal protection has been evaluating airborne bathymetric technology since 1992. By 2015, results from deep-sea airborne Lidar sensors compared to other types of sea measurements showed that airborne Lidar was suitable and able to penetrate the water up to 3x Secci depth. Secci depth refers to a measurement of the turbidity of water, i.e., the depth at which light can no longer penetrate the water.

Thanks to improvements in laser technology and more sophisticated algorithms, today it is possible to reach depths of -25m or more with a shallow-water sensor, such as the Chiroptera 4X, previously attainable only with a deep-sea sensor or echosounder.



▲ *Results of the airborne bathymetric survey with the Leica Chiroptera 4X.*

The French Navy's Hydrographic and Oceanographic Service (SHOM) Tests iXblue DriX USV

Testing and Analyzing Uncrewed Survey Methods

The SHOM – the French national hydrographic service – is planning to replace most of its aging sea-going assets in the near future and, in this context, a four-week sea trial took place in Brest, on the Atlantic coast of France, in September 2020. These trials involved two DriX USVs, as well as the French Navy hydro-oceanographic vessel *Beautemps-Beaupré*, in an area very familiar to the SHOM, where major differences between traditional survey methods and autonomously executed surveys could easily be spotted and analyzed.

▲ *Figure 1: DriX on the deck of BHO.*

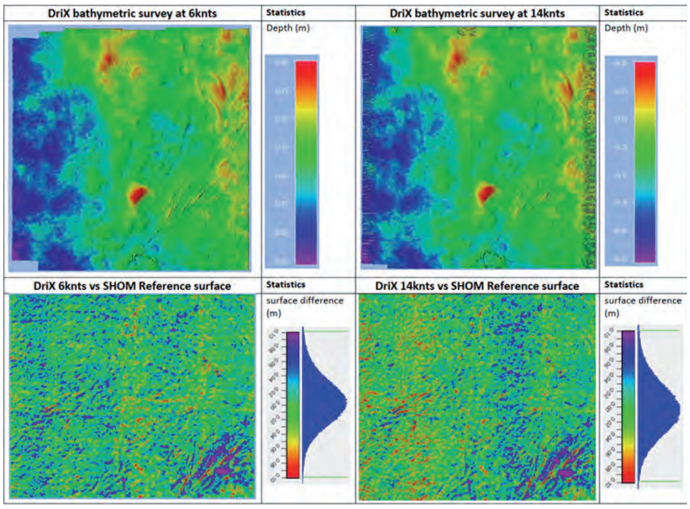
"The two DrixX USVs performed more than 1,100 nautical miles of navigation during these trials."

BATHYMETRIC SURVEYS AND LINE KEEPING

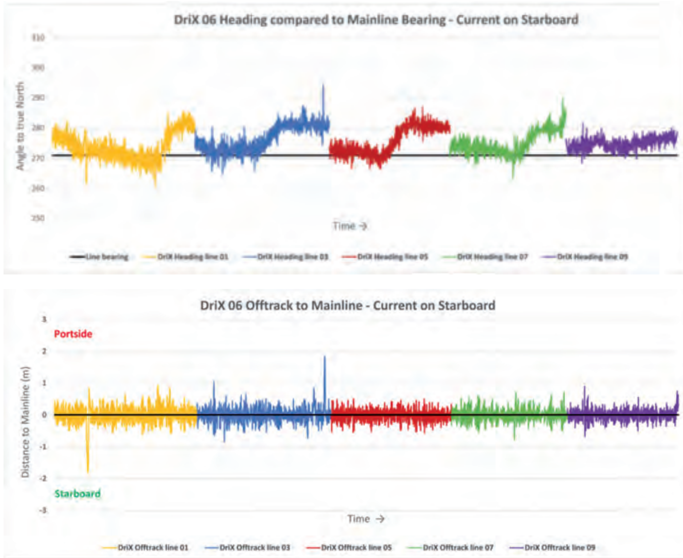
During a period of two weeks, a single DriX performed hydrographic and geophysical surveys. Subsequently, two DriXs operating simultaneously performed the same surveys during a period of 10 days. The quality of the bathymetry of several of SHOM's reference surfaces was assessed, ranging from 10m up to 210m in depth, and at different speeds. The survey sites were at the "Fosse d'Ouessant" with a depth of around 200m, the "Pierres Noires" at 60m, the "Carré Renard" at 20m and the Bay of Douarnenez at 10m.

At the same time, a survey was performed by the RV's own manned hydrographic launches. This allowed a direct comparison between two assets fitted with the same Kongsberg EM2040C and performing in the same environmental conditions.

The following figure displays two surveys performed by the DriX at both 6 and 14 knots on the Carré Renard on a 0.5m grid size. A comparison was made each time with SHOM's reference surface.
Depth ranged from 18.5 to 20.25m.
On the comparison chart, the data distribution is between -0.10m and 0.10m, with a mean difference of 0cm for the 6kn survey and 1cm for the 14kn survey.



▲ *Figure 2: DriX survey at 6 and 14 knots of the SHOM's reference surface "Carré Renard".*



▲ *Figure 3: DriX line keeping in cross tidal current.*

LINE-KEEPING CAPABILITY

The DriX line-keeping capability was monitored when surveys were performed just north of the "raz de Sein" during spring tides, with a side current of up to 2.5 knots. The first figure above on the right illustrates the DriX autonomous heading adjustment while running survey lines (one line for each colour), compared to the theoretical line bearing (black line). The second figure shows the evolution of the offtrack distance to the theoretical line. Each line is about three kilometres long.

It is worth noting that the DriX autopilot constantly adapts to the environment in order to match the CoG (Course over Ground) to the line plan. This is generally achieved 99% of the time, within a metre.

OBSTACLE AVOIDANCE CAPACITY

Among the dozen DriX functionalities tested during these trials, the DriX's obstacle avoidance capacity was put to the test with buoys and vessels deployed in the area and surrounding the DriX during its missions. The purpose of these tests was to determine possible improvement areas in DriX Artificial Intelligence dedicated to obstacle avoidance, and based on information provided by a Lidar and an infrared camera.

During navigation, the DriX is constantly aware of the situation around it and can change the course of its mission. This concept of operation is also known as supervised autonomy or the ability of the USV to operate autonomously to achieve high level mission goals, while being supervised by a remote operator who can take over the USV control whenever the circumstances require it.

The obstacle avoidance test was conducted in two parts:

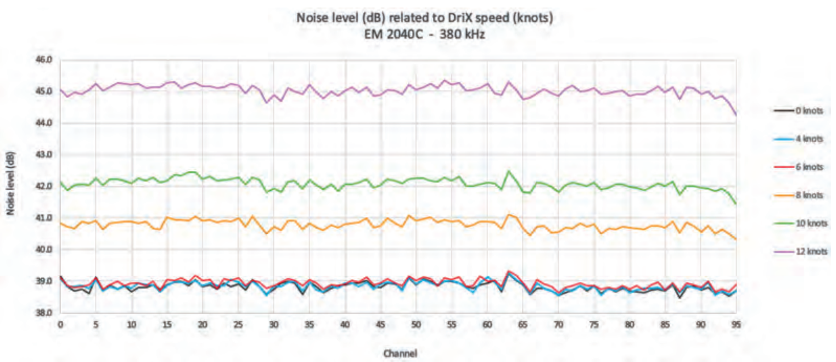
- The DriX's ability to avoid anchored or drifting objects (buoys of several sizes from 10 to 40 cm radius were placed on the DriX's path).
- Ability to avoid moving objects (several vessels from fast rescue boats to survey launches sailed in collision course towards the DriX from different angles and at different speeds. In a second section, two boats circled around the DriX to monitor DriX detecting capabilities and trajectory calculation).

The obstacle avoidance capacity was also tested in a real life situation during the survey phase.

At the time of the trials, the radar was still under development and not integrated into the DriX Obstacle Avoidance System. This reduced the DriX's capacity to detect high-velocity targets. Without the radar, the DriX obstacle avoidance system relied on the detection ranges of the Lidar and cameras, seldom exceeding 200m, thus achieving a very limited provision of warning on fast incoming surface tracks. It is worth noting that since these sea trials, a radar has been added in order to enhance the Obstacle Avoidance algorithm. Additional external sources such as a vessel's AIS position, S57 interpretation, or defined exclusion zones are now also decoded to strengthen the algorithm.

QUIET ENVIRONMENT

Several noise tests were performed during the trials. This was done by recording data from the MBES transducer channels while the DriX was sailing at different speeds.
The DriX and the survey launch were both fitted with the same MBES (a Kongsberg 2040C). Noise measurements were extracted from the MBES



▲ *Figure 4: Noise level spectrum obtained with the Kongsberg EM2040C on the DriX.*

▲ *During navigation, the DriX is constantly aware of the situation around it and can change the course of its mission.*

built-in test function. Results show a level of noise significantly lower for the DriX-gondola-mounted 2040C than for the survey launch one (60dB at 6 knots), and the increase of noise was significantly lower. This will have three main benefits:

- The ability to perform surveys at higher speed with wider swath.
- The ability to increase range of detection and maximise swath width.
- Reducing post-processing time thanks to cleaner data (no spikes).

This noise difference was due to several factors :

- The position of the transducer in the gondola with respect to the DriX hull
- The hydrodynamic shape of the DriX and the gondola
- The material the gondola is made of

The table below illustrates the effects of noise on the detection range and theoretical swath, depending on the depth, the type of signal (Frequency Modulated FM or Continuous Wave CW), and depth.

This theoretical range obtained at both 45db (DriX measurements) and 60dB (Survey Launch) was then evaluated in real conditions in the “Fosse d’Ouessant” area that is around 200m deep. Results show that the swath obtained in real conditions by the DriX is very similar to what was calculated in theory, and the gain in swath width in reduced noise environment conditions is more than double.

Based on other survey area tests, results computed by SHOM also show:

- IHO special order bathymetric survey validated at 10 knots for up to 20m of depth (sea state 1);
- IHO order 1a bathymetric survey validated at 13 knots for up to 20m of depth (sea state 1);
- surface covered per day with one DriX is up to five times more compared to a conventional survey launch;
- No impact of the sub bottom profiler acquisition on bathymetric data;
- Reduced time for post processing with a cleaner unspiked raw dataset.

Regarding that last point, using a DriX the figures observed during the trials were:

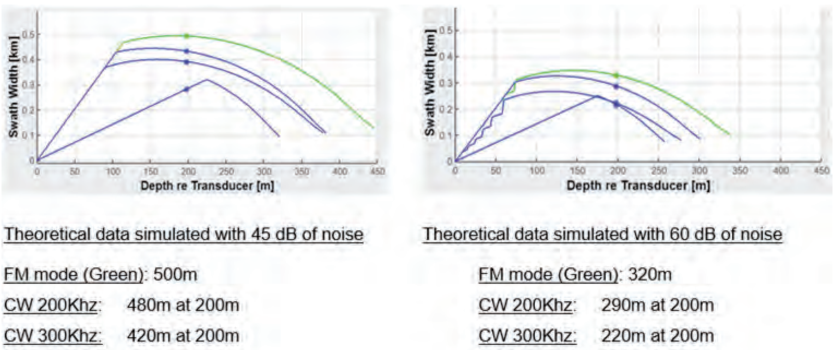
- Data collection: 1 day;
- Data cleansing: 0.3 days;
- Data reporting: 1 day.

VERSATILITY

The other interesting point is that the work environment for the hydrographer remains the same as on board traditional assets. The hydrographic computer is installed on board the DriX USV, and the hydrographer accesses it from the relative comfort of the mother survey vessel.

Concerning versatility, the DriX, as fitted for these particular trials, could not outperform the traditional survey launch, mainly due to its 2-metre draught. However, since the trials, iXblue has found solutions to reduce the DriX draught to under a metre, giving the USV access to these kinds of very shallow water areas.

The Drix, which has been in operation for more than 10,000 hours, is an 8m long Unmanned Surface Vessel (USV) dedicated to hydrography. It is able to conduct both remote-controlled and supervised autonomous operations (within visual range or Over The Horizon), even in complex weather conditions, thanks to a highly hydrodynamic monohull and a drop keel that provide the USV with great stability and balance, even in high sea states. This provides high seakeeping and line keeping (up to sea state 5) and speed capabilities (up to 14 knots) and offers optimum conditions for high quality data acquisition. Sensors are embedded within a gondola located 2m below the surface, in a highly reduced noise and bubble-free environment.



▲ *Figure 5: Theoretical swath width and range detection depending on signal type and depth*

ENDURANCE

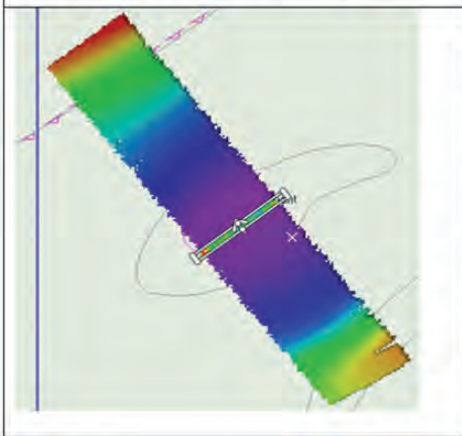
Endurance is always hard to determine accurately. It is hugely affected by the meteorological environment, as well as payloads and gondola shapes. Two trials were dedicated to this on 24/24 operations over two periods of three days each, with one and two DriXs. Although the speeds were not constant and the DriX configurations were different, an endurance of six knots for six days was extrapolated on this occasion. This is compared to a small, crewed vessel that has a maximum endurance of 12 hours.

HYDROGRAPHICAL CAPABILITY

Survey launches are currently able to perform sediment sampling and have the capability of towing additional sensors such as a magnetometer or a side-scan sonar. At the time of the trial, the DriX did not have the ability to tow these types of sensors, hence this gap in the analysis. Since the trials, iXblue has developed a new solution that allows the DriX to tow several magnetometers and a side-scan sonar whilst performing bottom imaging and/or UXO surveys. This now surpasses the ability of a survey launch, except for station tasks.

CONCLUSION

Thanks to the support showed by the French DGA, SHOM and the crew of the French Navy vessel *Beautemps-Beaupré*, iXblue was able to prove that the DriX USV is a useful hydrographic tool. In the time between the trials and the writing of this article, a lot has been done. The DriX is now able to perform its own sound velocity profile, to conduct Over The Horizon missions, a navigation radar has been implemented and a towing solution is being finalized for magnetometers and side-scan sonars, to name but a few new things. In the end, it was evident that interfacing new and old technologies could easily be done. The same goes for people.



Survey carried out by DRIX on the "Fosse d'Ouessant" (CW – 300Khz) – 200m depth

DRIX Swath	450 m
Theoretical swath with 45 dB of noise	420 m
Theoretical swath with 60 dB of noise	220 m
DRIX / theoretical 45db	+ 7%
DRIX/ theoretical 60Db	+104%

▲ *Figure 6: Swath width obtained by the DriX in the Fosse d'Ouessant.*

sponsored article

IIC Academy Launches S-8B Marine Geospatial Information Programme

Although navigational charts play an essential role in guaranteeing safe passage through our oceans, the information they contain also has many other uses beyond safe journeying from point A to point B.

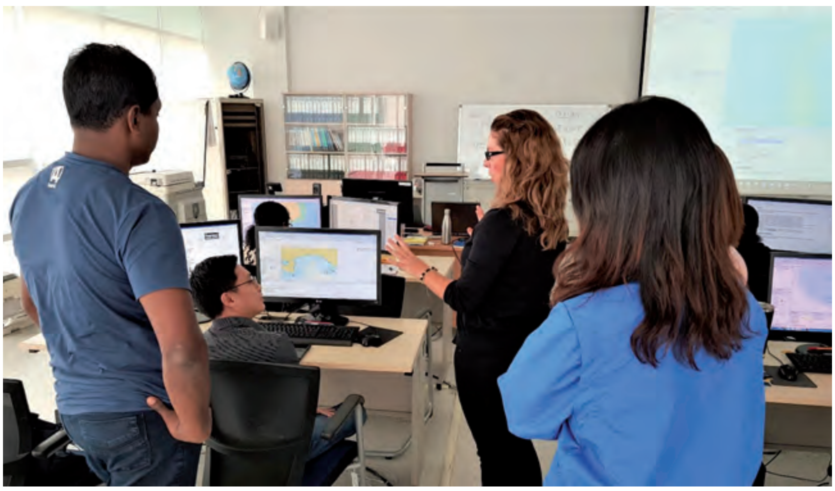
The IIC Academy has put together a comprehensive training course, focused on all the aspects of nautical chart production and the utility of charts beyond their purpose for safe navigation. Recognized by the FIG/IHO/ICA International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC), the S-8 Category B "Marine Geospatial Information Programme" is designed for those individuals interested in pursuing a professional career in Nautical Cartography.

ONLINE TRAINING DELIVERY

It is IIC Academy's goal to offer the S-8 Category B programme in a flexible manner, in tune with the health and safety requirements of the world today. The programme will be delivered online via remote learning. This includes instructor-led webinars and e-learning modules, combined with students' teamwork and discussion forums. In conjunction with the instructor-led webinars and lectures, students will be required to solve practical tasks, undertake quizzes and complete exams, before completing the Comprehensive Cartographic Project.

The Comprehensive Cartographic Project will also be carried out as a remote project, under the control and presence of IIC educators depending on the world situation. It will be undertaken over a continuous period of four weeks immediately after completion of all the modules of the Programme. Safeguards will be in place to ensure the integrity of the process.

Additionally, the programme's remote learning delivery will allow employees and employers the flexibility to customize the timing of the learning process so that it best fits within their work schedules, potentially enhancing the training through practical synergies.



▲ *Students review ENC features with IIC Instructor Noelle Beaudoin.*

S-8B PROGRAMME CONTENT

The programme content is structured into six Modules and each Module is comprised of lectures and exercises that cover the entire S-8 Category B content. Each module is constructed as a blended learning experience and begins with an instructor-led webinar to introduce the topic. The aim being to graduate successful and confident students as Category B educated nautical cartographers.

MARINE GEOSPATIAL INFORMATION PROGRAMME MODULES

• Foundations of Marine Geospatial Information: Introduction to the programme. A brief history of nautical charting. Overview of charting in the world today. Wider contribution of charting in the evolution of marine informatics.

• Data Assessment and Compilation: essential aspects of nautical chart production, with an in-depth study of the S-57 Object Catalogue, data sources, standards, and production tools available in the market.

• Production and Validation: important aspects of nautical chart production, covering topics like chart design, quality controls on source data, sounding selection and chart validation.

• Marine Environment: Elements of Geology, Geophysics, Oceanography, Meteorology and Law of the Sea.

▲ *S-8B students discuss a class exercise with IIC instructor Noelle Beaudoin.*

- Marine Spatial Data Infrastructures: Concepts, evolution, practical deployments, role of MSDI in marine national and regional development. The evolution of standards into S-100 and its role in MSDI.

- Remote Sensing: Remote sensing concepts, principles, and practice.

The course materials consist of enhanced audiovisual lectures, videos, and online resources. The distance learning materials are modified from the live lecture materials, adapted for e-learning and self-paced study.

LEARNING MANAGEMENT SYSTEM (LMS)

IIC Academy manages the programme through its use of a cloud-based Learning Management System (LMS). The secure LMS can be accessed by students and instructors from desktops, tablets, and modern mobile devices. Native applications for iPhone & iPad are also available. Supported features include video conferencing (with record and replay), forums, message boards, progress monitoring, and schedule pages. Remote proctoring is utilized.

PROGRAMME TIMELINE

IIC Academy's Marine Geospatial Information Programme – Global Delivery runs for a total of 22 weeks, from 6 September 2021 to 22 April 2022. Participants will have an elapsed period of 30 weeks in which students are expected to complete the 22 weeks of the programme via remote learning.

INTERESTED?

Those interested in enrolling in the programme or wanting further information can visit: www.iictechnologies.com/sites/default/files/S8B/S8BProgram.html

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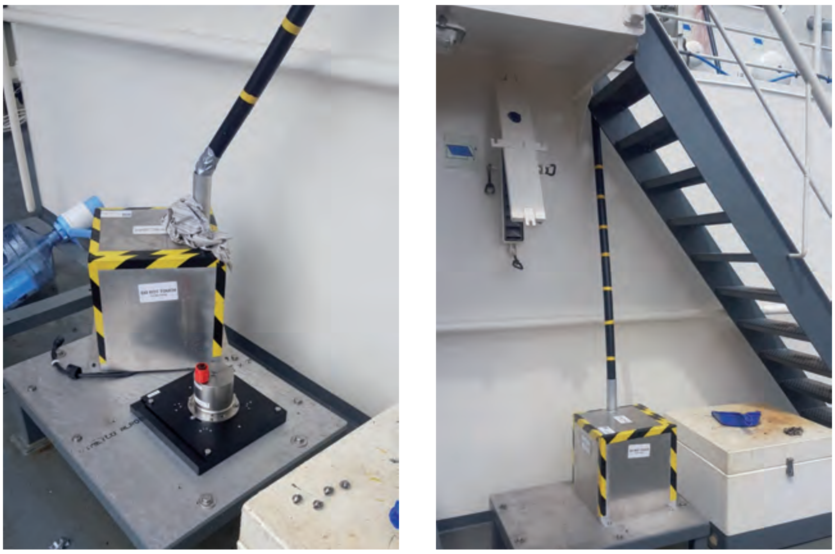
The Installation, Calibration and Verification of a POS MV *OceanMaster* System

Mobilising a POS MV *Ocean-Master* for Hydrographic Survey

As with most new vessel charters, A-2-Sea was starting from scratch when mobilising the Noortruck with its new Applanix POS MV *OceanMaster*, so careful consideration was required for sensor location. The placement of GNSS antennas, IMUs and sonar equipment can directly affect system performance.

▲ *The Noortruck was mobilised in Germany with the Applanix POS MV OceanMaster. The vessel will allow A-2-Sea to fulfil its offshore survey requirements.*



▲ *Applanix IMU mounting location with protective covering and cable routing solution.*

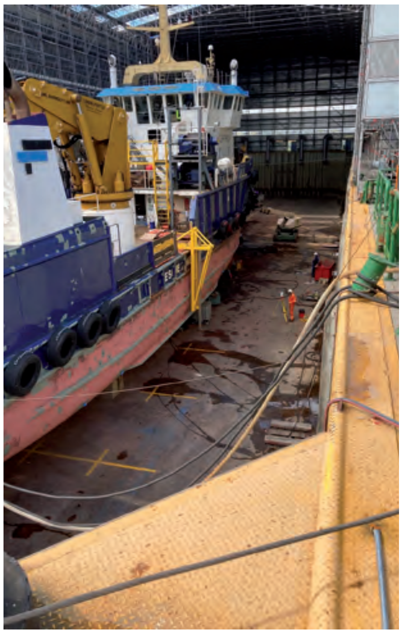
A precise and thorough dimensional control survey, sensor calibrations and equipment verifications are vital for high-quality hydrographic data production. The Applanix POS MV *OceanMaster* is perfectly suited to a vessel the size of Noortruck, due to the accuracy the system provides over longer lever arms.

INSTALLING THE INERTIAL MEASUREMENT UNITS (IMU)

In order to ensure redundancy, A-2-Sea identified two IMU locations on the vessel. The primary IMU was installed in a location that was identified as secure, elevated above the deck and close to the centreline and centre of rotation of the vessel. A-2-Sea Design Engineers measured and designed an aluminium plate and box to support, secure and protect the IMU. The Applanix base plate could then be secured on to the aluminium plate before being boxed in.

A secondary IMU location was also identified in the cofferdam space (under the wheelhouse). This was identified as it was secure, protected and close to the centreline and centre of gravity. Positioning this location close to the entrance to the cofferdam allowed for the clear line-of-sight access for the dimensional control survey. Again, an aluminium plate was designed by A-2-Sea engineers as an intermediate plate between the cofferdam deck and the IMU plate. The secondary location allowed for redundancy should there be any issues with the primary location.

A-2-Sea designed an antenna mounting frame to provide an optimal location for GNSS data reception.



A surveyor conducting a dimensional control survey of the Noortruck.

The Applanix Mounting Plate is a bespoke design capable of accommodating a variety of IMU types. The principle behind the design means that surveyors can survey in the mounting plate, giving them the flexibility of swapping out IMUs without having to re-survey misalignment angles or offsets.

A-2-Sea had the luxury of two locations and two mounting plates, giving it flexibility.

INSTALLING THE GNSS ANTENNAS

The Applanix POS MV *OceanMaster* uses GAMS (GNSS Azimuth Measurement Subsystem) to aid the IMU in heading calculations. This unique feature uses two GNSS antennas to determine a GNSS-based heading that is accurate to 0.01deg when blended with the inertial navigation solution.

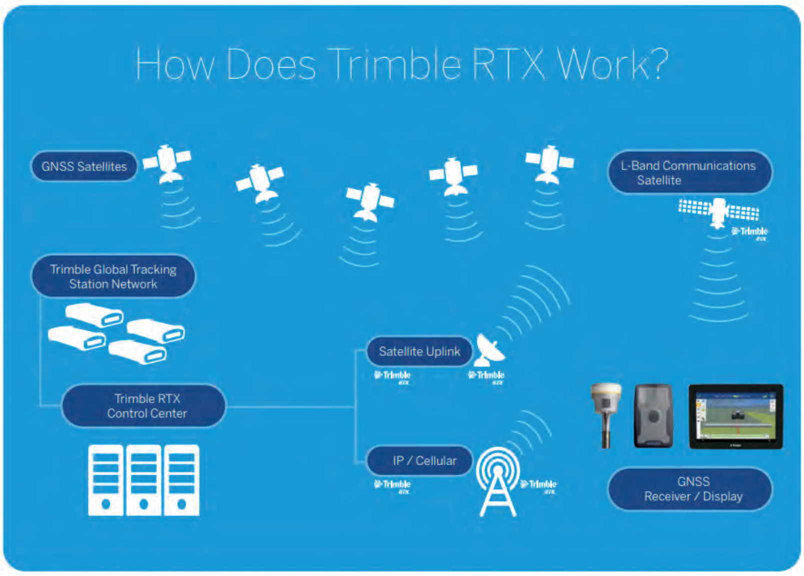
To optimise antenna location, A2Sea engineers were required to come with a design to ensure a secure and rigid mounting location, free from external interference. Multiple antenna mount points were made available and measured to provide different options and backups.

THE DIMENSIONAL CONTROL SURVEY

The installation on the Noortruck took place while the vessel was in dry dock, ensuring a stable platform from which to

Baseline Vector	Dimensional Control Survey	GAMS Calibration	C-O
X Component (m)	0.070	0.079	-0.009
Y Component (m)	3.995	3.998	-0.003
Z Component (m)	-0.007	-0.017	0.010

Table: A comparison of GAMS baseline vectors from the dimensional control survey and dynamic GAMS calibration. Small residuals validated the dimensional control derived figures.



Trimble RTX, a globally available network providing centimetre level corrections over L-band satellite and internet.

carry out precise Total Station Dimensional Control Survey.

Surveyors adopted the technique of defining a vessel reference frame, then establishing sensor locations and rotations with respect to that vessel reference frame (VRF). A Common Reference Point (CRP) was defined as the target on the IMU housing, with all sensor offsets measured relative to this location. As well as sensor offsets, the vessel Centre of Rotation (COR) was also defined, which is key for optimal Heave measurements.

All Total Station coordinates were within ±0.5mm for each ordinate. These values were obtained by observations from multiple station setups and the mean obtained, showing on average a standard deviation of 0.5mm.

During the measurement process, permanent and recoverable control points were defined throughout the vessel within the specified tolerance of ±0.01m relative (at the 95% confidence level) in X, Y and Z.
Similarly, all sensors were established within the VRF to within a tolerance of ±0.02m relative (at the 95% confidence level) in X, Y and Z.

The final step was to determine the IMU frame with regard to the vessel frame. By extending the baseline of the IMU plate, the misalignment angles were determined. The IMU mounting plate has precisely machined grooved sides in the X and Y directions allowing a bar to be placed along these edges to increase the baseline length with which the mounting angle is measured. The longer this baseline, the more precisely the angular component can be computed from the 3D coordinate values.

THE VERIFICATIONS

GAMS

During the Dimensional Control Survey, the Primary and Secondary antenna locations were precisely measured and the X, Y, Z baseline vector components determined. To verify these measurements, a dynamic GAMS calibration was completed at sea. By starting with zero values in the GAMS parameter setup, a series of dynamic manoeuvres were completed, allowing the POS MV to calculate the GAMS parameters automatically. The results from the dynamic calibration were within close agreement to those measured in the dimensional control:

The values from the Dimensional Control were used going forwards as these were deemed more precise. The dynamic GAMS calibration is dependent on quality GNSS measurements and sufficient vessel dynamics, which can often be hard to achieve on larger vessels. Hence the GAMS calibration process acts as a validation, checking for gross errors in the dimensional control survey.

POSITION CHECKS

Whilst alongside, position checks were carried out using RTK enabled Leica GNSS receivers. The GNSS antennas were placed at previously measured control points and position data was logged. These control points were also defined as nodes in QPS QINSy software, to which the POS MV data was interfaced.

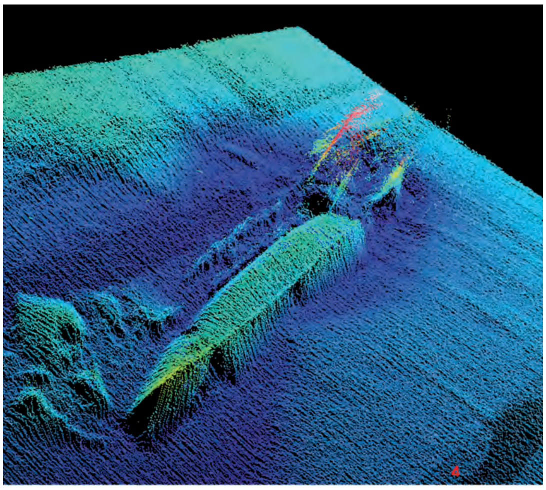
The POS MV was utilising the real time Trimble RTX correction service data delivered over L-Band, to provide centimetre level accuracy.

Trimble RTX provides centimetre level accuracy on a global level. Trimble RTX utilises real-time satellite measurements from a global network of tracking stations, along with highly accurate atmospheric models and algorithms to generate Trimble RTX corrections. These corrections are then broadcast to the receiver via a set of geostationary satellites or over the internet.

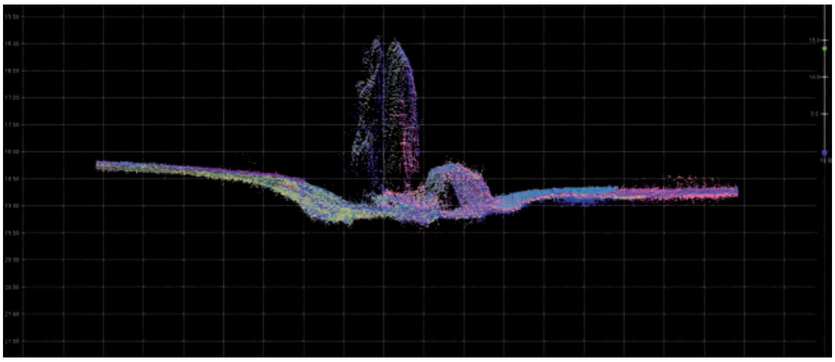
A comparison of RTK GNSS data and POS MV GNSS aided inertial data, translated to nodes within QINSy, showed a close agreement, meeting the project specification.

R2 Node Comparison – Leica RTK GNSS w/SmartNet vs QPS QINSy w/Trimble RTX			
System	**Average Easting (1σ, m)**	**Average Northing (1σ, m)**	**Average height (1σ, m)**
QPS QINSy w/Trimble RTX	414440.833 ±0.016	5814458.731 ±0.015	50.084 ±0.034
Leica RTK GNSS w/SmartNet	41440.807 ±0.009	5814458.689 ±0.018	50.086 ±0.032
Average Difference (1σ,1Hz)	***Δ Eastings (m)***	***Δ Northings (m)***	***Δ Height (m)***
	0.025 ±0.019	*0.043* *±0.025*	*-0.001* ±0.045

▲ *The position verification results comparing the RTK GNSS with POS MV position solution.*



▲ *Multibeam data showing a distinct seabed feature. The robust and accurate solution provided by the POS MV OceanMaster, in combination with Trimble RTX, allows confident validation and identification of existing and new seabed features.*



▲ *Seabed features also provide a useful tool for calibration and verifications. This image shows the alignment of multiple Multibeam swaths over a feature, confirming angular misalignments have been correctly applied during the Multibeam Patch Test.*

With the POS MV installed, calibrated and verified, further sensor calibrations specific to the project were carried out.

ONGOING WORK

The Noortruck is currently engaged in nautical charting work for the Civil Hydrography Programme off the east coast of the UK. As part of a collaboration between Applanix, Trimble and A-2-Sea, Trimble RTX was activated over L-Band through POSView, the control software for the POS MV *OceanMaster*.
With a fast convergence time, the system was achieving centimetre level accuracy within minutes of activation. The Trimble RTX solution allowed A-2-Sea to complete calibrations and verifications as well as provide an accurate real time solution during survey operations.

Part of their ongoing survey scope is to report uncharted features on the seabed within a strict 24-hour time frame. The POS MV with Trimble RTX corrections allowed them to do this with confidence.

CONCLUSION

A-2-Sea successfully completed the mobilisation of their Applanix POS MV *OceanMaster* on the Noortruck, taking careful consideration of sensor location, undertaking a precise and thorough dimensional control survey, sensor calibrations and equipment verifications, thus ensuring the acquisition of high-quality hydrographic data.

The successful cooperation between Applanix, Trimble and A-2-Sea allowed the testing of the Trimble RTX correction service, which will provide valuable data as the solution starts to become more available to the marine market.

For more information on the Applanix POS MV hardware and POSPac processing software, please visit www.applanix.com or contact marinesupport@aplanix.com

For more information about the Trimble RTX correction service, please visit https://positioningservices.trimble.com/industries/marine/

For more information on A-2-Sea and its services, please contact info@a2sea.co.uk or visit www.a2sea.co.uk

Author Bio

Nick Smart – Technical Sales Support, Applanix.
Nick is an experienced Hydrographic Surveyor with over 10 years' experience. He joined Applanix in 2020 to provide pre-sales support.

Liam Flynn – Survey Operations Manager, A-2-Sea.
Liam is an experienced Hydrographic Surveyor with over 8 years' experience. Liam has been managing the survey department at A-2-Sea since 2019.

The Ultimate USVs: Set to Sail

The Smallest and Most Cost-Effective Drone with a Multibeam Sounder

GPASEABOTS, a GPAINNOVA Group company located in Barcelona (Spain) and specializing in marine robotics and solutions for maritime and inland water operations, has recently developed a USV based on the WASSP S3r, one of the world's most cost-effective professional survey and mapping multibeam sounders available. Its unique characteristics and technology provide the perfect solution for applications such as hydrography, search and rescue (SAR) and mooring inspection.

To design and create this multipurpose platform, the SB 100 PRO model, GPASEABOTS combined WASSP's extensive technical knowledge with its own naval engineering and marine robotics know-how. As a result of this, the company was able to launch the smallest and most cost-effective USV with a multibeam echo sounder on the market. This means that several sectors will be able to benefit from a device that multiplies the functions offered by any other aquatic surface drone.

EASY TO TRANSPORT AND DEPLOY

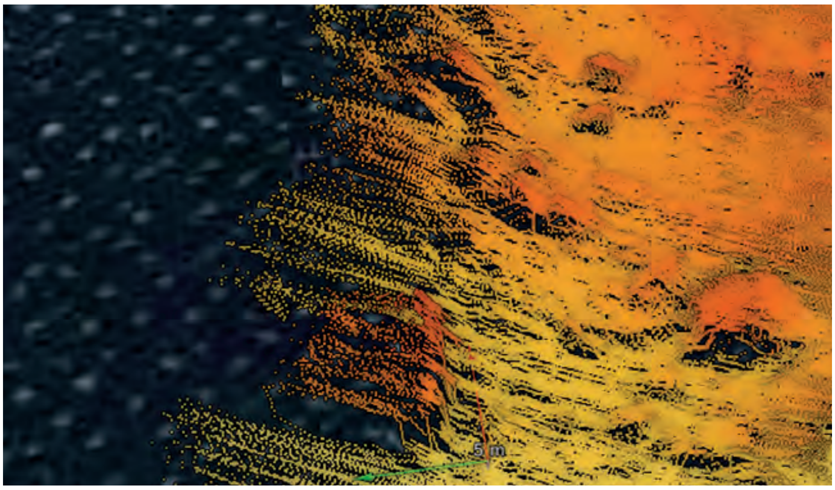
One of the main advantages of the new SB 100 PRO equipped with a WASSP S3r (an IHO S-44 standard Multibeam) in comparison to other USVs is its ease of deployment. Owing to its intuitive use and its fast and convenient transportation (103cm x 75cm x 56cm and weighing 21kg without accessories), it can replace traditional boats in calm waters, where precision and accuracy in the results prevail over covering large areas of water. The GPASEABOTS' USV, which is designed and manufactured under the "Ready to nav" concept, can be used in urgently needed bathymetries or similar interventions in commercial harbours, marinas, rivers and lakes.

For these missions, only a drone and a ground station are required. In addition, all the tasks can be carried out by a single operator, which saves resources and dramatically cuts operating costs without reducing effectiveness.
Once in place, the only procedure needed is to switch on the devices, the USV, the ground station and the controller. This is followed by a quick connection to our own RTK base or a NTRIP server to obtain the RTK corrections for the GPS. After quickly planning the mission, the drone is floated in the water in order to cover the maximum amount of area in the shortest time possible. As a result, it gets reliable data from the sea bottom instantly. Fortunately, GPASEABOTS' USVs have more than enough autonomy for everyday usage and to fulfil their tasks satisfactorily, without having to recharge.

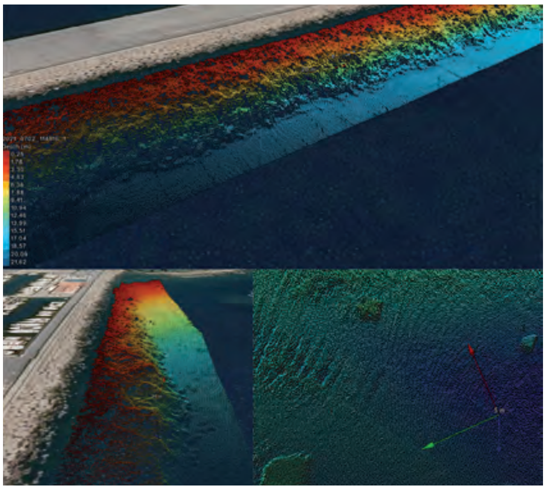
This is why SB 100 PRO has proved that it is perfectly possible to implement field work in the morning, to obtain results at midday and to make consistent decisions in the afternoon.

REDUCING HUMAN RISK AND HUMAN ERROR

Drawing on GPASEABOTS' unmanned systems experience, its drones are especially designed to access confined,

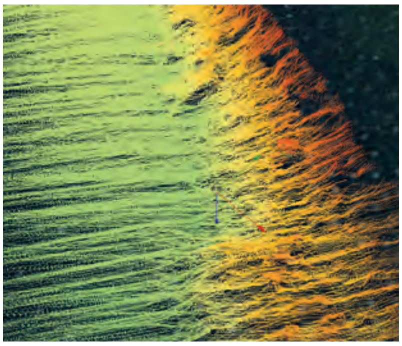


▲ *Identification of blocks in maritime works.*

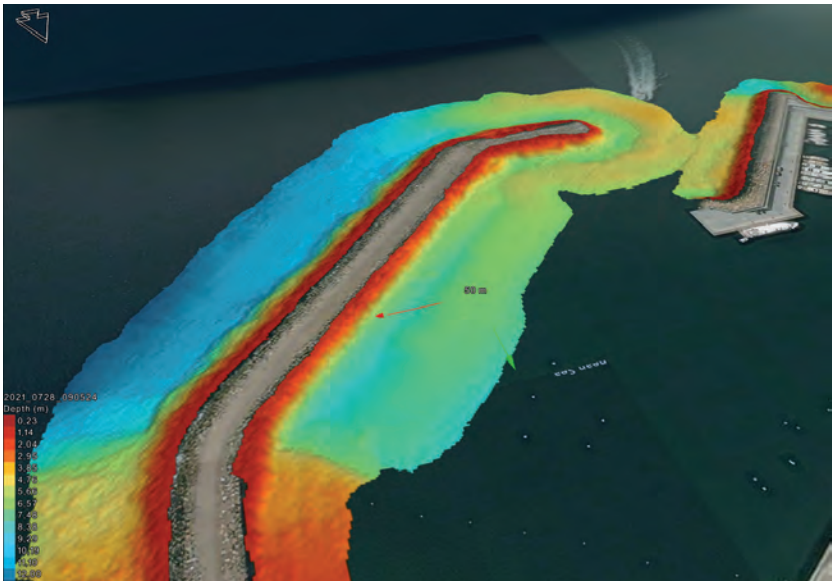


▲ *Breakwater construction monitoring.*

▲ *Mooring identifications for vessels inside port.*



▲ *Inspection of a breakwater front.*



▲ *Multibeam Bathymetry with WASSP S3 integrated in SB 100 PRO.*

narrow and high-risk areas. Thus, these devices deliver enhanced performance to any operations and drastically lower risk to human life, which assures the safety of workers. The lack of training, inadequate breaks, working speed or unsuitable safety equipment can increase those risks.

These devices reach areas that cannot be covered by traditional ships. In addition, since the USV automates all sorts of missions, they significantly reduce the human error factor.

READY TO HOST ALL TYPES OF PAYLOADS

GPASEABOTS' experience shows that the combination of naval engineering, marine electronics and cutting-edge instrumentation can bring optimal solutions in very diverse fields.

The most common of these accessories are side scan sonars, single beam echo sounders, WASSP S3 (or S3r) multibeam echo sounders, Sound Velocity Sensors (SVSs), Sound Velocity Profilers (SVPs), created by Valeport; Acoustic Doppler Current Profilers (ADCPs), several types of cameras (thermal, underwater and for mooring inspection and control); multiparameter sounders to measure water parameters (including temperature, pressure, conductivity, salinity and turbidity); sub-bottom profilers, water samplers and winches for lowering and retrieving instrumentation into a water column. Inertial Measurement Units (IMUs) are manufactured by SBG Systems which provides motion and navigation solutions in highly compact and robust sensors available at different levels of performance: from miniature Ellipse sensors to mid-range Ekinox and high accuracy Apogee models.

SB 100 PRO is a USV that can integrate almost any type of marine instrumentation, depending on the goals pursued.

BEST-IN-CLASS EQUIPMENT FOR HYDROGRAPHY

A SB 100 PRO model equipped with WASSP S3r is suitable for almost all types of tasks in hydrography, the science that measures and describes the physical features of bodies of water, especially continental water resources. This drone is ready to create nautical and bathymetric charts and seabed characterizations to guarantee the sustainable management of fisheries. It will also help us to learn more about marine habitats, including ocean deserts or dead zones.

GPASEABOTS' USV can also perform high quality water analysis. With regard to this topic, it is worth highlighting that increasingly demanding environmental standards and regulations - for instance, the Spanish ROM 5.1-13, a Recommendation on Coastal Water Quality in Port Areas - are forcing a growing number of companies and institutions to take systematic samples and analyse the marine waters and sediments in harbours.

Aquatic drones are also extremely useful in dredging operations. Their use allows us to know the features of the seabed in advance. Additionally, USVs can continuously generate a map of the area, which helps in setting best procedure at any time.

Aquatic drones are also improving aquaculture, one of the fastest-growing sectors in the global economy and a key pillar in guaranteeing the planet's food resources. As stated in 2018 by the Food and Agriculture Organization of the United Nations (FAO), future demand for fish will come mainly from aquaculture. In this regard, USV missions can optimize fish farm results, while improving animal welfare and meeting consumers' concerns about food.

SUITABLE FOR A WIDE RANGE OF APPLICATIONS

GPASEABOTS' aquatic drones are suitable for visual or ultrasonic inspections in harbours and some other structures commonly related to engineering. They can successfully carry out missions in fields like security assessment, chain and mooring inspections, seabed clean-up activities and analysis of the impact of storms and natural disasters.

There is a growing demand for environmental studies, also known as environmental impact assessments (EIA), in order to prevent damage to the environment. USVs can support environmental studies with visual marine life inspection, marine habitat mapping and water sampling for studies on the physicochemical parameters.

Regarding tasks related to SAR, SB 100 PRO can search for people and artifacts in aquatic environments, guaranteeing the safety of those involved in the rescue mission at all times. Normally, these actions are carried out by emergency services teams and security forces (SF). Thanks to the multibeam sonar integration, the aquatic drones can cover a very large area in a short time for quick mapping, allowing safe emergency dive planning.

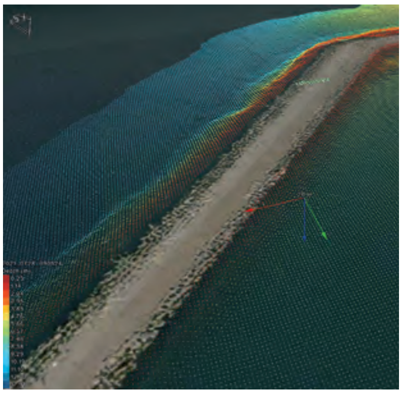
Aquatic drones can also be used in underwater archaeology in seas, oceans, rivers and lakes, for the location, identification and recovery of submerged structures, sunken wrecks or anthropogenic artifacts. Sometimes, these discoveries may have a positive effect on the tourism sector and on outdoor sports activities.

With regard to water cleaning tasks in harbours, a well-equipped USV cuts operational and maintenance costs and eliminates human risk and eventual risks from human factors.

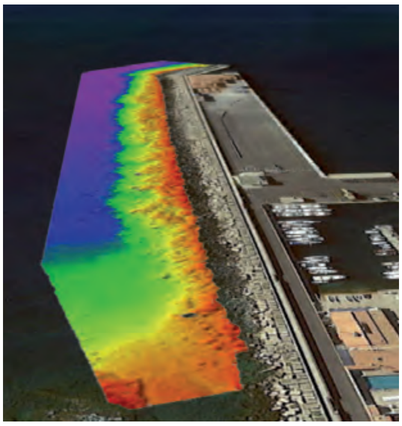
CONCLUSIONS

To conclude, the results obtained by GPASEABOTS in pilot tests and the feedback given by clients demonstrate that the company's expertise, its USVs and the use of WASSP instrumentation are a winning combination. The union of SB 100 PRO and a WASSP S3 sounder creates a very complete and cost-effective product, whose main benefits are operating cost reductions, faster missions and greater accuracy in the final results.

▲ *WASSP S3 Integrated on SB 100 PRO.*



▲ *Point cloud obtained after postprocessing data.*



▲ *Multibeam Bathymetry with WASSP S3 integrated on SB 100 PRO.*

About GPASEABOTS

Founded in Barcelona in May 2019, GPASEABOTS' activities focus on facilitating the analysis, preservation and restoration of the marine environment through the development of highly sophisticated solutions. This goal is being achieved by adapting the latest technologies in various fields to a sector that has always been affected by operational barriers. Nowadays, its product range includes microplastic-capturing buoys and USVs.
GPASEABOTS belongs to the GPAINNOVA Group, one of the fastest growing organizations in Europe according to the Financial Times.

More Information/references

https://www.gpaseabots.com/
https://www.gpainnova.com/

GPASEABOTS: Mi empresa I LinkedIn
GPA SEABOTS - YouTube
GPASEABOTS (@gpaseabots) • Fotos y videos de Instagram

About WASSP

WASSP Multibeam is a product developed by ENL group in New Zealand. ENL currently manufactures the WASSP Multibeam Sounder for Commercial Fishing, Sport Fishing, Hydrographic Survey, Super Yacht and more. ENL, founded in 1945, is now a subsidiary of Furuno and has a strong R&D focus, particularly in the field of the Multibeam Sounder.

www.wassp.com
Contact: Sales@wassp.com
Phone: +64 9 373 5595

About SBG Systems

SBG Systems is a leading supplier of inertial motion sensing solutions. The company provides a wide range of inertial solutions from miniature to high accuracy. Combined with cutting-edge calibration techniques and advanced embedded algorithms, SBG Systems' products are ideal solutions for industrial & research projects such as unmanned vehicle control, surveying applications, antenna tracking, and camera stabilization.
Contact: sales@sbg-systems.com

sponsored article

Object Recognition Enables Smart Robotic Behaviour

For many applications, we need to know what is where underwater. Side-scan sonar is one of the core sensors for imaging the bed of water bodies and it is increasingly being used for inland applications such as finding missing persons, dumped items and unexploded explosives. Traditionally, human operators analyse the images. However, side-scan surveys often take many hours, with repeated passes at different angles to obtain good images. As a result, operator fatigue can become a real constraint, even more so in poor weather or with less experienced operators. Object recognition software can now help make underwater surveys more effective by adding intelligence to side- scan and video data.

EvoLogics is a high-tech German company specialising in underwater communications, positioning, sensor systems and smart robotics. Most of its products are inspired by marine animals. For example, the S2C spread-spectrum communication technology is based on long-distance dolphin communication. The company has also developed an autonomous underwater vehicle inspired by manta rays. Many marine scientists use these products and they are also increasingly being used for professional and commercial applications.

SONOBOT

Over the years, EvoLogics has designed and built a number of innovative surface and underwater vehicles. The company has now launched a series of commercially available systems, initially of uncrewed surface vehicles (USV). Sonobot 5 is the latest version of their survey USV. The unit folds up, so a single operator can transport it in a car and deploy it. It can be fitted with a range of sensors (depth sounder, side-scan sonar, camera, etc.), WLAN and cellular communications, and a choice of GNSS options.

The modular design of the Sonobot 5 makes it a versatile platform for hydrographic surveying, monitoring and search and rescue in inland waters. Its basalt

▲ *Dutch Water Police training session with a dummy.*

fibre reinforced floats are light, strong and corrosion resistant so the unit can even be used in industrial wastewater reservoirs. The two propellers are driven by 500W brushless motors and are mounted in recesses for protection against impact and to prevent aquatic plants fouling the propellers. Sonobot is powered by two lithium-ion batteries, for an endurance of around 10 hours at typical survey speeds. The special controllers drive the motors with sine waves to minimise noise emissions to the payload electronics. EvoLogics builds the Sonobot in-house and even assembles the batteries itself.

For seafloor imaging, the Sonobot is equipped with a side-scan sonar at 300, 700, or 1200kHz depending on range and resolution requirements, and with an integrated echosounder for depth measurements. These are mounted in the centre section of the USV. All the data is processed on board and then transmitted to the operator over a WLAN or cellular link.

At the end of 2020, EvoLogics launched an exciting new feature for the Sonobot platform – real-time object recognition. The AI-based system runs directly on board the vehicle and analyses raw side-scan sonar output to detect and visually highlight various objects in the operator's control software on shore. A cloud-based ecosystem around the new feature provides users with regular updates and new detectable object classes. It also enables the upload of user datasets for the system to be trained for new object types – available for all users to download and use in their missions.

Object recognition was first offered to select Sonobot customers and over the following months went through extensive testing and optimization.

OBJECT RECOGNITION SOFTWARE

Philipp Bannasch, team leader sensor integration at EvoLogics, explains, 'Our Sonobot 5 USV is a truly high-tech platform for optimal side- scan surveys. To make it even smarter, we have now equipped it with AI-based automatic object recognition. It can autonomously find a wide range of objects underwater: our launch customers have been primarily interested in detecting missing persons, discarded objects, unexploded ordnance (UXO) and abandoned fishing nets.
'It takes training and experience to recognize object shapes in a sonar picture, and less experienced operators will often miss cues such as contours and sonar shadows. You have to look from multiple angles and normally make several runs at different headings. Thus a survey can be very time consuming and tiring for the operator who is often working under pressure, outdoors, in poor weather. So now the surveying robot needs to become smart and adjust its mission to what it sees.

'We developed a high-end object recognition system that runs on the USV itself and directly analyses the raw data, as cloud-based computing is not available in open water. We had to build neural network algorithms that work on sonar data, can handle huge data volumes in real time, and run on the dedicated embedded hardware. Then, any neural network must be trained to be effective and we have invested a lot of time in developing pre-trained models for missing persons and other objects, relevant to our key customers. We put much time and effort into selecting the right training data, augmenting, and fitting it. That has paid off, the system now detects objects in less than a second. We made sure the system comes with pre-trained object classes and is ready to go "out of the box".

'Many of our customers also train the software themselves for a particular type of object they are interested in: they perform scans of the objects of interest and upload their data into the cloud. We train the system for these objects and make the new object class available for download to all users, if we get permission.

'System operation is uncomplicated. After arrival at the site, the operator programs the Sonobot 5 with the survey grid and the type of object to look for, takes the unit out of the car, unfolds it and launches it into the water. The Sonobot will then follow the grid, process the side-scan data, and send the results to shore. The operator can watch the incoming imagery in real-time, and the object recognition system highlights any relevant findings.

'In calm waters, you get the best results at a speed over ground of around 0.8m/s. If there are waves, you can increase the speed to, say, 1.2m/s to make it easier to stay on course. The Sonobot 5 can actually reach a speed over water of 5m/s, so it can follow the survey grid even in strong currents and fast-flowing rivers.'

The object recognition has now been successfully tested by several customers such as the Dutch national water police unit. 'EvoLogics has recently added object recognition to our Sonobot system. As an operator, it's great to have an extra set of eyes, looking over your shoulder. It's work in progress but we will continue to train the software and hopefully it will lead to more recoveries and contribute to our mission to bring all missing people back to their loved ones.'

Gerd Heller of DLRG (German Lifeguard Association) explains 'We have already used the new AI-based sensor capabilities in some missions to retrieve lost equipment from rivers and lakes.'

Lukas Goldmann, an operator from the Underwater Archaeology Association Berlin-Brandenburg, adds that 'If you search for sunken underwater structures such as medieval housing and bridges, where large areas need to be scanned for subtle geometric hints on the ground, a well-trained neural network is a great help to distinguish between natural features and archaeological remains, saving a lot of time on both later analyses and follow-up dives.

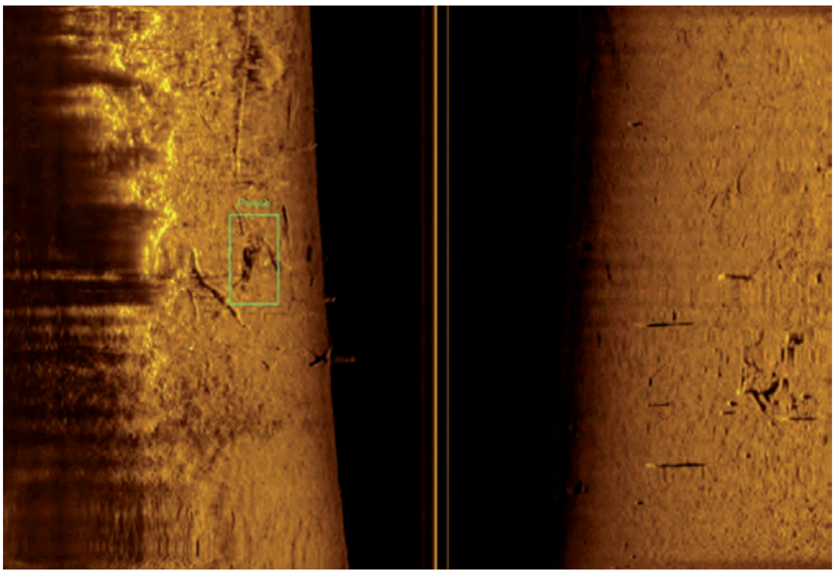
'Besides side-scan underwater imagery, the software also works with video from an onboard camera. This is especially useful for our autonomous underwater vehicles. You can patrol a predefined area on the seafloor, navigate the water by sonar systems, identify critical objects directly in the video feed onboard the submerged AUV, and then automatically surface it to establish a data link and alert the operator.'

Philipp Bannasch continues, 'We have completed testing and our object recognition with state-of-the-art hardware and software is now available, embedded into our commercial surface and underwater robots. For professional applications, especially in underwater searches where the stakes are often high, it can make a real difference to the success of a mission.'

CONCLUSION

A robotic system on or under water with object recognition capabilities can assist a wide range of users to make more effective side-scan sonar surveys of inland water bodies. Key applications include searching for missing persons, objects and UXOs. The same hard- and software also processes underwater video images obtained with UUVs for even more detailed surveys. As EvoLogics produces both the software and hardware in-house and has a large team of specialised scientists, the company can effectively support customers implementing the technology, and provide custom solutions where necessary.

For more information, please see EvoLogics.de



▲ *Object highlighted by the object recognition system.*

Locating victims of drowning accidents

Searches for missing persons after an accident on water can be a race against time, often with tragic results. Locating missing persons can be difficult as their bodies can be carried away by strong currents, or become entangled in plants, fishing nets or debris. Because a body absorbs the sonar beam, it can appear as an odd shape in a sonar image. Often the operator recognises the sonar shadow rather than the shape of the body. The appearance of a body in sonar images depends on many factors, such as the clothes the person is wearing and how long they have been submerged. Incidents often occur at night, in poor weather or in complex settings which make work difficult. This is where automatic, real-time object recognition can bring real benefits. If a potential target is found, its position has to be marked for further inspection by ROVs or divers, and for recovery.