Hydro INTERNATIONAL

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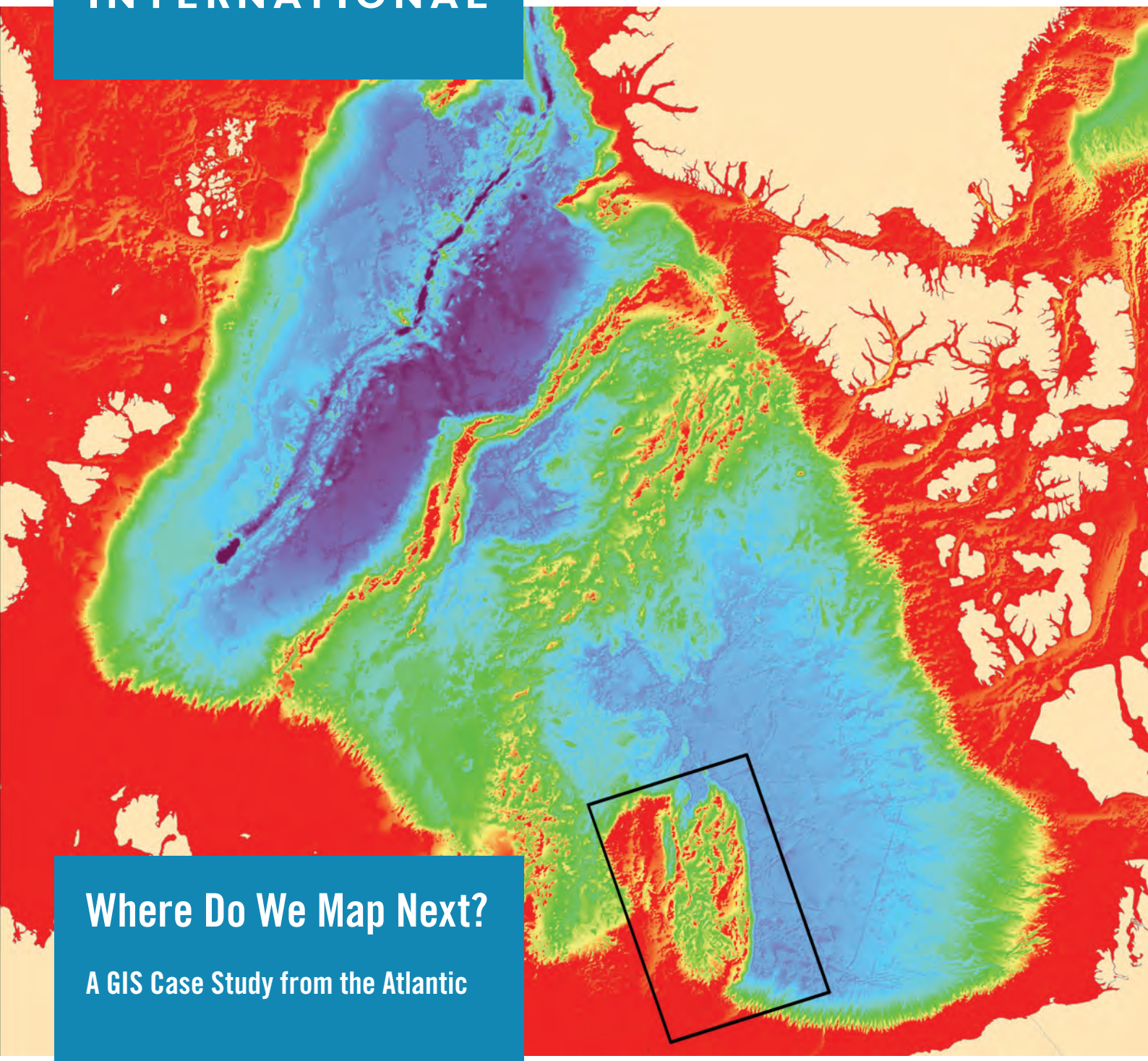
SEPTEMBER/OCTOBER 2018 | VOLUME 22 NUMBER 5



Where Do We Map Next?

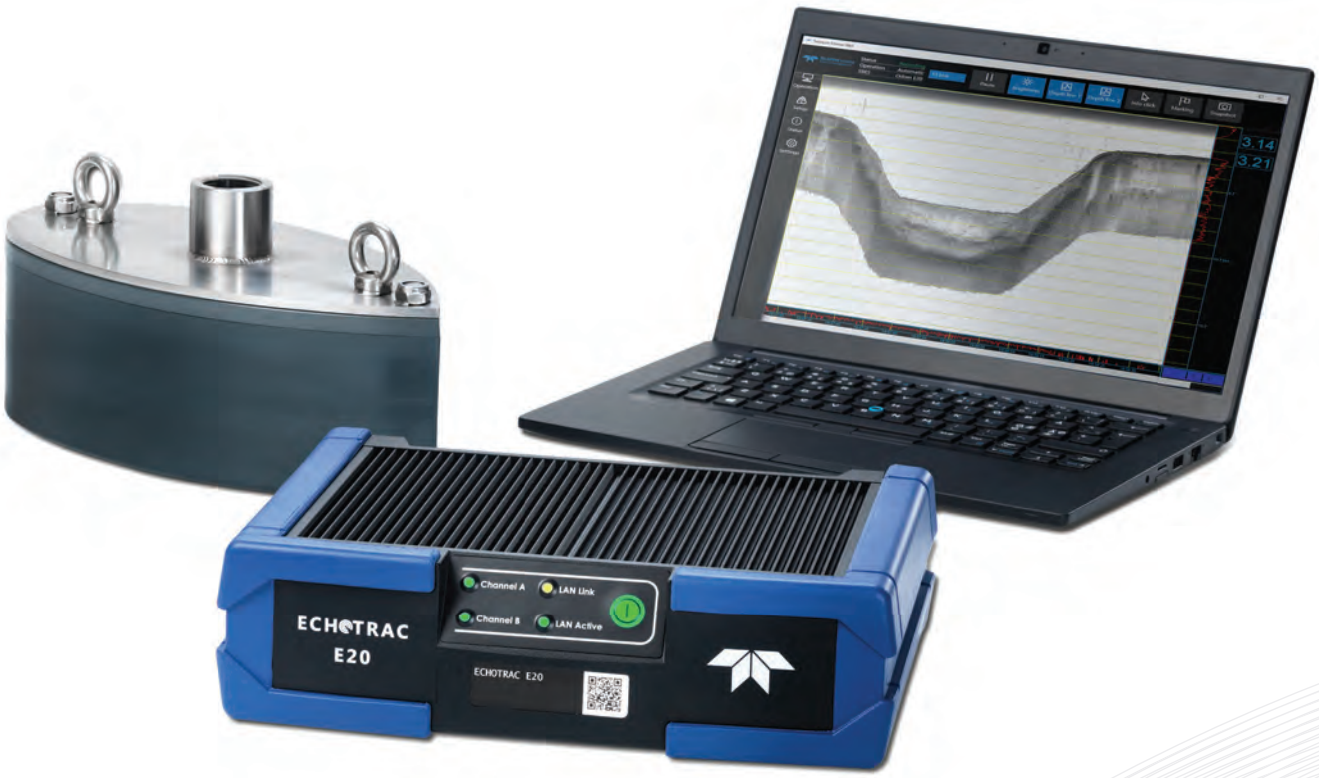
A GIS Case Study from the Atlantic

Automated Depth Area Generation for Updating NOAA Nautical Charts

Streaming Cloud-based ENC Data for a Real-time ECS

Teledyne Odom ECHOTRAC E20

The one tool you want to have on your boat all the time



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Hydro INTERNATIONAL

Hydro International is an independent international magazine published 6 times a year by Geomares. The magazine and related e-newsletter inform worldwide professional, industrial and governmental readers of the latest news and developments in the hydrographic, surveying, marine cartographic and geomatics world. Hydro International encompasses all aspects, activities and equipment related to the acquisition, processing, presentation, control and management of hydrographic and surveying-related activities.

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CHUKCHI PLATEAU

The front cover of this issue of *Hydro International* shows the IBCAO grid displaying the Arctic Sea with a black box outlining Chukchi Plateau. The availability of a digital bathymetry database and the current state of bathymetry information on Chukchi Plateau illustrates the opportunity for the MCD to update lacking bathymetry information using ESC surveys for soundings and the IBCAO grid for depth areas and contours.

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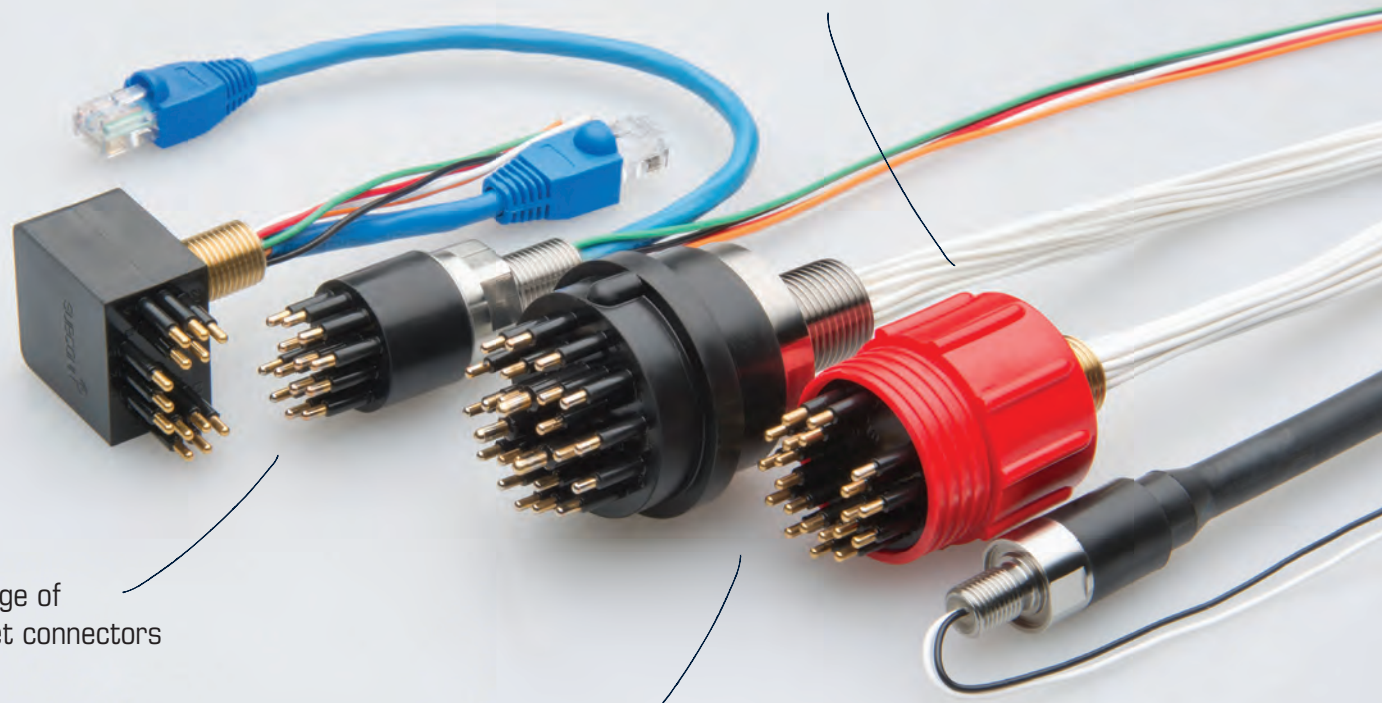

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Quality

▲ *Durk Haarsma.*

Crowdsourced bathymetry and blockchain are developments in hydrography that help achieve improvements in acquiring, storing, processing and disseminating survey data. In two op-ed pieces in this issue of *Hydro International*, one by Mathias Jonas, Secretary-General of the International Hydrographic Organization (page 6), and the other by Jennifer Jencks and Ashley Chappell, NOAA, United States (page 32), these developments are discussed in detail and some critical notes are provided. Rightfully so; we simply cannot put new technology into work without asking ourselves some very critical questions. The one question that stands out, is that of quality of data. Jonas hits the nail on the head with his advocacy to put quality first, solutions next. In both blockchain or crowdsourced bathymetry it is of the utmost importance to ensure that data that is used for safe navigation is safe – qualitative – and therefore authoritative. We simply cannot go through with new technologies without taking the quality into account, not merely for legal reasons, but also for one of the oldest fundaments of hydrograph: safety of navigation at sea.

Durk Haarsma,
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Maps and Imagination

This issue of *Hydro International* zooms in on a broad range of aspects within hydrography and oceanography. Although these and adjacent fields are often seen as a niche, it entails way more than some may think. This is well reflected in the September-October edition of our international magazine.

▲ *Wim van Wegen.*

One of the articles focuses on the development of a tool to derive depth area, contour and sounding vector data directly from gridded raster bathymetry surface data. Incorporating automated data-processing methods into nautical chart production means the start of a new era. The issue of timely updates to bathymetry data in geographic information systems will be eased and the marine public will be provided with better navigation data. The National Oceanic and Atmospheric Administration's (NOAA's) Marine Chart Division (MCD) plays a leading role in automated depth area generation for updating their charts. This automated depth area generation process allows MCD to update depth information on nautical charts in locations where authoritative sources have not yet surveyed while also informing the public of the quality of bathymetric data in the area.

The bottom of our oceans remains a fascinating topic. As a kid I was excited about maps. My parents took me and my brothers to flea markets, where atlases and maps were always among the main trophies. Maps stimulate the imagination – although I have travelled I've seen nowhere near all the countries or parts of the world, but thanks to my own interpretation I can more or less envisage what these parts of the world look like. I can imagine the landscape, the vegetation, the people living there, the architecture and so on. However, if you would ask someone else to depict the same spot on the map, the outcome may be very different. With the rise of the internet and the digitalisation of our society, the profession of cartography has undergone a makeover, and in addition, the internet has made it possible for everyone to see all corners of the Earth on their screens.

No room left for imagination? I would say there is still plenty of room left for it. And otherwise the oceans will provide plenty to explore. Only about 5% of the world's seafloor has been mapped in some detail. Since the ocean occupies roughly 70% of the Earth's surface, this leaves approximately 65% of the Earth (excluding dry land) unexplored. At *Hydro International*, we'd like to be your guide in this unknown world by covering the best stories, informing you about relevant case studies and explaining innovative technologies that help us to map the unknown. In the meantime: don't lose your imagination!

Wim van Wegen, content manager
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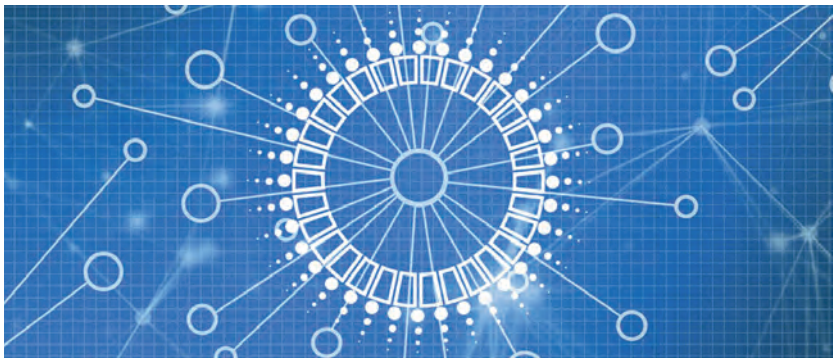
Response to Gert B. Büttgenbach's article 'How Blockchain will have an impact on Navigation' (*Hydro International* Volume No 2 2018, March 2018)

Will Blockchain Drop Anchor in Hydrography?

Indeed, it is a long and fruitful tradition to consider emergent technologies as a driving force for progression in hydrographic appliances. The invention of hydro-acoustic methods was made to measure the water depth of the Baltic Sea near Kiel; sea surveyors have been early adopters of any kind of radio position fixing devices including satellite-based systems; horizontal radar transmission is applied to measure wave characteristics and remote sensing is about to revolutionise the topographic measurements at sea. Finally, ECDIS was the first mobile geo-information system based on vector data – long before the first navigation app on a smartphone arrived. Now it is blockchain. This technology may certainly have a great potential but in my view different from the designation Gert Büttgenbach is suggesting. What I find misleading is his argument that blockchain should be instrumental in cracking a seemingly undue monopoly of national Hydrographic Offices for digital chart production hindering commercial success of private chart suppliers. The attribution of chart data as being 'official' is interpreted as a synonym for a protective measure – a closed shop from data collection up to dissemination of the final chart product. But this image does not meet the reality. Both components of nautical hydrography – sea survey, the most costly component of the provision of a hydrographic service, and digital cart production (of ENCs) – have, to a large extent, been tendered to private companies by many nations. The provision of ENC services is performed by private chart service suppliers and there are popular derivations from the applying IHO Standards S-57 and S-52 like b(athymetric)ENC and PortENC that are privately produced at the request of specific customers.

The fleet of commercial vessels on international voyages that is mandated to carry official ENCs comprises approximately 100,000 units, not a huge market considering the whole range of all that sail for leisure amounts to more than two million units for France alone. This market segment is fully open to digital chart solutions by private suppliers. A simple search on the internet for 'marine navigation app' provides dozens of hits – all based on private digital charts. The reason that IMO insists on the official status of nautical information for commercial shipping is simple: liability. Legally unlimited governmental liability is behind official nautical publications of any kind – whether printed or digital. Who else other than the governmental infrastructure could compensate potential losses and damages to the environment caused by ship accidents as a result of wrong navigational information? Surely no private company.

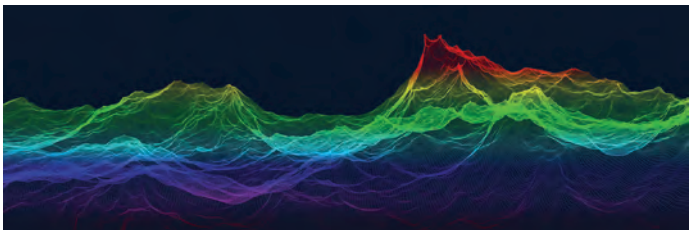


It remains a viable concept that national Hydrographic Offices express their authorisation and liability by the attribution of their navigation products as being 'official'. This attribute, however, has evolved into a second reputation: official data are widely understood as a synonym for high-quality data; produced with outmost care by highly qualified staff under rigid quality assurance to meet the high-class liability level designated to the final product. Those categories that build trust were developed over decades in a traditional analogue environment. But how can this quality level be quantified in a digital setting? With the arrival of autonomous shipping we have to expect, at least, the exchange of chart data between machines without much human intervention and an evaluation of quality. It becomes obvious that the quality label 'official data' is no longer sufficient to rely on. Instead, a comprehensive machine readable catalogue of data quality categories for all sorts of nautical information is required. With the big data issue for survey data in mind, such quality classification has to happen automatically as an inherent part of the data production process. The Member States of the IHO have started to face this issue with the establishment of a dedicated data quality working group. This group is mandated to consider any sort of digital datasets for navigation – not limited to ENCs or the isolated CATZOC problem. Finally, there is another challenge for marine navigation data, whether from 'official' or private sources: cyber security. It appears to me that blockchain could be at the right place here. The traceable true facsimile multiple copy mechanism may support authentication of datasets and may facilitate the safety of navigation in a new digital sense. ◂

Miros Launches Real-time Sea-state Data as Cloud-integrated Service

Ocean surface measuring specialist Miros Group will make dry measurements of sea state available through the cloud as a service. For customers this means flexible access to real-time data without having to cover the investment in data collection and transfer equipment. "Making sea-state data available in real-time through the cloud was a major step forward, but we believe that offering this as a pure service will be equally as important for our customers," explains Miros Group CEO Andreas Brekke. Brekke explains that Miros' line of Internet of Things (IoT)-based dry sensors, with no equipment exposed to water, is the key to the new service offering: "With a dry system there is virtually no maintenance once the system is in place. That allows us to be secure in providing the service without the customer having to pay for equipment maintenance." He confirms that customers may also purchase the sensors if they choose, and subscribe to the cloud service.

▸ *https://bit.ly/2yb2cwx*



▲ *Measuring the ocean surface.*

Mark Heine to Succeed Øystein Løseth as Fugro CEO

▲ *Mark Heine.*

Fugro's Supervisory Board has appointed Mark Heine as the new CEO and chairman of the Board of Management. He will succeed Øystein Løseth, who has decided to resign at the end of 2018 due to personal reasons. Løseth stepped down as CEO and chairman of the Board of Management on 1 October and will act as an advisor until the end of this year. He has been a member of the board since January 2018 and CEO since 26 April 2018. Mark Heine (born in 1973) started his career at Fugro in 2000 as geodesist on various onshore and offshore survey projects. As of 2002, he fulfilled several management roles in the Survey division with increasing responsibilities, allowing him to build up substantial international experience, both in the onshore and offshore business of Fugro. From 2012 he served as regional director Europe-Africa for the Survey division. In 2013, he became director of the Survey division and in April 2015 he was appointed as member of the Board of Management during the shareholders meeting. When Fugro's organisation was changed, he became responsible for the Marine division. Mark Heine holds a MSc in Geodetic Engineering from Delft University of Technology.

▸ *https://bit.ly/2C3IhSP*

AutoNaut USV Accompanies The Ocean Cleanup

An AutoNaut unmanned surface vessel (USV) has been launched alongside the revolutionary system of The Ocean Cleanup, the non-profit organisation deploying advanced technologies to rid the world's oceans of plastic. 'The Ocean Cleanup System 001', also known as 'Wilson', is undergoing extensive sea trials approximately 350 nautical miles from San Francisco to test the behaviour of the system. If all goes well, it will relocate to the Great Pacific Garbage Patch (GPGP) where it will begin the challenge of removing tons of plastic debris. The role of the AutoNaut USV is to conduct long-term monitoring of the surrounding environmental conditions and provide information on 'Wilson' itself. The AutoNaut USV is operating directly alongside The Ocean Cleanup's at-sea garbage-collection system. The small autonomous craft is overseen remotely by an operator at sea and a small team based on the south coast of England. Cameras on the AutoNaut's mast and hull provide a live-feed view of Wilson both from above and below the sea surface. Onboard sensors provide a scientific understanding of the environment by measuring the sea surface waves, oceanic currents, water quality and weather conditions.

▸ *https://bit.ly/2C2I02L*

▲ *AutoNaut USV.*

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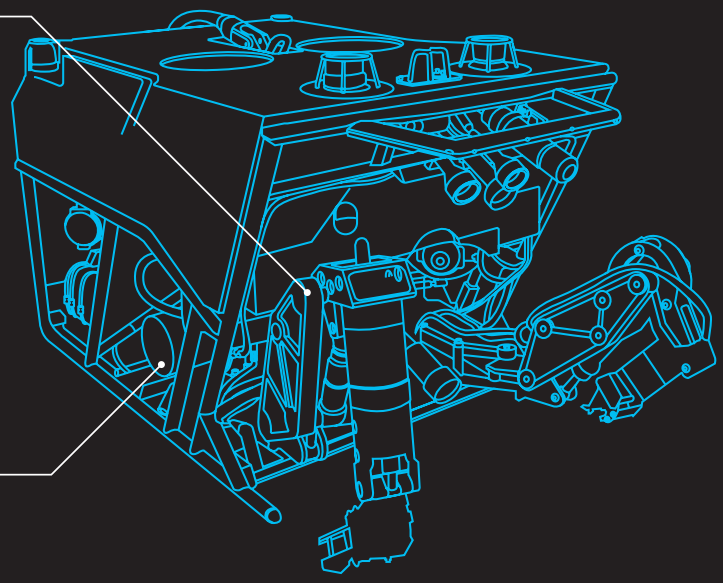

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UKHO Conducts Seabed Mapping in Dominica to Support Marine Economy

▲ *Dominica survey priorities.*

The UK Hydrographic Office (UKHO) has deployed a motorboat to survey the waters off Dominica as part of the Commonwealth Marine Economies (CME) programme. Following a stakeholder meeting with Dominica's Maritime Authority and wider government after Hurricane Maria in late 2017, priority survey areas were agreed to capture seabed mapping data of Dominica's main ports and approaches. The surveying in September 2018 focused on areas including Roseau, Portsmouth and Soufriere Bay. The mapping equipment used has no negative impact on the diverse ecosystems and marine life. Data from the survey will be used to update navigation charts of the region, as well as helping Dominica to meet its international maritime obligations, including respective elements of the Implementation of IMO Instruments Code (IIIC). These updated charts will reduce navigational risk and improve the safety of ships, cargo and crew, encouraging access for its growing cruise ship sector and maximising efficiency of trade by enabling ships to confidently increase cargo-carrying capacity.

▶ ***https://bit.ly/2Nvpnq3***

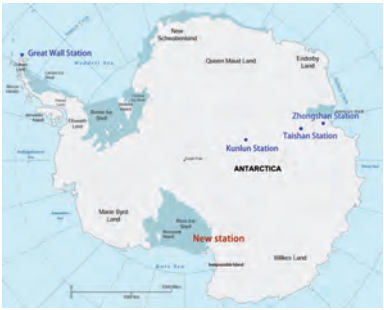
New EMODnet Bathymetry High-resolution Digital Terrain Model for the European Seas

▲ *3D visualisation of the Canary Islands.*

An upgraded version of the EMODnet Bathymetry digital terrain model (DTM) for the European Seas has just been released. This bathymetry product now offers higher resolution, powerful 3D visualisation functionality and extended coverage of Europe's seas. It is available free of charge for viewing, downloading and sharing by OGC web services from the EMODnet Bathymetry portal. The EMODnet DTM is a tool used for a whole range of applications in marine science, sustainable ocean governance and blue economy activities such as planning of pipeline trajectories, locations of offshore wind farms or planning of harbour extensions. In science, the DTM supports oceanographers in providing a base geometry for hydrodynamic models, marine geologists for studying morphological processes, and biologists in contributing to the generation of seabed habitat maps.

▶ ***https://bit.ly/2y6lwet***

Unmanned Technology Unveils the Mystery of Antarctica



▲ *China's Antarctica stations.*

Not long ago, China's fifth Antarctic scientific research station – the Ross Sea Station – officially laid its foundation stone on Inexpressible Island (74°54'S 163°39'E). While preparation and research already began a few years ago, the construction work will take another four years to fully complete. In November 2017, four unmanned surface vessels (USVs) from Oceanalpha Co., Ltd teamed up with the Antarctica expedition ship *Snow Dragon* all the way south to the Ross Sea to assist the construction project. The USVs worked for nearly 40 hours, completing a multibeam full-cover seabed topographic survey of five square kilometres. This not only fills the data gap in the region but also provides spatial geographic data support for marine navigation and the construction of the new station.

▶ ***https://bit.ly/2yeXxdd***

IMarEST Releases Report on Human Impact of Autonomous Ships

In a major piece of research, the IMarEST's Maritime Autonomous Surface Ships Special Interest Group (MASS-SIG) sought to gauge the potential impacts of self-governing ships and plot out a new course for the shipping industry's valued workforce. Autonomous technologies could create a competitive advantage for shipping companies, but adoption will vary significantly between market segments. This was one conclusion reached in an industry-wide investigation conducted by MASS-SIG. An initial survey went on to inform a roundtable discussion which in turn formed the basis of a report titled 'Autonomous Shipping – Putting the Human Back in the Headlines'. While only one in six believe that industry is fully geared up to exploit the autonomous or remote operation of commercial vessels in the immediate future, the general sentiment was that such technologies will deliver benefits over the long term. However, somewhat ironically, the success of unmanned ships will hinge ultimately on accommodating the human-in-the-loop.

▶ ***https://bit.ly/2E56US0***

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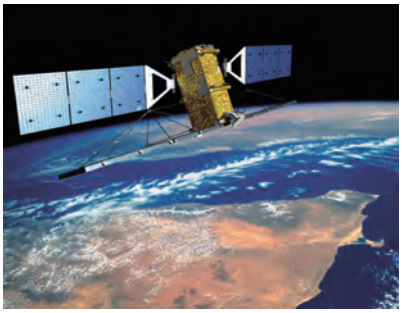
MDA Signs Multi-million Dollar SAR Information Contract with South Africa



▲ *RADARSAT-2 satellite.*

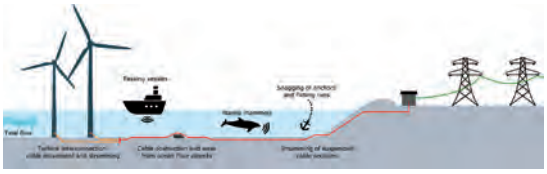
MDA, a Maxar Technologies company (formerly MacDonald, Dettwiler and Associates), has signed a multi-million dollar contract with the South African National Space Agency (SANSA) for a one-year maritime surveillance programme that includes the delivery of synthetic aperture radar (SAR) data products from the RADARSAT-2 satellite, using MDA's global network of ground receiving stations. The contract includes two additional option years. As part of the Presidential programme Operation Phakisa, SANSA has been tasked to acquire SAR imagery with the aim of enhancing the monitoring and protection of South Africa's coastal regions and oceans. Initiatives under this programme are considered crucial in accelerating the delivery of South Africa's development priorities. Operation Phakisa estimates that the approximate total contribution of coastal resources (marine fishing, port and harbour development, attractive lifestyles, recreation and tourism) is 35% of South Africa's GDP. The information provided by the SAR data contributes to ensuring improved governance and enables the securing of South African resources, such as the National Ocean and Coastal Information System.

▶ ***https://bit.ly/2E5Hxzs***

Integrated Subsea Cable Monitoring System Tested at EMEC

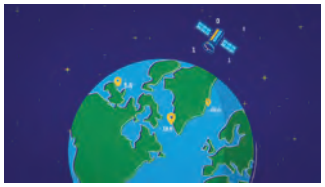
An innovate UK-funded project focused on developing a smart integrated monitoring system for offshore energy subsea cables has drawn to a close following successful tests at the European Marine Energy Centre (EMEC) in Orkney. The novel technology will ultimately lead to better maintenance and repair of underwater cables, reducing costs in the offshore energy sector. The 12-month Innovate UK-funded 'Cable Lifetime Enhancement via Monitoring using Advanced Thermal and electrical Infrastructure Sensing' (CLEMATIS) project demonstrated the technical and commercial viability of a new multifunctional distributed sensor system for the monitoring of subsea cable infrastructure in the offshore renewable energy sector. The CLEMATIS project included the Fraunhofer Centre for Applied Photonics and Synaptec, whose technologies were integrated into the system, and EMEC and SEA, who provided market intelligence, test equipment and facilities to enable the system to be tested in real life conditions. The project built on the 2016 desk-based ORCHIDS feasibility study which identified various breakthrough techniques that could be combined into a single power cable monitoring system and provide detailed fault prediction, dynamic thermal rating implementation and fault location.

▸ *https://bit.ly/2Rx46Q9*



▲ *Smart integrated monitoring system for offshore energy subsea cables. (Courtesy: Fraunhofer)*

Satellites Shed Light on Shallow Waters



▲ *Low-orbiting satellites equipped with light-measuring sensors.*

Keeping an eye on our waters is more important than ever, as widespread drought continues to sweep Europe this summer. The Earth's changing sea levels are crucial indicators of how our environment is fairing, but manual monitoring can be a labour-intensive, expensive and at times even dangerous task. Coastal areas provide additional complications, as shifting seabeds and currents make creating accurate and consistent water depth maps – also known as bathymetry – almost impossible. Satellites are ideally placed to address this challenge, however. Low-orbiting satellites equipped with light-measuring sensors can record how much light is reflected off the seabed, gathering and updating the information continually as they fly over. An ESA-backed group, led by TCarta, has developed a way of using this data to produce water depth maps, and making them available to anyone who could use them.

▸ *https://bit.ly/2QFsI8j*

Teledyne Gavia Introduces ASW Training Target Module

Teledyne Gavia, a global leader in the provision of low-logistics autonomous underwater vehicles (AUVs), has announced the recent delivery to an undisclosed military customer of a sonar transponder module (STM) for ASW training. The STM module made by Scanmatic AS of Norway and integrated into a Gavia payload module is capable of receiving and retransmitting sonar signals for training sonar operators. The STM consists of a flooded transducer compartment, an electronic compartment and a hydrophone that is towed behind the Gavia AUV. The STM is programmable to emulate different types of realistic submarine target characteristics including sizes and speeds for cost-effective and re-usable ASW training applications.

▲ *Sonar Training Target Module for Gavia UAV.*

▸ *https://bit.ly/2BZIUNr*

Ocean Aero Receives Multi-million Investment from Lockheed Martin Ventures and Energy Innovation Capital

Ocean Aero, builder of environmentally powered, autonomous, unmanned, underwater and surface vehicles (AUUSVs), announced that it has secured multi-million dollar strategic investments from both Lockheed Martin Ventures and Energy Innovation Capital (EIC) in a Series B funding round. This is Lockheed Martin Ventures' second investment in Ocean Aero and the initial investment for EIC in the unmanned maritime systems market. Both companies join Teledyne Marine as the primary investors behind Ocean Aero. Lockheed Martin Ventures' investment continues to increase the company's maritime capabilities with a focus on intelligence, surveillance and reconnaissance (ISR). EIC will provide Ocean Aero with significant growth opportunities in the energy and other commercial sectors. Ocean Aero's signature product is the Submaran, the first hybrid wind and solar-powered surface and subsurface vehicle designed for extended ocean observation and data collection. The Submaran participated with Lockheed Martin on a successful, multi-domain unmanned systems technology demonstration during a naval technology exercise at the Naval Undersea Warfare Center in Newport, Rhode Island. The Submaran relayed instructions to Lockheed Martin's Marlin autonomous underwater vehicle, instructing it to launch Vector Hawk, a small, unmanned aerial vehicle.

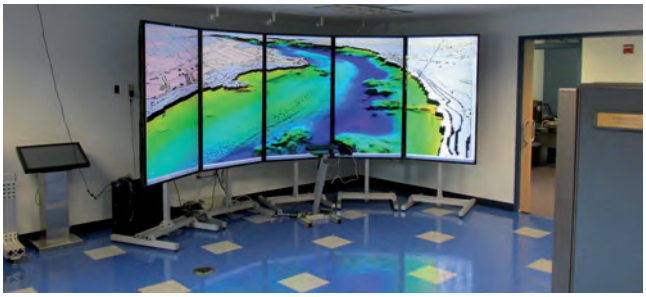
▸ *https://bit.ly/2QySEIK*

▲ *Submaran S10.*

CCOM at UNH Partners with FarSounder

The Center for Coastal and Ocean Mapping (CCOM) at the Joint Hydrographic Center at the University of New Hampshire (UNH) in the USA has added FarSounder as a partner in its Industrial Associates programme. As a globally recognised expert in 3D forward-looking sonar technology, FarSounder gives the students a new layer of information for their studies. In addition to providing students the benefit of identifying obstacles ahead of the ship, FarSounder's technology has a fascinating feature called Local History Mapping (LHM). This application draws a virtual 3D image of the ocean floor as a ship sails over. This bathymetric image is updated with every ping and can be displayed as an overlay on top of a chart.

▸ *https://bit.ly/2Nuv8Ey*



▲ *Center for Coastal and Ocean Mapping.*

Geomares Establishes Subsidiary for Technical B2B Marketing Services

Marketing and media company Geomares today announced that it is splitting off its marketing services and transferring them to a newly founded subsidiary: Factrics, marketing by facts. Durk Haarsma, director of strategy & business development at Geomares, explains: "This move represents a conscious choice to clearly separate our advertising and marketing services, both internally and externally. The Geomares brand remains an essential link in the interaction between professional buyers and businesses in the geomatics and hydrographic community." " We hope that Factrics will help us become the go-to digital marketing agency in the technical B2B industry, supported by our extensive industry experience in geomatics and hydrography, and in-depth knowledge of digital marketing," Haarsma adds. Factrics will actively contribute to the growth of its customers by developing, executing and optimising effective business-to-business (B2B) digital marketing campaigns. Factrics distinguishes itself through its unique combination of knowledge and experience of both the technical geospatial B2B industry and the world of online marketing.

▸ *https://bit.ly/2Nudvoz*

A Cloud-based Infrastructure Specifically Designed for Marine Navigation

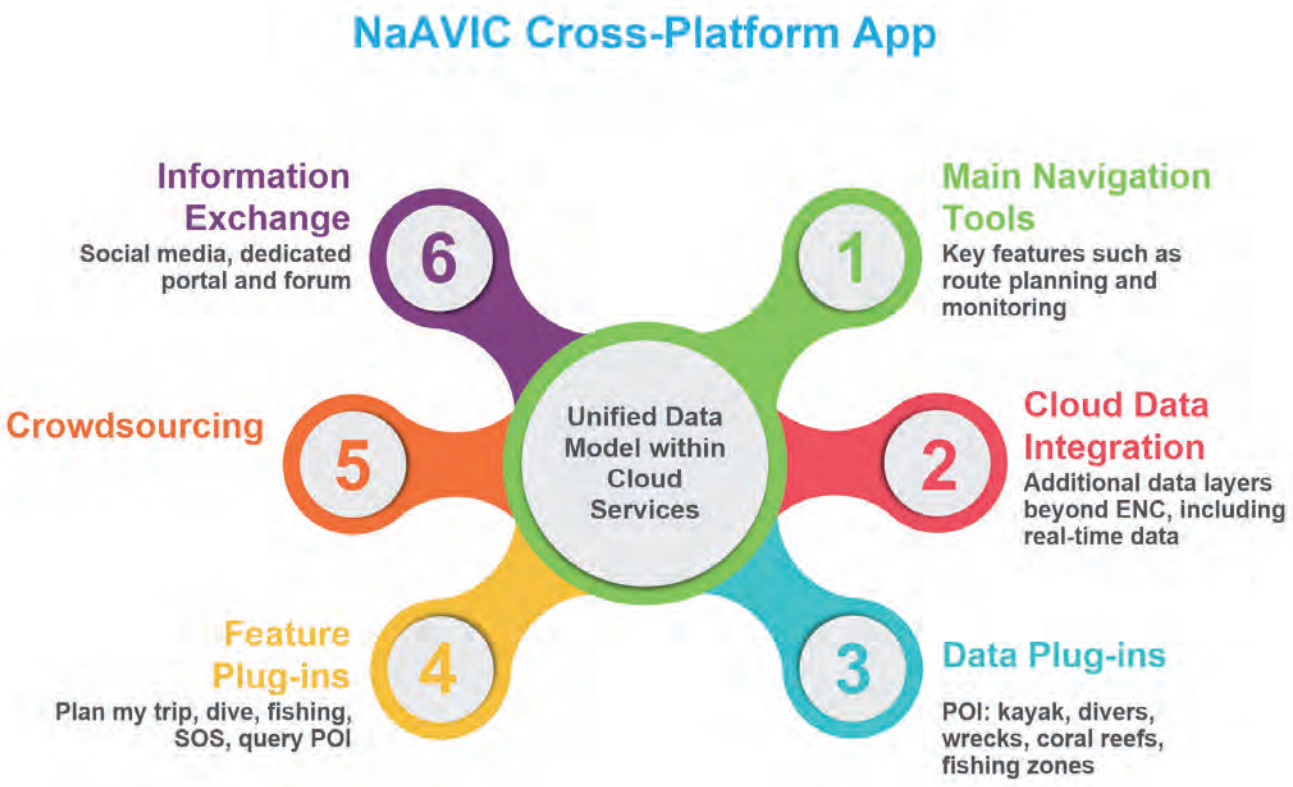
Streaming Cloud-based ENC Data for a Real-time ECS

A free and downloadable electronic voyage application that goes beyond the traditional Electronic Chart System (ECS) app whereby the data, including the ENC information, does not physically reside within the onboard computer. Instead, all data are streamed from an up-to-date database that exists in the cloud. The on-demand data delivery model is not confined to conventional chart data. Whilst it includes ENC-derived data as a base layer, it is also designed to take additional data layers. These layers can be user-selected according to their needs to enhance the ECS capabilities. As examples, the list can include raster satellite imagery, high-resolution bathymetry, weather radar imagery, predicted tides and currents, as well as real-time weather data streams along with domain-specific and local information. All data is streamed through an open source – open standards-based Nautilus Cloud system.

Figure 1: NaAVIC ECS features.

A Free ECS

NaAVIC, is a free and downloadable ECS app that can function on any mobile Android or iOS device. The app offers a comprehensive range of essential features needed to maintain safety and situational awareness while making navigation easier and more reliable. There is no downloading of data. All data, including chart data, is streamed in real-time from a fully maintained and up-to-date database. The data comes from the Nautilus Cloud, a cloud-based infrastructure specifically designed for marine data. The technology is designed to provide the basis for maintenance and distribution services for any marine data supplier. The Nautilus Cloud adopts a 'cloud native' approach where the technology is built from components designed to run in cloud environments as well as leveraging open standards and open source components throughout. The result is a flexible system with a much greater degree of interoperability. This can include the emerging S-100 framework, harmonised metadata, raster datasets and real-time sources. The NaAVIC ECS can operate on real-time and up-to-date information from data providers. This can include the government agencies looking to make more efficient the accessibility to their data without compromising its integrity. Figure 1 outlines the key features that NaAVIC offers.



▲ *Figure 2: Geospatial Features via Nautilus Cloud.*

Nautilus Cloud Framework

The data powering the ECS is supplied by the Nautilus Cloud, a cloud-based infrastructure for marine data, solutions and services for government organisations, industry and consumers. Nautilus Cloud leverages open source components as its base technology and utilises open standards wherever possible to build an enterprise-grade system which is flexible and has a much greater degree of interoperability with pre-existing components and multiple data sources. As such, Nautilus Cloud is optimised for the import, validation, data management as well as commercial distribution of marine geospatial data for government organisations, the marine industry and end consumers. Figure 2 illustrates the many additional ECS features that are supported by the Nautilus Cloud framework.

Key Features

One of the key features of Nautilus Cloud is the expansion of data holdings into a much wider family of related geospatial data products. It is designed to handle the many forms of marine geospatial data under the emerging IHO S-100 framework, harmonised metadata, raster, predicted and real-time sources. The modular design allows front-end applications to access the spatial data on any platform, from desktop and mobile platforms to OGC-compliant web services and web map tile services for onward consumption of data by other organisations.

Nautilus Cloud is designed to handle the many forms of marine geospatial data under the emerging IHO S-100 framework

The NaAVIC ECS app takes full advantage of many advanced features provided by Nautilus Cloud making it possible to operate on real-time and up-to-date information from charting agencies without the time-dependent updating and distribution process. This also includes being able to use real-time tides, weather, currents and other oceanographic information to provide more advanced features and data views that otherwise would not be possible. Thus achieving three important requirements for the ECS: content, quality and updating.

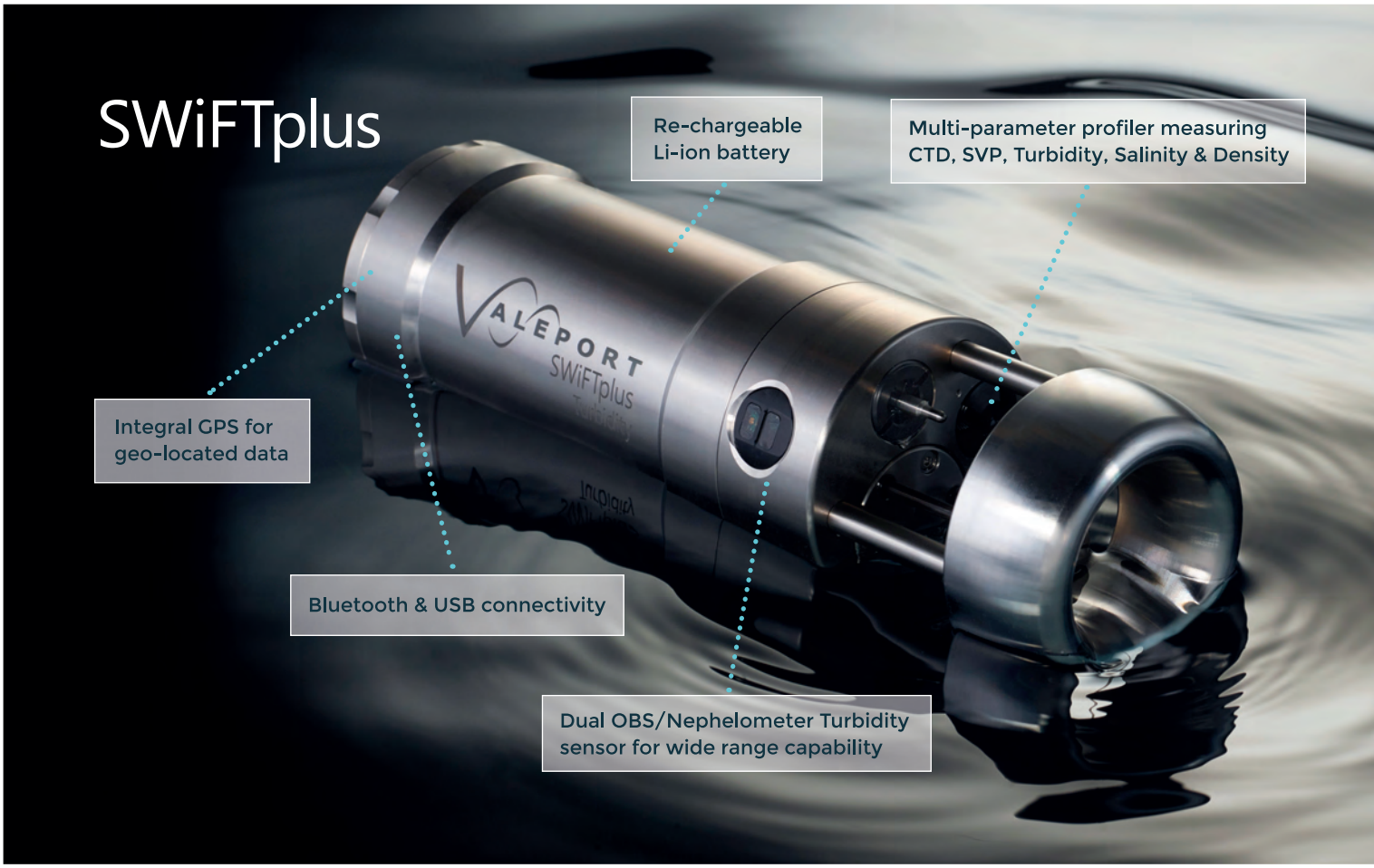
Maintaining Data Integrity

NaAVIC addresses the concern of reliable internet connection by providing smart, user-controlled data caching functionality. It is always capable of automatically caching to ensure reliable data availability. Users, based on their specific circumstances, will be able to set the app to auto-caching the required data ahead of time for a pre-defined area size. Alternatively, they can interactively define the area to cache before departure. Many users will likely use the app within nearshore coastal areas where modern data networks have the coverage readily available, so caching is an important fail-safe feature.

Enabling

The Nautilus Cloud innovation enables the data facilitator by introducing the following features:

- A 'cloud native' approach where the technology is built from components designed to be run in cloud environments.



- A strong integration between data distribution and storage/management.
- The Nautilus Cloud system leverages open source components as its base technology and utilises open standards wherever possible to build a low-cost system which is flexible and has a much greater degree of interoperability with pre-existing components.

Data will be intuitively useable to end users and to onward systems and derived applications

Engagement – Connecting the Producer and End User

The approach taken is a conscious attempt to connect the user of nautical data with the producer of nautical data. This engagement between supplier and consumer is something happening throughout the various domains within the geospatial industry. Data holdings are ever expanding and becoming more accessible, and now includes the S-100 framework, as well as harmonised metadata, raster and real-time sources.

The approach facilitates 'pluggable' architecture and thus allows for extensible and customisable data import into the system and future-proofs it for a wide variety of organisations. Additionally, the metadata management sub-system will provide the functionality needed to allow individual customers to easily generate metadata records compliant with their national metadata profiles.

Voyage Intelligent Visualisation

NaAVIC and the Nautilus Cloud also aim to support the next generation of Intelligent Visualisation technology – the right information at the right time - which adds a new dimension of customisation to traditional geospatial data engines. This will make data intuitively useable to end users and, through web services, to onward systems and derived applications.

Sharing the Journey

We are seeing it with land-based journeys and within recreational activities as a whole – people want to share. The desire to share experience comes with the desire to help and the desire to benefit from collective experience, particularly of like-minded people, with many people now relying more on social media than the more traditional commercial guides. Social media has facilitated collaboration, coordination and community.

Up until now, the ECS catered to the person controlling all aspects of the vessel, including its navigation. By utilising a cloud-based approach with data streaming, the NaAVIC ECS enables all members of an expedition to more actively engage in the voyage as well as sharing that voyage to fellow 'marine friends'. It also provides ways for everyone to have a much more enjoyable boating experience, including providing an easy way to monitor the route along with the main navigator,

see the basic boat information such as location, speed and heading, and exchange information about various points of interest with friends.

All users get access to community features, which include the ability: to post messages, to share pictures, to share location, to record and share voyages, and to add user objects with location sensitive notifications. It also allows community members to effortlessly support crowdsourcing activities by allowing them to use a set of pre-defined icons to capture a variety of items of interest to their specific sub-communities. For example, marking a fantastic new diving spot for the user community is as easy as dropping 'great diving spot' marker and the platform will automatically share such info with all other users or with a selected group or the info can be kept private if users want to keep their findings to themselves!

Flexible Business Model

Nautilus Cloud's commercial distribution interface assists organisations who need to sell data as part of their operating model. By offering both free and paid access to data the system gives organisations the ability to switch between free and cost-recovery models as their demands dictate. It allows the substitution of multiple disparate systems which may be already in place, with a system at substantially lower costs for implementation and support.

The system uses a highly standardised data output interface and a comprehensive approach to data integrity which is crucial in the modern marine data environment. By providing open and efficient access to marine data the system facilitates social and environmental value, e.g. by providing easy standardised access for data to be used for marine pollution prevention, alternative energy production and marine research.

Summary

NaAVIC, is a free and downloadable mobile ECS that represents a new approach where the electronic chart data does not physically exist within the onboard computer. NaAVIC attempts to thrust the sailing experience several steps further by enabling all members of expeditions to engage in the voyage and share that voyage to fellow 'marine friends'.

The data supplied to ECS app is provided by the Nautilus Cloud, a cloud-based infrastructure for marine data, solutions and services for government organisations, industry and consumers. Because of this approach, NaAVIC can operate on real-time and up-to-date information from charting agencies without the time dependent updating and distribution process. This would include real-time tides, weather, currents and other oceanographic information if such information were readily available.

The system provides a flexible business model by facilitating the ability to switch between free and cost-recovery models of data distribution as their requirements dictate. ◀

Derrick R. Peyton is presently the CEO of IIC Technologies and the Governing Council chairman for the IIC Academy. He has been involved in the geomatics community for over 40 years.

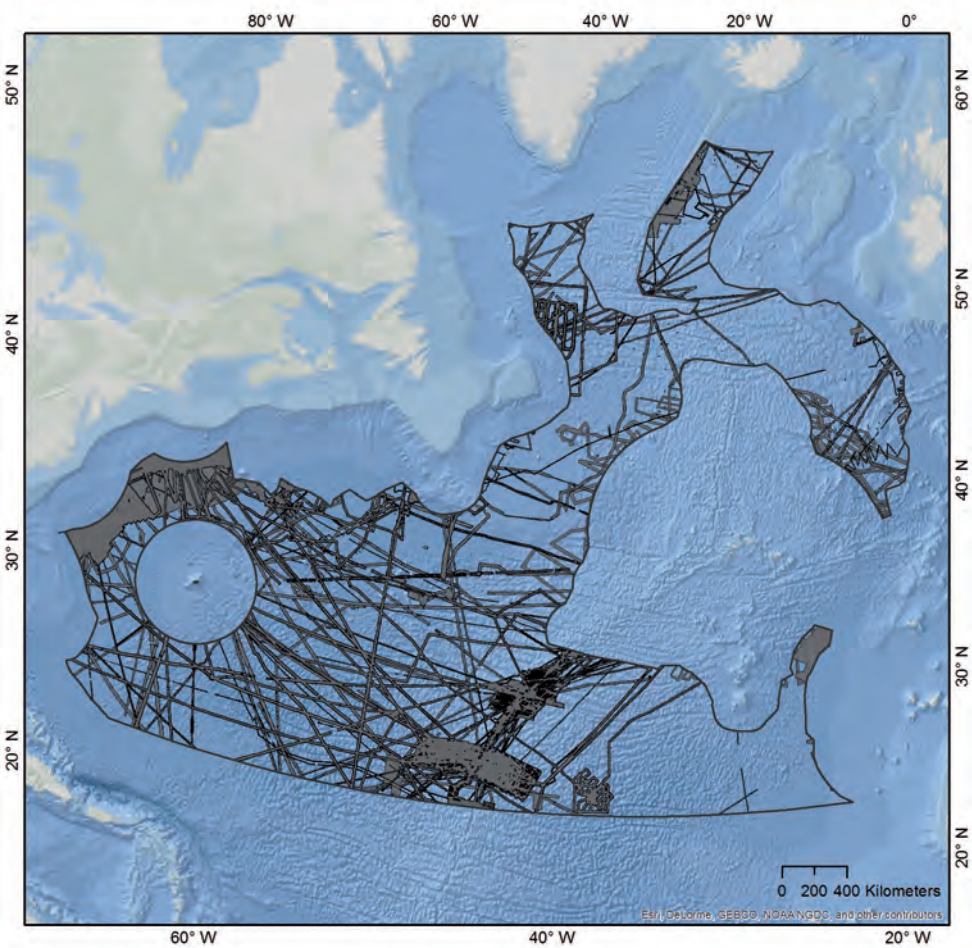
A GIS Case Study from the Atlantic

Where Do We Map Next?

Mapping the world's oceans is a tremendous task that would benefit from a prioritisation strategy. In this article, an in-depth presentation of one such approach is given: a GIS-based analysis that identified potential target areas for future mapping efforts in the North Atlantic Ocean. The authors state that more knowledge about the seafloor could be significantly accelerated if all bathymetric data were publically available.

A Worldwide Data Gap

Bathymetry underpins the safe, sustainable and cost effective execution of almost every human activity that takes place at sea, yet most of the seafloor remains virtually unmapped, unobserved and unexplored. In fact, less than 15% of the depth of the world's ocean waters have been measured directly and only about 50% of the world's coastal waters (waters < 200m deep) have ever been surveyed. Knowledge of the seafloor is a crucial factor in using the oceans, seas and marine resources for sustainable development and hence attaining the UN Sustainable Development Goal 14. With so much ocean floor out there that needs to be surveyed, how do we choose where to begin?



▲ *Figure 1: Map showing multibeam data in the study area from the Global Multi-resolution Topography Synthesis (GMRT), National Centers for Environmental Information (NCEI), EMODnet and from the Spanish and Portuguese National Archives (modified after Wölfl et al. (2017)).*

A Strategy is Needed

Even today, any mapping of the seafloor is likely to cover 'terra incognita'. So it may not seem particularly important to choose where to go - any mapping will yield new results. However, as global and regional campaign mapping initiatives (e.g.: Seabed 2030) gain momentum, more strategic approaches will be needed to avoid costly duplicative efforts and also to keep potential mapping-related environmental impacts (e.g. ocean noise) to a minimum.

Furthermore, there are regions within the ocean that are of potential special interest to a variety of stakeholder groups: prioritising mapping in these regions may have advantages in terms of the blue economy or developing sustainable ocean management plans.

An Idea is Born

The idea to analyse and identify seafloor mapping areas for future bathymetric surveys in the North Atlantic was initiated by the Atlantic Seabed Mapping International Working Group (ASMIWG), whose aim is to develop and implement a cohesive mapping strategy in the Atlantic Ocean. This working group was established in association with the 2013 Galway Statement on Atlantic Ocean Cooperation that was signed by Canada, the European Union and the United States to enhance cooperation and increase knowledge of the Atlantic through better coordination and collaboration in ocean observation efforts.

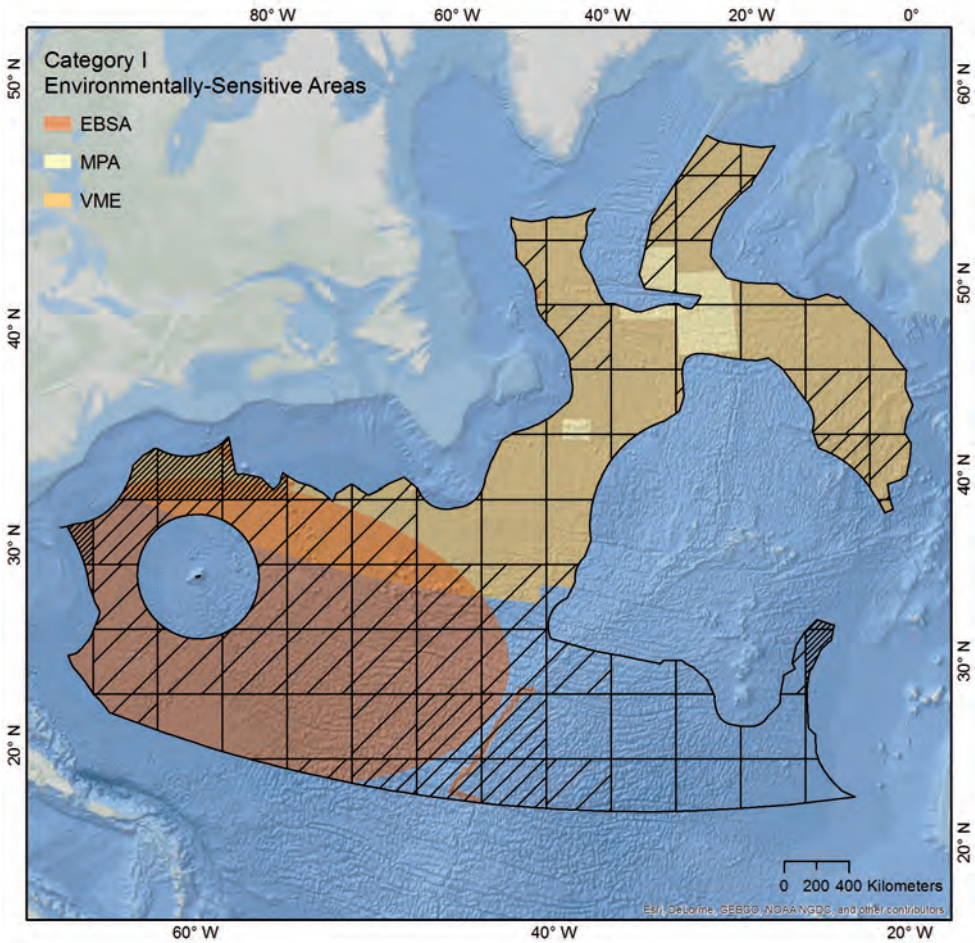
The working group set out to determine the priority of survey need, based on pre-defined

stakeholder parameters, of every 400 x 400km area within the North Atlantic High Seas area and to identify the three areas with both the highest suitability and least amount of previous bathymetric data coverage. The basic assumption was that the greater the number of stakeholder interests present at a certain site, the higher its suitability. The area size of 400 x 400km was chosen as being mappable within approximately 100 days using modern techniques, equivalent to a single cruise campaign involving three ships, one from each of the major Galway partners. The North Atlantic study area was defined as lying between 23°N (Tropic of Cancer) and 66°N (Arctic Circle), and excluding both national EEZ and their granted or pending extended continental shelf claims.

The Selection of Parameters

A key step in the analysis was to first determine where bathymetric data already existed. Perhaps surprisingly, this was not a trivial task as only a small percentage of existing multibeam data and associated geographic information is easily accessible through online portals such as the International Hydrographic Organization Data Centre for Digital Bathymetry, Global Multi-Resolution Topography Synthesis (GMRT) and EMODnet Bathymetry. To determine the current data coverage in an area, multibeam swaths accessed from these databases were combined and displayed. Where only ship tracks were available and the swath coverage was unknown, a buffer of 2.5km around the track was used (Figure 1). A single-beam density grid from NOAA, showing the number of soundings per 0.02° cell, was also analysed but not included in the data coverage calculations, due to the lack of significant spatial coverage of single-beam data in areas where multibeam coverage did not already exist.

The working group then identified a set of parameters based on the interests of various stakeholder groups (such as scientists, industry and environmental organisations) that factor in areas of public interest, sensitive marine areas and areas with marine resource potential. The following parameters were then included in the analysis:



▲ *Figure 2: Map of the study area showing the GIS parameter layers of category I -Environmentally-sensitive Areas (modified after Wölfl et al. (2017)).*

- Ecologically or Biologically Significant Marine Areas (EBSA)
- Marine Protected Areas Network (MPA)
- Vulnerable Marine Ecosystems (VME)
- Flight Lines (FL)
- Shipping Lanes (SL)
- Important Areas for Cobalt-rich Ferromanganese Crust Formation (FMC)
- Important Areas for Manganese Nodule Formation (MN)
- Important Areas for Massive Sulphide Formation (MS)

The parameters were grouped into three categories, i) Environmentally-sensitive Areas (EBSA, MPA, VME) displayed in Figure 2, ii) Areas of Public Interest (FL, SL) and iii) Areas with Marine Resource Potential (FMC, MN, MS), to ensure a balance between user-group interests. These parameters reflect the attributes a potential target area could possess in order to increase its priority for future planned bathymetric surveys. Which particular parameter within a category is of interest to any particular stakeholder depends on the individual stakeholder interest.

Identify three areas with both the highest suitability and least amount of previous bathymetric data coverage

The GIS Analysis

The target areas were defined using GIS techniques and included parameters of the marine environment as well as available information regarding data coverage. The GIS analysis was performed with ArcGIS 10.4, but can also be performed with other common GIS software. First, the three categories were integrated into the GIS as individual geospatial vector layers (shapefiles) and transformed into raster layers of 1 x 1km cells. These layers were then combined using an overlay technique and

an expression executed to add up the cell values. The desired outcome of the analysis was to obtain information about the suitability of every cell as a target area by assigning it a suitability value. Therefore, a value of one or zero was assigned to each cell for every raster layer, depending on the presence or absence of the respective category in the cell. The result is a map showing the spatial overlap of the three categories. A very low suitability would result from the absence of all categories in a cell, a low suitability for the occurrence of one category, a medium suitability for the occurrence of two categories and a high suitability for the occurrence of all three categories.

Results and Discussions

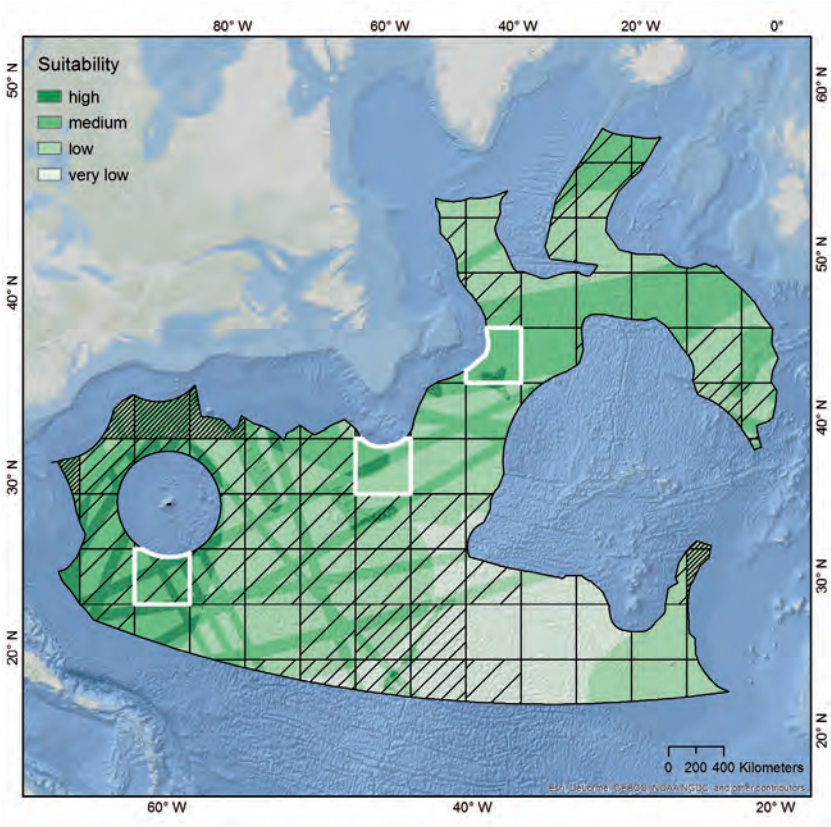
Figure 3 shows the results of the suitability analysis based on select stakeholder interests. For visualisation purposes, the multibeam data coverage was classified into four bands (0-25%, 25-50%, 50-75% and 75-100% of the area mapped with multibeam data) for each polygon. A high occurrence of desired attributes at a specific location results in a high suitability as a potential target site. The three regions of highest priority singled out by this analysis have not only a high occurrence of desired attributes, reflected in a high suitability class, but also a relatively low multibeam data coverage.

The first target area, in the north of the study region, includes the Milne Seamount located close to the continental slope and reaching abyssal depths of 6000m. Milne Seamount is part of the Milne Seamount Complex, a Marine Protected Area. 13% of this area was classified as highly suitable, the rest, of medium suitability, with all three categories represented. Only 13% of this area has been mapped in detail.

Southwest of the Milne Seamount Complex is the Sohm Plain Area. With 24% of the area mapped, the seafloor has been characterised as being made up of abyssal plains and hills. 14% of the area is classified as highly suitable with all three categories occurring. The remaining area shows medium and low suitability classifications.

Directly east of the US coastline and north of the Caribbean is the Sargasso Sea Area. Almost half of this target area is highly suitable (45%), the

A GIS analysis can be easily adjusted and repeated to include new criteria depending on interest or new data



▲ *Figure 3: Result map showing the suitability of the study area and the three selected target areas (modified after Wölfl et al. (2017)).*

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Colin Devey is Professor of Oceanic Volcanism at GEOMAR in Kiel, Germany. His research centres on the fluxes of heat and materials from the Earth´s interior to the seafloor, trying to understand how the oceanic crust and ocean water interact over geological time. His present focus is on finding ways to map large areas of the seafloor to make useful geological maps relevant for global mass balances, mineral prospection, marine protection and spatial planning.

For the past nine years, **Jennifer Jencks** has been working at the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) in Boulder, Colorado. She is the director of the IHO Data Center for Digital Bathymetry, leads the NCEI Ocean and Coastal Mapping Team, manages global marine geophysical data archives, and is actively involved with many national and international seafloor mapping projects. Before joining NCEI, Jennifer worked offshore for the Integrated Ocean Drilling Program and for a geophysical consulting firm in California. She earned her BSc in Geological Engineering from the University of Mississippi and her MSc in Ocean Engineering from the University of Rhode Island.

other half, medium suitability with the presence of all three categories. This area is mostly categorised as the abyssal plain although a small area likely reaches below 6000m water depth and so into hadal regions and shows 26% data coverage.

Conclusions and Outlook

Identifying the three target areas using a selection algorithm and a GIS-based overlay technique, is one approach to answering the question "Where do we map next?". However, we acknowledge that the interdependencies between some of the selection criteria (e.g.: data coverage density and the designation of Environmentally Sensitive Areas) can lead to the suitability of some areas being underestimated. For example, many marine protected areas are designated based on knowledge of the seafloor (e.g.: data coverage). Therefore all presently unmapped regions warrant further study and may harbour features of particular stakeholder interest. Changing this situation and so gaining more knowledge about the seafloor could be significantly accelerated if all bathymetric data were publically available and accessible to all.

The value of a GIS analysis is that it can be easily adjusted and repeated to include new criteria depending on interest, or new data as they become available. It provides an objective way to prioritise mapping areas. We think that this approach can contribute to filling the large knowledge gaps in our oceans by highlighting unmapped areas and suggesting potential mapping targets.

From Pilot Analysis to Data Collection

On 12 July 2018, the NOAA Ship *Okeanos Explorer* left Norfolk, VA to conduct a 24-day exploratory mapping expedition in the Sargasso Sea Area (Figure 4). The objectives of the first US-led mapping effort in support of the Galway Statement on Atlantic Ocean Cooperation were to collect critical baseline information about the unknown and poorly understood deepwater area. The expedition mapped over 52,000 square kilometres (20,400 square miles), an area almost three times the size of New Jersey, and acquired multibeam bathymetry, backscatter, sub-bottom and water column sonar data. More information on this expedition can be found on NOAA's website. ◀

▲ *Figure 4: NOAA Ship* Okeanos Explorer *at sea. (Image courtesy of Art Howard/NOAA OER)*

Further reading:

Wölfl, A.-C., Jencks, J., Johnston, G., Varner, J.D., Devey, C.D., (2017). Where to Go Next? Identifying Target Areas in the North Atlantic for Future Seafloor Mapping Initiatives. The Journal of Ocean Technology, 12(4), 28-42.

Ifremer's Explorations and Research

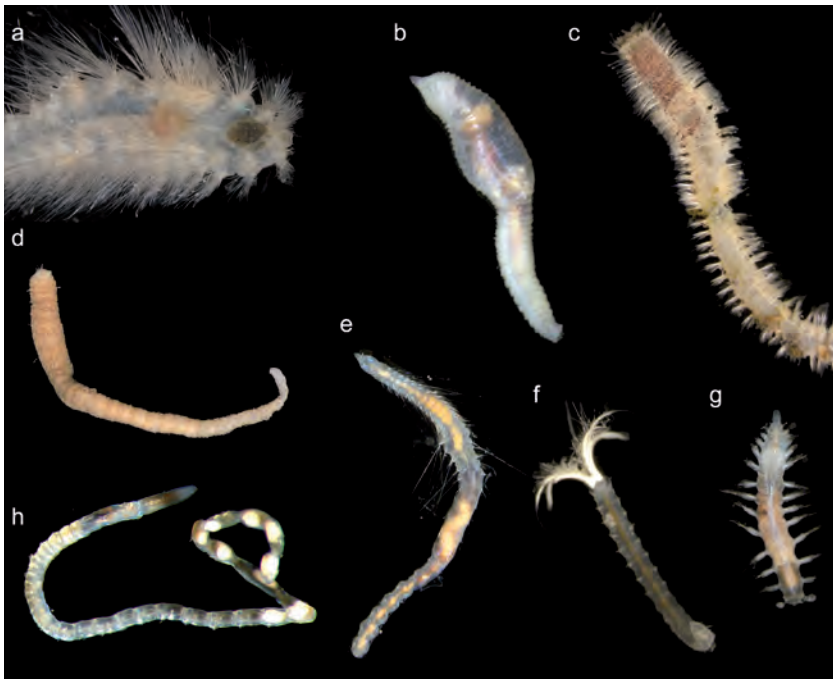
Understanding Deep-sea **Minerals and Ecosystems**

France and Ifremer have had a long involvement in the discovery and study of deep-sea mineral resources and their associated ecosystems. With a rather unique position in the marine research landscape, Ifremer is actively involved in the deep-sea both as a contractor with the ISA and as an integrated marine science research institute. The HERMINE 2017 exploration cruise on the French polymetallic sulphides exploration contract is an example of combined mineral exploration and scientific investigations.

In the seventies, France was amongst the pioneer nations that discovered the metal-bearing hydrothermal sources and explored the polymetallic nodule deposits in the Clarion Cliperton Fracture Zone (CCFZ) located in the northern central Pacific. A strong commercial interest for these potential sources of minerals initially triggered an important exploration activity by countries such as China, Germany, India, Japan, Korea, France, etc. Then, in the 1980s, unfavourable market conditions halted this exploration.

The last two decades have seen a renewed interest for these potential sources of minerals sparked by factors such as the rise of metal prices, the development of low-carbon technologies increasing the demand for some minerals and geopolitical issues. Exploration of the three types of deep-sea mineral resources - polymetallic nodules, in abyssal plains; polymetallic sulphides (PMS), along mid-ocean ridges and in back-arc basin context; and cobalt-rich ferromanganese crusts, on seamounts - has therefore been an item of increasing interest on the international agenda.

As an integrated marine science research institute, Ifremer plays a particular role in the French national strategy for the exploration and exploitation of the deep seabed minerals. Under the sponsorship of France, Ifremer has signed two exploration contracts with the International Seabed Authority (ISA), which regulates the activities related to deep-sea minerals exploration and exploitation in the Area. The institute also conducts fundamental and applied research related to both the geological and environmental aspects of deep-sea minerals as well as technology developments.



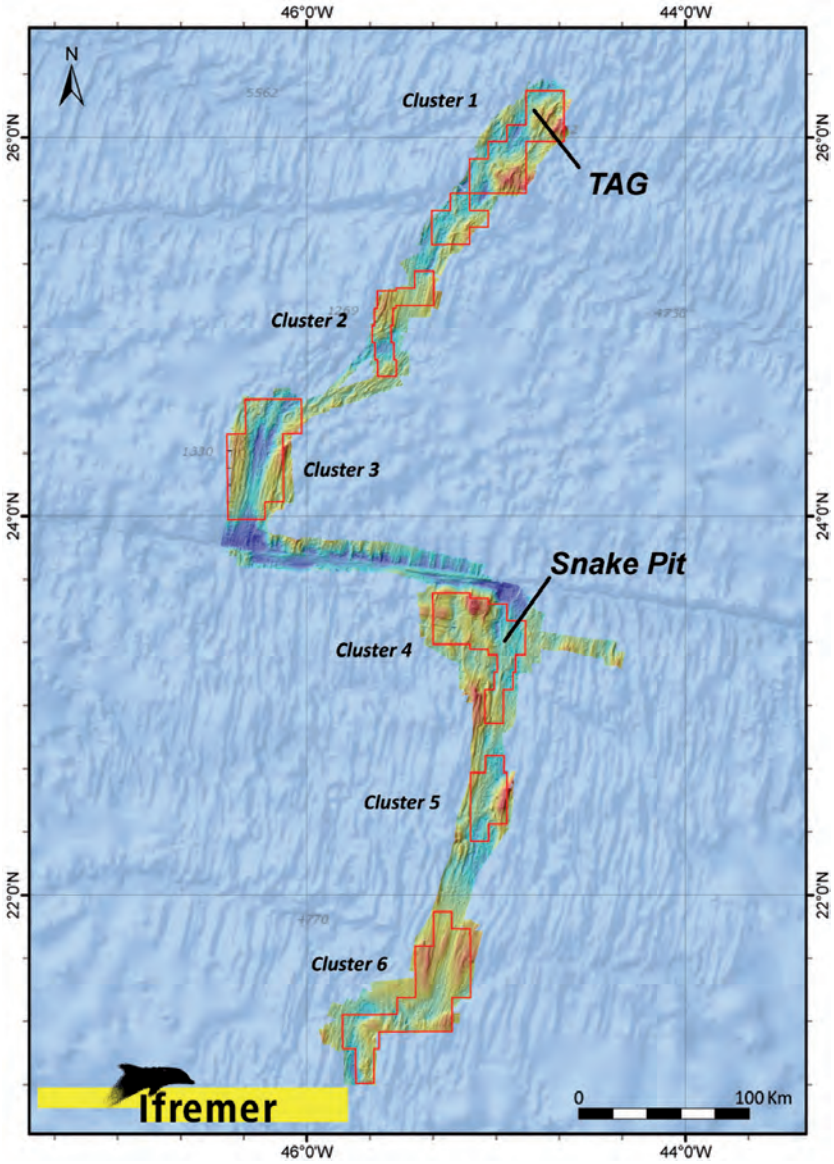
▲ *Figure 1: Diversity of polychaetes families in the CCFZ area : (a) Amphinomidae, (b) Travisiidae, Travisia sp., (c) Poecilochaetidae, Poecilochaetus sp. (d) Flabelligeridae, (e) Cirratulidae, Chaetozone sp. (f) Sabellidae, (g) Syllidae, Anguillosyllis sp. et (h) Lumbrineridae, Lumbrinerides sp. ©Ifremer*

Ifremer's Exploration Contracts with the ISA

The exploration contract for polymetallic nodules, signed in 2001, covers an area of 75,000km² in the CCFZ and was extended for five years in 2016. Investigations conducted so far have resulted in a first estimate of the mineral resources and a better understanding of the benthic ecosystem. For instance, studies led within the JPI Oceans pilot action have highlighted the diversity and importance of the epifauna associated with the nodules and found that recovery of the fauna from previous small

experimental mining simulations, up to 37 years old, was very slow (Vanreusel et al., 2016). Despite this progress, our knowledge about the functioning of these ecosystems and their resilience remains too limited to evaluate the potential impact of the exploitation of nodules. These questions are therefore the focus of our current activities.

The exploration contract for PMS was signed in 2014, for a period of fifteen years, and covers an area located on the Mid-Atlantic Ridge, spreading from 21°N to 26°N at an average depth of 3,400m. The activities, planned as part of the exploration programme, aim at locating hydrothermal vent fields and extinct seafloor massive sulphides, estimating the mineral resources in the contract area and assessing the biodiversity and environmental parameters at a regional and local scale over the sites of potential mining interests.



▲ *Figure 2: Map of the French exploration contract for polymetallic sulphides on the Mid Atlantic Ridge with its six clusters containing the 100 exploration blocks. ©Ifremer*

Research Activities

In addition to the activities performed as an ISA contractor, Ifremer also conducts fundamental and applied research on the deep-sea, which is one of the institute's strategic themes, with the following objectives:

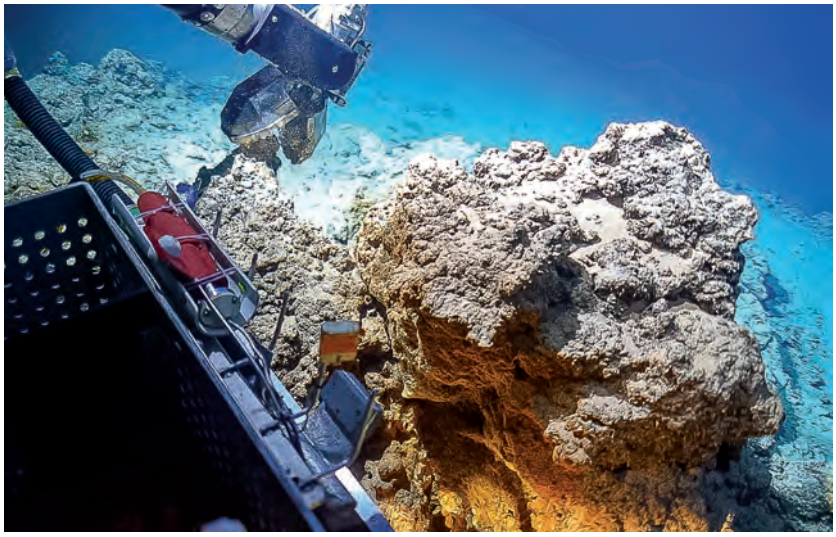
- To understand the geo-biological processes controlling the creation of the mineral resources;
- To develop technologies and methodologies for innovative and multi-scale exploration, observation, analysis and monitoring;
- To describe and understand the composition, structure and functioning of deep-sea ecosystems.

A collective scientific assessment group, led by the CNRS (Centre National de la Recherche Scientifique), provided a summary of the international scientific knowledge available on the environmental impacts of exploration and exploitation of deep-sea mineral resources. It also identified the scientific barriers and research and development activities required to break them (Dyment et al. 2014). Although recent studies and projects have partly improved our knowledge and filled some of the gaps identified, this knowledge remains inadequate.

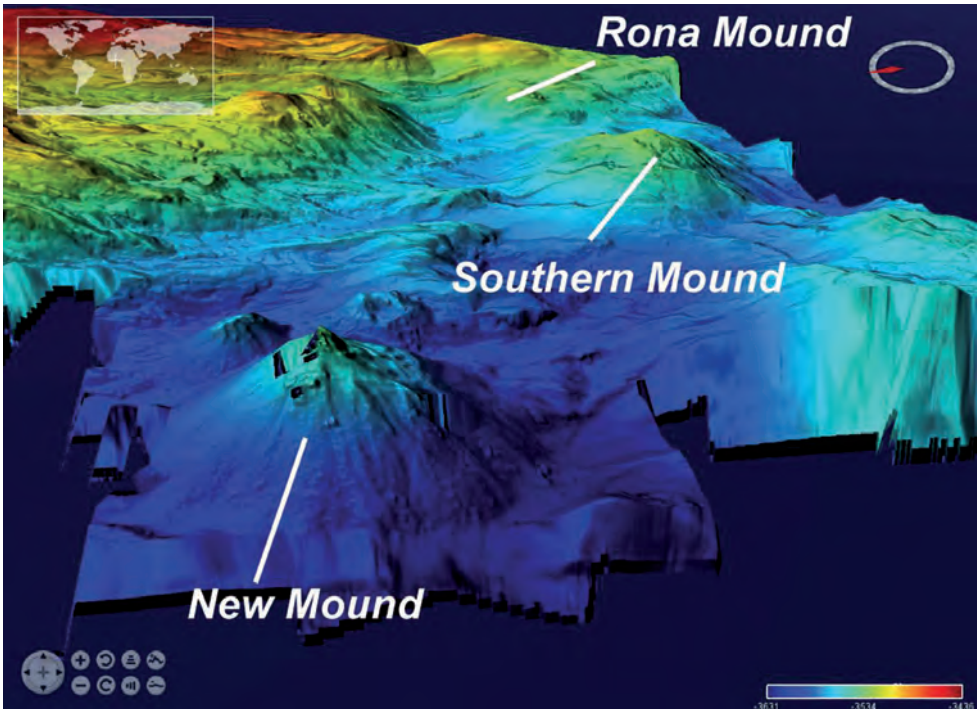
The JPI Oceans pilot action 'Ecological aspects of deep-sea mining', led by Geomar, has shed some light on the CCFZ ecosystems composition (Figure 1) and on the potential impacts of polymetallic nodules exploitation by assessing the biodiversity and recovery of sites that had seen small experimental mining simulations over decadal timescales. However, the size of these experiments is not representative of future commercial scale operations and does not allow for a proper assessment of their impacts. To overcome these limitations, a new JPI Oceans project, named 'Mining impact', has started. This project will set up a comprehensive monitoring programme to ensure an independent scientific investigation of the environmental impacts of an industrial nodule collector components trial, planned by the Belgian contractor DEME-GSR in 2019.

Activities include locating hydrothermal vent fields and extinct seafloor massive sulphides

Ifremer, in collaboration with the Sorbonne University, the MNHN and the Mediterranean Institute of Oceanography, currently leads a research project on the hydrothermal vent ecosystems. The data collected during two scientific cruises (BICOSE 1 & 2 in 2014 and 2018; http://dx.doi.org/10.17600/18000004; http://dx.doi.org/10.17600/14000100) on TAG and Snake Pit vent fields, located in the French exploration contract, have already brought some interesting results. Research carried out includes ecotoxicity studies (Auguste et al., 2016), which will assess the effects of the minerals released in the water column during exploitation of the ecosystems.



▲ *Figure 3: Sampling of an inactive hydrothermal chimney by the Nautile's arm during the exploration cruise Hermine 2017. ©HERMINE 2017, Ifremer*



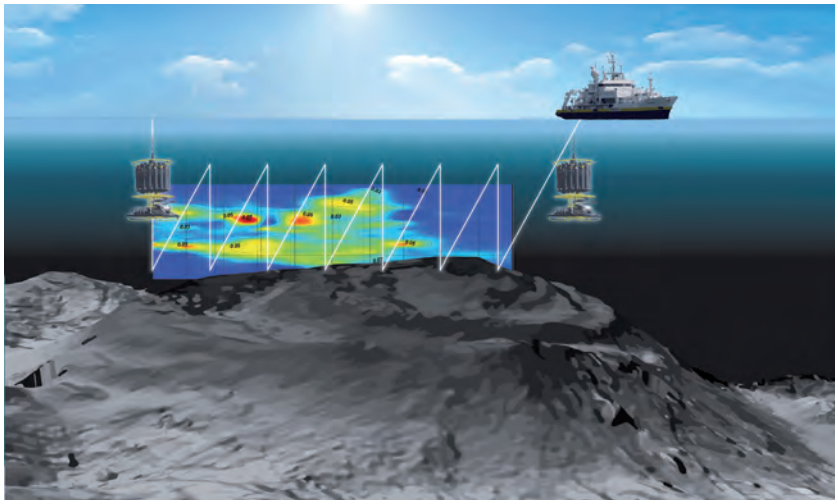
▲ *Figure 4: Map of inactive mounds in the TAG district area from high-resolution ROV based bathymetric surveys. ©HERMINE 2017, Ifremer*

Recent Exploration on Polymetallic Sulphides: the HERMINE Cruise, R/V Pourquoi Pas?

The HERMINE cruise (http://dx.doi.org/10.17600/17000200) is part of Ifremer's programme of activity under its exploration contract for PMS with the ISA. The cruise, held from 13 March to 28 April 2017, targeted the exploration of active and inactive PMS and the quantification of natural chemical input of the hydrothermal plume to the water column. The cruise strategy was built around three objectives: (i) regional exploration including the detection of plume anomalies and the research of PMS deposits, (ii) local exploration of a PMS district and (iii) integrated study of a natural hydrothermal plume. This '3-in-1' cruise required us to optimise the various operations with the daytime being devoted to dives, on board the Human Occupied Vehicle (HOV) *Nautile*, and the nights being mostly dedicated to CTD/Rosette operations.

The preliminary results of the HERMINE cruise are:

- Regional Exploration. About half of the campaign was dedicated to the objective to complete the mapping of the six clusters and search for new active hydrothermal sites along the 800km of the contract area (Figure 2). Targets included recent volcanic ridges and areas with potential exhumed mantle (i.e. oceanic core complex). Based on the relatively short time spent on such a large area (~10,000km2), the results are very positive since two very different types of mineralisation were discovered. Very old and oxidised sulphide deposits were identified off-axis in cluster 4, and the mineralised quartz veins (Fe, Cu) discovered in cluster 6 represent an unusual type of mineralisation in the ocean. In addition, at least seven new active hydrothermal fields were detected.
- Local exploration of TAG district. One of the objectives was to identify and sample mineralisation on inactive areas (Figure 3). More than twenty hydrothermal mounds ranging from a few tens to 400m in diameter were studied (Figure 4). The mineralisation was concentrated on a relatively small area of 4x6km, which makes it, with the exception of the Red Sea, the highest local density of hydrothermal mineralisation currently known in the oceans. This mineralised district might represent a potential for several tens of millions of tons of ore. Additional studies are necessary to discuss the meaning of this unusual density of PMS. Biological and microbiological studies were also conducted to understand biodiversity and ecosystems functioning on the active and inactive sites.
- Integrated study of the TAG hydrothermal plume. In-situ analysis and sampling of the rising plume was carried out with the HOV *Nautile*. Sampling of the non-buoyant plume involved the deployment of CTD/rosette sampling equipment as shown in Figure 5. The objective was to study the metals, gas and larval dispersion, the microbial diversity and metabolic activity in the hydrothermal plume. Hydrothermal fluids and water samples collected will allow us to (i) understand the dynamics of the natural plume, (ii) quantify natural chemical input in the water column, and (iii) evaluate the dissolved and particulate trace metal dispersion of the TAG plume. Eventually the findings on the natural plume will contribute to future deep-sea PMS mining impact studies.



▲ *Figure 5: Theoretical « Tow-yo » profile of the CTD deployment and data interpretation to identify the hydrothermal plume. ©HERMINE 2017, Ifremer*

Conclusion

Ifremer continues its long-standing involvement related to the deep-sea by providing public policy support, and as such, holding the two French exploration contracts with the ISA under the auspices of and sponsored by France, and by pursuing its contribution to major scientific research. Research themes span from understanding the processes that control the formation of the deep-sea mineral resources to the functioning of the different ecosystems. With the renewed interest in these potential sources of raw material, it is of paramount importance to expand our knowledge of these ecosystems and to assess their resilience and the impact that exploitation would have. This research, often conducted in the context of international collaborative projects (JPI Oceans Mining Impact, EU FP7 MIDAS, H2020 MERCES etc.), also provides information for the development of the legal framework, the Mining Code, that is currently being drafted by the ISA to regulate exploitation of the deep-sea minerals in the Area. ◀

Research themes span from understanding processes that control the formation of the deep-sea mineral resources to the functioning of different ecosystems

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Sébastien Ybert

Sébastien has over 15 years' experience in both the industry and the research sectors. With an MSc in Mechanical Engineering, he has worked as a project manager in shipbuilding and marine renewable energy companies in France and overseas. He joined Ifremer in 2010 to assist in the set-up of the research insititute France Energies Marines where he was in charge of the test sites development before returning to Ifremer in 2016 as the Deep-sea minerals and Marine Renewable Energy coordinator. As such, Sébastien manages Ifremer's deep-sea minerals exploration contracts and the 'Pourquoi pas les Abysses?' project, which aims to accelerate the knowledge acquisition on deep-sea biodiversity by using environmental DNA and New Generation Sequencing technologies.

Ewan Pelleter

Ewan Pelleter received a PhD in Earth Sciences from the University of Lorraine at Nancy in 2007. He then spent a few years in Canada (Geological Survey of Canada, Québec) and France (French Geological Survey, Orléans) working on Iron Oxide Copper Gold Deposits (ICOG). Ewan has been a marine geologist with Ifremer since 2010 and he started working on seafloor massive sulphide deposits as a member of the FUTUNA project, a public-private partnership dedicated to the exploration of seafloor massive sulphides in the French EEZ of Wallis and Futuna. Since 2010, Ewan has participated in 6 research cruises and was co-chief of the HERMINE cruise (2017) that focused on the French exploration area in the Mid-Atlantic Ridge. His research focuses on understanding the metallogenic processes related to the formation of deep-sea mineral resources.

Pierre-Marie Sarradin

Pierre Marie Sarradin heads the Deep Sea Ecosystem Study Research Unit (2009 –now) at Ifremer. He works on the dynamics of hydrothermal vent ecosystems. He leads the EMSO-Azores deep-sea observatory on the Lucky Strike vent field. He was member of the Collective scientific expertise committee on the Environmental effects of deep-sea mining (2014) and of the Deep-sea working group, European Marine Board (2015). He coordinated the FP6 EU EXOCET/D project dedicated to the development of new instrumentation to study the deep sea.

He participated in 19 at sea cruises (PI or co PI on 9) using the HOV Nautile or the ROV Victor 6000.

He completed his PhD in Analytical Chemistry at Université de Pau et des Pays de l'Adour (1993). After a short stay as Associate Professor, he joined the Deep Sea Ecosystems laboratory at Ifremer in 1994.

Automated Depth Area Generation for Updating NOAA Nautical Charts

National Oceanic and Atmospheric Administration's (NOAA's) Marine Chart Division (MCD) is currently revising production efforts using an 'ENC-first' approach in order to provide a seamless and tiled geographic coverage. Currently, ENC production workflows within MCD require cartographers to manually manipulate data in the Nautical Information System (NIS) to update navigation products. This MCD addressed this production bottleneck by developing a tool to derive depth area, contour and sounding vector data directly from gridded raster bathymetry surface data.

Production of Electronic Navigational Charts (ENCs)

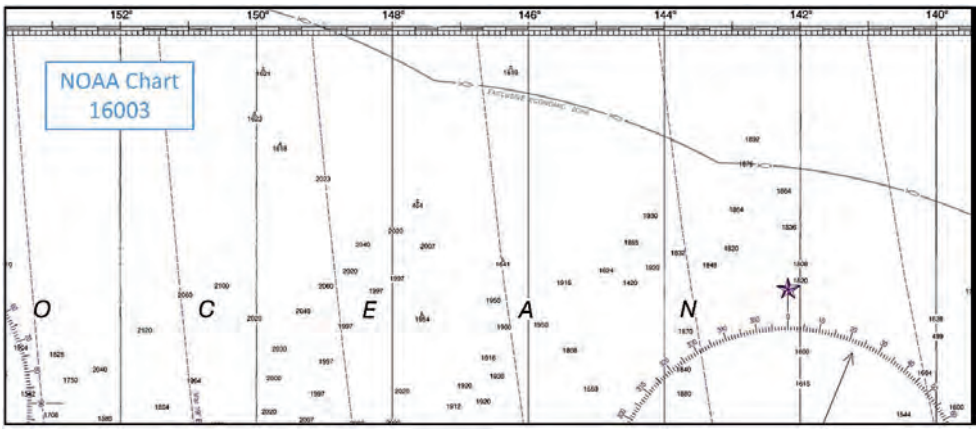
Over the past decade, automation of data compilation procedures within NOAA's Office of Coast Survey (OCS) and MCD, OCS' division responsible for updating nautical charts, has become crucial to efficiently update and distribute nautical information to the public. In the current workflow, MCD ingests a variety of data (e.g., hydrographic, aids to navigation, bridges, pipe and cable information, and land marks) from numerous providers including state and federal agencies, as well as international agencies. All this information is retained in the NIS, a geographic information system used to create navigation products for the marine public. In order to keep the NIS up to date and due to the nature of the data sources, it is important that updates to nautical charts are applied as soon as possible; however, this can be particularly difficult due to the volume of information being processed. Additionally, manual updates to the NIS can require slow, repetitive and error prone production processes.

Over the past year, MCD has implemented a re-scheme approach that will improve the overall charting suite through changes to chart formats, scales, data compilation and symbology. Six new usage bands and their twelve compilation scales will conform to IHO S-57 and the majority of S-101 ENC format specifications. Regardless of the quantity of scales, larger scale charts will display greater detail than smaller scale charts.

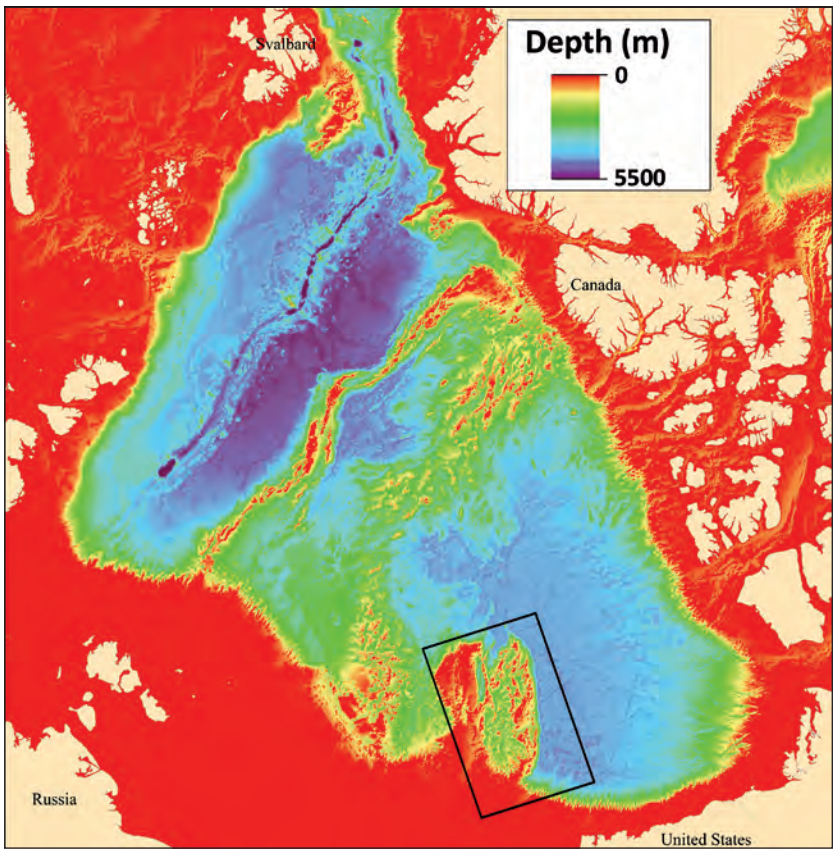
Automatic creation and attribution of the nautical vector features

Production Goal: Workflow Enhancement

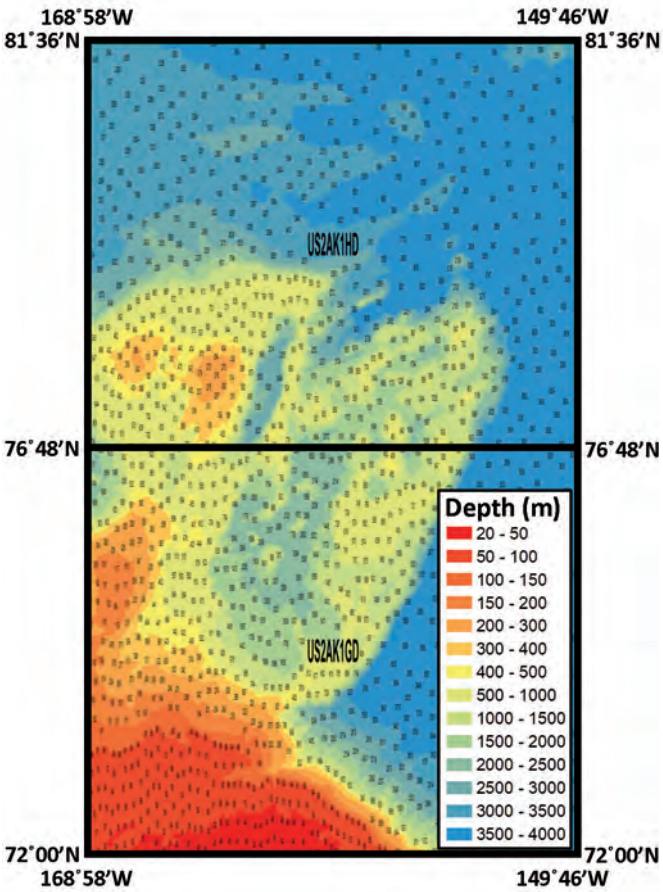
The focus of this paper is workflow enhancement for ingesting bathymetry data. The goal of this effort is to increase efficiency of MCD's production by incorporating automated data-processing methods into nautical chart production. Regardless of whether incoming bathymetry is manually or automatically processed, all data must be scaled to fit MCD standards. Nautical charts are produced at varying scales, which are intended for different



▲ *Figure 1: Gaps in depth information (NOAA Chart 16003).*



▲ *Figure 2: IBCAO grid displaying the Arctic Sea with a black box outlining Chukchi Plateau.*



▲ *Figure 3: Tool output for two new charts covering Chukchi Plateau.*

uses. The new gridded ENC coverage approach reduces the number of current chart scales from 131 to 10 unique scales. This concept of generalisation is intrinsic to the field of cartography and propagates through the data-processing methods necessary to update scaled digital maps.

Chukchi Plateau

The Chukchi Plateau is a subsea ridge extending north from the continental shelf of the United States into the Arctic Ocean. Charting products in this area are required under the United States extended continental shelf programme. Current nautical charts over the offshore areas near the Alaskan North Slope are at scales of 1:700,000 and 1:1:587,970 (NOAA Charts 16003, 16004, and 16005). Depth information is limited on these charts and even contain soundings with 'no bottom detected' that were collected during the 1930s or earlier (Figure 1). Updating depth information on these charts requires the use of bathymetry surveys that were not collected by NOAA hydrographic survey vessels.

Over the past 15 years, the US Extended Continental Shelf (ECS) surveys included high-resolution multibeam sonar surveys in the region north of the Alaskan north-slope margin and on the Beringian margin. The data have been also included in the digital bathymetry database of the International Bathymetric Chart of the Arctic Ocean (IBCAO) initiative. The availability of these datasets and the current state of bathymetry information over Chukchi Plateau illustrates the opportunity for the MCD to update lacking bathymetry information using ESC surveys for soundings and IBCAO grid for depth areas and contours (Figure 2).

Results

The IBCAO bathymetry data was processed with MCD's depth area tool to generate depth area, contour and sounding features at a scale of 1:640,000 (Figure 3). The output data are topologically correct in that depth areas do not overlap, contours do not collapse on themselves, and soundings are located on the correct side of the contours. Furthermore, the outputs are properly attributed and contain the NIS database schema, which allows cartographers to load the vector features back into the database without the need to reformat or digitise individual features. Manual cartographic edits may be required for aesthetics and boundary conditions; however, the workflow for cartographic compilation has greatly improved through the automatic creation

and attribution of the nautical vector features. The results of this study over Chuckchi Plateau are currently being processed by MCD to create two new ENCs at a scale of 1:640,000 (US2AK1GD and US2AK1HD) that were released in July 2018.

Discussion

The MCD's depth area tool provides an output that can be immediately incorporated into the chart production workflow; however, challenges still remain with efficiently incorporating these types of additional bathymetry datasets into nautical charts on top of the current volume of data being ingested. Furthermore, all incoming bathymetry data to MCD must be internally assessed and assigned data quality classifications based on the instrumentation, provider and available metadata associated with each survey. This automated depth area generation process allows MCD to update depth information on nautical charts in locations where authoritative sources have not yet surveyed while also informing the public of the quality of bathymetric data in the area. Automating portions of the workflow for updating nautical chart depth information is an effective means to increase efficiency and reduce human error, thus allowing the MCD to keep nautical products as accurate and up to date as possible. This tool has greatly reduced the production time for new Arctic charts. These chart products themselves follow the new 'ENC first' approach in providing a seamless transition between charts within the same usage band. As such, this automated depth area generation tool and other automated workflows are being incorporated into chart production in order to process larger amounts of data over shorter periods of time. These new nautical chart production practices will mitigate the issue of timely updates to bathymetry data in the NIS, and in turn, provide better navigation data to the marine public. ◂

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Noel Dyer is a developer and cartographer with NOAA's Marine Chart Division (MCD). Mr Dyer earned his BSc (2011) and MSc (2016) from George Mason University and is beginning his PhD at the University of Maryland, College Park (2018). His interests include: geospatial analysis, workflow automation and spatial data infrastructures.

Shachak Pe'eri is currently the branch chief of the Chart Standards Group at NOAA's MCD. Dr Pe'eri earned his PhD from Tel Aviv University, Israel. Dr Pe'eri is also affiliated with the Center of Coastal and Ocean Mapping (CCOM), the University of New Hampshire (UNH) and the University of Maryland, College Park.

Rovins Nano: A Cost-efficient and Compact INS for Flexible Subsea Operations

iXblue, a global leader in the design and manufacturing of state of the art navigation and subsea positioning solutions, is constantly striving to think of new innovative systems and develops cutting-edge technologies to meet its customers' ever evolving demanding requirements in terms of operations efficiency.

iXblue's Rovins Nano provides attitude stability and accurate positioning with a drift of 0.2% of the travelled distance.

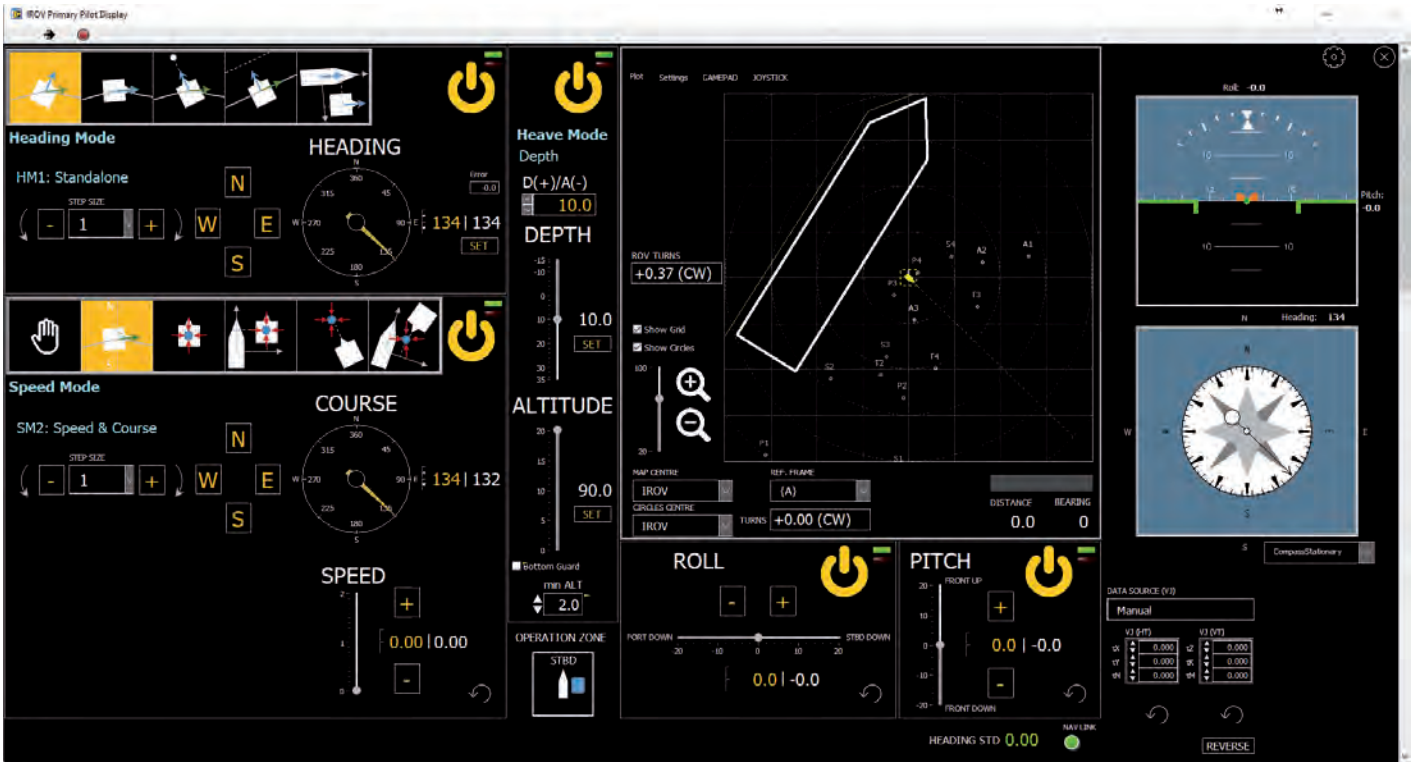
The company has developed a complete range of field-proven subsea inertial navigation products that are recognised for their reliability and unrivaled performance. The iXblue range of inertial products offer a very flexible solution, suited for a wide range of subsea operations. The entry level product in the range is Rovins Nano. Dedicated to ROV navigation, it offers attitude stability, provides accurate positioning of the ROV (with a drift of 0.2% of the travelled distance), and can go to depths reaching 4,000 metres. With a heading accuracy of 0.15 degree secant latitude, iXblue's Rovins Nano offers a competitive advantage to its users with an entry class focus.

Compact and lightweight, Rovins Nano allows more of the precious ROV Payload (weight and space) to be dedicated to tooling, allowing for more responsive and flexible subsea operations that lead to important productivity and cost reductions, even saving vessel time and costs.

ROVs Automation for Efficient and Safer Operations in High Seas and Currents

iXblue Rovins Nano has thus lately been chosen by the University of Limerick's Centre for Robotics & Intelligent Systems (CRIS) for the development of a new INS-based navigation & control suite, OceanRINGS. Part of a larger institution known as MaREI, CRIS aims to research the use of smart automated ROVs for challenging marine applications.

"We have experience using iXblue's Phins for many years on our larger Observation class vehicle



▲ *OceanRINGS Control & Navigation Suite.*

ROV Latis and this INS, coupled with the development of our OceanRINGS control suite, gives us our full 6 degree of freedom precision navigation and DP subsea with thruster fault tolerance and accommodation. For our newest smaller ROV Áed we have chosen Rovins Nano as a smaller, more compact precision navigation system ideal for our precision flight control needs," explains Prof Daniel Toal, director of CRIS.

iXblue Rovins Nano is used by CRIS as part of the vehicle control system to provide some of the most advanced dynamic positioning capabilities available today. By current practice, ROVs are flown using camera (and sonar) feedback from scene to pilots for remote manual control with simple track-line displays. There is little automatic control and ROV operations are dependent on highly skilled pilots in areas affected by significant disturbances from currents or waves.

Moving to higher levels of ROVs autonomy will enable faster response time to disturbances, as well as higher accuracy in navigation and control over that of a manual pilot. This will, in turn, allow for safer operations in higher sea and tidal states while also extending operational weather windows.

This is why the CRIS teams, who have been focused on ROVs automation, have recently developed a 300msw survey class ROV, known as Áed, the operational capacity of which has already been proven thanks to successful trials in wave & tidal test tanks in MaREI, as well as low sea states. CRIS also trialled a Thruster Fault-tolerant system which, using the onboard INS system, monitors errors in course and heading to detect thruster faults.

"The Áed ROV was designed with a focus on thrust-to-drag ratios, using CFD analysis of frame and thruster control optimisation to allow for high fidelity and stability," explains Dr Gerard Dooly, Research Fellow at CRIS. "The navigation suite was one of the most critical factors and the use of iXblue Rovins Nano, coupled to a Nortek DVL, allowed us to achieve high-precision subsea navigation without having to compromise on the weight and size of the vehicle due to navigation payload."

iXblue's Rovins Nano, compatible with both iXblue and third-party acoustic positioning products, offers customers operating on the challenging offshore market a versatile and cost-efficient inertial navigation solution that can be suited for any subsea operation. Being user-friendly, it offers valuable time savings in terms of configuration, installation and operational use and provides flexibility and efficiency for successful subsea operations. ◀

▲ *ROV Áed.*

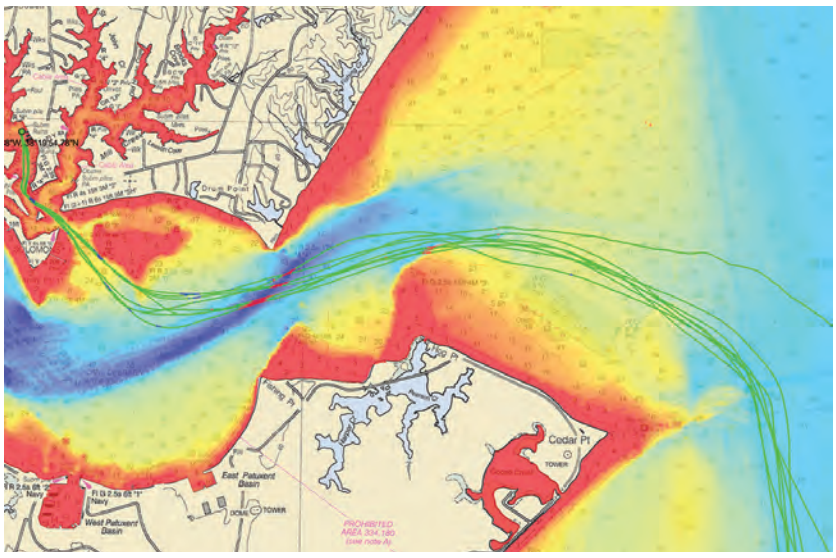
Working Together to Map the Gaps

Earlier this year, NOAA announced the end of a testing phase for the development of a new crowdsourced bathymetry database. The public can now access the bathymetric observations and measurements from citizen science volunteers and crowdsourcing programmes through the International Hydrographic Organization (IHO) Data Centre for Digital Bathymetry (DCDB) Data Viewer. This operationalised database allows free access to millions of ocean-depth data points. The database also serves as a powerful source of information to improve navigation products and the general knowledge about seafloors, according to NOAA.

Since 2014, the IHO has encouraged innovative ways to gather data and data-maximising initiatives so that we can better understand the bathymetry of the seas, oceans and coastal waters. Most recently, the IHO is advancing the Seabed 2030 initiative to map the world's oceans by 2030. Crowdsourced bathymetry (CSB) is a powerful source of information to supplement the more rigorous and scientific bathymetric coverage done by Hydrographic Offices, industry and researchers around the world.

Crowdsourced bathymetry can help to identify areas where nautical charts need updates, and where we should conduct proper hydrographic surveys. In some cases, crowdsourced bathymetry data can fill in gaps where bathymetric data is scarce, such as unexplored areas of the Arctic and open ocean. CSB is also very useful along shallow, complex coastlines that are difficult for traditional survey vessels to access; these areas may be more frequently visited by recreational boaters, whose data could help illustrate seafloor and shoaling trends just from the repeated trips they make along their favourite coasts.

The key to successful CSB efforts are volunteer observers who operate vessels-of-opportunity in places where charts are poor or where the seafloor is changeable and hydrographic assets are not easily available. Most ships and boats are already equipped to measure and digitally record their depth in coastal waters, and an ever-increasing number of vessels can even take measurements in deeper water. The CSB vision is to tap into the enthusiasm for mapping the ocean floor by enabling trusted mariners to easily contribute data and augment our current bathymetric coverage.



▲ *Figure 1: NOAA's Bay Hydro II crowdsourced bathymetry test tracks overlaid in green on multibeam survey data demonstrates how changes can be detected. Image courtesy of NOAA.*

At NOAA, we are a big supporter of CSB; we provide archiving, discovery, display and retrieval of global crowdsourced bathymetry data contributed from mariners around the world. The CSB database is part of the IHO DCDB and is hosted at NOAA's National Centers for Environmental Information (NCEI), offering access to archives of oceanic, atmospheric, geophysical and coastal data. CSB also nests under the Integrated Ocean and Coastal Mapping initiative, with a goal of 'map once, use many times'. While it is a less exact form of mapping, NOAA sees that CSB has an important role to play in filling in bathymetry database gaps.

CSB comes into the database through a variety of trusted sources or nodes (e.g. partner companies, non-profit groups) that enable mariners to voluntarily contribute seafloor depths measured by their vessels. People can submit their data anonymously or provide additional information (vessel or instrument configuration) to enrich their dataset. The

▲ *Figure 2: Fishing boats such as these can help us map the ocean floor. Image courtesy of NOAA.*

trusted node compiles the observations and submits them to the IHO DCDB, where anyone can access the data for commercial, scientific or personal use. Sea-ID, a maritime technology company, provided early testing and support and is currently working to encourage data contributions from the international yachting community. Ongoing participation from Rose Point Navigation Systems, a provider of marine navigation software, helped kick-start the stream of data from a crowd of mariners.

The crowdsourced bathymetry database now contains more than 117 million points of depth data, which have been used by hydrographers and cartographers to improve nautical chart products and our knowledge of the seafloor. NOAA, working with George Mason University, is using the database depths to assess nautical chart adequacy, determining when areas require updated survey information, and identifying chart discrepancies before an incident occurs. The Canadian Hydrographic Service has also used this dataset to update several Inside Passage charts along the coastal routes stretching from Seattle, Washington, to Juneau, Alaska.

NOAA invites more maritime companies to support this crowdsourcing effort in their systems by making it simple for users to participate. For example, Rose Point Navigation Systems further promoted the IHO crowdsourced bathymetry initiative by moving the option to collect and contribute bathymetry data to a more visible section of its programme options menu.

Crowdsourced efforts and the crowdsourced bathymetry database are poised to become a major source of information for not only improving nautical chart coverage and accuracy, but also for international mapping efforts such as Seabed 2030.

Any mention of a commercial product is for informational purposes and does not constitute an endorsement by the US Government or any of its employees or contractors. ◀

World Hydrography Day 2018 Celebrated in Jakarta

On 17 September 2018, the Indonesian Hydrographic Office (Pushidrosal) organised an international seminar in Jakarta, Indonesia, to celebrate the 97th anniversary of World Hydrography Day (WHD). The objective of the seminar was to enlighten participants' perspectives on the need for high-quality bathymetric data for more accurate maritime planning and governance. This objective was aligned with the World Hydrography Day 2018 theme: 'Bathymetry – the foundation for sustainable seas, oceans and waterways'.

The seminar delivered topics related to the need for high-quality bathymetry data for enhancing the confidence level of the users, the role of the Hydrographic Office in building a smart nation, the importance of the national Hydrographic Office for a state, and hydrography's role in and contribution to a state's economic development.

In his opening remarks, Rear Admiral Harjo Susmoro, Indonesia's Chief Hydrographer, said "All members of IHO reiterate their commitment to raising awareness of the importance of hydrography; in particular through maintaining standards and publishing in correlation with the relevant international standards, providing capacity building and assistance to those countries where hydrographic services require improvement, by encouraging the collection and discovery of new hydrographic data through programmes such as crowdsourcing and satellite-derived bathymetry, and by ensuring the widest possible availability of this data through the development of national and regional Marine Spatial Data Infrastructures".

The speakers at the seminar included:

- Mr Budi Halim from Indonesia Ship-owners Association (INSA): 'The need for Electronic Nautical Charting (ENC) for economic value and its role in sustainable development of marine transport operations' (INSA)
- Mr Eric Fremouw from Reasonuance Consultants/Veris Australia: 'Bathymetry usage for maritime infrastructure'
- Dr Parry Oei, Singapore Chief Hydrographer: 'Enhancing regional cooperation to provide high-quality bathymetry data in strategic sea lanes'
- Prof Dr Ir Rokhmin Dahuri, MS from Indonesian Experts: 'The importance of hydrographic role to support sustainable seas, ocean and waterways'
- Dr Mathias Jones, Secretary General of IHO: 'Data-centric hydrography bringing marine knowledge into effect'.

The seminar was also attended by Rear Admiral Harjo Susmoro, Hydrographer of Indonesia, and Rear Admiral Tim Love OBE, National Hydrographer UKHO, among others.

The origins of this seminar can be traced back to the message of the Indonesian President, Joko Widodo, who during his inaugural court on 20 October 2014 highlighted a statement that Indonesia will finally return to its roots and identity as a maritime nation. This will be based on five key areas of development or 'pillars': maritime culture, maritime economy and resources, maritime infrastructure and connectivity, maritime diplomacy, and maritime security. Those pillars are jointly constructing the so-called Global Maritime Fulcrum (GMF) vision. This vision will reflect in Indonesia's geopolitical contexts, which will govern a novel geostrategy for both regional and global recognition.

The strategy within the GMF vision emphasises the need for an intensified connectivity among islands in the archipelago. The Maritime Highway programme is expected to improve exchange of goods and resources between regions throughout the Indonesian ocean territory. New ports and sea routes shall be opened along with building of new passengers and cargo vessels. With the escalating marine traffic, the need for data and information along the waterways will be on the rise. Ensuring safety and security of shipping and protected sea environments will be part of the development. An effective marine highway will be the backbone of the maritime economy and is one of the pillars of GMF vision.

It is the obligatory mission of the Indonesian Hydrography and Oceanography Center (Pusat Hidrografi dan Oseanografi - Pushidrosal) as one of Main Command Forces under the Indonesian Navy in carrying out ocean survey, mapping and research. Issuing nautical publications and prediction of dynamics of ocean environments for the purpose of safety of waterways navigation add to Pushidrosal's obligatory mission. The mission is not only for the benefit of the armed forces but also for greater public interest. As a state member of the International Hydrography Organization (IHO), Indonesia is represented by Pushidrosal. ◂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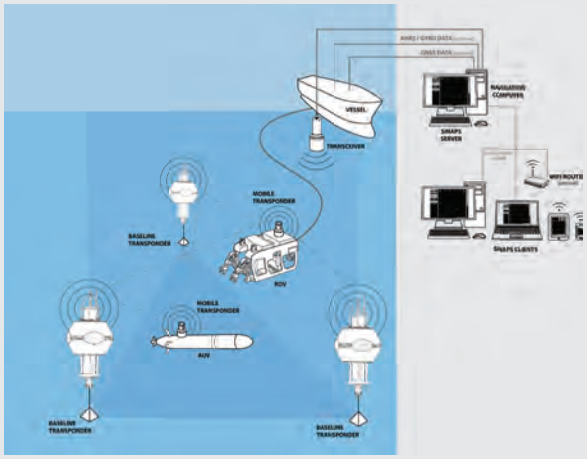

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