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JULY/AUGUST 2018 | VOLUME 22 NUMBER 4

New Challenges for Digital Chart Production

Advanced Technical Solutions Need to Be Implemented

Streaming Data Processed Live to the World Wide Web

Unmanned Surface Vehicles Monitoring Lava Flow

Hawaii's Kilauea Volcano Eruption

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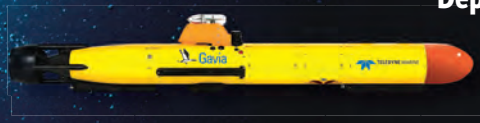

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Hydro INTERNATIONAL

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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The July-August issue of *Hydro International* highlights a wide variety of topics within the hydrographic industry, ranging from High Density Bathymetry ENCs to how communication and remote control solutions can transform survey operations. On the front cover, the SEA-KIT Unmanned Vessel in action. The SEA-KIT is a long-range, long-endurance, ocean capable unmanned vessel with a range of over 10,000 nautical miles.

Doable

▲ *Durk Haarsma.*

Close to a million square kilometres of bathymetric data has been handed over to the GEBCO Seabed 2030 project. The majority of this data came from the search for the missing Malaysian airliner MH-370. An update sent out by the Nippon Foundation – GEBCO Seabed 2030 Project for World Hydrography Day (on 21 June), noted this major contribution and applauded the fact that it was not only public data – such as that from the Australian Hydrographic Offices – but also private data from the likes of Fugro and Ocean Infinity. If you have 25,000 square kilometres of bathymetric data lying around, or stored somewhere, and you donate the data to GEBCO Seabed 2030, you will be recognised through a 'Roll of Honour'. It looks like those companies that have been donating the large amounts of data, adding up to the total of the million already mentioned, are trendsetters and that there will definitely be more that follow. The total of the world's oceans' surface is 360 million km^2. If one million km^2 was covered in one year, we need roughly another 35 years, but we only have half of that left until 2030. I am not counting all the kilometres that have already been mapped through the centuries. Although speeding up is still necessary, it all looks less daunting than when this ambitious project was started. In fact, it looks doable!

Durk Haarsma,
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Building the Digital Highway

▲ *Mark Pronk.*

▲ *Wim van Wegen.*

The development of autonomous shipping is making its way into our lives. This is presenting new challenges, but certainly also new opportunities. ASVs have slowly but gradually managed to get a bigger footprint In the hydrographic surveying domain over the past few years. The survey performed during the Hawaiian volcano eruption demonstrated the benefit of using ASVs in hazardous environments. In addition, the versatile equipment on-board gives better insight into these unique events. Communication is a key element when working with autonomous operations.
The fundamentals have to be re-invented. As described in the article by Vegard Haugen – 'Optimising Workflows on the Maritime Information Highway' – nowadays, vessels are self-contained. With the introduction of broadband capabilities and ASVs the hydrographic industry should to re-think the way in which survey missions are being carried out. Interesting multi-platform cases in combination with multibeam, AUVs, ASVs and even relay balloons are described in his article. Very much related is the use of aquatic drones. The use of aquatic drones demonstrated that hydrographic data could be collected, processed and results broadcasted live to the World Wide Web directly from the ASV via a regular cellular network. It highlights that broadcasting of live processed multibeam results directly from survey platforms through regular cellular networks to the World Wide Web is possible. Again this gives new opportunities for survey operations.
Also highly recommended is the article 'New Challenges for Digital Chart Production'. Hydrographic Offices have realised that bathymetric data is not sufficiently represented in ENCs. High Density ENCs are the future. Over the coming years, hydrographic organisations will need to decide on taking the step into regular production of High Density Bathymetry ENCs. Advanced technical solutions are available and will have to be implemented to cope with the new challenges, says author Friedhelm Moggert-Kägeler of SevenCs in his article.

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From Vision to Action: The Nippon Foundation–GEBCO Seabed 2030 Project Appeals for Crowdsourced Data

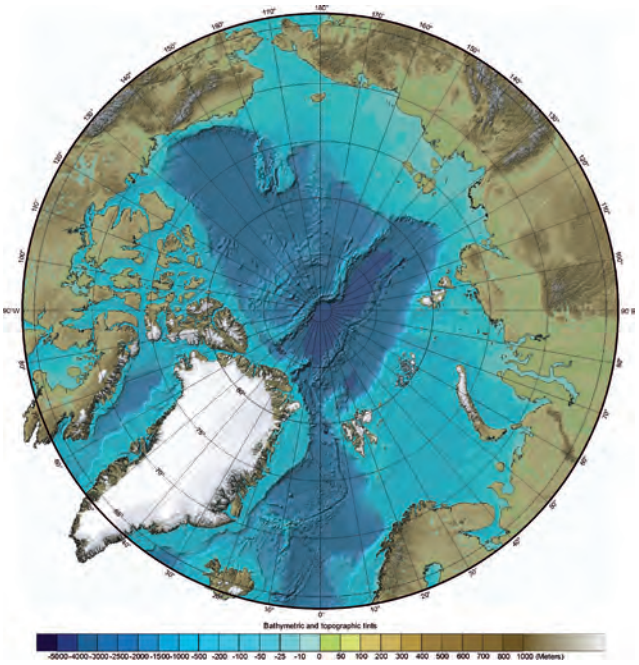
In February this year, just eight months after being proposed by Mr Yohei Sasakawa, Chairman of The Nippon Foundation, at the United Nations Ocean Conference in June 2017, The Nippon Foundation-GEBCO Seabed 2030 Project was operationalised. Its aim is to map the entirety of the world's ocean floor by 2030: a significant undertaking, which will require international cooperation and collaboration on an unprecedented scale.

It is commonly stated that less than 20% of the seabed has been mapped using direct measurement. Scientists working on the Seabed 2030 Project Team, however, have reviewed these calculations against their acceptable resolution framework. By these standards, only 6% has been sufficiently mapped.

Given this increased scale and scope of the Project, its policy of crowdsourcing bathymetric data has taken on renewed importance. By utilising assets already at sea, from fishing boats to transport vessels, research ships to cruise-liners, everyone in the maritime community has a potential role to play in mapping the gaps.

Millions of vessels worldwide have at least basic sonar on-board. While multibeam is the gold standard, single-beam data is equally valuable. Most craft utilise this technology for navigation, with data points recorded by on-board computer systems. Guidelines on how this data can be donated to the Project are currently being drawn up by a working group at the International Hydrographic Organisation's Data Centre for Digital Bathymetry (DCDB), a repository in Boulder, Colorado. These guidelines will be published on the Project's website, enabling anyone – from individuals to research organisations and multinational corporations – to upload their data for the benefit of science.

Once uploaded, Seabed 2030's regional centres will incorporate the crowdsourced data into bathymetric products, before it is integrated into the GEBCO grid by the Global Centre based at the National Oceanography Centre in Southampton, UK.



The International Hydrographic Organization Data Centre for Digital Bathymetry (IHO DCDB) was established in 1988 to steward the worldwide collection of bathymetric data.

The Project is already achieving significant results. Thanks to recently announced partnerships with Fugro and Ocean Infinity, 220,000 square kilometres of private sector bathymetric data – an area almost equal to the landmass of the UK – has been uploaded to the DCDB. This data, estimated to be worth tens of millions of dollars, should encourage other data donors to support the project.

Combined with 710,000 square kilometres of open source data recently released by Australia, this year's map will include at least 930,000 square kilometres of high-resolution data not previously included in the GEBCO grid – an area about the size of Nigeria. This total does not yet include additional contributions expected later this year.

The Intergovernmental Oceanographic Commission (IOC) of UNESCO recently announced that it will coordinate a decade of ocean science (2021-2030), in support of the UN's Sustainable Development Goal 14. The international community is banding together, and a global movement toward a greater understanding of our oceans is building. Crowdsourcing data will ensure that everyone on the seas can play their part, so that by 2030, our oceans will no longer be treated as a forgotten frontier.

Wave Gliders Collect Live Ocean Data from Hawaii's Kilauea Volcano Lava Flow

Two Liquid Robotics' Wave Gliders (autonomous ocean robots) were deployed to capture live ocean data close to where lava flows into the ocean from Hawaii's Kilauea Volcano. By using this unmanned technology, scientists had the rare opportunity to study the effects of the lava entering the ocean, the plume it creates and the interactions of the lava and seawater directly from the surface of the ocean. Very few volcanic eruptions and lava flows have ever been monitored in real-time from the ocean before.

▸ *http://bit.ly/2KXkRAi*

▲ *Two Wave Gliders at Kilauea Plume.*

Extreme Sea Levels Predicted to Increase along Global Coastlines

A new study has predicted that future global warming will lead to an increase in 'extreme sea levels', with subsequent flood risks to coastal infrastructure and human populations. Extreme sea levels occur through a combination of high tides and extreme weather events, which can generate storm surges and high wind waves. These phenomena are exacerbated by progressive rises in mean sea level and predicted increases in tropical cyclone activity. For the first time, researchers have taken account of all these processes to assess the future risk of extreme sea levels to the year 2100.

▸ *http://bit.ly/2zo7Y0M*

▲ *Global warming will lead to an increase in extreme sea levels.*

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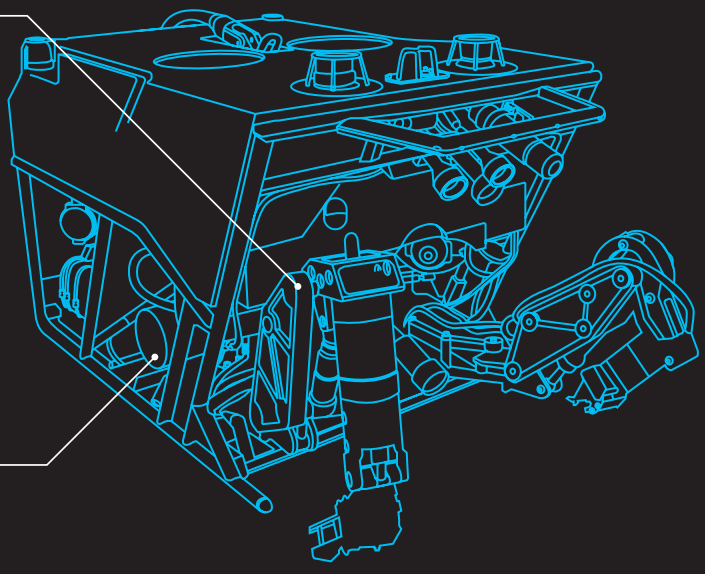

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United Kingdom Ready to Lead the World on G7 Healthy Oceans Commitments

▲ *UK Hydrographic Office headquarters in Taunton.*

Ocean plastics, coastal resilience and the Blue Economy were high on the agenda at the G7 summit in Canada in June 2018, where a commitment to support and drive ocean science and sustainability was signed. The Charlevoix Blueprint for Healthy Oceans, Seas and Resilient Coastal Communities sets out G7 commitments on ocean plastics, and creates a blueprint for the development of a more sustainable and climate-resilient future for oceans and coastal communities, with a focus on ocean science and effective, transparent data gathering and utilisation. As a leading maritime nation, the UK is well placed to support many of the goals set out in the blueprint and is ready to spearhead the expansion of global interest in ocean data.

▶ ***http://bit.ly/2ukxLS2***

Ocean Infinity's Search for MH370 Ends

▲ *The area where Ocean Infinity surveyed the southern Indian Ocean.*

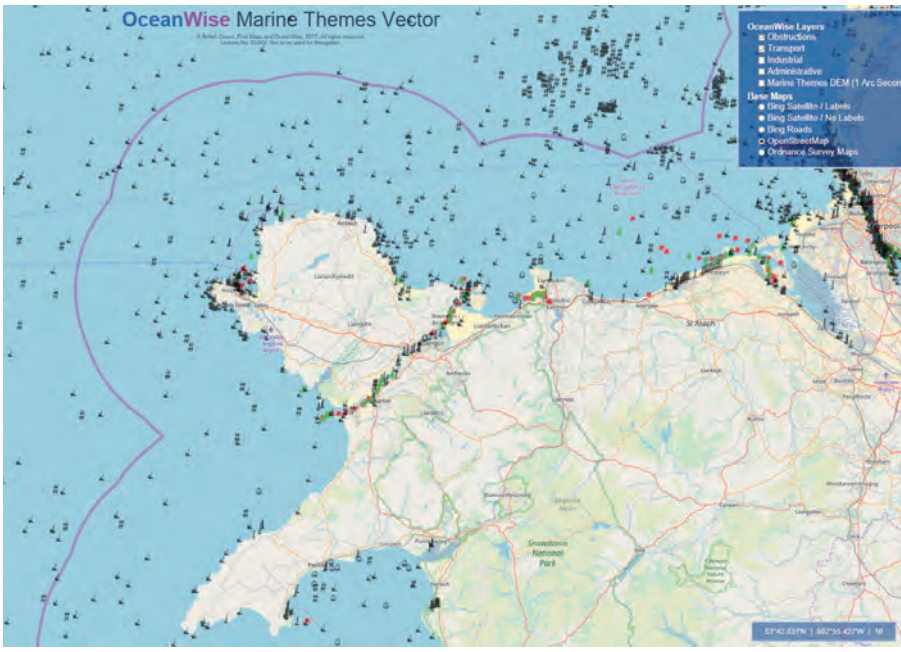
Ocean Infinity, a technology company specialising in collecting high-resolution seabed data, has announced that its current search for the wreckage of Malaysian Airlines Flight MH370 will shortly be coming to an end. The aircraft disappeared en route from Kuala Lumpur to Beijing on 8 March 2014 with 239 people on board. In January of this year, the Malaysian government agreed to pay Ocean Infinity as much as US $70 million, provided that the company would solve what has become modern aviation's biggest mystery. During the course of its operation, Ocean Infinity searched and collected high-quality data from over 112,000 square kilometres of seabed in the southern Indian Ocean, overcoming both challenging conditions and terrain with its deep-sea survey vessel *Seabed Constructor*. The total area covered, in a little over three months of operational days, is far in excess of the initial 25,000 square kilometre target and almost the same area as the previous search achieved in 2.5 years. Unfortunately, the search has been without success.

▶ ***http://bit.ly/2uhTj1z***

Scottish Government Awards OceanWise with 4-year GIS Marine Data Contract

OceanWise has been awarded the framework agreement for the provision of GIS marine data to the Scottish government. The company will be delivering marine mapping data products and services including Marine Themes Vector, Marine Themes Digital Elevation Model (DEM), Raster Charts and Raster Charts eXcluding Land (XL) to central government departments and agencies as well as regional councils, all of whom will benefit from having access to the data for decision support and asset management. OceanWise's data mapping products have been designed to provide data that is fit for purpose, in the right format, accurate and up to date. Marine Themes Vector, for example, has been engineered into logical data layers for easy loading and efficient use in desktop and web-based geographic information systems (GIS). The data attributes have been specifically designed to provide the best possible information for analysis. Chart boundaries have also been removed to create a seamless, simplified dataset.

▶ ***http://bit.ly/2NCQVeL***



▲ *Demo data for Marine Themes Vector with Obstructions & Transport layers selected.*

First International Satellite-derived Bathymetry Day is a Success

With over 45 delegates from more than 15 countries around the world, the first international Satellite-derived Bathymetry Day (SDB Day) organised by EOMAP was a great success. For the first time all relevant players came together on 6 and 7 June 2018 to anticipate what lies ahead for satellite-derived bathymetry (SDB) technology in the next years and to discuss future opportunities for providers and users. EOMAP CEO, Dr Thomas Heege, commented: "The support for the SDB Day was fantastic. All relevant institutions – hydrographic offices, marine industry, service providers and research institutes – picked up on the themes of capabilities, data integration, requirements and quality standards. Joint considerations are really coming to the fore, which is great to see."

▸ ***http://bit.ly/2KG8Zqh***

▲ *SDB Day participants.*

Researchers Map Seafloor Near Pine Island Glacier

The Pine Island Glacier in Western Antarctica is not only one of the fastest flowing ice streams in the Southern Hemisphere, over the past 11 years, four major icebergs have calved from its floating tongue. In February 2017, researchers on board the German research icebreaker *Polarstern* successfully mapped an area of seafloor previously covered by shelf ice. A comparison of these new maps with satellite images of the ice stream reveals why the glacier suddenly retreated toward the coast: at important points, it had lost contact with the ground, as the experts report in *The Cryosphere*, an online journal of the European Geosciences Union.

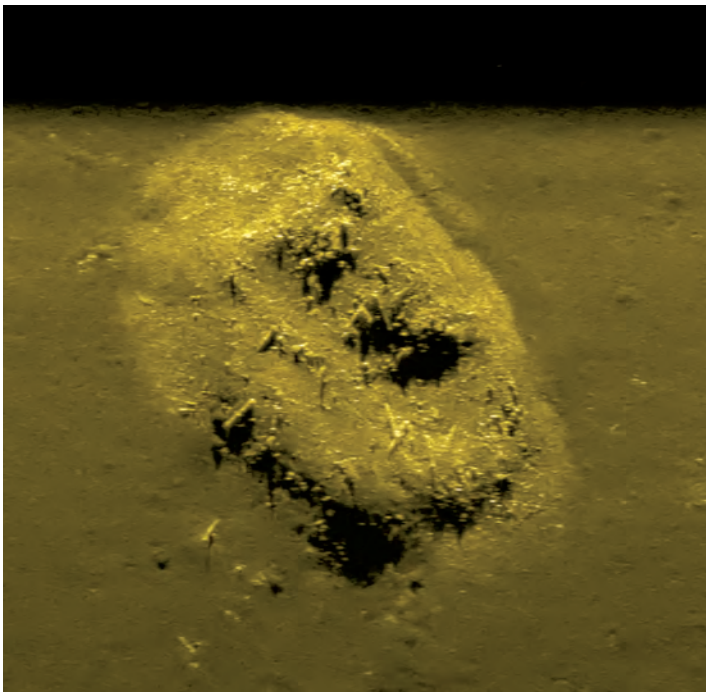
▸ ***http://bit.ly/2N0VzBM***

▲ *German research icebreaker* Polarstern.

EdgeTech Sonar Instrumental in Discovery of US $17 Billion Spanish Galleon *San Jose*

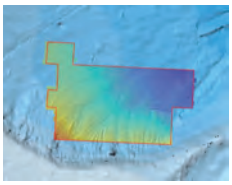
EdgeTech, a leader in high-resolution sonar imaging systems and underwater technology, was key to the discovery of the most valuable shipwreck in the world. Sought after by treasure hunters for more than 300 years, the wreck of the Spanish Galleon *San Jose* was finally discovered on 27 November 2015 but only just recently made public. The search was performed by the Woods Hole Oceanographic Institution (WHOI) Remus 6000 autonomous underwater vehicle (AUV) equipped with an EdgeTech 2200 side-scan sonar. AUV mission planning and sonar data analysis for the project was supplied by GK Consulting of Derry NH. The *San Jose* was a 62-gun flagship galleon of a Spanish fleet carrying gold, silver and emeralds from the mines of Peru back to Spain. It was sunk on 8 June 1708 in a battle with the British off Cartagena, Colombia. The ship sank so quickly that there were only 11 survivors of the 600 people on board.

▸ ***http://bit.ly/2KLVS7e***



▲ *Side-scan sonar image of the* San Jose *shipwreck.*

Successful Licensing of Canada's East Coast Geochemical Data



▲ *High-resolution bathymetry data acquired by Fugro.*

Fugro and one of its partners, Amplified Geochemical Imaging (AGI), have reported recent success selling licences for data from a frontier region offshore Canada. The data was acquired during a hydrocarbon seep survey, heat flow and geochemical coring campaign in the large Orphan Basin, situated on the continental margin of Newfoundland. The comprehensive data package is being licensed from both Fugro and AGI and includes multibeam echo sounder data (bathymetry, backscatter intensity and water column), sub-bottom profiler data, heat flow measurements and shipboard geochemical screening analyses. Shore-based screening and advanced geochemical analyses, including biomarkers on select samples, are also included.

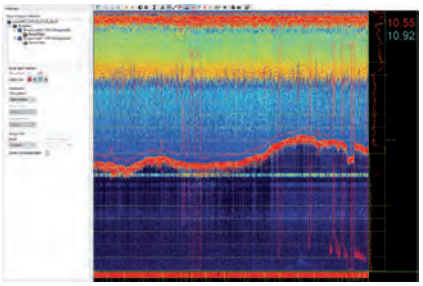
▸ *http://bit.ly/2KKW4nf*

USVs Cause Lively Discussion at China-Israel Summit

Unmanned Surface Vessel (USV) technology was a topic of hot discussion at the 4th edition of the China-Israel Innovation & Investment Summit, which was held in Zhuhai, China, from 2-4 July 2018. Yunfei Zhang, the founder of Oceanalpha, was invited to give a speech, as one of the top technical experts. He stated that surface robots, represented by USVs, will subvert the traditional operation in the marine field, while the core of unmanned boats is AI technology. This speech was in line with the trend shown as both Israel and China are actively developing USV technology. Israel has always been known for its prosperous technology industry and innovative capabilities and enjoys the reputation of being the Silicon Valley of the Middle East. Israel also excels in the USV field. As early as 2003, Israel launched their USV project, the Protector, which has been in development now for 15 years. Israel currently commands mature USV technologies in the field of advanced maritime security and intelligence surveillance.

▸ *http://bit.ly/2zrv2M5*

Teledyne PDS Introduces New Ways of Visualising and Controlling Single Beams

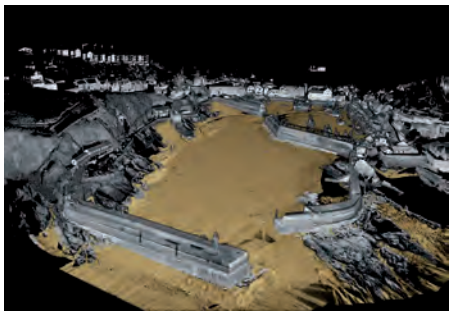


▲ *New SBES Online echogram view in Teledyne PDS.*

Teledyne PDS has released a new view to display single beam echogram data and to control the single beam device. The Online SBES Echogram view and features have been developed to enable single beam users in the hydrographic and dredging markets to be more agile in their survey processes. The new features eliminate the need to use external visualisation or command and control software, enabling more screen space for the actual survey information. Currently, Odom DSO data (EchoTrac single beams) and RESON GT data (Navisound single beams) are supported.

▸ *http://bit.ly/2m05nAG*

Innovative New Survey Vessel Secures Grant Support from Marine-i



▲ *3D view of Mevagissey Harbour.*

Marine-i, the EU-funded programme set up to boost the marine technology sector in Cornwall and the Isles of Scilly, has made a grant award to a pioneering hydrographic survey company, Ultrabeam Hydrographic. This company provides ultra-high-resolution hydrographic surveys for clients with marine-based assets, such as harbours, subsea pipelines and oil and gas platforms.

Ultrabeam has developed an innovative new type of unmanned surface vessel, the Ultra-USV, a 3-metre catamaran which has been designed to gather fast, accurate and highly detailed survey data in challenging locations. It is believed to be the first unmanned survey vessel of its kind. As well as carrying a full suite of high-tech survey equipment, this compact craft is powered by 4 electric thrusters in a vectored thrust layout. This thruster configuration means the craft can make very precisely controlled movements in any direction, similar to the way an aerial drone operates. This has huge advantages for marine surveying work.

▸ *http://bit.ly/2u3BK60*

United Nations Meeting Discusses Anthropogenic Underwater Noise

▲ *Dr Hale presenting his paper.*

From 18 to 22 June 2018, the United Nations Meeting of the Consultative Process on Oceans and the Law of the Sea was held at the United Nations Headquarters in New York. The theme of the meeting was 'Anthropogenic underwater noise'. Richard Hale, a director of the EGS Survey Group, was invited to attend the meeting as a representative of the International Cable Protection Committee (ICPC), together with the ICPC's representative to the United Nations, Ms de Juvigny.

The topic on the first day of the meeting was 'Sources and environmental and socioeconomic aspects of anthropogenic underwater noise'. On a global scale, commercial shipping is the source of most underwater noise, generated throughout the year. Other offshore activities, such as seismic surveys for oil exploration and the pile-driving used to install offshore wind turbines, generate more intense sounds for periods from around a week to a few months.

▸ *http://bit.ly/2KZXICJ*

Oregon State University to Lead Building of Second Ship for National Research Fleet

Oregon State University has received US $88 million from the National Science Foundation (NSF) to lead construction of a second regional-class research vessel to help bolster the nation's ageing academic research fleet. The NSF selected Oregon State in 2013 to lead the initial design phase for as many as three new vessels, and the National Science Board authorised as much as US $365 million for the project. Last summer, the NSF awarded OSU a grant of US $121.88 million to launch the construction of the first vessel, which Gulf Island Shipyards in Louisiana is building and OSU will operate. It was the largest grant in the university's history. The company is about to begin physical construction of the OSU-bound vessel, which is scheduled to be delivered to Oregon State in spring of 2021, and fully operational after a year of outfitting and testing.

▸ *http://bit.ly/2u6oopB*

▲ *Drawing of the second research vessel.*

USV to Map Lakes and River Sediment Movement in Norway

▲ *The Inception Class Mark 2 USV.*

Swathe Services has announced that an Unmanned Surface Vessel (USV), designed and built by Unmanned Survey Solutions in Hayle, Cornwall, has been purchased by Trondheim University for research studies in Norway. The Inception Class Mark 2 USV was built by surveyors for surveyors. It has been designed for hydrographic surveys and data acquisition in ports and harbours, lakes and rivers, shallow coastal or enclosed inland areas. James Williams, managing director of Swathe Services said: "We are proud to have been selected to provide the Department of Civil Engineering with a complete Multibeam Echo Sounder (MBES) system along with the USS Inception Mark II USV. The department at NTNU selected state of the art equipment including an R2SONIC 2020 MBES, SBG Ekinox2 Inertial Navigation System (INS), Valeport sound velocity sensors and Hypack software for data acquisition and post-processing."

▸ *http://bit.ly/2Jb1VfX*

A Survey with Aquatic Drones and CARIS Onboard

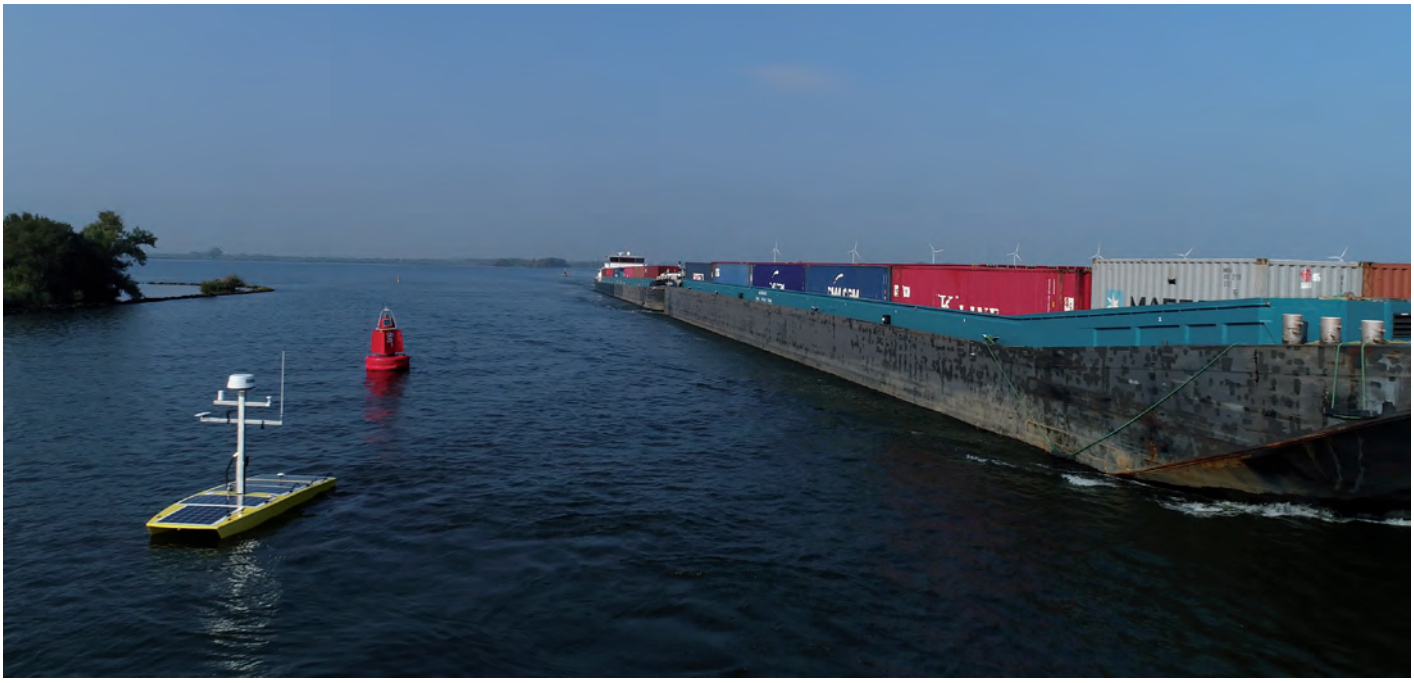
Streaming Data Processed **Live** to the World Wide Web

The Dutch government is currently focusing on autonomous technologies. Autonomous cars can already be found on Dutch highways and now Rijkswaterstaat (The Ministry of Infrastructure and Water Management) has also started to automate survey processes on rivers, together with the company Aquatic Drones. The use of autonomous vehicles creates new opportunities for traditional surveys. Equipped with hydrographic instruments, the vehicles can collect data remotely in increasing volumes, in challenging environments and with less risk to personnel.

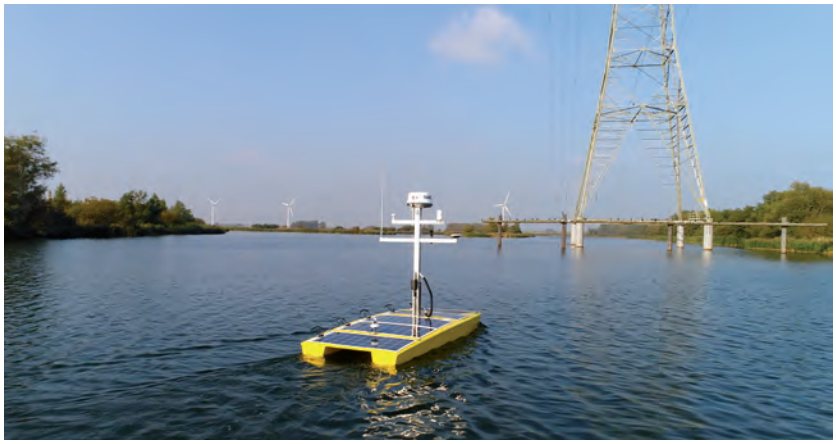
One of the challenges will be the quantity of the data collected and having to post-process it. Traditional methods with acquisition and post-processing software will have to be abandoned. The data coming directly from the multibeam or side-scan sonar can be directly entered into the processing software, without the need of acquisition software. Aquatic Drones together with Teledyne CARIS and partners carried out a successful pilot for Rijkswaterstaat on the River IJssel in the Netherlands, demonstrating the capabilities of ASVs and new solutions for autonomous processing.

Preparation for Autonomous Survey

The aquatic drone was equipped with Teledyne CARIS Onboard, Teledyne Reson T-20P, Teledyne Reson PDS, Ixblue Phins and Septentrio AsteRx-U GNSS systems from Navigation Solutions. The survey systems' offsets were accurately measured by Star Mountain. PDS was mainly responsible for the line planning, while CARIS Onboard took care of the innovative way of processing. Communication for the controls of the aquatic drone and CARIS Onboard data transmission was made possible by a regular 3G / 4G cellular network from T-Mobile.



▲ *Multibeam survey between breakwaters.*



▲ *Aquatic Drones with multibeam survey suite.*

▲ *Live 3D multibeam data from Onboard in HIPS and SIPS.*

Geospatial data for the area around Doesburg was downloaded from the Dutch national PDOK website to enable mission planning and for live analyses during the survey mission. The Dutch National Spatial Data Iinfrastructure (PDOK) is a central facility for unlocking geo-datasets of national importance. This is up-to-date and reliable geospatial data for both the public and private sectors.

Prior to the survey a processing workflow was defined and uploaded to CARIS Onboard. The user can define its own processing workflow based on the needs of the survey project and can even alter the workflow during the mission where needed. The settings were remotely uploaded to the aquatic drone using the CARIS Onboard geospatial Web App. The workflows are based on the known HIPS and SIPS Processes.

Autonomous Survey Platform

The platform used for the mission was provided by Aquatic Drones. The aquatic drone is designed in such a way that the platform can be used as a multi-purpose drone. In addition to the pilot multibeam survey, the aquatic drone also carried out sub-bottom surveys to identify Unidentified Explosives and can be tailored to host other sensors as well. The USV has a twin hull and has a large cargo bay to house the hardware for the controls of the sensors. The aquatic drone can survey for about 12 hours before a battery has to be changed and is capable of sailing in strong river currents. The Reson T20-P was installed between the two hulls for this particular mission. In order to perform the mission and to ensure safety, Aquatic Drones designed and integrated a sophisticated obstacle avoidance technology.

Survey Mission on the River IJssel

The survey location and demonstration to Rijkswaterstaat was performed on the River IJssel near Doesburg, the Netherlands. The River IJsel is a major Dutch river that is about 125km long and 70 metres wide. The aquatic drone surveyed the River Ijssel for approximately 6 hours. The aquatic drone performed very well in the challenging environment. Despite the strong currents and suction currents in this sizeable river, the aquatic drone easily managed to sail for these 6 hours and also maintained its speed upstream.

Automated Processing and Web-enabling

Once CARIS Onboard received the processing workflow, the software automatically carried out the processing according to the defined workflow. In this particular case the processing workflow was designed to process the bathymetry of the S7K datasets coming from the Reson T20-P, although it is possible that the normalised backscatter from the Reson T20-P was not processed for this exercise by CARIS Onboard. When manually steering a vessel one needs to see instantaneous coverage of the survey area, autonomous surveys this is not specifically required. Therefore, data can be directly ingested from the multibeam sensor into CARIS Onboard. Once CARIS Onboard finalised the first survey line on the River IJssel , the grid was made available to the CARIS web-service on the survey platform. Each subsequent survey line was then automatically processed and added to the gridded surface, resulting in a complete surface. The processed grid was live streamed to CARIS Onboard's WebMap making it available over the internet to the people onshore in Doesburg as well as in the CARIS office in the Netherlands.

Data Transmission

The traditional methods for transmitting survey results from a ASV are often carried out through a regular file transfer. Due to the increasing raw data volumes, this can be constrained by the cost and availability of bandwidth. This problem becomes even worse for daily, intensive surveys and becomes cost inhibitive. In addition to compressing the raw data down to a processed surface, CARIS Onboard makes use of the CSAR gridding technique, which is based on the quad tree principle. The CSAR gridding method makes it possible to transmit data to anyone, without transferring the whole dataset. You then transmit per package of data in the order of kilobytes rather than the Gigabytes when transmitting the whole dataset.

During the preparation of the demonstration in Zeeland, the Netherlands, the coverage provided by the telecom provider was not ideal. Nevertheless, the CSAR technology was still able, with speeds of as little as 1 Mbit, to visualise the data in the CARIS office. In addition, by publishing the data to a WebMap, CARIS Onboard allows multiple users to interact independently with the live-stream, which is clearly an advantage over remote desktop control (e.g. TeamViewer) which only allows a single user to control the screen.

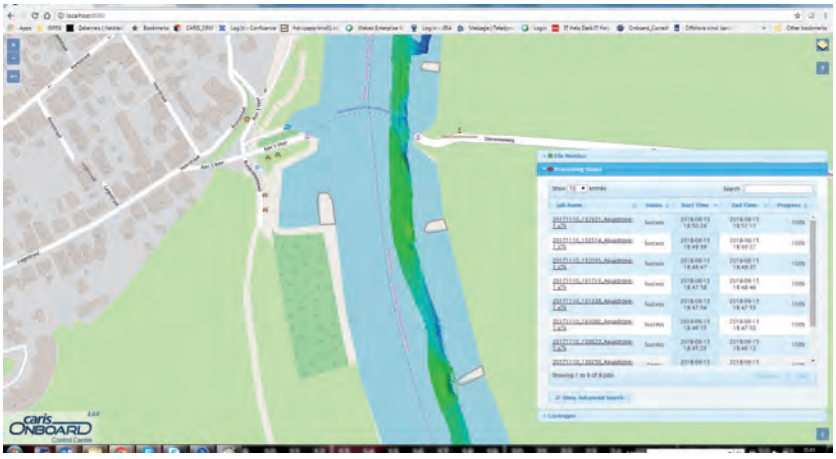
Remote Access to the Data

During the survey, the processed results were visualised through a web portal. Furthermore,

the processed data was opened in the desktop products Easy View and HIPS and SIPS. In these applications the data could be compared to the available legacy data and other available spatial data. In the CARIS office, a difference grid was calculated instantaneously between the incoming data and the legacy data.

Scalability Processing

The interesting prospect for Autonomous Surface Vehicles is that they have the potential to work in in groups or so called swarms. The first concepts where multiple ASVs are used during a survey in combination with manned vessels are already available. Aquatic Drones also has the potential to grow towards surveying in groups. The acquisition costs and the operational costs of ASVs are relatively less expensive than a manned survey vessel , where the difference increases the larger the survey vessel. Using ASVs for surveying tasks will challenge organisations for processing. In order to remain efficient, CARIS Onboard can process the data for multiple drones. In the end, the hydrographic expert will maintain and oversee a fleet of ASVs while performing the final quality checks on the data. Although the post-processing was not carried out for the demonstration, a user could still directly open the processed data in HIPS and SIPS afterwards. In cases, for example, where more accurate post-processed navigation data is available, better beam pattern correction for a mosaic is needed, or one would like to perform tidal correction in a different way, then the processed data is opened in HIPS and SIPS straight away and final edits can be made. ◂



▲ *Onboard Web-Portal with processed multibeam data.*

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Advanced Technical Solutions Need to Be Implemented

New Challenges for **Digital Chart Production**

Hydrographic Offices have realised that bathymetric data is not sufficiently represented in Electronic Navigational Charts (ENCs). A few aspects of this topic have already been touched upon in the presentation *Innovative approach in automated contour generation …* [1] that was presented at Hydro 2017. This article focuses on the challenges of high density bathymetry chart production and introduces a new approach to cope with it.

In the past, ECDIS users have repeatedly complained about the lack of bathymetric detail in Electronic Navigational Charts. The resolution of depth information is too coarse to adequately display the extent of areas that are safe for navigation.

The article *Bathymetric ENCs in Confined Waters* [2] that featured in *Hydro International* (June 2018) explains this in an excellent manner.

Recent Initiatives by IHO and Hydrographic Offices (HOs)

In the last few years the topic has been discussed at various IHO meetings (HSSC, ENCWG, etc.). Most HOs supported the initiative for High Density Bathymetry ENC production, but concerns were expressed, including additional manual effort, 5 MB file size limit for ENCs, and new ENC layout.

In February 2018, UKHO announced [3] that it had issued a High Density ENC. The ENC covers a small area of the Bristol Channel (2.2 by 1.3km). To confirm accuracy the results were checked manually. In addition, the Australian Hydrographic Office published a paper [4] describing their successful experiences with the production of High Density ENCs. The article *Bathymetric ENCs in Confined Waters* [2] mentioned earlier describes the long way AHO had to go until they were in a position to successfully produce High Density Bathymetry ENCs.

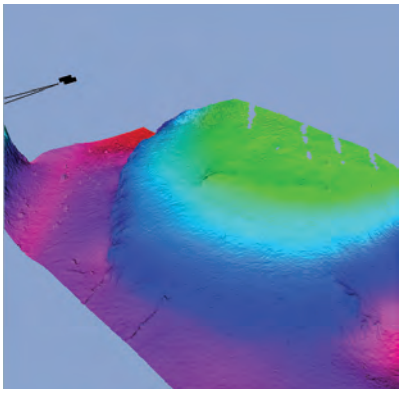
The transition from a proof of concept to the implementation of an operational service is the next big challenge.

Existing Solutions for the Production of High Density Bathymetry ENCs

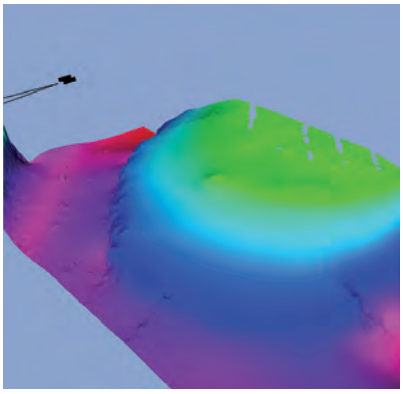
Solutions for the automated production of High Density Bathymetry ENCs have existed for many years. Despite the fact that the data is usually technically correct and standard compliant it misses the cartographic 'touch'. All solutions have in common that the main focus was given to automation and efficient processing of large data volumes. Often the resulting contours are jagged, not generalised to scale and prone to clutter. Some manufacturers use 'cookie cutter' methods to update ENC depth information. Hence the resulting ENC bathymetry is not smoothly integrated and resembles a single bathymetry patch. Other manufacturers have come up with solutions where high density bathymetry is maintained and provided in separate S-57 layers complementing the regular ENCs. Nevertheless, all of these manufacturer-specific solutions have been implemented successfully on a regional basis in close cooperation with local stakeholders and authorities (ports, waterway authorities, pilots). They have not been designed to be used in ECDIS at all. The data is mainly used in portable navigation systems for pilots. However, from an HO perspective it may not fulfil all quality standards.

A New Approach to High Density Bathymetry ENCs

More recently an approach has been introduced that provides an improved solution for the production of High Density Bathymetry ENCs. It reduces the amount of manual work required for the creation of contours and selected soundings, supports automation and honours cartographic principles. Ideally the workflow should start where the underlying source datasets are managed. In this respect, the 'Seamless Point Surface' concept that was also



▲ *Raw elevation model.*



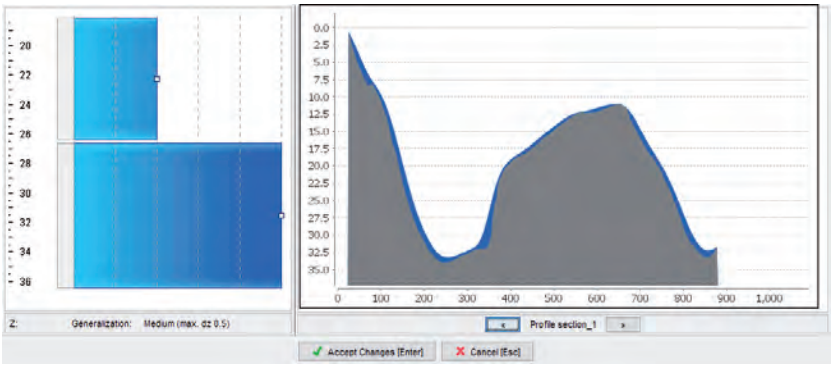
▲ *Generalised elevation model.*

introduced in the Hydro 2017 presentation [1] fits perfectly.
The new approach derives contour lines from a Nautical Elevation Model (NEM). A NEM is a shoal-biased smoothed-out and generalised underwater terrain model. It can be imagined as a draped sheet over rough bottom topography. If a little bit of tension is applied to this sheet it will form a smooth surface. This new surface touches the original model at shallow peaks and bumps and smoothes out noisy terrain and deeper holes.

Creating the contours directly from a rough source terrain model would result in 'noisy' and jagged contour lines. Usually line smoothing algorithms are not shoal-biased. This is why a Nautical Elevation Model is used instead. If derived from a smooth surface, the resulting contours have a smooth appearance as well. This is not only an aesthetic aspect but contributes to better chart readability and overall acceptance. The shoal-biased character guarantees that the resulting contours correctly represent the minimum depth.
The Nautical Elevation Model can be generalised to a distinct product scale. The degree of generalisation is controlled by means of a parameter set that is used by the processing algorithms.
Some aspects of the Nautical Elevation Model are similar to the cartographic extraction methods of the Navigation Surface approach [4]. Both use a kind of sheet model for generalisation and smoothing of gridded bathymetry. Such sheet models, however, tend to 'over-generalise' steep terrains and features like edges of dredged or natural channels. This is why the Nautical Elevation Model integrates methods to dynamically configure the degree of generalisation at different vertical levels.

Once the appropriate generalisation parameters have been defined and the Nautical Elevation Model has been generated contours can be created. An additional process automatically creates the area-polygons of the depth areas between the contour lines.

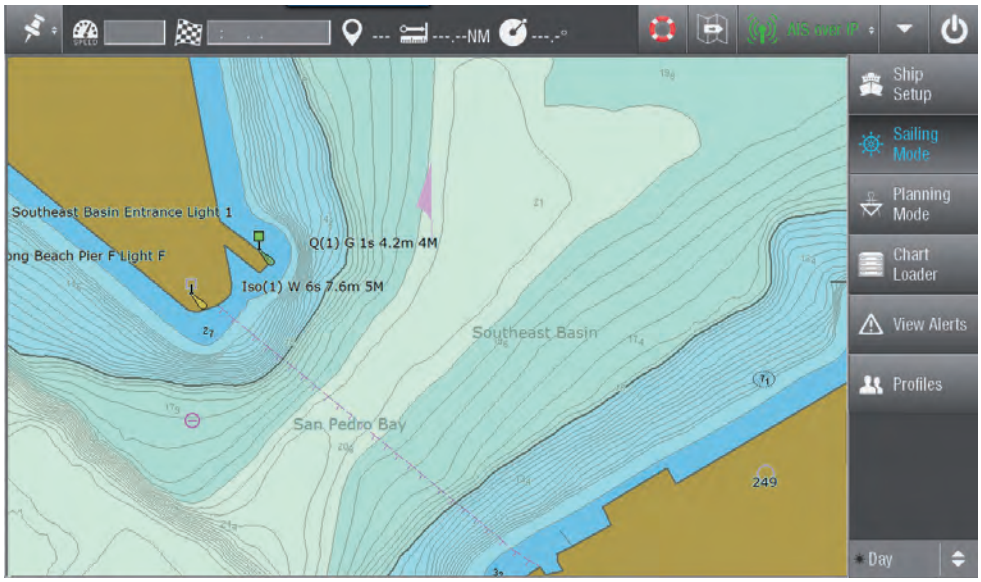
The proposed solution can be used to generate contours at much denser intervals than usually found in traditional ENCs. Special effort was made to make sure that the results comply with the strict topology rules for ENCs (IHO S-57, ENC Product Specification, and S-58 Validation Checks).
When contours are created at metre or sub-metre intervals not all contouring algorithms achieve error-free results. This is especially true



▲ *Configuring the degree of generalisation.*

in terrains where contours are getting pushed very closely to each other. It might be worth mentioning that we are not only talking about obvious errors that are visible to the human eye. Even visually insignificant errors can be the reason for erroneous S-57 topology and must be avoided.
Once automated production workflows for the generation of High Density Bathymetry Charts are in place it is no longer practical to check and validate the results visually/manually. Solutions that allow for automated validation are required. To confirm the reliability of the new contour generation methods, S-58 validation software was extended and improved to be able to handle the large number of lines and areas. Dozens of high density S-57 datasets were created and repeatedly tested with the new S-58 validation software in order to fine-tune the contour generation process. Finally a no-error quota of 99% was achieved. This means one dataset out of 100 would require manual corrections.

How S-100 Deals with High Density Bathymetry
IHO's S-100 is the framework for the definition of multiple future digital products required by the hydrographic and maritime community. Within the S-100 family S-101 is the new specification for ENCs, and S-102 describes a gridded representation for high density bathymetry.
S-101 ENCs can include high density contours in the same way as S-57 ENCs. Both represent depth information by means of soundings, depth contours and depth areas. Hence the production procedures described above are suitable for both S-57 ENCs and S-101 ENCs.
S-102 uses a completely different model for depth information. It is based on a gridded structure and does not use line or area features. In a high-resolution S-102 grid (e.g. 1m x 1m) each 1 by 1m grid node represents a single depth value.
S-102 is seen as bathymetric complement to ENCs in ECDIS. It has some advantages over the line and area bathymetry of ENCs: it allows



▲ *High Density Bathymetry ENC in ECDIS.*

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for 3D display of depth information, it is suitable for applying advanced water level correction models (e.g. to show real water depths) and it can represent bathymetry close to survey resolution.
However, since S-102 has some disadvantages as well (large file size, too much detail and tendency to cause clutter), high density bathymetry in S-101 ENCs and S-102 gridded bathymetry should complement each other.
Up to defined depths, larger scale ENCs could contain high density bathymetry where they cover channels and fairways. The data should be complemented by S-102 gridded bathymetry in congested or extremely shallow waters and areas where safe navigation is affected by strong variances of water level.

Conclusion

HOs will face new challenges if they decide to take the step into regular production of High Density Bathymetry ENCs. Advanced technical solutions are available and will have to be implemented to cope with the new challenges. The introduction of S-100 based digital products will provide additional options. ◂

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Friedhelm Moggert-Kägeler has an educational background in Geodesy/ Hydrography and holds a degree in both fields. He joined SevenCs in 2000 and he has worked in various positions ever since. His long list of activities range from S-57 data production and training, customer support, research and development, to product management. Today he is responsible for the overall coordination of the company's product management. Moggert-Kägeler has long-term experience and specialised knowledge and expertise in the domain of electronic chart production and has expert knowledge on relevant IHO standards. He regularly represents our company at IHO working group meetings, industry conferences and exhibitions.
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Going Where No Humans Should Go

Unmanned Surface Vehicles Monitoring Kilauea Volcano Lava Flow

The Kilauea volcano eruption on Hawaii's Big Island has captivated the world. The images broadcasted each day convey the power of the molten lava flowing from the Kilauea volcano to the sea. Its continuous flow is devastating neighbourhoods and communities, has filled pristine Kapoho Bay, and is ultimately changing the shape of the Big Island of Hawaii forever. Liquid Robotics decided to mobilise their unmanned surface vehicles to help scientists better understand the dynamics of this rare volcanic event.

Kilauea's eruption provides a rare scientific opportunity to study the impact of the lava flow on the ocean and its marine life. However, collecting ocean data during a live volcanic event is extremely difficult and as a result rare. In recent history this has only been done a handful of times and for limited time periods. Why? The danger. On the US Geological Survey's Hawaiian Volcano Observatory website, they warn of the hazards of being around the lava entry points. Flying debris and sudden explosions from the interaction between the lava and water can occur. This interaction produces 'laze', a corrosive seawater plume laden with hydrochloric acid and fine volcanic particles, that can irritate the skin, eyes and lungs. Did we mention scalding water temperatures? Certainly not an environment for humans to operate in.

But suitable for an ocean robot like Liquid Robotics' Wave Glider, the world's most experienced unmanned surface vehicle.

Liquid Robotics' Hometown Mission to Monitor the Lava Flows

Given this disaster was occurring on a place Liquid Robotics' calls home, i.e. the Big Island of Hawaii, it didn't want to just stand by. Liquid Robotics wanted to help. They decided to mobilise their Wave Gliders to help scientists better understand the dynamics of this rare volcanic event.

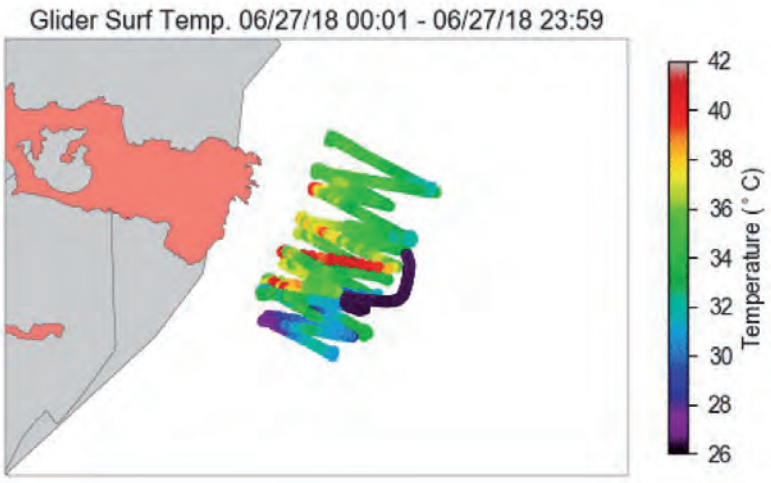
Working with Dr Steve Colbert from the University of Hawaii at Hilo, Tina Neal, scientist in charge from US Geological Survey's Hawaiian Volcano Observatory (USGS-HVO), and Dr Jesse Kroll, Massachusetts Institute of Technology (MIT), they configured two Wave Gliders with sophisticated sensors and cameras (see side insert) and sent them on their mission to measure and monitor the water conditions, air quality, underwater acoustics and plume flows. As noted, it's a rare opportunity to gain real-time data on the impact of a live lava flow on water temperatures, coral reefs, fish populations and other marine life. Measuring laze from the ocean will provide insights into the air quality and patterns caused by the hazardous toxic fumes.

Wave Glider #1, named Wa'a

- Seabird CTD - sub-mounted - measures conductivity, currents and pressure (depth) from the lower sub

▲ *Kapoho Bay before and after the lava flow from the Kilauea eruption. (Images courtesy of U.S. Geological Survey's Hawaiian Volcano Observatory)*

▲ *View of the Kilauea lava flow from the Wave Glider named Wa'a'. (Image courtesy of Liquid Robotics)*



▲ *Water temperature data collected by the Wave Glider Wa'a' on 27 June. Temperatures, 500 metres from the flow, were measured at 49C/120C. (Image courtesy of Dr Steve Colbert, University of Hawai'i at Hilo)*

- Seabird CTD - float mounted - measures conductivity, currents and pressure (depth) from the surface
- Turner Instruments C3 Fluorometer - float mounted - measures fluorescence in the water
- GPS Waves float mounted - GPS sensor for monitoring ocean wave dynamics
- Airmar 200 WX Weather Station - measures wind speed, barometric pressure; air and wind temperatures and relative humidity
- Sulfur Dioxide (SO) Sensor - on the mast - measures air quality for toxic gas
- Hydrophone Payload - sub-mounted to capture underwater acoustics
- Leopard Camera - float mast mounted
- GoPro Camera

Wave Glider #2

- Turner Instruments C3 Fluorometer - measures fluorescence, chlorophyll, turbidity
- MOSE Datawell Wave sensor - measures wave height and direction
- Seabird CTD - sub-mounted at 4m - measures conductivity, currents and pressure (depth)
- GPS Waves - float mounted - measures wave heights and dynamics
- Teledyne Acoustic Doppler Current Profiler (ADCP) - measures current speeds
- Airmar 200WX weather station - float mounted - measures wind speed, barometric pressure; air and wind temperatures and relative humidity

The mission, approved by the US Coast Guard, will continuously collect oceanographic, atmospheric and acoustic data outside the restricted lava area for three to four weeks (ending in late August 2018). Using unmanned vehicles makes it possible to safely go where no human wants to—near the live lava flow, approximately 100 metres from the entry point. The Wave Gliders will repeat a precise, zig-zag course collecting data continuously, day and night.

Early Insights - Scalding Water Temperatures

As Liquid Robotics were preparing for the mission, they were told that the estimated water temperature 100 metres from the lava entry point would be around 35C/95F degrees. When the first Wave Glider arrived on site, approximately 500 metres from the entry point, the on-board fluorometer recorded an actual temperature of 49C (120F). This is dramatically different and shows the importance of live, in situ data. Water temperature measurements taken below the surface around the Wave Glider's sub were approximately normal.

Many questions arise from these extreme water temperature recordings. How does the heat affect the local currents, winds and wave heights? Are these conditions extreme enough to affect ocean properties to a small degree for a substantial distance? What is the increased temperature effect on the coral reefs and fish populations? Answers to these and many others will become clearer as the researchers analyse the data.

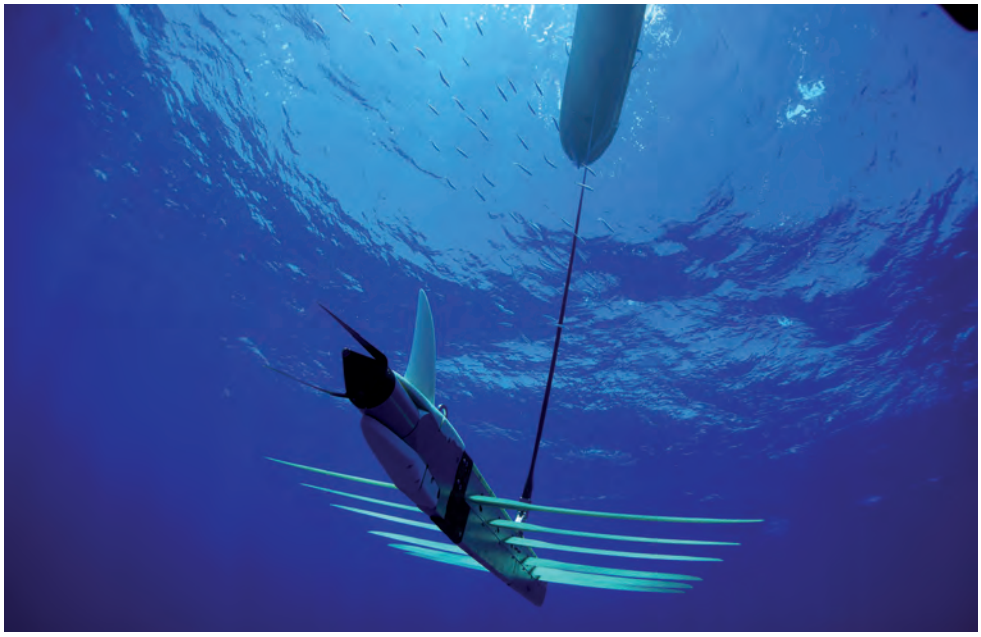
Measuring Thermal Fronts with Wave Gliders

Advanced research into the dynamics of ocean fronts and their impact on ocean ecosystems is being done by Monterey Bay Aquarium Research Institute (MBARI). Their ongoing research uses Wave Gliders to autonomously detect and track upwelling fronts based on the

horizontal gradient of near-surface temperature measured by the vehicle. A perfect approach to track and measure the ocean fronts and plumes generated from the Kilauea lava flows.

Working with Liquid Robotics, MBARI researchers quickly applied this method to studying the thermal front between the lava-heated water and the colder surrounding water. They programmed the Wave Glider tracking on a zig-zag path. Their algorithm calculates the horizontal gradient of temperature in real-time. When the gradient exceeds a threshold, the vehicle reports front detection, continues flight for a short time (to cover the frontal zone), and then turns onto the next zig-zag leg. The Wave Glider zig zags through the front at high spatial resolution to map the front and track its temporal evolution.

MBARI's work using Wave Gliders to 'auto-pilot' tracking of ocean fronts during the Kilauea volcano lava event will help scientists better understand the impacts of thermal lava plumes on the ocean's phytoplankton - the foundation of the ocean's ecosystem.



▲ *Subsea view of the Wave Glider with the Float on the surface of the ocean (top) and the Sub (centre), 8 metres below. (Photo courtesy of Liquid Robotics)*

Autonomous Systems - Keeping Humans out of Harm's Way

The Kilauea volcano lava mission is a prime example of the benefit of using ocean robots to collect important data when the risk to humans is too high. Using Wave Gliders, researchers can comfortably stay on shore analysing data versus venturing out on research boats that pose high risks. With autonomous systems, the need to actually manually collect the data required for research will soon be an approach of the past. This will reduce the costs and risks to scientific and commercial research.

Thanks to autonomous systems, the need to actually manually collect the data required for research will soon be an approach of the past

A Treasure Trove of Data

These are early days for this amazing mission. Scientists will be analysing the data for some time. However, Liquid Robotics' are confident that this data will provide rare insights into how the Kilauea volcano lava flow is actually impacting the Hawaiian Island coastline, ocean and marine life. A treasure trove of data that will provide insights on how we can better protect and care for the Hawaiian Island ocean ecosystems, its people and their generations to come. ◀

▲ *First view of the volcanic plumes from Kilauea' lava flow. (Photo courtesy of Liquid Robotics)*

Ryan Carlon is responsible for Liquid Robotics' Global Commercial Environmental Assessment team that focuses on supporting the Science and Research community. He joined Liquid Robotics in 2012 and has been leading the sales initiatives for the Science and Research community ever since. Under his leadership he has helped establish the Wave Gliders for the Research Programme and the Science & Research User Group. Carlon joined Liquid Robotics with a decade of experience in robotics and advanced software development for both unmanned maritime vehicles and vision-based mapping, localisation and navigation systems.

Expanding Operations Over the Horizon

Optimising Workflows on the **Maritime Information Highway**

By providing vessel to vessel and vessel to shore communication independent of satellite or cellular networks, the Maritime Broadband Radio (MBR) system from Kongsberg introduces possibilities to transform survey operations. Potential applications include delivery of raw data to shore and providing a communication and remote control channel for multiple survey launches and unmanned surface vessels in a single operation.

MBR is designed to connect operational assets and teams by delivering high-performance and barrier-free communications, without the need for expensive infrastructure. This enables the system to unlock a new age of collaboration for complex operational tasks. A MBR network can securely carry a diverse array of information, from real-time video to survey data, and remotely situated teams can work together seamlessly, coordinating systems and activities for optimal performance, safety and operational success.

As a high bandwidth, dynamic communication system with the capability to deliver a data link exceeding line of sight, the system unites people, allowing them to work side by side, even when separated by long distances. Objectives, expertise and real-time insights can be seamlessly shared, supporting awareness and understanding and therefore operational efficiencies.

Unlike satellite, WiFi or mobile network platforms, MBR requires no specialised infrastructure. There are no subscriptions, no rental agreements and no complicated and costly data charges – just predictable pricing and reliable, high-quality performance, with no moving parts and no need for regular maintenance. This makes it a simple to use, and an easy to install and maintain solution for enhancing efficiency in many maritime operations, including bathymetric surveying. With a suite of different MBR product types available, where each one provides seamless, high-capacity data exchange and reliable performance, the system is emerging as a transformative solution for survey operations.

MBR antennas have software controlled dynamic pointing direction for optimal link path, so with a good antenna location there is no limitation in manoeuvring or vessel speed. Loss of connection during turning, rolling and pitching is a real challenge for vessel communications during surveys, but the MBR has far more resilience and can maintain a connection during very tight manoeuvres and even when obstacles arise during an operation.

Optimising the Workflow

MBR can allow more data to be sent to units in the network, so that experts can act on it during,

▲ *The Maritime Broadband Radio is a smart antenna designed for use in any application where digital high-speed reliable communication and data transfer is crucial for efficient and safe operation.*

▲ *Data transfer between vessels and assets via the MBR network.*

▶ *During the operations, an aerial drone supplied streaming images, the tethered relay balloon, named OceanEye, was elevated from the ASV Telematron.*

rather than after a survey. This means it will be possible to amend a vessel's survey path quickly, enabling focus on interesting areas almost immediately, or to repeat incomplete or corrupted lines. With the current workflow, these areas may not be discovered until the vessel comes home, so further investigations would require another full and expensive mobilisation.

With access to quality data there is potential even to re-think the very foundations of how, and where hydrographers work. Today's survey vessels are mostly self-contained, but if high-quality survey data can be transferred and monitored faster, more reliably and for less cost than using satcom, it is possible to place more experts in central operations centres, either on board a mothership or on land. From here, these experts could control and service multiple vessels and assets.

This approach can enable applications for Autonomous Underwater Vehicles (AUV), Unmanned Surface Vessels (USV), smaller survey launches and even Unmanned Aerial Vehicles (UAV), using a single mothership as a base and/or with a central control centre. Establishing such an operation with tangible benefits can only happen if the mobile assets can communicate and deliver full-quality survey data using IP connectivity.

Connecting Multiple Assets

This multi-asset approach has already been tested using the MBR. In an exercise called Autonomous Network of Heterogeneous Vehicles (ANOHV), four autonomous units – UAV (Unmanned Aerial Vehicle), USV, AUV and a tethered relay balloon – were guided from a mothership in various tasks requiring precise coordination from the command centre, and with each other. MBR provided the one central element without which the operation would not have been possible: communication.

The exercise had multiple goals, including demonstrating AUV operations using a multi-vehicle, multi-platform network, but also to demonstrate integrated operations using high-bandwidth communication between all nodes in the network. During the operations, an aerial drone supplied streaming images, the tethered relay balloon, named OceanEye, was elevated from the ASV Telematron, which also shadowed HUGIN, an AUV developed by Kongsberg. The command centre for the exercise was located onboard R/V *Gunnerus*, the research vessel of the Norwegian University of Science and Technology.

▲ *The HUGIN AUV collected bathymetric data and identified pre-set targets.*

The HUGIN AUV collected bathymetric data and identified pre-set targets, even performing a mid-dive redirection on command from the R/V *Gunnerus* via a relay station, using MBR and an acoustic communication link, demonstrating flexibility that opens new opportunities for use of AUVs. And although the command centre during ANOHV was at sea, the same operations would be possible with MBR, with access to the same data communication speeds if it was ashore and within range.

MBR-based Surveying in Colombia

MBR has also been demonstrated in several live survey operations with the Kongsberg EM 2040C multibeam echo sounder and Seapath 330/130 motion/positioning systems installed onboard a survey launch. One of these demonstrations was part of Kongsberg's efforts to introduce new technologies and applications during the CINTECMAR congress which was held at the end of 2016 in Barranquilla, Colombia.

Once all the systems had been installed and tested the live demonstrations were started with actual multibeam survey operations up to the mouth of the Rio Magdalena River (about 11 kilometres from the Convention Centre). During the demo, there were live interactions with the crew on board the survey launch and the Kongsberg staff at the CINTECMAR congress venue. Using MBR, the on-shore team was able to give instructions to the crew on board about certain survey operations based on the multibeam datasets that were being transferred from the craft as soon as they were collected, also via the MBR.

Though small in scale compared to the multi-asset potential of MBR, the demo explored the ways in which the system can help the industry to rethink how marine survey operations can be conducted; from remote assistance and live technical support (trouble-shooting, equipment inspection, etc.) to immediate dataset sharing with experts in an operations centre. While allowing for dynamic vessel operations, MBR also provides a way to quickly check that multibeam datasets have been properly collected the first time, allowing any technical issues to be tackled in time so that there will be no need to return to the survey area.

While allowing for dynamic vessel operations, MBR also provides a way to quickly check that multibeam datasets have been properly collected the first time

Enabling On-shore Experts

Operations so far have been conducted at ranges beyond 50km, depending on antenna height. While this introduces ship to shore communications at quite a distance from the coast so that many operations can benefit immediately, much of the focus now is on communication and control involving seaborne assets vessel to vessel, either manned or unmanned.

Considering the size of raw multibeam/sonar datasets, MBR does not provide live streaming to the operations centre, regardless of whether it is on a mothership or on land. However, based on typical dataset sizes, it is usually possible to start the processing of data at the centre within 30 minutes of the survey starting, which is an improvement over waiting for a vessel to return to port and having the hard drives delivered to the office. Additionally, Kongsberg Maritime's Subsea division has already developed software for its hydro-acoustic systems to ensure they leverage the potential of MBR effectively and efficiently.

There is also the issue that the application of unmanned vessels and high-bandwidth communication technology could reduce the global workforce dedicated to surveying. However, the applications for MBR are more about optimisation and re-configuration of current processes and not replacing the human element – the skill of the hydrographer will still be needed, but they may be working from an operations centre controlling multiple assets rather than dedicated to a single ship or launch.

Operating large, manned ships is one of the larger cost drivers in complex operations at sea, and using a fleet of smaller vessels with additional autonomous assets can reduce costs and eliminate risks to crew. Essentially, though, it could improve performance, as access to central resources provides an even broader knowledge and experience base for survey operations. MBR is the first system that can truly enable this multi-asset approach and transform survey workflows for more efficiency. ◀

Vegard Haugen is area sales manager at Kongsberg Seatex. He has over 15 years of experience at the Norwegian Coast Guard, where he worked his way up to Commander. His experience in leading large operations where comprehensive communication systems were lacking convinced him of the great potential that lay in optimising operations through better communication.

A Bright Future Ahead for iXblue's New USV

Rethinking the Traditional Model for **Offshore Operations**

Back in May 2018, the conspicuous red hull of DriX, iXblue's new unmanned surface vessel (USV), could be seen sailing the waters of the Caspian Sea. Hidden from view, 2 metres below the surface, iXblue acoustic synthetic baseline positioning system, Ramses, was performing a highly-accurate rig positioning operation for Total E&P, the world's fourth-largest Oil & Gas company.

A global leader in the design and manufacturing of innovative solutions dedicated to the offshore Energies, Ocean Science and Defence markets, iXblue was contracted by Total E&P to conduct this box-in operation using DriX, a new revolutionary platform enabling more flexible and reliable offshore operations such as subsea tracking, positioning and monitoring.

Rig Positioning Operation

Total E&P was looking to trial new solutions on the highly-competitive offshore market by reducing the time needed for operations such as the box-in of its wellheads, while still acquiring excellent and highly-accurate positioning information. The Oil & Gas company needed a solution that could offer more flexibility compared to using the more costly vessels already busy conducting other operations and that might not be available when needed.

"Total E&P was looking for a flexible and cost-efficient solution to conduct a specific rig positioning operation off the coast of Baku, Azerbaijan" explains Olivier Cervantes, vice-president Marine Services at iXblue. "Right after we launched DriX, Total E&P saw the high potential of our new USV. Coupled with Ramses acoustic positioning system, it truly offers offshore operators a revolutionary platform to conduct their operations with flexibility, saving both precious vessel time and money with no compromise on data quality or safety".

DriX and its operating team left their home port in La Ciotat, France, and traveled all the way to Baku, Azerbaijan, for this mission aiming to provide highly-accurate positioning of the rig's wellhead at depths of 500 metres, for future drilling operations.

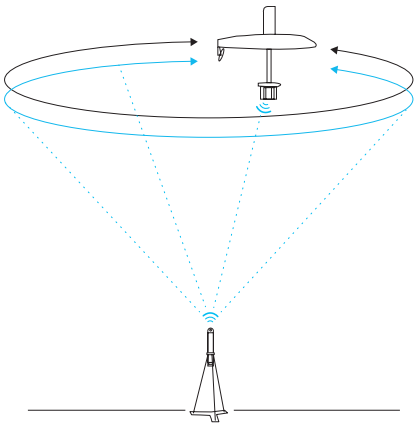
A first series of tests was carried out by the iXblue and Total E&P teams in the Port of Baku, before the transit of DriX on the supply vessel, *Jura*, to the rig location, 100 kilometres off the coast of Baku.

Precise Positioning Data

The box-in operation itself was then carried out by DriX and Ramses Long Baseline (LBL) and a sparse LBL intelligent transceiver that precisely measures the distance to the transponder previously installed on the wellhead. In order to acquire precise positioning data, DriX was positioned over the transponder and performed circles of both 300 and 500 metres radius in opposite directions. By doing so, Ramses was able to measure accurate distances from various angles and could then compute the precise average position of the transponder.

During the job, all survey data was logged both remotely, thanks to the WiFi link, and on DriX itself where local copies were stored to secure operations.

Survey principle sketch



In less than 3 hours total time on site, where traditional box-in operations usually last from 6 to 10 hours, four box-ins were conducted on the same drill point. The data collected by DriX and Ramses proved to be excellent, showing better than <10cm dispersion between all positions produced and comparing extremely well to the Total E&P average USBL reference position of 1.5 metres.

Thanks to the DriX wave piercing shape that keeps the slamming effect to a minimum to ensure the utmost stability of the platform and to the USV's gondola, located in an optimum data gathering environment, 2 metres below the surface, in noise-reduced and bubble-free surroundings, the mission was able to be successfully conducted at speeds of up to 8 knots, or twice as fast as traditional data-acquisition methods.

Reduced Amount of Data

The operation duration was also significantly reduced thanks to the smaller diameters of the circles that DriX had to perform around the wellhead. Indeed, most acoustic positioning companies, which determine the diameter size according to the depth at which the transponder is located, would have had to perform circles of 1 kilometre in diameter for a 500-metre depth and acquire a minimum of 800 ranges. Defined years ago, these operational constraints are commonly recognised as providing suitable mitigation against the effect of cumulated noise sources coming from GNSS, acoustics or heave etc.

However, thanks to GNSS accuracy, Ramses ranging and INS precisions, combined with perfect control of mechanical mounting, these sources of uncertainty were greatly reduced on DriX, ultimately reducing the amount of data required to converge to decimetre performance over the water column and hence lowering operational constraints of the box-in mission.

"Overall, this trial made with iXblue using their DriX and Ramses was a real success" states Frédéric Auger, chief surveyor at Total E&P. "I am convinced that this new technology developed by iXblue will bring high benefits for future survey and positioning works".

During this test with Total E&P, four box-ins were successfully conducted, all of them producing repeatable positions whatever DriX speed (up to 8 knots) or circle radius (300m or 500m), the fastest one taking less than 17 minutes whilst perfectly matching all other results.

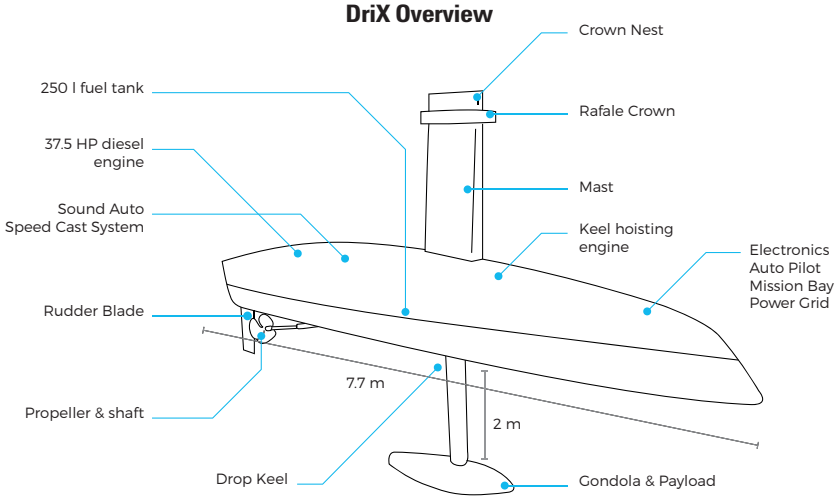
High Accuracy Box-in Techniques

Achieved calibration time and precision at a speed of 8 knots opens extremely interesting perspectives of high-accuracy box-in techniques being applied in real-time for pipe-lay and touch-down monitoring operations, providing decimetre accurate positions of ROVs whatever the lay back or the water depth. Graph A illustrates the possibility for surveyors to evaluate the positioning accuracy they can expect from a fully equipped DriX for TDM operations, depending on their operational constraints such as water depth and pipe-lay vessel speed.

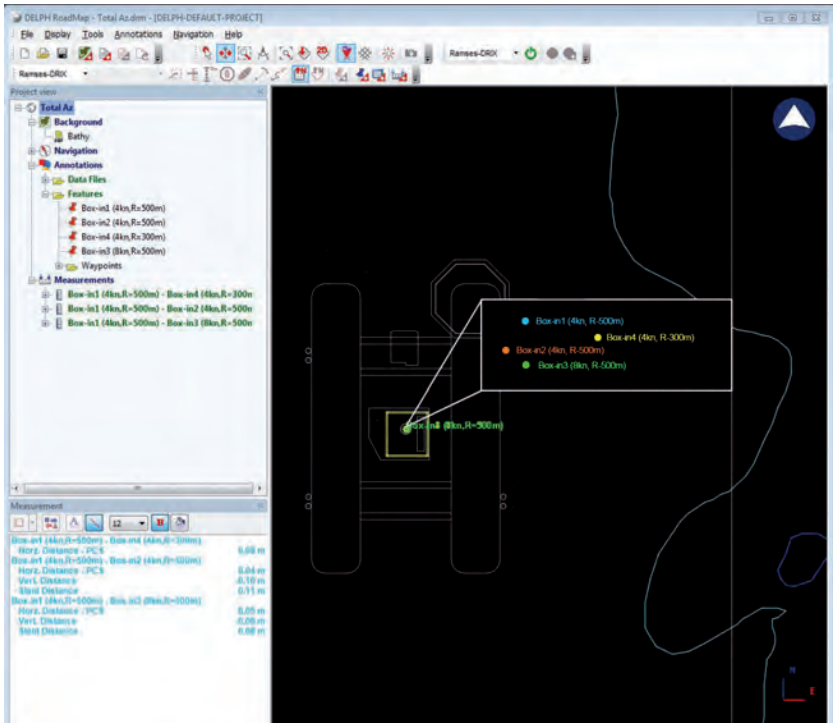
From grid B for example, a pipe-lay vessel working in a 1000m offshore field, and with a limit of 10 minutes for average fixes on quad-joints, can expect, with DriX, better than 10cm positioning accuracy without having to deploy any transponder on the seabed, thus saving several days of operation over a typical pipe-lay campaign.

With DriX, iXblue offers offshore operators a revolutionary platform that disrupts the traditional model for subsea operations by providing a cost-efficient, reliable and flexible solution and was able to impress Total E&P during its trial in Azerbaijan. Along with the global Oil & Gas company, other offshore operators have shown great interest in DriX, promising a bright future ahead for iXblue's new USV. ◂

DriX Overview



Graph A: Decimeter repeatability on conducted calibrations



Graph B: Estimated performance for 5-10-20min box-in with DriX

An Analysis of the Techniques and Benefits of These Methods

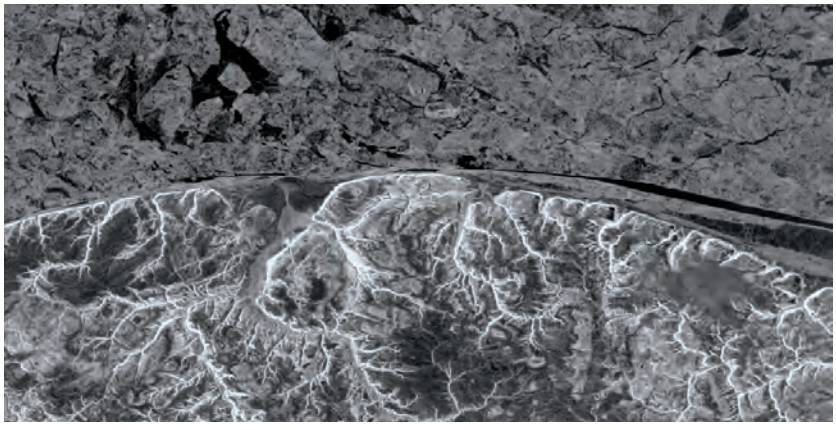
Mapping the Seafloor with Remote Sensing and Satellite Imagery

Seventy percent of the Earth is covered by water, but so far just seven percent of it has been surveyed (Mars, Venus and Moon are better surveyed). Hydrography as a science has changed dramatically since the first measurements made by Alexander Dalrymple and James Cook with lead lines and sextants. Single-beam echo sounders were invented in the 1920s; a technology still used today for mapping the seafloor. This method of using echo sounders can produce very high-resolution bathymetric data but the high operational costs and the slow working process make it economically unsuitable for covering large areas. However, with the ongoing expenses of the offshore industry over the last decades, scientists and engineers had to develop better and more effective technologies to map the seafloor. Such technologies are the airborne technologies. Over the past decades there has been an increasing interest in airborne and satellite-derived bathymetry data. This article explains the methods of remotely mapping the seafloor in detail and their advantages and the disadvantages.

With the increasing number of satellites observing the Earth, remote sensing data of the oceans is widely available. Optical, synthetic aperture and altimetry data are the three types of satellite-derived bathymetry data.

Optical Satellites

Optical satellite images obtain information on the water depth by analysing the spectral changes of the seafloor. This method is very effective for nearshore shallow waters. The idea behind this method is the usage of the reflectance intensity of different wavelengths of sunlight that are captured by the satellite sensors. This method has been further advanced by two major developments in the technology; the first being increased resolution of satellite data which allows for sufficient level of detail of the seafloor mapping, and secondly the design of robust and standardised algorithms and workflows. The classification of the datasets depends on two parameters: spatial resolution and pixel size. Of course, the most important factor is the spatial resolution: "The ability to map the seafloor in highest detail, the amount of spectral information and the bit depths in which they are recorded, signal-to-noise-ratio and the geolocation accuracies" [Hartmann, 2017]. There are four types of classification: very high-resolution datasets with better than 2m spatial resolution, high (<10m), moderate (<100m) and coarse (several hundred metres).



▲ *Figure 1: Northwest Passage sea ice contrasts with the coast of Baffin Island, Canada, in this ALOS-PALSAR image taken 8 March 2011. (Courtesy: JAXA, METI)*

Synthetic Aperture Radar (SAR)

SAR is a method that is used for capturing the seafloor further from the coast. SAR works by detecting the changes in the wavelengths in the deep waters. The radar works by transmitting electromagnetic waves and then collecting, digitising and storing their echoes for later processing. The backscatter data detected by SAR depends on the roughness of the sea surface and the length scale of the roughness.

Satellite Altimetry

The basis of satellite altimetry is the known process of emitting a radar pulse and measuring the time it takes for the reflection to be detected. The biggest errors that mostly affect the altimetry-derived sea level are the orbit errors and errors in the environmental and geophysical corrections applied. It can be said that the satellite altimetry is unique among ocean remote sensing techniques because it provides us with much more information on the Earth`s gravitational field: the shape and the structure of the ocean floor, the integrated heat and the salt content of the ocean and the geostrophic ocean currents, than any other remote sensing technique. The global coverage measurements and the revisit time of several days makes this method one of the most frequently used. The accuracy of satellite altimetry varies between the satellites. The average claimed accuracy for global mean sea level averaged over a 10-day orbital cycle is 2-4mm. The biggest disadvantage of satellite altimetry is "the contamination of the radar signal near the coast when the reflection of the radar pulse is partly due to the ocean surface and partly to land" (Gomis, Monserat et al., 2012). As a consequence, the standard altimetry data is unreliable at distances shorter than 40km from the coast.

Whereas most debates were previously related to the resolution and the accuracy, the cost of purchasing satellite images has dropped significantly over the past years. However, there is one large disadvantage of satellite imagery: the inability to wait for improved weather conditions (i.e. cloud coverage). We are probably approaching the day when we will have both aerial cameras and Lidar systems combined in one device to provide both data at the same time.

Another advantage of satellite imagery is the fact that we can use them as a time lapse. This information is vital to humanity to realise how large our impact on the planet is as well as to understand the range of natural disasters such as hurricanes, tsunamis and fires in recent years.

Airborne Remote Sensing

When discussing airborne remote data gathering one must not forget 'Secchi Depth', the methodology used to measure water turbidity or transparency. This measure is crucial for the accuracy of all airborne surveying techniques because it is the ability of the light to penetrate into the water. The turbidity or the transparency depends on the amount of particles within the water column. To measure the water clarity we need a 'Secchi Disk' (Fig. 2). The most effective seasons for measuring 'Secchi Depths' are spring and autumn (spring has slightly better Secchi depths, but autumn has a longer time window and the weather is easier to predict).

Aerial Photogrammetry

Essentially photogrammetry is a combination of various aerial photography shots to create 2D or 3D models and derive measurements from them. Aerial photogrammetry is the process of taking pictures of large areas of land by mounting advanced digital cameras from the underside of an airplane.

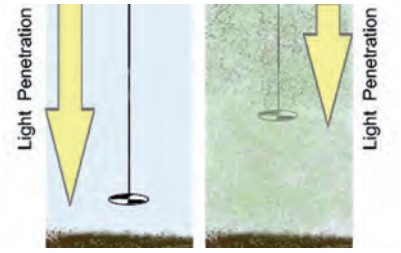
If we compare the resolutions of aerial photography and satellite images, then the aerial photography has significantly better values. Comparing results from providers shows that Vexcel, for example, can provide aerial photography with a resolution of around 6.5cm. Satellite imagery is also quite accurate: GeoEye-1 can supply the user with panchromatic imagery down to 4.1cm resolution.

However, nowadays the resolution is just a small part of the specifications. The development of 3D models, GIS and CAD connections and the advances in automated image extraction are shifting the aerial photogrammetry to advanced work flows.

Light Detection and Ranging (Lidar)

Lidar is a method that uses both green and red light to survey a coastal region above and below sea level. The green light penetrates into the water body and captures the seafloor, whereas the red light is not able to penetrate the water body and therefore bounces back from the water surface. By using both colours it is easy to distinguish the water surface from the water column and water body floor.

As mentioned above, the most crucial thing to take into account is the Secchi Depth. Another important consideration is the power of the system. The more powerful the Lidar system is, the more it will penetrate into the water. Therefore, the Lidar systems on the market are split into one of two types depending on their

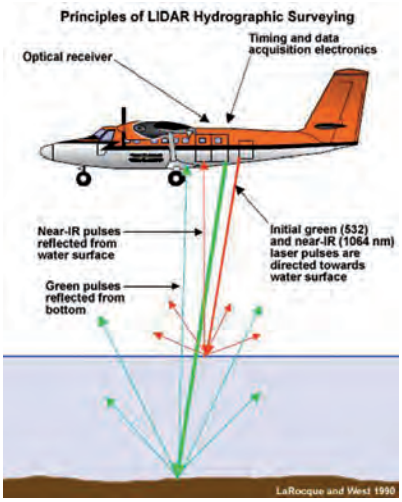


▲ *Figure 2: 'Secchi Disk' method to measure the transparency of the water (Source RMB Environment Laboratories)*

penetration into the water column. One system type is able to reach 1 to 1.5 times Secchi depth and the other 2.5 to 3 times Secchi depth. At ideal viewing conditions the sea/river bed can be detected down to around 10m depth.

Other issues for the airborne cameras and lasers are the weather condition (fog, high surface waves, rain, and sun glint), bad detection and recognition of underwater features, and the data gaps due to vegetation or suspended sediment issues with bad backscattering. These gaps need to be filled by hydrographic surveys.

The Lidar data has a more area-wide homogeneous spread and a substantially bigger density of points per square metre when compared to the data derived from an echo sounder, SBES or MBES, which makes the morphological model produced from the Lidar data more plausible. The measurements both have: a very high accuracy (± centimetres, depends on the depth) and a very high resolution (between 20 to 30 points per m2). There are different types of measures describing the quality of the Lidar systems: vertical and horizontal accuracy, depth of the water



▲ *Figure 3: Principles of Lidar hydrographic surveying. (Source: LaRocque and West)*

measurement, distribution of the points and footprint size.

Conclusion

It is evident that bathymetric airborne laser scanning, photogrammetry and satellite imagery will not replace traditional hydrographic surveys, however, these techniques are complementary to shallow-water mapping. The combined method of airborne satellite imagery, Lidar systems or aerial photogrammetry together with acoustic surveys, leads to a powerful and very effective manner to create maps of the seafloor. This is due to the fact that the acoustic surveys in areas with shallow waters (5-10m) require significant efforts and costs and are quite often very difficult to access. Contrary to that is the depth range in which airborne methods work optimally. Therefore, the combination of both methods form an affordable data map from the very shallow to the very deep. Furthermore, the overlapping between both methods can serve as a calibration and validation of the methods and as a proof of the quality of the data.
Nowadays, the comparison between satellite imagery, aerial photogrammetry and Lidar is not as simple as it used to be. There has been great progress on many fronts including computation, knowledge, services and last but not least, in software and hardware. So the best technique to choose depends greatly on its usefulness and whether it matches the goals we determine. ◂

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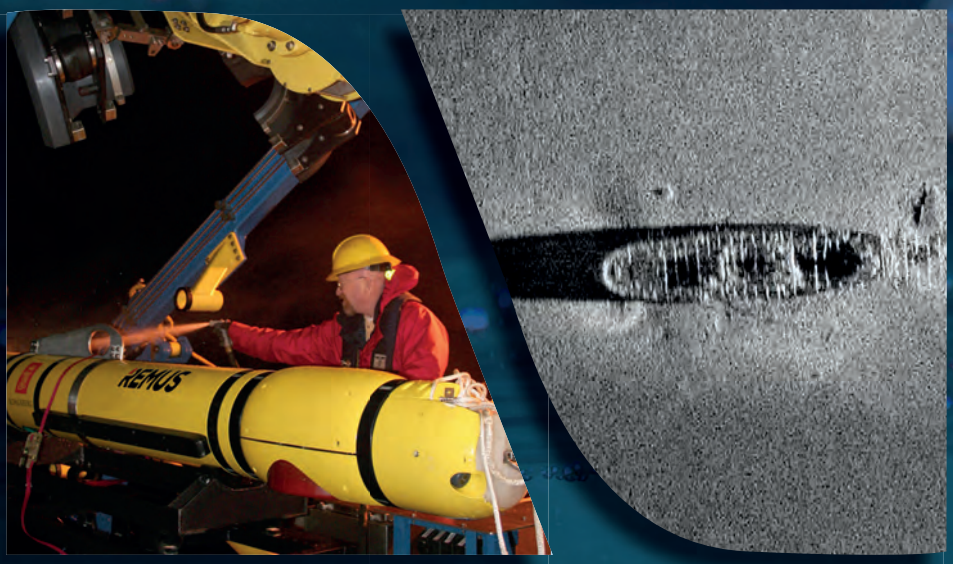

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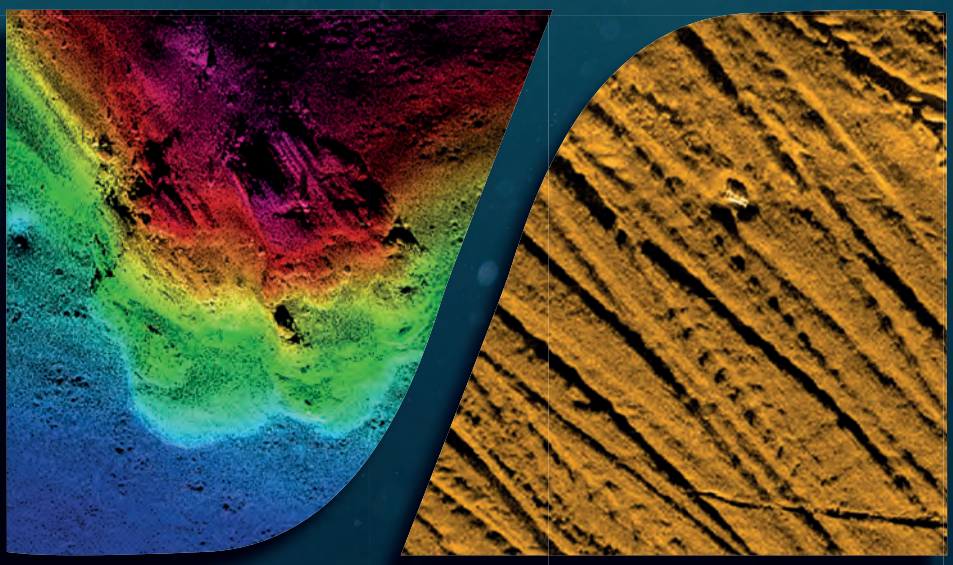

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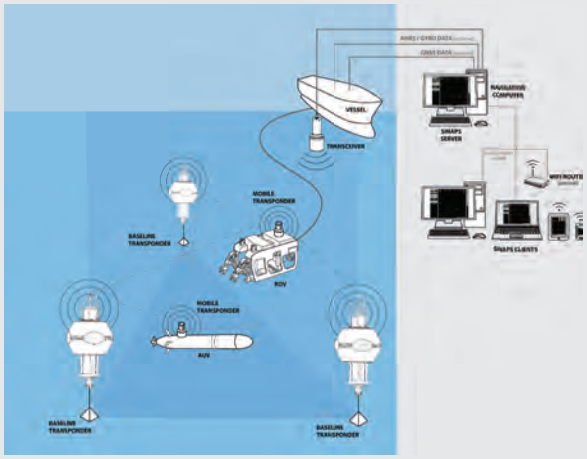

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