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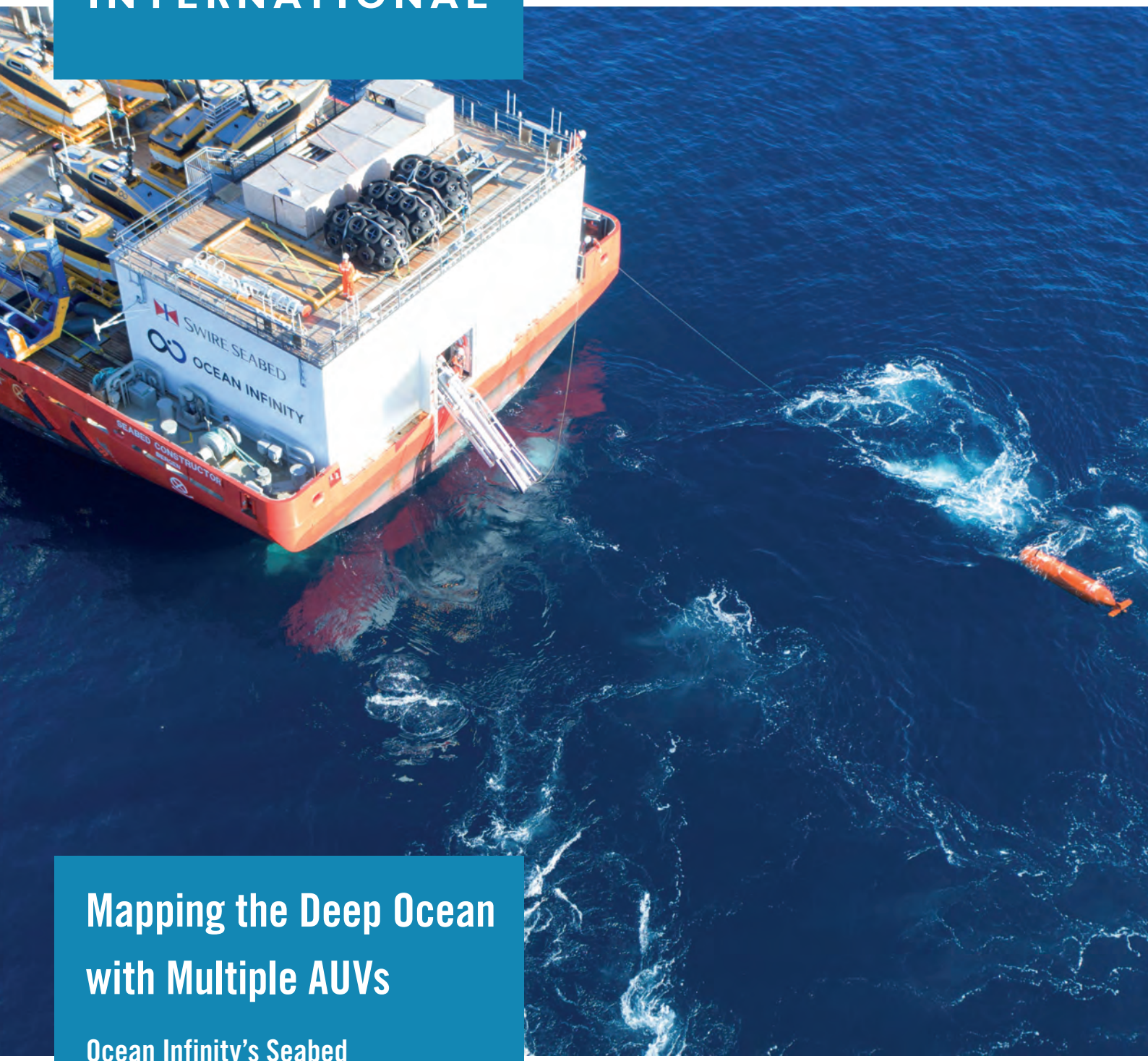

Mapping the Deep Ocean with Multiple AUVs

Ocean Infinity's Seabed Exploration Project

How Blockchain Will Have an Impact on Navigation

The Nippon Foundation-GEBCO Seabed 2030 Project

The Making of RV *Kronprins Haakon*

New Norwegian Ice-breaking Research Vessel

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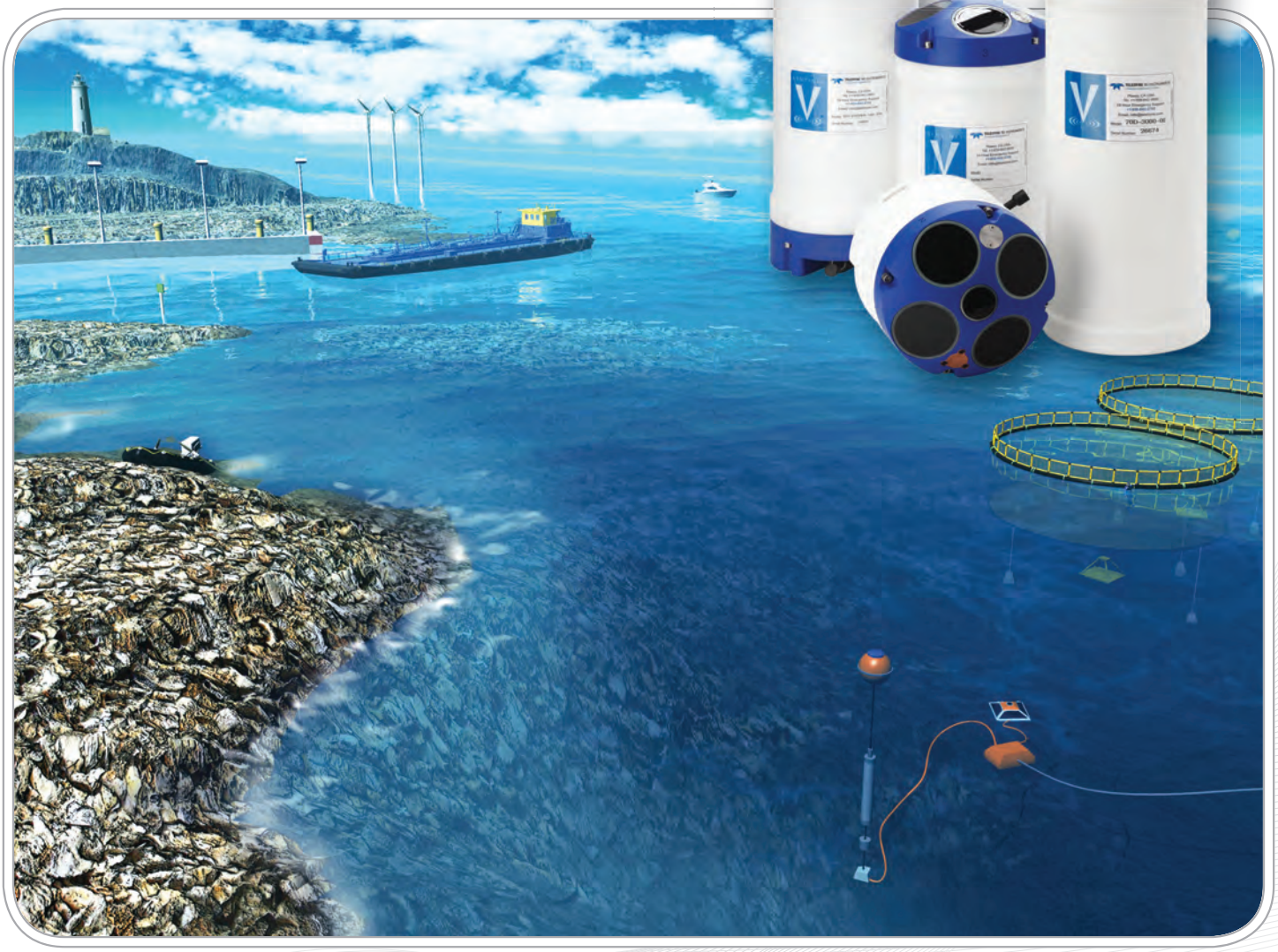

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Hydro INTERNATIONAL

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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MAPPING THE DEEP OCEAN

On the front cover: AUV recovery to the purpose built hanger on the back deck of *Seabed Constructor*. Ocean Infinity's seabed mapping campaign commenced in the summer of 2017. The Ocean Infinity team is made up of individuals from multiple disciplines, who have gained vast experience with deep-sea exploration operations in the past. Read the full story from page 24 onwards.

Geo-matching

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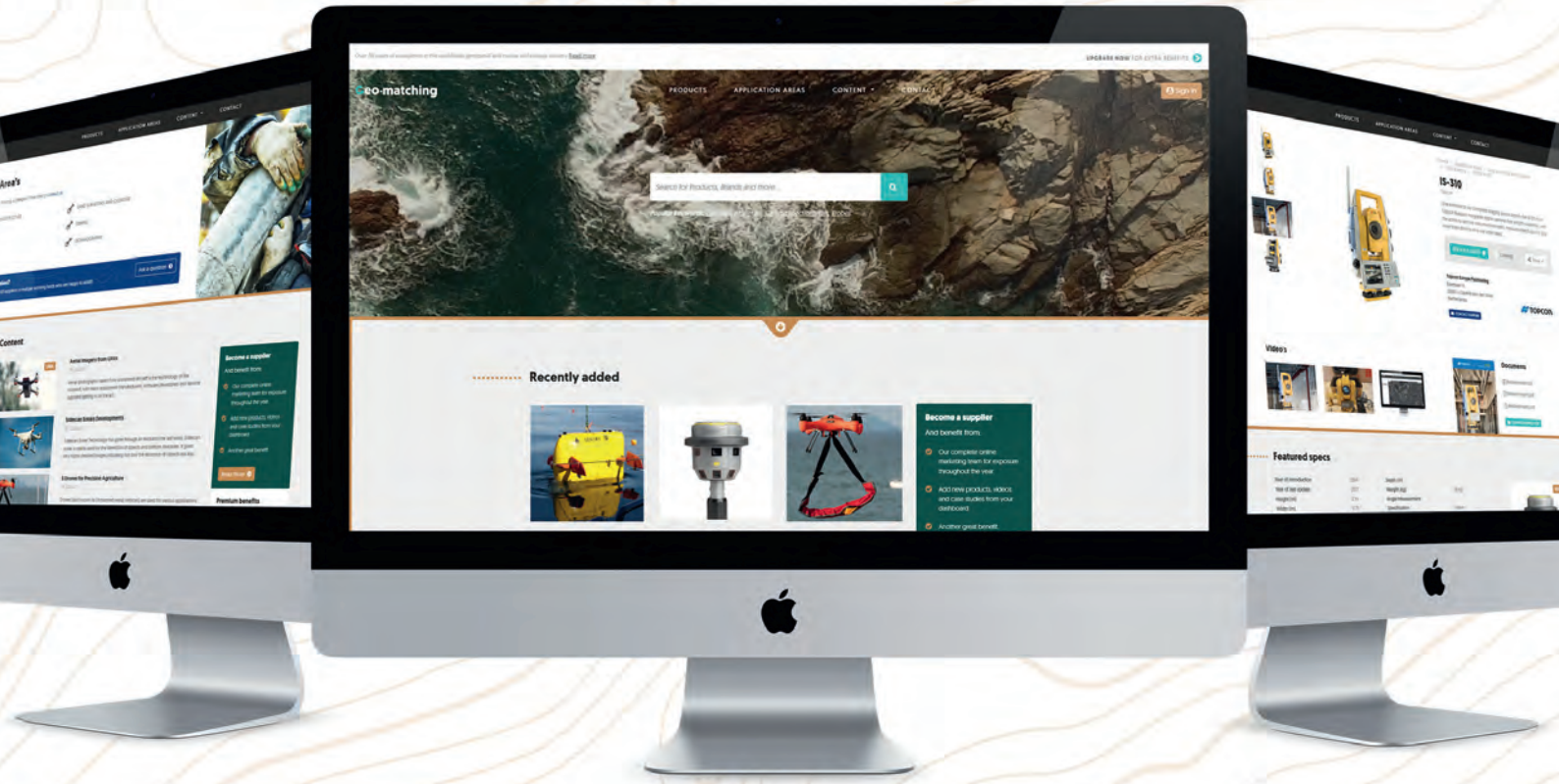

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Bathymetry for Ecology

Canadian hydrographers and land surveyors came together a few weeks ago in Victoria, British Columbia, for the 2018 Joint Canadian Hydrographic – National Surveyors' Conference. Eric Peterson of the Tula Foundation/Hakai Institute opened the conference with a bang. In his impassioned presentation, he explained how bathymetry is used in monitoring the ecosystems in the Pacific temperate rainforest in order to keep track of the consequences of climate change in this mighty landscape of Western Canada and the North West of the United States. Although we have all seen them many times before, images showing how glaciers will be almost entirely diminished in just a few years' time remain extremely shocking, and the consequences of their disappearance hardly bear thinking about. The fact that bathymetry can play an important role in monitoring and can therefore give us insight into, and help to optimise, preservation – not only of this fragile ecosystem, but also of similar systems all over the globe – was humbling to me. At the same time, it set the stage for an inspiring week in which I became even more aware of the potential importance of developments in hydrography for the future of our planet.

Durk Haarsma,
director strategy & business development
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The Quest for Content

At *Hydro International* we continuously strive to provide you with relevant articles, focusing on the explanations behind hydrographic surveying technologies, on challenging projects, on the latest innovations within our industry, and also on companies' views of the market. This would not be possible without your valued feedback, of course, and your input for new ideas. Therefore, we encourage you to suggest or contribute to articles on any topics which you feel deserve more attention in our publication. Feel free to share your thoughts with us. After all, you are the ears and the eyes of the hydrographic industry, and we really appreciate your help! So if you'd like to tell us about a story we should publish, have got some valuable insights to share or want to give your opinion on our editorial focus, please don't hesitate to send us an email: wim.van.wegen@geomares.nl. We look forward to hearing from you!

Wim van Wegen, content manager
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HYDRO ALPHABETICAL LIST OF ADVERTISERS

Faster and Deeper

The hydrographic world is exploring new ways to survey faster and deeper. Ocean Infinity demonstrates the capabilities of autonomous surveying and explores an unknown path. In this particular setup, AUVs are being used in combination with unmanned surface vessels (USVs). For many companies, surveying in conjunction with USVs allows for larger production for a fraction of the cost associated with normal manned operations. Even if legislation demands a line-of-sight survey, working with USVs in combination with a manned platform gives operational and commercial benefits for seafloor mapping. The design and build of the Arctic vessel *Kronprins Haakon* highlights that AUVs can also be a valuable asset during surveying in challenging Arctic environments. Nevertheless, scientific marine research involves more than just seafloor mapping, of course, and the equipment required for this is still too large to handle on autonomous platforms.

Interestingly, the software landscape is also changing. Most of us have already heard about cryptocurrency and the use of blockchain. Some people have made quite a lot of money through Bitcoin, for example. Perhaps surprisingly, Maersk Shipping thinks that blockchain could solve complex cargo documentation issues. In this issue, Gert Büttgenbach explains how blockchain could be potentially beneficial for the marine charting environment. Driven by the demand of autonomous shipping and automation, HOs might have to accept that the traditional way of producing and sharing charts is no longer sustainable. These completely new approaches will impact the role of the hydrographic and oceanographic expert. The experts will have to leave the traditional way of surveying and charting behind and prepare themselves for a future where automation, autonomous operations and digitalisation will play a far greater role.

Mark Pronk, contributing editor

SEABED 2030 Needs Your Data

On 20 February, the Nippon Foundation-GEBCO Seabed 2030 project became operational. Its task: finish mapping the 84% of our oceans still unmapped. Simultaneously an 18 page concept paper lays out the morphological statistics, technological realities, and data assembly structure that can ensure success. Bathymetric input from HOs is urgently requested.

In the two years since F-FOFM basically formulated Seabed 2030, amazing progress has been made. Companies like Fugro are making swath mapping transit tracks through unmapped areas available (viz. GEBCO's slogan 'Map the Gaps'), and encouraging clients to contribute decimated grids from their proprietary datasets. Others like Ocean Infinity are pioneering swath mapping by multiple AUVs and ASVs. Countries have also made national and regional mapping compilations available, viz. EMODnet, Baltic Sea, Gulf of Mexico-BOEM, Bering Sea Fisheries, Great Barrier Reef, MH370 search area.

At present, some 700 multibeam equipped ships are at work acquiring new data. Aware of the 'Map once, use many times' slogan, they are acknowledging the need to get their data into Seabed 2030's growing global compilation.

For the deeper areas (200-11,000m), where national and proprietary pressures are minimal, completion of the task by 2030 appears possible (viz. 348 years work for one vessel). For the shallower areas (<200m), 619 years work for one vessel is estimated. Due to the propensities of the world's 155 coastal states, this is problematic. For many of these shallow areas, there is a very large volume of sequestered proprietary data (viz. SHOM's 75,000 analog field sheets). Soundings released on charts in ECDIS or ENCs probably represent only around 1% or less of holdings, and are likely shoal-biased.

I experienced the value of these legacy fairsheets during my years working on IBCM. The UK Hydrographic Office provided me with copies of the post-World War I surveys of Egypt, Palestine and Cyprus. Digitisation of some 35 fairsheets around now-divided Cyprus, done in the 1930s and 1950s, yielded 183,000 soundings for the continental shelf. A simple 25m TIN interpolation produced a good representation of the numerous canyons on the island's narrow shelf.

With time, it is likely that following UNCLOS's Article 76 determinations, up to 84 countries' extended continental shelf (ECS) datasets might be contributed, potentially accounting for over 30 million km², or 1/12th of the Earth's total saline waters. Hopefully, preparation of these submissions will have also involved a bathymetric compilation of the shallows.

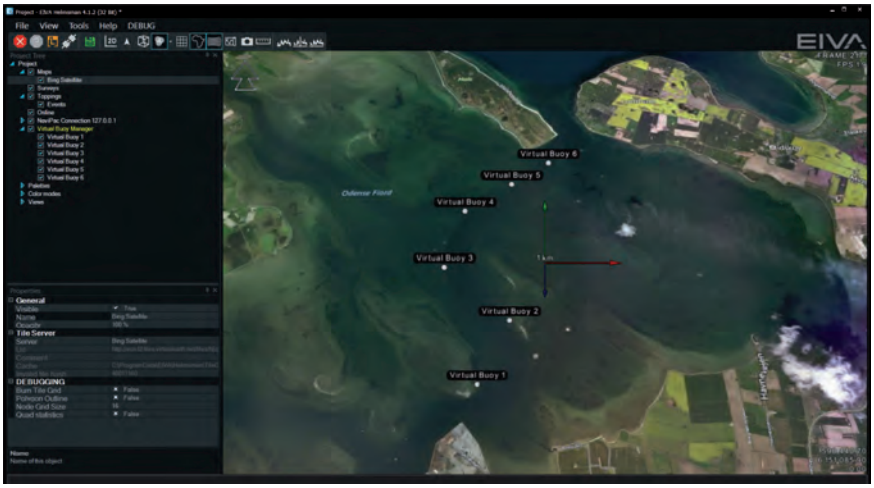
My own contribution is preparation of a 100m grid for the seas around Arabia; Red, Arabian and Oman Seas, Persian Gulf and Indian Ocean to 10°S. Some 600 Russian, British, American, Omani, Iranian and Saudi charts provide spot soundings, and hydrographic contours that, while far short of swath mapping, do produce a far superior view of the seafloor than what already exists. As these areas include large areas of clear shallow waters, my MSc student Shahar Levenson has been using my digitised shallow soundings and 2 and 5m contours to extract shallow bathymetry using LANDSAT 8 imagery from EOS Land Imager's cloud-based website. Discussions are ongoing about developing schemes for presenting the shallowest depths for a scene and then receiving the satellite – derived bathymetry (SDB). While deepwater soundings barely specify depth for a 30" grid, they add significantly to the SID values calibrating the satellite altimetry, especially for future altimetry from lower satellites with non-repeating orbits.

www.mdpi.com/2076-3263/8/2/63/html
https://bit.ly/2E4fEm8

Virtual Buoy Solution Eliminates the Need to Deploy Marker Buoys

Danish hardware and software engineering specialist EIVA has introduced a new system solution that offers an alternative way to ensure safe navigation by marking channels, shoals, wrecks and so on, as well as during harbour expansions and other construction projects. NaviSuite Perio provides harbour and other waterway authorities with the possibility of replacing marker buoys with virtual buoys that are managed via a software user interface. Even though they are never actually deployed, they are still displayed to AIS users as actual buoys at a given location in the water.

▸ *https://bit.ly/2IbRvMX*



▲ *NaviSuite Perio.*

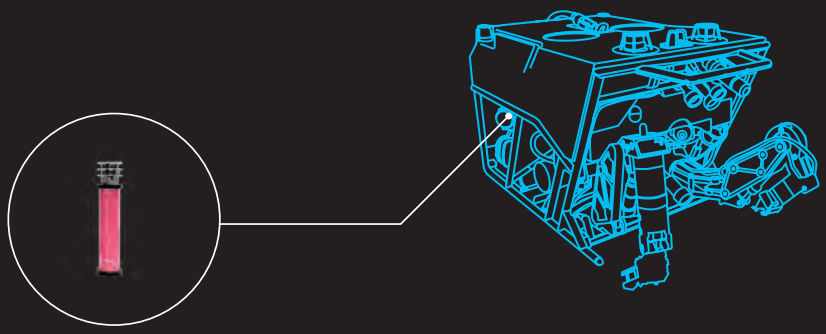
Fugro Leads Marine Industry in Support of Global 'Seabed 2030' Initiative

▲ *Fugro Equator survey vessel.*

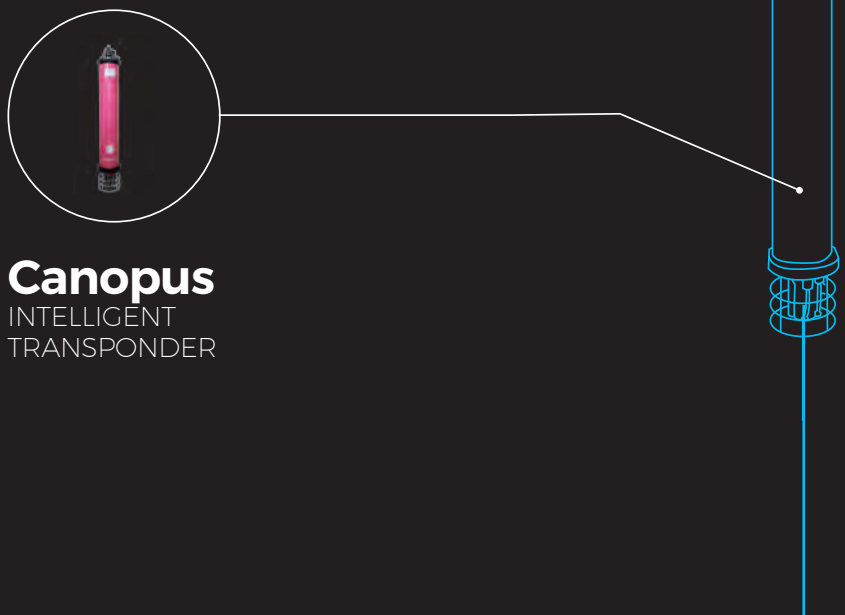
Fugro is leading the marine survey industry in support of NF-GEBCO Seabed 2030, a global initiative to produce a definitive, high-resolution bathymetric map of the entire world's ocean floor by the year 2030. The initiative is being facilitated by the General Bathymetric Chart of the Oceans (GEBCO) project in partnership with The Nippon Foundation (NF) as a means to inform global policy, improve sustainable use and advance scientific research. Much less than 20 % of the world's oceans are mapped using modern survey techniques and Fugro recognises the importance of accurate seabed measurements (bathymetry) to numerous government, scientific and industry applications. David Millar, Fugro's government accounts director in the Americas, explains "As the world's largest offshore survey company, Fugro is in a position to help close this data gap, and we are committed to doing our part through the Seabed 2030 project."

▸ *https://bit.ly/2Gj1D5V*

Taking LBL to the next generation.



Ramses
NEXT GENERATION
ROV TRANSCEIVER



Canopus
INTELLIGENT
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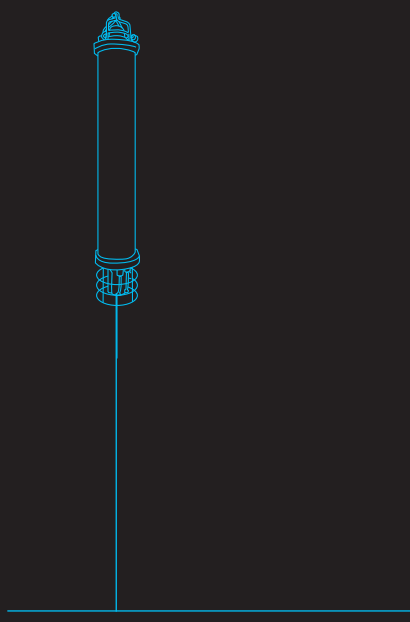
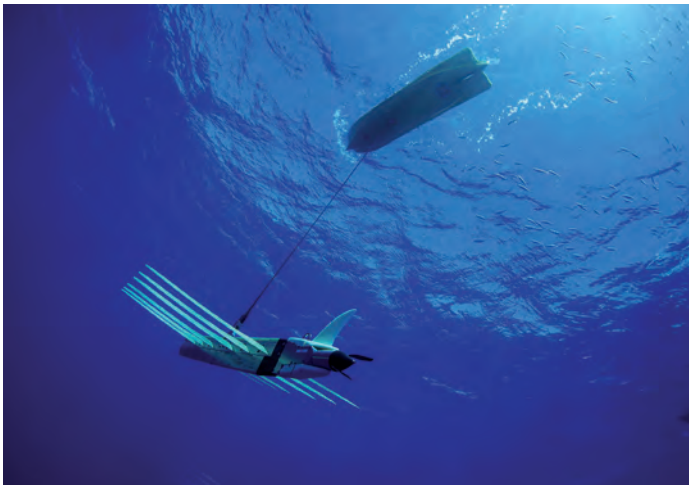


iXblue

Japan Coast Guard Expands Wave Glider Fleet to Advance Ocean Observation

The Japan Coast Guard (JCG) announced the expansion of their unmanned ocean observation fleet of Wave Gliders to the 9th Regional District, headquartered in Niigata, Japan. This growth is part of JCG's multi-year, ocean monitoring programme to provide enhanced, real-time situational awareness of ocean currents, wave activity, and weather along Japan's coastlines. Prior to this expansion, JCG deployed fleets of Wave Gliders in four regional districts, forming the first, unmanned ocean observation network in Japan's history.

▸ *https://bit.ly/2E117HB*

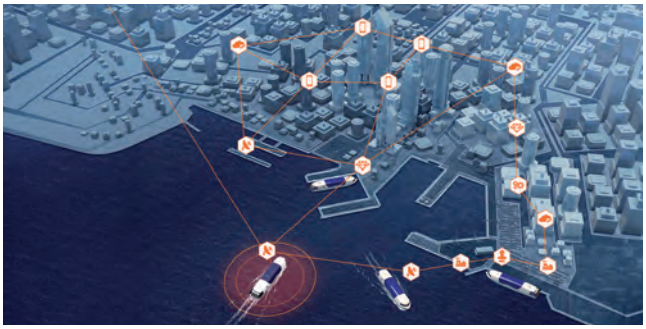


▲ *Liquid Robotics Wave Glider.*

Wärtsilä Acquires Transas to Accelerate Smart Marine Ecosystem Vision

Technology group Wärtsilä is in the process of acquiring Transas, a global company headquartered in the UK. The move will speed Wärtsilä along its path towards its Smart Marine Ecosystem vision. Established in 1990, Transas is a global market leader in marine navigation solutions that include complete bridge systems, digital products and electronic charts. The company is also a leader in professional training and simulation services, ship traffic control, as well as monitoring and support. Transas leverages the latest in machine learning and artificial intelligence to create a unified cloud-based platform for managing operations across the entire marine ecosystem.

▸ *https://bit.ly/2E06fMp*



▲ *Connecting smart ships with smart ports.*

3D at Depth Launches Subsea Survey Support Services

3D at Depth, an expert in subsea Lidar laser technology, has officially launched its subsea survey support services to help clients realise additional value from their underwater 3D data. The new integrated offering will optimise underwater survey campaigns through a comprehensive range of client deliverables designed to enhance workflow efficiencies, support engineering and analysis and provide insight into long-term asset and environmental integrity.

▸ *https://bit.ly/2pKz6jh*

▲ *3D at Depth's subsea Lidar VR platform.*

Autonomous Technology Helps to Discover Historically Significant Shipwrecks

Greensea Systems, a manufacturer of marine robotics, has provided the inertial navigation, system control and autonomy technologies utilised in the recent historic discoveries by Vulcan Inc. of the USS *Lexington* and *Juneau* shipwrecks. RV *Petrel*, owned by Paul A. Allen, found the USS *Lexington* on 4 March at 3,000 metres below the surface, resting on the floor of the Coral Sea more than 500 miles off the eastern coast of Australia. This discovery was quickly followed by the sighting of the USS *Juneau* on 17 March, 4,200 metres subsea off the coast of the Solomon Islands.

▸ ***https://bit.ly/2GAgwEg***

▲ *Control room onboard the* RV Petrel.

Valeport Presents Latest Sensor and Software Updates

Valeport, a leader in oceanographic, hydrographic and hydrometric instrumentation, used Oceanology International in London to launch a number of developments across its range including new probes, visualisation software and a portable tide station. Launched at Oi18, the new unique probe, SWiFTplus, combines the power of the SWiFT SVP and a turbidity sensor. SWiFTplus uses Valeport's world-leading high-accuracy sensor technology and incorporates turbidity observations with sound speed, temperature and pressure sensor technology coupled with the convenience of Bluetooth connectivity and rechargeable batteries.

▸ ***https://bit.ly/2pMpHa3***

▲ *Valeport SWiFTplus.*

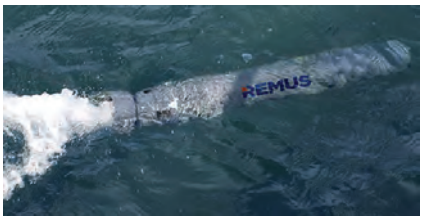
ASV Global Working on Containerised Autonomous Marine Laboratory

ASV Global is working with the National Oceanography Centre (NOC) to develop a containerised autonomous marine laboratory for use in developing countries. The project is part of the Commonwealth Marine Economies (CME) programme, a UK government-funded programme which aims to support Commonwealth Small Island Developing States (SIDS) develop and sustain marine economies by ensuring the marine resources that belong to them are better understood and managed. One output of this programme is the development of a containerised autonomous marine environmental laboratory (CAMEL) that will be utilised by the CME delivery partners – namely the NOC, the UK Hydrographic Office and the Centre for Environment, Fisheries and Aquaculture Science (Cefas) – to map and monitor hydrographic, oceanographic and geophysical parameters as part of a range of high-quality marine science datasets and providing valuable training as part of capacity-building efforts.

▲ *ASV 'C-Worker 4' autonomous vessel.*

▸ ***https://bit.ly/2GjoIeI***

Hydroid Introduces New High-speed Micro AUV



▲ *The REMUS M3V.*

Hydroid, a subsidiary of Kongsberg Maritime, has released the new groundbreaking REMUS M3V compact, one-man portable autonomous underwater vehicle (AUV). Low-cost and ready to use right out of the box, this micro AUV supports numerous applications including search and survey, intelligence, surveillance and reconnaissance (ISR), marine research and multi-vehicle missions. The REMUS M3V can dive up to 300 metres in depth. It is a true A-size (36 inch x 4.875 inch) vehicle with no fins or appendages outside the A-size envelope and can be used for multi-domain deployments.

▸ ***https://bit.ly/2IXJjRs***

Bibby HydroMap and iXblue Announce AUSV Partnership

Bibby HydroMap, one of the leading providers of hydrographic and geophysical surveys in the UK and Northern Europe, has partnered with iXblue to bring 'DriX', a new autonomous unmanned surface vessel (AUSV), to the European market. Specifically designed with a revolutionary hull shape optimised for both coastal and offshore missions, and manufactured using state of the art composite materials, DriX operates with the utmost stability, guaranteeing the best possible results, with excellent and unmatched performance offshore. In a step change for autonomous survey, DriX offers up to 7 days of data acquisition endurance at speeds of up to 14 knots. Multiple navigation options are also available ranging from full autonomy, to autopilot, remote supervisor action, a 'follow-me' function and a 'hovering' mode, all COLREG compliant.

▸ ***https://bit.ly/2GkRHZO***

▲ *iXblue DriX AUSV.*

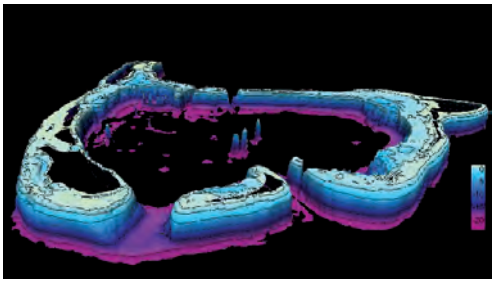
SBG Releases Navsight Marine Solution

▲ *SBG Navsight.*

At this year's Oceanology International in London, UK, SBG Systems released the Navsight Marine Solution, a full high-performance inertial navigation solution designed to make surveyors' tasks easier in both shallow and deep water. Navsight Marine Solution integrates the latest generation of gyroscopes, accelerometers and GNSS receivers. Navsight provides high-performance motion and navigation data as well as a real-time heave accurate to 5cm. To allow surveying when wave frequencies are large or complex, the solution comes with a delayed heave feature. If higher performance is required, the surveyor can count on Qinertia, SBG's INS/GNSS post-processing software.

▸ ***https://bit.ly/2GBGXth***

EOMAP Wins Satellite-derived Bathymetry Contract for Tuvalu Atolls



▲ *Satellite-derived bathymetry data grid for a tropical atoll area.*

EOMAP has been awarded a contract for providing satellite-derived bathymetry (SDB) for seven atolls of Tuvalu. The project was awarded through a competitive bid contract issued and overseen by the UK Hydrographic Office (UKHO). Satellite-derived bathymetry is a new technique using modern satellite capabilities to provide remote, rapid and dense bathymetric information over extended areas, said Dr Knut Hartmann, director client services at EOMAP. He explained that unlike other survey methods it offers remote mapping of shallow-water zones and supports applications such as safety of navigation, reconnaissance surveys, coastal zone management or hydrodynamic modelling.

▸ ***https://bit.ly/2pIFYwS***

Trimble Launches Powerful Multi-application GNSS Solution

At Oceanology International 2018, Trimble announced its new MPS865 (marine positioning system) multi-frequency and multi-application GNSS receiver. The Trimble MPS865 is a highly versatile, rugged and reliable global navigation satellite system (GNSS) positioning and heading solution for a wide variety of real-time and post-processing applications for marine survey and construction. It brings a new level of connectivity to the marine positioning user, and features integrated communications options such as WiFi, UHF radio, cellular modem for internet connectivity, Bluetooth and MSS satellite-based correction channels.

▸ *https://bit.ly/2I93wma*

▲ *MPS865 GNSS receiver.*

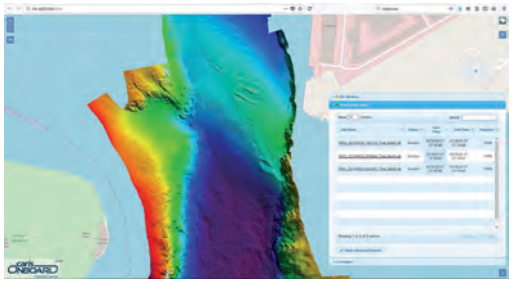
Sidus Solutions Releases New 4K UHD Subsea Camera

▲ *Sidus' New 4K UHD subsea camera.*

Sidus Solutions, a leader in subsea video cameras and technology, has once again engineered a groundbreaking subsea camera. The SS490 is a 4K UHD subsea camera that provides superior video image quality at four times the resolution of 1080 full-HD images, maintaining full 4K resolution while providing excellent focus with a 20x zoom and a combined optical and digital zoom of 144x. The SS490 delivers better picture quality than non-4K models due to its use of high dynamic range (HDR). This is especially helpful with varying lighting conditions such as working with multiple ROVs or reflectivity from stainless-steel objects.

▸ *https://bit.ly/2q0UvoA*

Real-time Mapping and Visualisation in CARIS Onboard 2.0



▲ *CARIS Onboard 2.0.*

Teledyne CARIS has announced the release of CARIS Onboard 2.0. CARIS Onboard enables users to apply processes automatically to their data in near real-time, resulting in minimised data conversion and processing times. By making the processed products available at the office or on a survey vessel during survey operations, CARIS Onboard helps to improve value and survey efficiency by reducing the turnaround time and helping to ensure that data quality and coverage requirements are met before leaving an area. Focused around the latest web map technology, the redesigned control centre dynamically controls and monitors the automated system. Products generated including surfaces, backscatter mosaics, and the survey track lines are live-streamed during acquisition and accessed through a web browser.

▸ *https://bit.ly/2Gxtkbp*

Oceaneering Updates C-Nav GNSS Receiver

Oceaneering has announced the release of the C-Nav5000 GNSS receiver, which uses 252 tracking channels capable of tracking phase and code of all available constellations, including GPS, GLONASS, Beidou and Galileo. Correction signal tracking has been increased to three channels to ensure continuous precise point positioning (PPP) data, improving satellite tracking, accuracy and safety. Following the philosophy of the C-Nav3050, the C-Nav5000 hardware is designed to offer optimisation and longevity supported by a multi-year plan for software feature additions.

▸ *https://bit.ly/2q3U1hx*

▲ *C-Nav GNSS solution.*

L3 OceanServer Unveils Advanced Iver AUV

L3 OceanServer has announced its new Iver Precision Workhorse (Iver PW) autonomous underwater vehicle (AUV). The new Iver PW is the first in a family of highly capable commercial AUVs to address a wide variety of customer missions, including survey research and mapping, sub-surface security and environmental monitoring. "Undersea missions are evolving, and L3 is uniquely positioned to develop military and commercial solutions using next-generation processing, autonomy and power technologies to enable new capabilities and missions," comments Daryl Slocum, general manager of L3 OceanServer.

▸ *https://bit.ly/2q2Uqjz*

▲ *Iver Precision Workhorse.*

N-Sea Reinforces UXO Expertise with ScottishPower Renewables Campaign

UK and Netherlands-based subsea provider N-Sea is part way through a multi-million pound unexploded ordnance (UXO) clearance campaign for ScottishPower Renewables. The contract for UXO clearance works commenced in December 2017 and includes UXO inspection, identification and clearance on the array area and export cable route of the East Anglia ONE Offshore Windfarm, located in the southern North Sea approximately 45km southeast of Lowestoft. The work scope, which will be completed later in spring 2018, requires a flexible multi-vessel approach in order to ensure completion in line with the timescale of windfarm construction.

▸ *https://bit.ly/2EjzUAo*

New Norwegian Ice-breaking Research Vessel

The Making of RV *Kronprins Haakon*

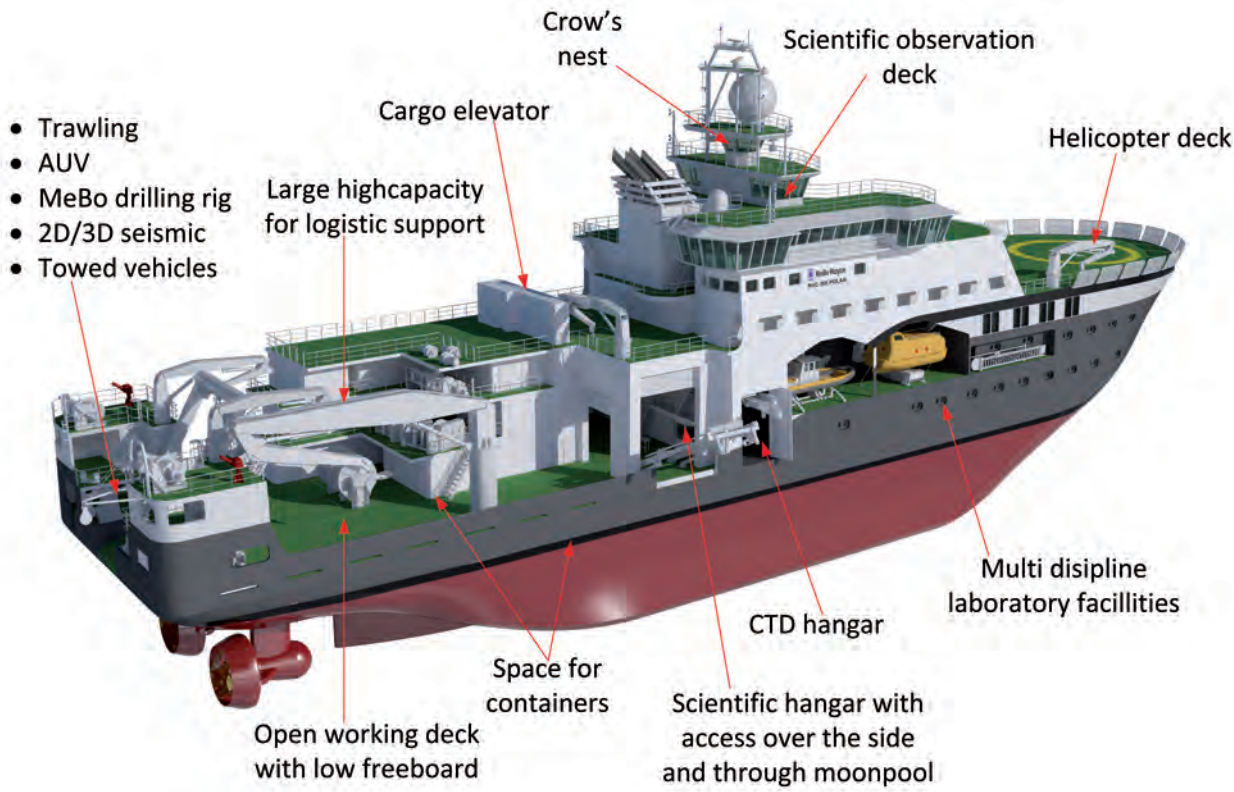
Norway is a maritime country with a very long coastline, and on top of this it is also very much a polar nation with 80% of its sea territory and 45% of its land mass north of the Arctic circle. It is the only country with territorial claims both in the Arctic and the Antarctic. In spite of this, Norway has not had a purpose built polar research vessels since Roald Amundsen's *Maud* (1917), instead relying on converted commercial vessels for these purposes. This is about to change when *Kronprins Haakon* comes into service in 2018.

Kronprins Haakon has been a long time in the making. The design contract was awarded to Rolls Royce Marine in 2008, but it was not until 2013 that the Norwegian Parliament allotted €145 million for the construction and outfitting of the vessel. The vessel is currently undergoing final outfitting at VARD Langstein after being delivered from Fincanteri in March 2018.

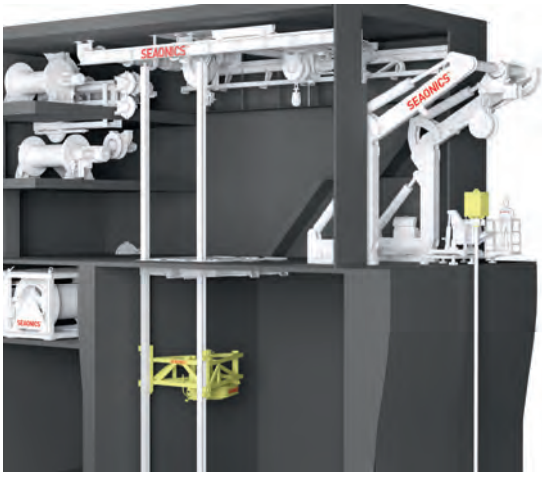
Year-round Operations

Kronprins Haakon is a multi-purpose research vessel built according to the new Polar Code as a PC3 Ice-breaker class ship, suitable for year-round operations in multi-year ice. The Norwegian Polar Institute, the Institute of Marine Research, and the University of Tromsø will use her jointly, mainly in the Arctic, but also in the Antarctic.

With its 100 metres (330 feet) in length and 21 metres (70 feet) breadth, the vessel will cater for up to 55 persons, including scientists, researchers, students and crew members. It will be a good observation platform for researchers for their work under extreme climate conditions. The ship is a multi-purpose vessel that will cover different fields of research work such as stock



▲ *Kronprins Haakon has been designed to carry two helicopters.*



▲ *The cursor system for deployment through the moon pool.*

▲ *The MeBO seafloor drill platform installed on Celtic Explorer.*

assessment, oceanography, geophysics, marine biology and marine geology.

The vessel is designed to carry two helicopters, with the helicopter hangar and the landing platform in the bow area.
The vessel is designed with a large open work deck where the stern is formed like a stern trawler and in addition to 'ice gallows', trawl winches have been installed for both pelagic and bottom trawling, enabling the vessel to trawl in both open and ice-covered waters.
On the port side of the stern there is a hangar for deploying the Hugin AUV.

The work deck also has facilities for seismic operations and a seafloor drill rig, such as the MeBo driller, and with its grid of container fixing points it can deploy, tow and recover a variety of mobile equipment and towed vehicles, using the A-frame installed at the stern.

▲ *Ægir 6000 ROV on Kronprins Haakon.*

Handling Equipment

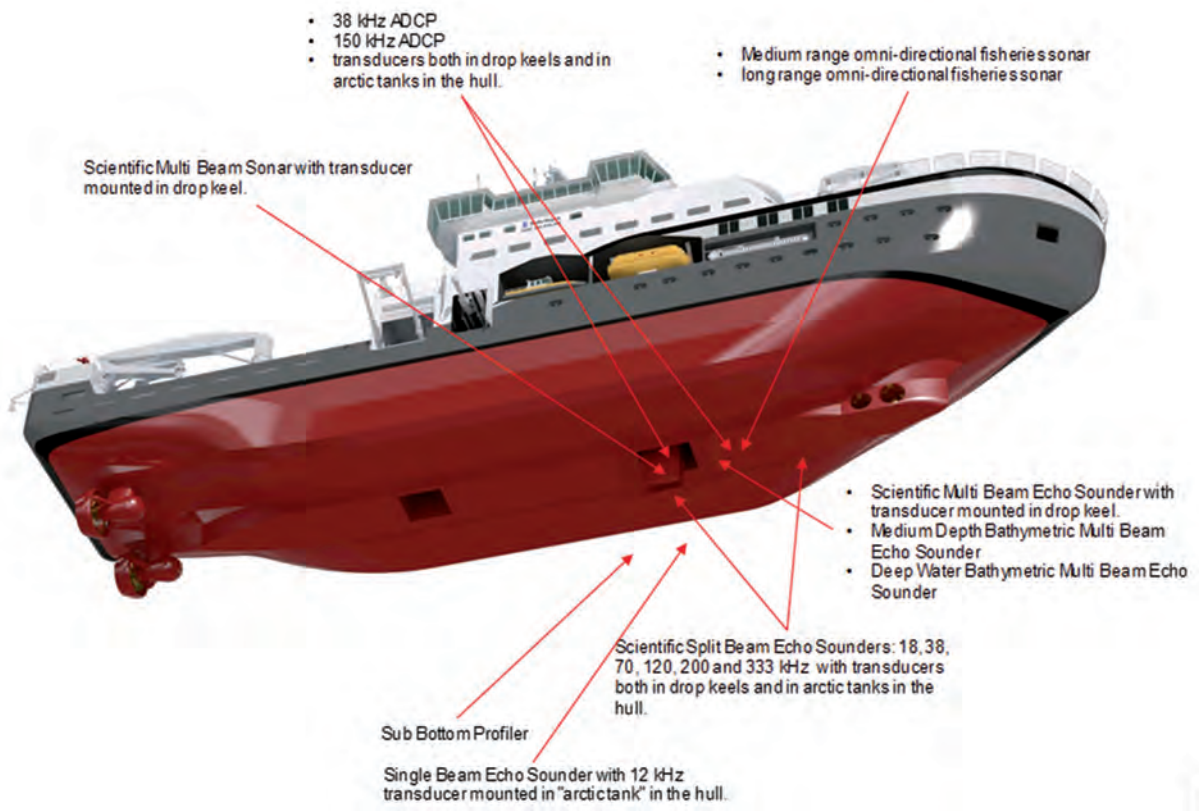
In front of the working deck there is the main hangar, with a 3 x 4m moon pool and opening to the starboard side, for deployment of ROVs such as the Ægir6000, Kley France Giant Calypso corer and other instruments for sampling the water column or the seafloor. There is also a separate CTD hangar for water samples next to the main hangar. The Norwegian company Seaonics has delivered complete state of the art handling equipment for extreme conditions, and the package includes winches, cursor system for safe moon pool deployment of ROV and scientific equipment, deck cranes, and over board systems, including A-frames and launch and recovery systems (LARS).

Laboratories

Inside the ship there are 15 laboratories for the researchers on scientific cruises, including Wet Geology/Benthos laboratories for analysing coring samples, ice samples and to determine invertebrate species composition, abundance and size from benthic sediments, and an isotopic lab to monitor radioactive contamination (gamma and beta emitters) in the environment and an environment toxicology laboratory to study the harmful effects of various chemical, biological and physical agents on living organisms. There are also laboratories to examine water samples, collections from plankton net and fish collected from the trawl. Most of the laboratories are located on the 3rd deck, which is the same as the working deck, to make the workflow as easy as possible. To store and conserve samples during the cruise there are four cooler rooms and two freezer rooms. In addition, there is space for three container laboratories outside on the work deck. The vessel also hosts an auditorium for 50 persons and a separate education lab. On the 9th deck, above the bridge, there is an observation room for sea mammal and bird observations.

Contradictory Requirements

Designing a research ice-breaker is not an easy task. On one hand you have the demand for a silent vessel with minimum Underwater Radiated Noise (URN) and bubble free zones for all transducers, and on the other hand the need for extreme force when breaking ice. Head of Design at Rolls-Royce Marine, Mr Einar Vegsund, is responsible for the design of *Kronprins Haakon*, and says the following about his work on this design;
"Noise signature and air bubble sweep down is a challenging task for all Oceanographic research vessels and even more challenging for ice-going vessels since the hull and propulsion systems must be designed to meet the extreme environmental conditions in polar areas.
As Ship Designers, we have to balance several contradictory requirements and find the optimum balance between efficiency, noise, ice-breaking capability, redundancy, reliability, manoeuvrability, seakeeping, etc.
Main source of underwater radiated noise is normally the propellers. Due to the requirements for manoeuvrability in ice covered areas an azimuthing type of propulsion system was selected, even though this is not the type of system with the lowest noise signature, and a huge effort was made to optimise the system and make it acceptable (propeller, electric motors, steering gear etc.).
The new RV *Kronprins Haakon* is ice classed acc to PC-3 ICE-BREAKER notation and the propellers must have the strength to 'eat' ice of 1.5m thickness. The vessel will be equipped with two ducted, 5 bladed fixed pitch propellers with a diameter of Ø4500mm and has been designed to be free of sheet cavitation at speed up to 11knots.
Design propellers have been tested and verified in the large HYKAT cavitation tank at HSVA, Germany. Other machinery and auxiliary systems has been designed according to low noise principles being resilient mounted on well stiffened foundations.
A high number of acoustic sensors are hull mounted in the forward part of the vessel and exposed to disturbances from air and particles generated by the bow as it pierces the water and waves. In order to avoid damage to the sensors from ice they are flush mounted and protected by titanium windows. Any piece of equipment protruding the hull will be damaged when the vessel is ice-breaking and therefore no



▲ *The hull as seen from below.*

gondola or appendix is allowed. The hull itself has an extreme requirement for smoothness and welded connections are grinded to avoid vortexes. The vessel is also designed with a carefully designed keel diverting the water flow from the bow away from the sensors at the bottom of the hull. Computational Fluid Dynamics (CFD) software are probably the best tool to use when investigating details of hull design and arrangement of hydro acoustic sensors and Rolls-Royce used this actively during the entire ship design process."

Acoustics package

Under the keel the ship is outfitted with a large acoustics package from Kongsberg Maritime (KM). This package includes deep and medium depth multibeam systems for bottom mapping, including the EM 302, EM 710 and EA 600, while systems such as SBP300 and TOPAS can be used to look at sub-bottom structures. Position reference will be provided by the state of the art and industry standard HiPAP 501 system. Also part of the delivery is the KM series of Simrad scientific systems, including a new EK80 wideband split beam fisheries acoustics system, modern scientific multibeam systems ME70 (looking downwards) and MS70 (looking sideways), and omnidirectional sonar SH90 in addition to the new SU90 that can detect and track biology for several kilometres around the vessel. *Kronprins Haakon* will also carry the new Simrad FX80 trawl monitoring system, which can provide a live camera feed from the vessel's sampling trawl.

Unlike other existing research ice-breakers the *Kronprins Haakon* is designed and equipped with acoustics that can both measure and quantify biology in all components of the marine ecosystem. Quantitative multibeam (ME 70 and MS 70) and omnidirectional sonar systems (SU 90 and SH 90) target areas close to the surface and near the bottom where traditional echo sounders cannot be used.

Two keels

Also, unique to the *Kronprins Haakon* is its ability to collect scientific data both when operating in ice and in open waters. To achieve this, the vessel is equipped with two retractable keels (drop keels) that secure an optimal environment for the acoustic instruments. Two drop keels are needed because there is not enough space for all the equipment in one keel. The port drop keel contains: ADCP 38 kHz and EM 710. The starboard drop keel contains: EK 80, MS 70, ME 79, ADCP 150 kHz. However, as the drop keels cannot be deployed when the vessel is breaking ice, the *Kronprins Haakon* also carries an additional acoustic package of flush mounted EK 80 echo sounders in ice protected arctic tanks, so data can be collected even when the vessel is operating in ice. Communications and navigation systems are mainly supplied by Norwegian companies, for example the K-Bridge Integrated bridge system from Kongsberg Maritime and Dynamic Positioning (DP) system from Rolls Royce Marine. These systems will assist the crew with safe sailing and operations.

Acknowledgement

Many thanks to Øystein Mikelborg, Per Wilhelm Nieuwejaar and Einar Vegsund for their contribution to this article. ◀

Jan Bremnes is employed by The Institute of Marine Research (IMR) as senior engineer at the Department of Instrumentation. During the building process of *Kronprins Haakon* he was responsible for instrumentation and laboratories on the vessel. He is an electronic engineer with many years of experience in different fields such as underwater acoustics, survey technics and the TV industry.

Distributed Ledger Technology and Sea Charts

How **Blockchain** Will Have an Impact on **Navigation**

The blockchain technology can potentially change the process of compiling sea charts. Since not all of us are acquainted with terms like 'blockchain' and 'distributed ledger' let us first see the inner workings of this technology by giving an example. You can proceed to the next subtitle without missing the point if you know about DLT (Distributed Ledger Technology).

DLT Demonstrated – a Familiar Example

The captain's logbook is a legal document – it is not to be tampered with. Although it is hard to hide, a forger can potentially modify it. The simplest way is to remove a page or two which will not go unnoticed but information will be lost forever.

Should there be even one copy of the logbook to prevent inconsistencies, and if the records were always identical, and done at exactly the same time, a forgery would be impossible.

However, all copies would still be held in one and only one location, i.e. on board of the ship whose name the logbook carries. If the ship sinks and no crew member can save a copy of the logbook the information within is lost forever. Another case is when the logbook is locked away to withhold information from the public. This centuries old problem can be now solved by a combination of state of the art technologies – computing, digital communication and the 'blockchain'.

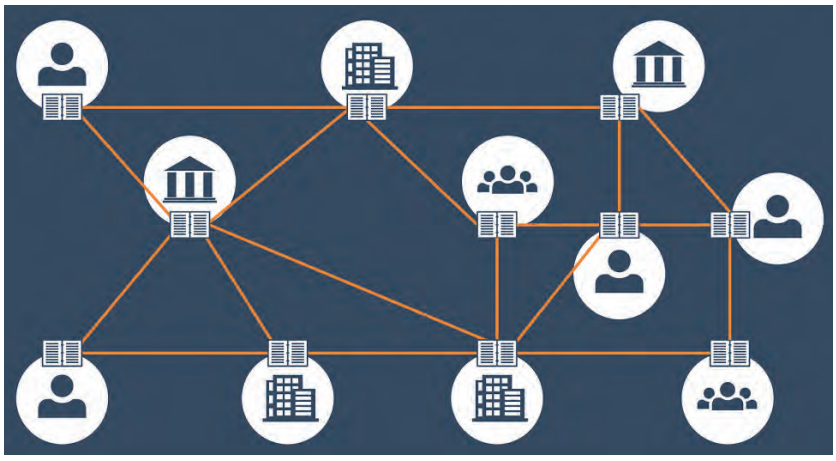
A 'blockchain' is nothing else than a public ledger (a logbook openly accessible to anyone) that exists in multiple copies spread over the internet, and of which each copy has identical content. In addition, the records are no longer done with a pen but digitally.

Nowadays, a vessel equipped with a computational device and access to the internet by, for example, satellite can send encrypted logbook entries to servers worldwide where a copy of the logbook will be held and each entry will be verifiable by the captain's digital signature.

What truly matters is that charts be reliable, accurate and up to date

To ensure that no information goes missing the logbook servers are in constant communication with each other to synchronise the content of their logbook copies. The servers close a page in the ship's logbook (the equivalent of a 'block') if a majority of them agree that they hold identical copies. Diverging copies are ignored. An encrypted checksum of the verified 'block' page is computed, so that later modifications can be detected. Next, a link to the following page is added as the 'chain' of 'blocks' grows. The ship's logbook has been now turned into a volume of indestructible and non-modifiable copies held in a blockchain by means of DLT; nobody can tamper with its contents, and only a global disaster would destroy all of its copies.

The logbook example demonstrates the potential of the DLT technology. In fact, DLT is already applied in container handling and it will revolutionise shipping in general. In navigation, however, it is less obvious why and how to employ the blockchain.

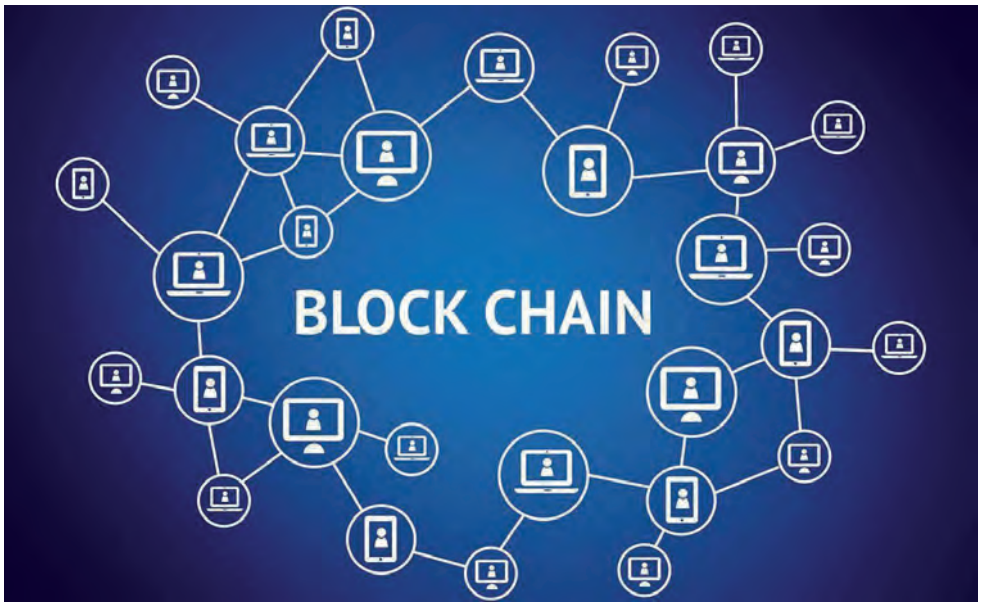


▲ *Figure 1: Distributed ledger technology involve the sharing of ledgers between different people and organisations. (Source: The Cabinet Office's Open Innovation Team, UK)*

The Blockchain and the Sea Chart – Foreseeable Implications

Sometimes, mother nature has to open our eyes for us to see what is needed. As two hurricanes in a row devastated the Caribbean Sea in the autumn of 2017, it became clear that the profession of hydrography is at a crossroads. Until now, it was not easy to assess the reliability of a chart, one had to rely on the word of the Hydrographic Offices (the reliability diagrams for example) or of a chartmaker in general. But the situation is about to change. Blockchain has appeared. In essence a public ledger, or public track record, the blockchain records every action (or 'transaction'), and everyone who has access to the internet can verify it. The Distributed Ledger Technology (DLT), as the blockchain construct is often called, will change the way of operation of industries as well as the organisation of whole countries. The HOs of the world will have to accept this technology too. The users will require every single operation on data in chart production to be documented. Looking further into the future, ships will soon be fully automatic, self-navigating and the artificial intelligence that controls them will rely on the full documentation of charts.

The use of DLT when compiling a chart will lay open the originator of the survey data which went into the chart, its time stamp, the identity of the chart compiler, and the means of the generalisation used. Mariners will be able to check the reliability and usability of any chart, whether produced by the HOs or by private entities, and chose one that is most accurate and appropriate for their needs. Furthermore, it is to be expected that independent, private chartmakers will adopt this technology much faster than the HOs. This will create a completely new situation by making commercial charts certifiable and classifiable. An independent and neutral network of servers (or 'nodes') that maintain 'the sea chart blockchain' had to be setup to initiate such verification services but this appears to be only a matter of motivation since the technology is readily available and is in public domain.



▲ *Figure 2:Impression of the Blockchain system.*

▲ *Figure 3: Norwegian chemical company Yara International has teamed up with another Norwegian company, Kongsberg, to build an autonomous cargo ship. (Courtesy: Yara International).*

'Unofficial charts' on the Horizon?

It is a known, albeit ignored, fact that private chartmakers are more than capable of producing charts of high quality and reliability. Modern standards such as IHO S-44/S-57/S-100/S-102 have made it possible to produce digital charts of unparalleled precision that can easily be distributed without the need to run a printing plant that requires heavy investment. Speaking of the Caribbean, modern cruise ships would not be able to enter small ports without tailor-made charts that have not been available from the relevant HOs and were contracted out to private chartmakers. But, again - these ships have to take legal risks using such charts because of the SOLAS regulations that stipulate charts by HOs, ignoring the fact that the very same ships would run a risk of running aground using them exclusively.

This will place the IMO, the HOs, and all bodies whose services rely on the IMO rules, like the insurance and the certification industry, in a predicament. The justification for the monopoly of the official charts is likely to be challenged.

Financing More Surveys

Shortly before Irma and Maria swept the approaches to the Virgin Islands and way up to Florida, the umbrella organisation of the HOs,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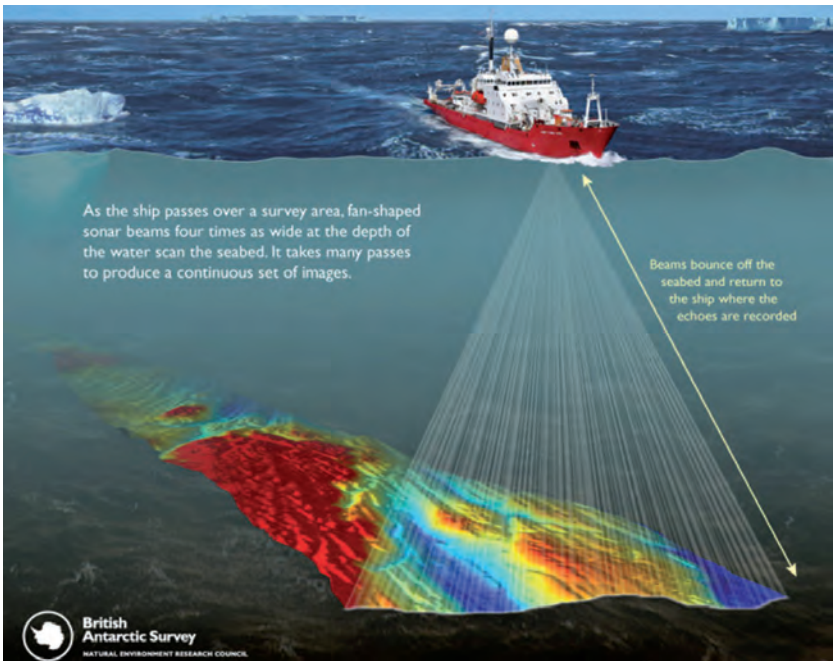

▲ *Figure 4: Multibeam bathymetry explained.*

i.e. the International Hydrographic Organization (IHO), had called out for crowdsourcing of bathymetric data. Their Crowdsourced Bathymetry Working Group (CSBWG) is examining 'how best to incorporate, manage and use bathymetric data acquired by other than conventional means'. To collect these data the IHO set up its Data Centre for Digital Bathymetry (DCDB).

In parallel, the International Harbour Master Association (IHMA) has asked its members to comment on the IHO initiative. It goes without saying that the IHMA itself is interested in the production of better approach charts to meet the demands of the ever larger vessels, and increasing traffic. Some ports are even making their own charts, and pilots are using 'unofficial' i.e. not IMO-backed ENCs compiled by services other than their local HO. As a rule, port ENCs are more accurate and more up to date than the official ones.

Where is this leading to? Asking for freely available bathymetry is one thing, but financing it is another. Although installing a data recording device onboard a commercial vessel or a pleasure craft that collects single beam bathymetry while going in and out of ports can be seen as a contribution to the safety of shipping, it also means an investment, even if relatively small. In addition, this type of bathymetric data can be used to confirm or otherwise the actuality of an existing chart, but it is not enough to make a new chart. For this we need serious, professional, multibeam, in other words expensive, bathymetry to be done.

Production of the navigational charts has been an exclusive domain of the national HOs for a long time

Funding and organising a survey campaign by national authorities is a major task and takes time, time that disaster areas such as the Caribbean do not have.

Conclusion

Production of the navigational charts has been an exclusive domain of the national Hydrographic Offices (HOs) for a long time. The International Maritime Organisation (IMO), an organ of the United Nations, stipulates in their Safety Of Life At Sea (SOLAS) regulations that only the charts made by the HOs meet the carriage requirements for commercial shipping. Every ship has to meet these requirements to be considered seaworthy by the port control, coast guards, seafarer unions, and the insurance industry.

So, doesn't calling out for more accurate and up-to-date bathymetry in reality mean asking for crowdfunding rather than crowdsourcing?

Which leads us directly to the question: why should private capital invest in a survey of a fairway, let alone the vast coastal areas when it is made clear that this is the domain of national HOs, which are often run by governments that are not used to sharing their data, not to mention the income from the sales of charts?

Offering return on investment is essential when asking for private capital. Though one can think of a world where the HOs pay license fees to commercial entities for their bathymetric data in a private-public-partnership (PPP) arrangement, it is not likely to happen any time soon on a big scale. There must be other ways.

It is firmly believed that the time has come to start trusting the privately produced/ commercial nautical charts, to put them on the same level as the official ones and to clarify the relevant liability issues. Technology is available and in place.

If the private sector is to pour money into the production of nautical charts to help out the HOs in their task to ascertain the safety of navigation and the international shipping then we need a new basis for mutual trust. The DLT technology offers a way forward for a renaissance of the profession of private chartmakers working shoulder to shoulder with HOs who are free to join the effort on the same basis.

This will be of great benefit to international shipping. Navigators, captains and pilots will be able to use the best nautical data available, no matter whether it is of 'official' or 'private' origin. IMO regulations should follow suit.

What truly matters is that charts be reliable, accurate and up to date. ◀

Gert Büttgenbach is a graduate of ISSUS Hamburg/Germany. After his career as a nautical officer, he studied IT and joined ISSUS in 1986 to participate in ECDIS related R&D. During the German ECDIS trials from 1990 to 1991, his team developed the first production environment for ENCs. In 1992, Büttgenbach co-founded SevenCs and helped to launch ChartWorld.com. SevenCs delivered software to ECDIS OEMs, for ENC production and for use in VTS projects. He has been a permanent observer to the IHO Working Groups that developed the IHO S-57 standard. The Presentation Library for ECDIS and the automatic updating of ENCs is based on his contributions.
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Introducing iXblue's Integrated Solution

An Integrated Approach to **Subsea Navigation and Positioning**

▲ *Canopus intelligent transponder.*

iXblue are particularly known for their Fiber-Optic Gyroscope technology, in particular Octans, Hydrins and Phins in the surface navigation realm, Rovins, Rovins Nano and Phins Subsea when it comes to ROVs. The rise of the AUVs has seen a large adoption of iXblue's OEM INS range, Phins Compact C3, C5 & C7. Some people also know the company for being the first to introduce a USBL system with an integrated INS. The INS embedded deep within iXblue Gaps USBL system allows it to be completely calibration free, making it the first truly portable USBL system.

Ramses is a product that enables an advanced form of LBL (acoustic synthetic baseline positioning system - ASBL), which has been making some major impacts recently. Being specifically designed to be the perfect aiding tool for an INS, Ramses is an intelligent acoustic range meter which is able to stop the drift inherent to an INS by passing it ranges to even a single beacon.

Intelligent seabed beacon

When operating on a 1km X 1km lawnmower pattern survey, Ramses has been shown to allow decimetric positioning of a tow fish with just one beacon deployed on the seabed, irrespective of water depth. More recently MMT used Ramses in over 2000m of water to position an ROV to decimetric precision with just 1 beacon per 1.8km of route.

IXblue already has the widest range of INS on the market, as well as unique USBL and Sparse array / ASBL capabilities, but this year sees two major steps forward for iXblue in the subsea positioning world. The first is the completion of iXblue LBL capability with the introduction of a new highly intelligent seabed beacon.

The Canopus beacon is a 4000m rated MF beacon with integrated release hook, tilt and pressure sensors. In addition, there are optional SV and High Accuracy pressure sensors as well as the capability to interface external sensors. Internal data logging, telemetry, high-speed modem and a range accuracy better than 1cm complete the picture.

The second major step forward is the introduction of a new software layer to integrate the various existing products into a truly integrated positioning system.

Unified system

While the new Canopus software ties all the existing products together into a unified system, allowing a single user interface for controlling and monitoring multiple subsea positioning components from a single location, iXblue still maintains the philosophy of stand-alone components. For instance, each Canopus beacon provides a web-based interface for configuration and monitoring. Both wired or wireless Ethernet connections are available to the beacon to allow configuration or monitoring as appropriate. Full control is also available via the acoustic link.

The Canopus software allows a user to:

- Plan the operations
- Deploy the devices
- Operate the system
- Post Process

The planning of an operation starts with an analysis of the expected sound velocity profile and digital terrain model in order to estimate the expected propagation characteristics. From this, an estimate of acoustic range can be made. The beacon array layout can then be produced, with coverage being displayed interactively. Accuracy estimation maps can be produced based on the DTM, propagation characteristics, proposed array layout and INS grade to be used. Finally, knowing all the above, it is possible to estimate the beacon battery life for the array.

Accuracy and positioning

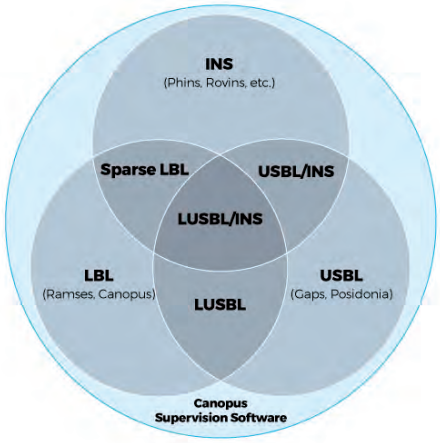
When it comes to deploying the devices, the Canopus software will automatically detect devices on the network and will integrate them into the system. Beacons may be programmed over WiFi, and all interfacing between devices is handled. Once the beacons have been deployed on the seabed, it is then necessary to calibrate them. This can be achieved through a guided calibration process using a mix of traditional Box-in, SLAM, or Mutual Array techniques.

Data post processing is handled by iXblue Delph INS, allowing full settings management, data exclusion, data import, and enhanced processing

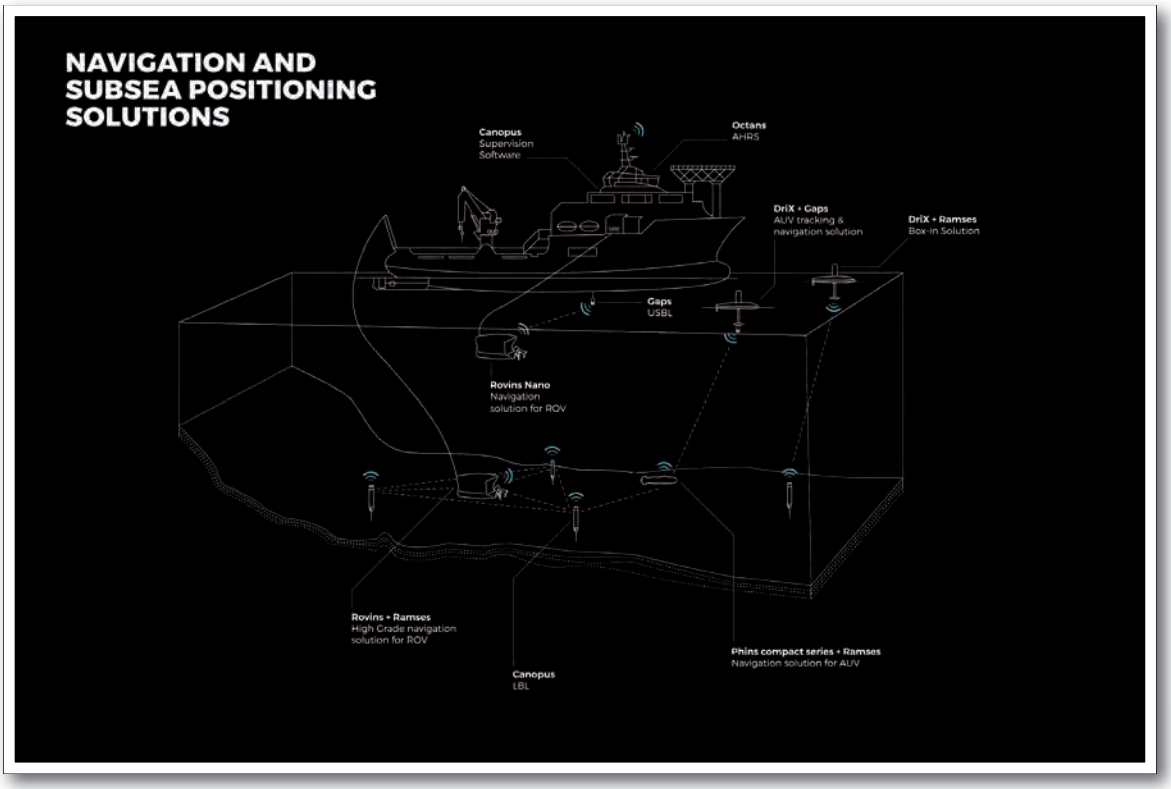
In operation, the software dynamically controls all aspects of the array, ensuring only the correct beacons for the operating area are interrogated, and only at a rate required to meet the accuracy specifications. Positioning performance is monitored and recurrence rate or beacons in use may be changed to ensure the desired accuracy is met.

The final part of the picture, data post processing, is currently handled by iXblue Delph INS, allowing full settings management, data exclusion, data import, and enhanced processing. The recent addition of water density management to Delph INS brings hydrographic grade bathymetry with full swell reduction.

With the introduction of the new intelligent Canopus beacon and supervision software, iXblue now offers a new global subsea positioning system that provides ultimate performance, time savings, with less equipment to be deployed and no compromise on accuracy.



Canopus software.



Navigation and subsea positioning solutions.

Ocean Infinity's Seabed Exploration Project

Mapping the **Deep Ocean** with Multiple AUVs

Ocean Infinity's seabed mapping campaign commenced in the summer of 2017. The Ocean Infinity team is made up of individuals from multiple disciplines, who have gained vast experience with deep-sea exploration operations in the past. Their combined knowledge and insight led to the idea to undertake deep-sea mapping operations using up to eight Autonomous Underwater Vehicles (AUVs), paired with eight Unmanned Surface Vessels (USVs). This novel concept is explained in more detail in this article.

Ocean Exploration

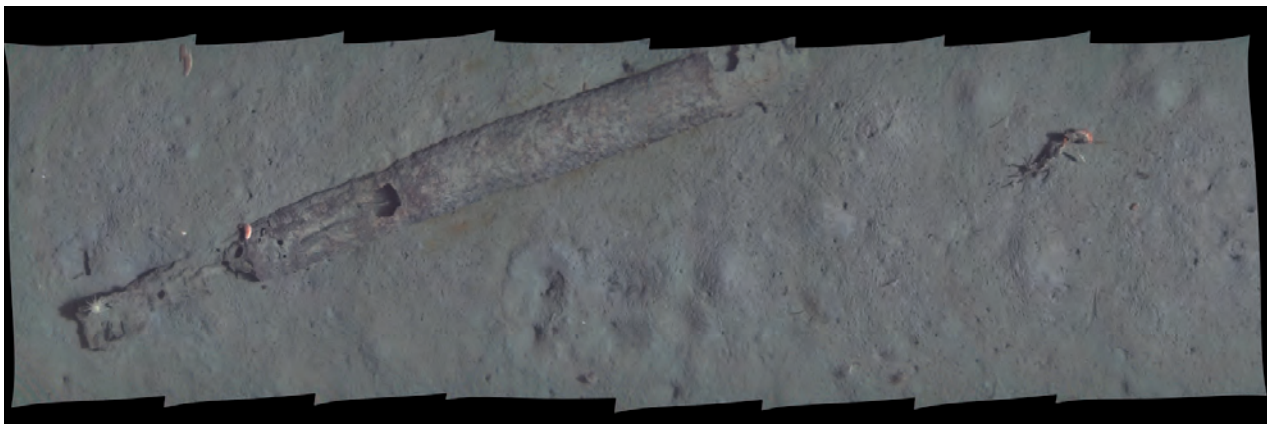
Human inquisitiveness drives us to explore. This has led man to delve below the surface of the oceans. Our ability to understand the undersea world has continually progressed, driven in part by technological developments. Early attempts of pearl divers, for example, to fashion primitive goggles, had profound consequences in demystifying the world which lies beneath the waves. For the hydrographic surveyor, comparable advances can be seen, in progressions from lead line soundings, to the first echo sounders, and onto swath sonar systems. The field of vision for the surveyor has been widened through using modern high-resolution mapping technologies. Yet, despite advances in physical sensors, our choice of survey platform has limited our ability to map the deep oceans. Due to the physical properties of seawater, and the associated propagation and attenuation of sound within the water column, limitations are imposed on surveys undertaken using hull-mounted sensors on surface vessels. The advent of tethered submersible survey platforms such as ROVs and tow fish have reduced the distance between sonar head and seabed, however to make further progress in mapping the undersea world we need to mirror characteristics of the fish who have evolved effectively to navigate this aquatic environment. We have come closer to this in adopting the AUV as a survey platform.

AUV Shoaling

Until relatively recently AUV surveys have involved one vessel and one AUV. This mode of operation is resource intensive and imposes clear limitations on our ability to map extensive ocean areas far from the coast. In contrast, many species of fish swim in shoals and as a result expand the field of vision of the group beyond that of the individual, enhancing their collective ability to spot predators or food. Ocean Infinity have applied this principle to AUV surveys by assembling a fleet of AUVs, all of which are deployed from a single Host Surface Vessel (HSV). By pairing the AUVs with USVs, their operational range can be extended even further. Each AUV communicates with a USV via a through-water HiPAP sonar system, while the USVs communicate with the HSV via radio links.

Survey Platform

Multiple Kongsberg HUGIN AUVs are used in this mission, each with a 6000m depth limit and equipped with Side-scan Sonar, Multibeam



▲ *Figure 1: Widened Field of Vision - image acquired during a recent Ocean Infinity project.*

echo sounder, Sub-Bottom Profiler (SBP), magnetometer, CTD, and HD camera (CathX Ocean still), and optional turbidity, methane and CathX laser sensors.

Project Start-up

One year ago this ambitious operation was just a vision, now it is a reality. Today surveys are being undertaken far from the coast using a shoal of eight AUVs. Taking the plan from the drawing board to the ocean was not, however, simple. Many challenges and hurdles had to be overcome along the way. The Ocean Infinity solution is complex and required a wide range of skills, the expertise of multiple organisations, and necessitated constant focus, energy and teamwork, as plans frequently needed to be rethought and timelines re-evaluated.

Ocean Infinity was launched at a time of low market activity in the subsea sector. It is believed the lull in market activity provided the perfect opportunity to bring together a team of experts with proven experience in this field. For example, whilst many companies have been making redundancies, Ocean Infinity's key partner Swire Seabed has formed a new survey office in Bergen.

Constant development and re-evaluation permeate not only the technology but the approach to the whole business, and so has extended beyond mobilisation into the early subsea missions. Much of the technology used and processes employed are original, so needed to be improved, enhanced or augmented. If we consider the crew numbers required to man a single AUV survey operation, it was not feasible to multiply these numbers by eight. Therefore, we were required to optimise performance and incorporate a high level of automation within each stage of our workflows. The larger scale of the operations Ocean Infinity undertakes (i.e. surveying of extensive areas of seabed) has helped make application of these automated processes possible. One particular area where high levels of automation have been implemented is within optimisation of data-processing tasks.

▲ *Figure 2: HUGIN AUVs in the hangar on* Seabed Constructor.

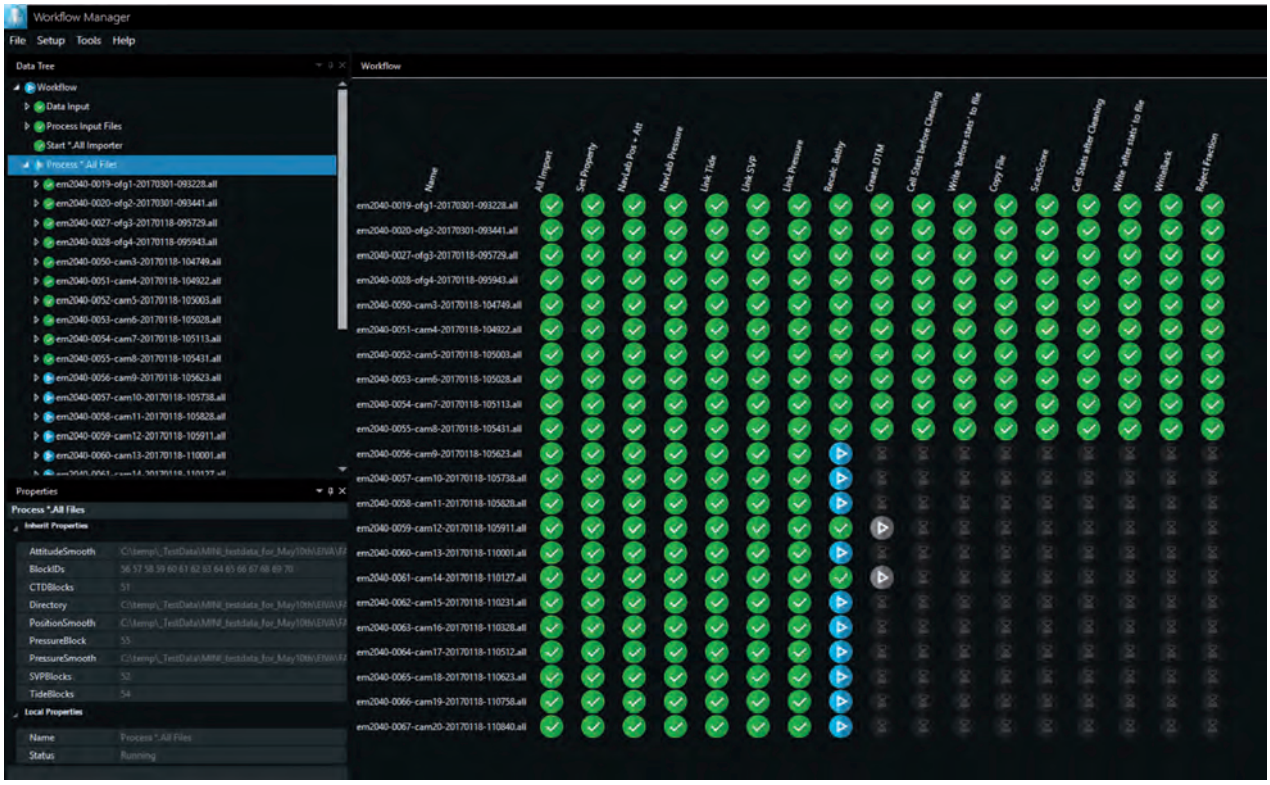
▲ *Figure 3: The* Seabed Constructor *back deck with USVs.*

Technology in this field is continually evolving

Automation of Data Processing

Ocean Infinity have been working closely with our software suppliers in creating new automated routines for processing the vast amounts of data generated by our fleet of AUVs. This process commenced long before equipment mobilisation and we entered dialogue with multiple software suppliers at an early phase of the project's inception. We have benefitted from research and development undertaken in tandem, between our data processors and technicians of EIVA, iXblue, Esri/Geodata, and CathX. Extensive work has been undertaken, in collaboration with EIVA, in developing a Work Flow Manager system, which automates processing steps undertaken on data which is downloaded from the AUVs, and removes the requirement to complete as many manual logs.

The user interface developed incorporates a crawler function which alerts processors to when folders are ready for use (see Figure 4). iXblue have enabled processing steps undertaken on geological data to be optimised. This is essential as, even though the team of geologists on board has been expanded beyond what is common for single AUV operations, the extensive data volumes necessitate implementation of new techniques. Following preliminary processing phases raster deliverables are generated onboard, steps to achieve this have also been optimised within ArcGIS; our GIS supplier Geodata have developed scripts in line with our requirements, to automate GIS processes. We are also drawing on their Geocap extension for dealing with SBP data in our GIS. The goal of these steps is to increase reliability and to reduce the number of man-hours required to prepare



▲ *Figure 4: EIVA Workflow Manager.*

data offshore. Yet, with so many novel processes underway, it is easy for an outsider approaching the project for the first time, to be overwhelmed by its apparent complexity.

Data Management

Operations involving up to eight AUVs with a heavy payload of sensors, generate substantial amounts of data. Over time, the data acquired and transferred onshore quickly becomes 'Big Data'. This means that consideration must be given to how this data will be managed and presented. The current plan is for data processing and preparation to mainly be undertaken on the vessel. Deliveries transferred onshore take the form of standard raster files (in .Tiff format), with associated vector background/meta data (supplied in SSDM format). The server system offshore operates in the form of an onboard Cloud, with each data processor using a virtual PC. This enables us to benefit from enhanced processing performance, made possible through distributing tasks over multiple virtual machines. The data, once transferred onshore from the vessel, is uploaded to the Cloud.

Pairing AUVs with USVs extends their operational range even further

This data is then made available to users and clients, using an ArcGIS Enterprise solution. This solution makes a new generation of deliverables possible, where clients no longer need to rely on data transfers using physical drives, but can view and download data via web applications. This can also potentially enable users to incorporate data deliverables into their own applications using Web Map Services (WMS) or Web Feature Services (WFS). By doing so, we are looking to future-proof our data deliveries, moving beyond the era of traditional paper charts, to geospatial data supplied directly to the user, potentially wirelessly, over the internet.

The Future

Ocean Infinity is only at the start of its journey of seabed exploration. The technology and processes outlined above are currently among the most advanced available, however, technology in this field is continually evolving, so an ongoing process of research and development is underway to ensure that new developments are incorporated into the Ocean Infinity solution. During 2018, we plan to install the next addition to the survey spread, an EM302 hull-mounted deepwater MBES. This will enable us to carry out essential reconnaissance surveys of unknown areas prior to deploying the AUVs. One natural consequence of mapping such deep, remote regions of the ocean, is that there is lack of available datasets which we can use for planning purposes. This fact also adds to justification for the endeavour Ocean Infinity is embarking on. Further expanding the seabed area Ocean Infinity are capable of surveying, a 9th AUV will be added to the fleet in December 2018. This AUV will be configured to enable it to operate under ice, and will be equipped with a Synthetic Aperture Sonar (HISAS). Also an upward facing EM2040 MBES will be installed, which can be used to survey the underside of ice. This system is already scheduled to be used in a scientific research project early in 2019. ◀

Al Rumson is a hydrographic surveyor, currently working with data management and analytics. He has worked in the hydrographic industry since 2006 and has primarily been based in Norway since 2011, working with DOF Subsea and Swire Seabed. He has a degree in Hydrography from the University of Plymouth, and is currently a PhD Candidate at Cranfield University, focussing on management of coastal datasets.
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French Coastal Survey Using ALB

From Concept to Feasibility in **Aerial Mapping**

Starting in 2005, the French Naval Hydrographic and Oceanographic Office (Service Hydrographique et Océanographique de la Marine [SHOM]) and the French National Geographic Institute (Institut National de l'Information Géographique et Forestière [IGN]) began conducting a series of coastal surveys of metropolitan France and some overseas territories, as part of the national project Litto3D.

The coastal areas were at that time poorly described, hence airborne bathymetric Lidar data were used to create a continuous altimetric dataset of the coastal zone. The purpose of this project was to produce better risk management prevention plans for floods, landslides and earthquakes, and to support economic development strategies, environmental protection policies and scientific studies that require the knowledge of the near shore topography and bathymetry.

The Setup

From 2005 to 2015, SHOM built a strong expertise in the Airborne Lidar Bathymetry (ALB) technical field by subcontracting data acquisition to survey companies. In February 2016, the French Ministry of Environment officially decided to finalise the maritime part of the Litto3D programme. Up to half the costs of a regional ALB survey could be directly funded.

This decision opened a new perspective. Instead of subcontracting survey companies,

▲ *Figure 1: The SHOM operating team in the field.*

▲ *Figure 2: Area of interest in Normandy and Hauts-de-France.*

▲ *Figure 3: The HawkEye III system onboard the Cesna 208 grand caravan.*

SHOM could now run and operate its own ALB capacity with the guarantee of being financially supported. It was decided to launch a call for proposals for a three-year full service ALB. The selected company would have to provide the bathymetric Lidar system as well as the aircraft and its pilots, the training of the laser operators (Figure 1), and would have to take care of the maintenances/calibrations and deal with the administrative support (flight permits, insurance policy, etc.).

Planning the Mapping Mission

Leica Geosystems and CAE Aviation, who won the tender, mobilised their efforts to offer a comprehensive theoretical and practical training programme to SHOM's team on the use of Lidar and the software associated with this technology.

The first survey conducted in Normandy and North of France (Figure 2) used the Leica HawkEye III, an airborne multi-sensor deepwater bathymetric and topographic Lidar system (Figure 3), mounted on a Cessna 208 Grand Caravan.

During the data acquisition in Cherbourg in September 2016, the HawkEye III captured full waveform in rather favourable environmental conditions; the wind was relatively calm with flat seas and without fog in the survey area. In addition, the Leica MissionPro software with the 3D virtual globe view helped in the preparation and planning for the flights, and the Leica FlightPro flight management and sensor control system assisted in the data collection.

The results of this first topo-bathymetric survey exceeded SHOM's expectations. As the water column in the English Channel is globally turbid, the goal was to reach the 5 metre isobaths. In many areas, the laser penetration overtook the 10m depth. The work achieved on morpho-sedimentary cells was impressive. For this first deployment, SHOM had only planned to survey the western part of Cotentin peninsula, but after 4 weeks, the northern and half of the eastern parts had alsobeen covered (more than 300km of coastline). Leica Geosystems Lidar technology worked perfectly with no failures occurring during the first mission.

The Challenge

Given these positive findings, SHOM has continued the Normandy and North of France survey in 2017, a major operation along 'La Manche' coastline, from Baie du Mont-Saint-Michel (western Normandy) to the Belgian border. Two more topo-bathymetric surveys will take place (in May-June and August-September 2017) and will enable SHOM to generate a complete geographical product by mid-2018. The expected coverage goes down to 5 metre isobaths and up to 400m inland.

These upcoming deployments include real challenges for SHOM as Mont-Saint-Michel is known for the highest tides in Europe (more than 14 metres between lowest and highest astronomical tides). If the flights are correctly scheduled during low tides, the SHOM team can benefit from the tides. The inclement weather might be another obstacle to overcome, but the main difficulty will remain the turbid coastal waters of the English Channel. SHOM will again take advantage of the HawkEye III to provide high-resolution and accurate deep bathy, shallow bathy and topography data.

An important goal in these kinds of survey is to have a smooth transition between topographic and bathymetric data, but this interface between land and sea is not easily measured. Due to tides, currents and wind, the clouds of turbidity have a tendency to accumulate near the shore. Rivers mouths and more generally rains can also bring a lot of sediments, which partially obstruct the optical path of an airborne Lidar. Breaking waves can even generate 'white waters', which are impenetrable by laser. Hence, the most challenging environmental conditions are often faced in these very coastal areas, between 0 to 10m depths. However, the topo-bathymetric Lidars, launched by equipment providers since 2012, have offered a major technological breakthrough - they are not as powerful as usual bathy Lidar, but their higher Pulse Repetition Frequency offers denser bathymetric point clouds (3 to 4 points per square metre) to surveyors. Even in turbid waters and with the help of dedicated software, it becomes achievable to detect the sea floor.

The HawkEye III includes a Leica Chiroptera topo-bathymetric system and can achieve perfect earth-sea continuity thanks to its various sensors (3 channels: topo, topo-bathy also called 'shallow', and pure bathy also called 'deep'). This technology ensures SHOM that there will be no gaps in the Digital Terrain Model (DTM), which is essential for the end product (Figure 4 and 5). The Litto3D geographical reference frame is used for many purposes in metropolitan France and French overseas territories, including shoreline management, economic development, environmental protection and risk prevention. It is especially used to model maritime flooding, due

▲ *Figure 4: Final DTM West of Granville (Normandy).*

to storms, tsunami or long-term sea level rise. Wrong data could completely bias the conclusions of such studies, which is of course not acceptable for scientists, but also not for stakeholders. Litto3D intends to enlighten decision making on the littoral.

On the software side, Leica Geosystems also provides the Leica Lidar Survey Studio (Leica LSS) to pre-process the waveform and position data to create classified point clouds. An important feature of LSS is the 'Turbid Water Enhancement' algorithm, which is obviously helpful in complex areas. The SHOM team can also review the deep bathymetry, the shallow and the topographic Lidar data at the same time, including reviewing the images taken at the same location as the point cloud data. In terms of cost-effectiveness, compared to shipborne surveys in the past, topo and bathy survey had to take place separately and SHOM had to launch a complex merging data process. With Leica Geosystems technology, this step is no longer necessary.

An Innovative Solution

SHOM is responsible for conducting surveys in difficult areas and the partnership with Leica Geosystems has given them peace of mind by dealing with all the other aspects of the project, such as system installation, calibration, technical and aeronautical maintenance.

The Lidar technology has been widely used in monitoring various natural hazards. Due to the high accuracy of the captured data (if one considers a Lidar point expressed in the French legal geodetic system RGF93, its coordinates absolute precision is less than 20cm for topo dataset and less than 40cm for bathy dataset), the technology is today used in the field of oceanic sciences, including a DTM and bathymetric mapping. The HawkEye III is a simple-to-use sensor optimised for the most demanding survey requirements: 'full sea-floor search' has of course not yet been reached, but SHOM commonly labels airborne bathymetric Lidar datasets in CATZOC B (IHO S-57). ◀

Due to the high accuracy of the captured data, Lidar is used in the field of oceanic sciences, including a DTM and bathymetric mapping

▲ *Figure 5: Final DTM West Bretteville-sur-Mer (Normandie) slightly textured by orthophoto.*

Yves Pastol is the French expert for Airborne Lidar Bathymetry (ALB). He is one of the two founders of the Litto3D team in SHOM, and he has worked with many survey companies and most of the existing bathymetric systems since 2005. He gives university level courses related to ALB in France. During the 18th JALBTCX (Joint Airborne Lidar Bathymetry Technical Center of Expertise) workshop, which took place from 6-8 June 2017 at the Savannah International Trade and Convention Center, Georgia, USA, Yves Pastol received the '532 award' for his life-long dedication to Airborne Lidar Bathymetry.

After several years on survey vessels, **Yves-Marie Tanguy** started to work on sea levels referenced to the ellipsoid in 2011, the year in which he also joined the Litto3D team. He is now the head of the project for SHOM, and is in charge of 15 engineers and technicians specialised in hydrography.

Report on Oi18

Industry Takes a Technology Tour at **Oceanology International**

London's docklands became home to a fleet of both manned and unmanned surface and subsea vehicles during this year's Oceanology International 2018 (Oi18), reflecting an increasing focus on connected autonomous systems in the ocean space.

Situated alongside the London ExCeL exhibition halls, this year's Oceanology International 'dockside' saw vessels of all sizes moored up, while underwater vehicles and unmanned surface vehicles took advantage of open water to carry out practical on-water trials and demonstrations of their latest technology.

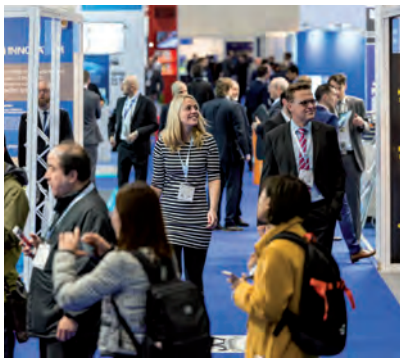
On the Water

One of the most eye-catching of these demonstrations was when iXblue showed the potential of its iconoclastic new unmanned survey vehicle, the DriX. While the majority of next-generation unmanned autonomous vehicles are typically either classic single-hull forms or catamaran designs, the sleek DriX resembled more of a surfaced submarine, its high tower rising out from its classic hydrodynamic-shaped, Kevlar-reinforced composite hull, as it cut though the water at surprising speeds.

What the viewer could not see, however, was the thin counterbalancing keel that allowed the DriX its tight turning radius. At the keel's tip, 2m below the waterline, was a gondola that housed the electronic sensors, keeping the sensitive electronics far away from any interference noise generated from the diesel motors above. At the show, Bibby HydroMap proclaimed that they had become one of the early adopters of the vehicle – partnering with iXblue to bring DriX to the European market.

Away from the Water

There was also plenty to see inside. First-time exhibitor Xocean showed its large unmanned catamaran in a public space (shared with a SMD Quasar ROV). Xocean only recently completed sea trials in Carlingford Lough, but has already placed an order for a second boat. The catamaran is powered by a 2kW diesel generator and 640W solar panels that work in



conjunction to keep the 5kWh lithium battery charged and able to power both the payload as well as the electric thrusters. Travelling at 3.5kn, the catamaran has an 18-day or 1500 nautical mile range. Interestingly, the company says that it can offer surveys on a no data - no fee basis, where it accepts all the risk in terms of weather. Xocean estimates it can work at around a third of the cost of conventional manned survey methods.

Another autonomous vehicle designer, Ocean Aero, said that it plans to supplement its 10m-rated Submaran S10 vehicle, with a newer, higher capacity, 200m-rated model, called the S200, later this year. The Submaran is powered mainly by a wing sail that can retract, and by pumping 660L of water into the hull, the entire vessel can submerge. This could be to evade severe weather, avoid detection or simply for subsurface data gathering. Back on the surface, solar panels gather energy to power the sensors, observational systems and its auxiliary thruster. The latest design features antennae added to the front and back of the vessel.

Another well-established vehicle design, that will shortly see a larger capacity addition to the range, is the Autonaut. The 3.5m vehicle is soon to be joined by a 5m version. In the new iteration, the rudder system has been redesigned to make it more resilient and manoeuvrable while there is additional space and potentially more power for the payload. Autonaut is currently looking to make the boat capable of operating in the Southern Ocean in winter and to that end, the company has been speaking with universities to look for solutions to icing and collision avoidance. As solar panels are not going be as effective in winter months, the vehicle many need an alternative power source to provide the on board electricity – maybe an energy harvesting device or a fuel cell.

Under the Water

Like the surface equivalent, it was no surprise that autonomous underwater vehicle (AUV) manufacturers were also showing their latest designs. L3, for example, showed the new 300m-rated Iver PW (Precision Workhorse). The new vehicle is powered by NMiH batteries, which gives the vehicle a capacity of 2000Wh that translates as 40 nautical miles of use and in doing so, making it twice as powerful as the original version.

Teledyne's well established Gavia AUV is a small hand-portable vehicle, able to work in 500-1000m water. The vehicle is characterised by its modularity - adding or subtracting functional modules to the main body to extend or match its intended requirements. In a departure from this, however, Teledyne has now expanded its offering by introducing a novel vehicle able to work at up to 6000m. Called the Sea Raptor, it is aimed at the search and recovery, salvage, exploration, construction support, oceanography and marine archaeology markets. The first vehicle will be delivered later this year for a customer in China.

While Teledyne is expanding out of the small AUV market, KONGSBERG subsidiary Hydroid is expanding into it with the announcement of its new M3B vehicle. This M3B micro AUV is small enough to fit into a submarine or be deployed from the air. It typically surveys at 3-4kt but can reach speeds of over 10kt. It has a deployment duration of up to 6 to 8hrs.

KONGSBERG was also present dockside with Hushcraft and the GEBCO-NF Alumni team, to show-off the USV Maxlimer – a unique Unmanned Surface Vessel (USV) / Autonomous Underwater Vessel (AUV) concept that was built for the $7 Million Shell Ocean Discovery XPRIZE competition. The nine finalists for the competition were announced during the Catch the Next Wave conference on the final day of Oi18.

One company at the show, Evologics, said that using unmanned surface vessels, such as its Sonobot, can increase the efficiencies of AUVs. The more the vehicle moves underwater, the greater its position becomes uncertain unless it can recognise a point of known position such as a beacon or landmark. By sailing the Sonobot directly above the AUV, however, it can receive satellite or wireless signals for position fixing and relay this to the AUV below in a two-way communication that also allows the receiving of information about AUV status, eg., battery life.

Of all the stands at Oi18 exhibiting AUVs, as many as two thirds to half of these stands offered a remotely operated vehicle (ROV). This ranged from large companies such as Saab Seaeye, that exhibited a wide range of electric vehicles, to micro or mini vehicles such as from Gnom, Video Ray or Deeptrekker. At the show, Saab Seaeye announced that they had added a Falcon ROV to expand Subsea Technology & Rentals (STR), the global rental fleet of inspection class vehicles.

All-electric Vehicles

For many years, global ROV manufacturer Forum offered a wide range of electric vehicles under its Sub Atlantic brand. At the show,

however, Forum launched its XLe, the first of five all-electric vehicles that will extend from small observation vehicles up to a size and capacity approaching hydraulic vehicles. As the company introduces each new vehicle over the next 4-5 years, it will start to phase out the old SubAtlantic equivalent.

Elsewhere, SEAMOR added the Mako ROV to its product line. The Mako is capable of carrying 14kg (30lb) as a standard build, and is upgradeable to 22.5kg (50lb). This higher carrying capacity permits larger instrumentation such as multi-beam imaging sonars, to be integrated.

Non-vehicle products

It would be very misleading to suggest that Oi18 was all about vehicles. STR, for example, showed its latest Sea Spyder, a drop camera frame able to incorporate lights, video, stills cameras and strobe flash/units. The original version of Sea Spyder was aimed at shallow-medium water depths up to 500m, but the latest iteration operates over longer cable lengths for operation down to 1000m.

Edgetech launched its 6205S combined side-scan and bathymetry tow fish as well as the 4205 which is a tri-frequency unit, a first for a towed side-scan. This gives the operator the ability to use any two of three frequencies built into the system.

Valeport unveiled its Swift Plus, which not only measures sound velocity, temperature and pressure, but it computes salinity density, conductivity and importantly, it also measures turbidity. The company is aiming the Swift Plus at the environmental monitoring market, particularly the dredging sector where measuring turbidity is particularly important. Using its multibeam echo sounders requires sound velocity and density measurements anyway, so this does everything in one.

Impact Subsea showed what it claims to be the world's smallest imaging sonar. Called the ISS 360, it is optionally available with an integrated Attitude and Heading Reference System (AHRS). This provides heading, pitch and roll informing the operator how the sonar is sitting and which direction the sonar is pointing at all times.

Tritech exhibited its new Gemini 720im - billed as the world's smallest multibeam sonar. This is important because the limited payload of many small ROVs has historically ruled out a multibeam. The size and weight of the Gemini 720im, however, removes this obstacle.

Sonardyne showed the Micro-Ranger 2, its smallest ever underwater target tracking system. This is Sonardyne's third ultra-short baseline (USBL) acoustic tracking system although Ranger 2 and Mini-Ranger 2 were designed for complex and deepwater survey and positioning operations, the new entry-level model introduces features that make it good for supporting diving and small vehicle operations in rivers, lakes and coastal waters.

iXblue launched its Canopus beacon and software which essentially gives the company a full long baseline capability. Imenco showed its fish farm camera system. Datawell developed a new system to record air temperature on its buoys.

There were far too many new and innovative products at the show to cover them all, but with Interspill being co-located with Oi18 and with the authoritative conference programme, Oi18 was certainly an outstanding event in the 2018 underwater technology conference calendar. Roll on 2020, which is when the next London edition will be held at ExCeL from 17-19 March. The next event on the calendar though is Oi China 2018, which will take place from 23-25 October 2018 in Qingdao, followed by Oi Americas 2019, taking place from 25-27 February 2019 in San Diego. ◂

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The Nippon Foundation-GEBCO Seabed 2030 Project: Defining 'Mapping the Ocean Floor'

The Nippon Foundation-GEBCO Seabed 2030 project was officially launched by Mr Yohei Sasakawa, chairman of The Nippon Foundation, at the United Nations Oceans Conference in 2017. The project supports the UN's Sustainable Development Goal 14 – 'To conserve and sustainably use the oceans, seas and marine resources for sustainable development' – and will lead to a greater understanding of the ocean and its processes.

The goal of the Seabed 2030 project is simple: to map the entirety of the world's ocean floor by the year 2030. This ambition has undoubtedly caught the attention of the public and is a mantra that will drive the project. But in order to be a useful benchmark against which success can be measured, 'mapping the seafloor' must be well defined.

Ideally, the seafloor should be mapped to the same level of detail as the best maps on land. The limitations of optical imaging through water, however, require the use of acoustic techniques. The project's target mapping resolutions are based on acoustic mapping from surface vessels, and that is inherently depth dependent. Bathymetry resolution is not 'one size fits all'. For the purpose of computing resolution goals for Seabed 2030, the project's establishment team of leading ocean mapping experts considered what is achievable with multibeam echosounders (MBES) with beam geometries of 2° × 2°. Given that high-quality MBES data can be retrieved to a maximum swath width of about four times the water depth, these target resolutions are determined by the footprint of data acquired from the outermost beams – at approximately 60° either side of the point directly beneath the MBES.

Based on these assumptions, the table below shows the feasible resolution of state-of-the-art 2° × 2° deep-water multibeam sonar installed on surface vessels. The Nippon Foundation-GEBCO Seabed 2030 project will consider an area of the seafloor 'mapped' if at least one sounding falls in a grid cell for a given depth as shown in the table.

Feasible resolution based on state-of-the-art 2° × 2° deep-water multibeam installed on surface vessel, calculated at 60° from nadir.

Depth Range	Grid-Cell Size	% of World Ocean
0–1500 m	100 × 100 m	13.7
1500–3000 m	200 × 200 m	11
3000–5750 m	400 × 400 m	72.6
5750–11,000 m	800 × 800 m	2.7

The fact remains that less than 20% of the world's ocean floor has been mapped using modern methods, and to map the entire ocean floor at these resolutions by 2030 is a significant undertaking. Its success relies on collaboration between the scientific community, international organisations, national hydrographic organisations and the private sector. The Nippon Foundation-GEBCO Seabed 2030 project is already teaming up with some of the world's leading private-sector offshore survey companies such as Fugro to acquire MBES data gathered in transit. It is also currently exploring the viability of acquiring or crowdsourcing data from more than one million fishing boats and tens of thousands of cargo, passenger and cruise ships and private yachts – effectively creating a new fleet of research vessels.

In February 2018, Mr Yohei Sasakawa called on the international community to rally together to support the project's goal. To date, almost 3,000 individuals and 40 organisations have responded to that call, providing The Nippon Foundation-GEBCO Seabed 2030 project with invaluable knowledge and networks that now span more than 50 countries. And this is just the beginning. ◂

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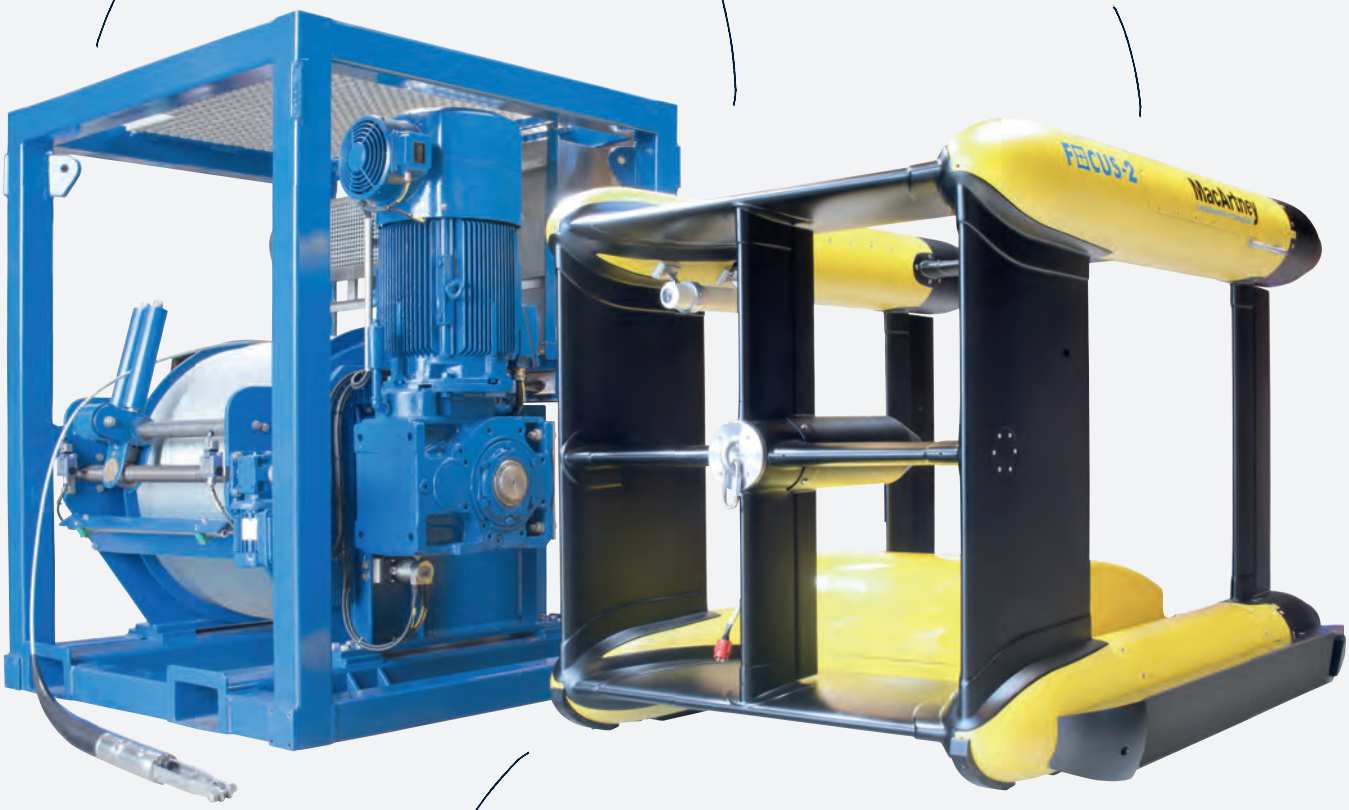

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