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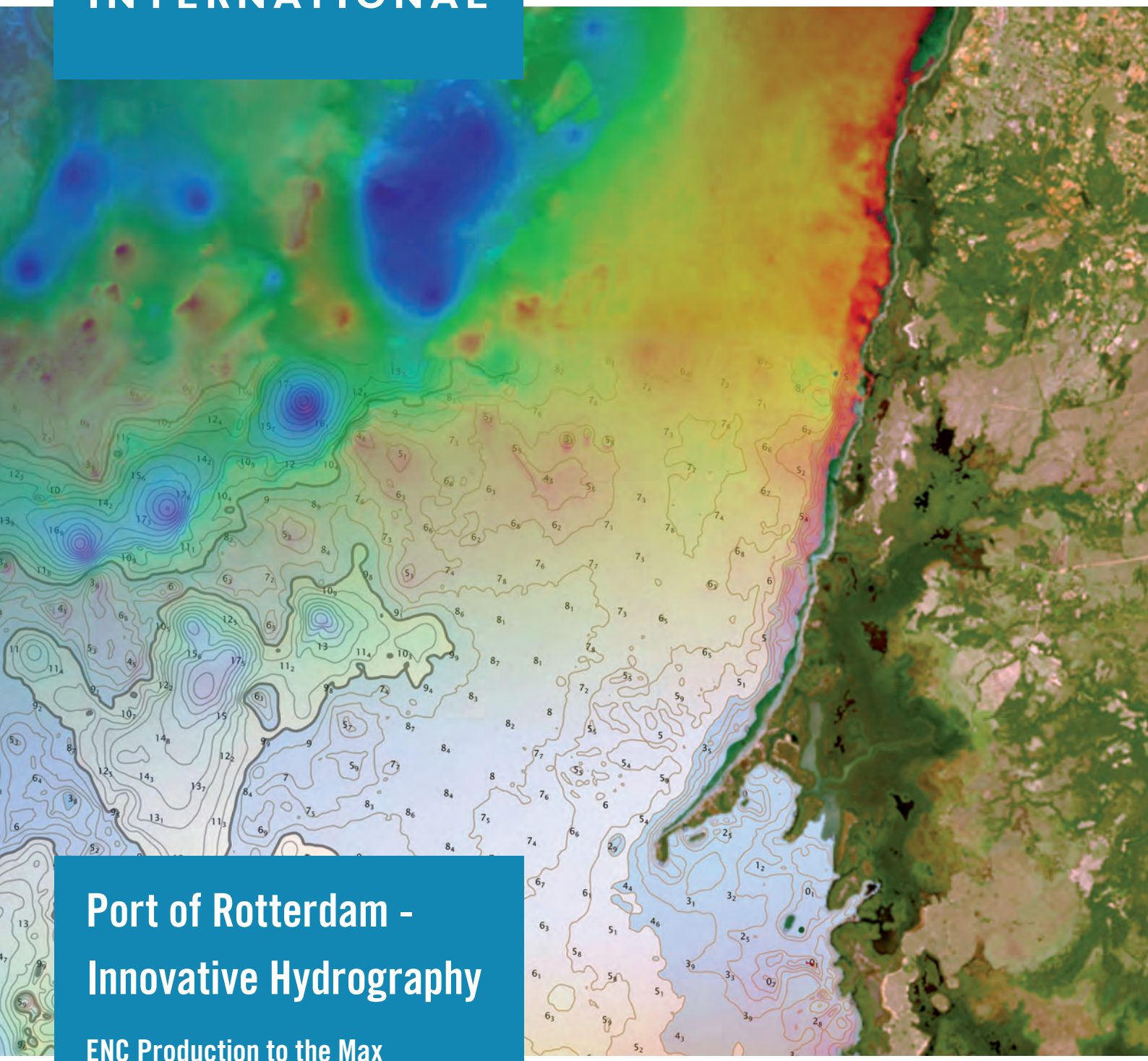

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Hydro International is an independent international magazine published 6 times a year by Geomares. The magazine and related e-newsletter inform worldwide professional, industrial and governmental readers of the latest news and developments in the hydrographic, 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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TRANSITION TO A BATHYMETRIC ELECTRONIC NAVIGATION CHART

The front cover of this issue of Hydro International shows the transition from Landsat satellite imagery, to a satellite-derived bathymetry surface, to a bENC (Bathymetric Electronic Navigation Chart). The location is Golfo de Guanahacabibes, Cuba. (Image courtesy: TCarta – www.tcarta.com)

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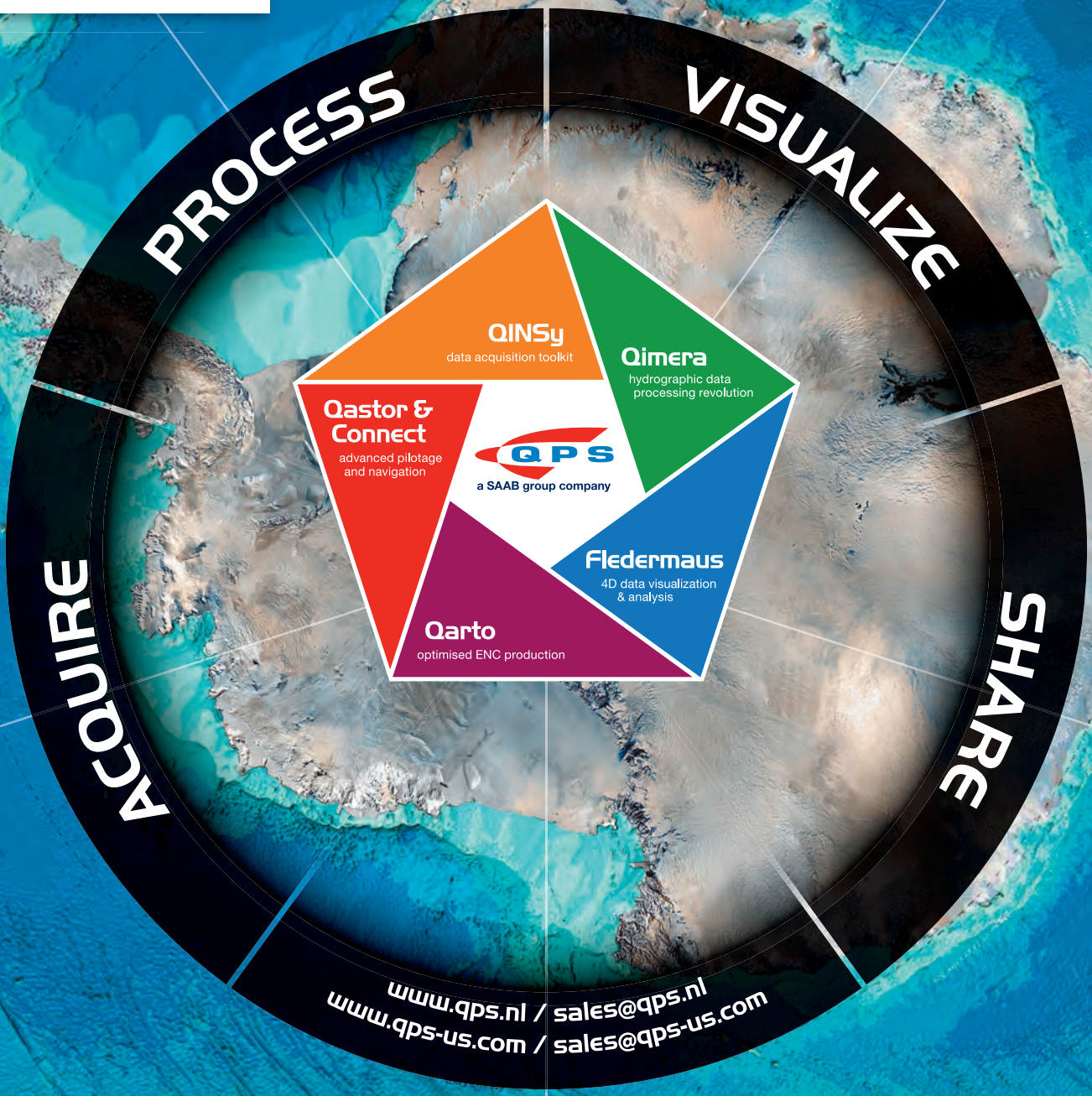

Antarctica by Martin Jakobsson
(Stockholm University)

ENCs at the Heart

Hydrography should serve much more than just safe navigation. We've tried to bring across that message over and over in recent years. The blue economy is equally important as business case for hydrographic surveying. To name just a few examples: tourism and offshore renewables are areas that greatly benefit, in fact, they are even dependent on good data about the seafloor. But every now and then, it's good to put the application that has always been the heart of hydrography, namely navigational charts, at the centre of attention. Especially now that 1 July 2018 is around the corner and ECDIS carriage requirement will be mandated for any new and existing vessel of relevant size on international voyages. Secretary-General Jonas of the International Hydrographic Organisation shares his view on this historic event in this issue's IHO contribution on page 32. Furthermore, on page 14, Antonio Di Lieto, Mike Prince and Alvaro Sanchez, describe the High Density (HD) Bathymetric Electronic Navigation Charts (bENCs) of the Australian Hydrographic Office as next-level examples. (b)ENCs get a well-deserved mention at the heart of this Hydro International. Enjoy the read!

Durk Haarsma,
director strategy & business development
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Navigating through the Unknown

I recently read the fascinating book *The Island at the Center of the World*, Russell Shorto's masterpiece on the epic story of the Dutch colony centred on Manhattan that shaped New York. It is also the story of great explorers such as Henry Hudson and Peter Stuyvesant, who crossed the ocean and became the director-general of the colony and a key figure in the early history of New York City. It is hard to imagine that those brave men chose to raise their sails and set course for the New World, which was actually also setting course for the unknown. Don't forget that those brave men did not have accurate marine charts, let alone Electronic Navigation Charts (ENCs). Hudson was probably more in need of a reliable map of the world or the globe, as he – after he had made two attempts to find the Northeast Passage to China – was determined to find a Northwest Passage to Asia. Employed by the Dutch, he passed Nova Scotia, Cape Cod and finally ended up at the river that was named after him: the Hudson River, and the island of Manhattan. New Amsterdam was established here; the Dutch settlement that later became New York City. This all happened at the beginning of the 17th Century. Now, four centuries on, there still is a lot to discover. For example, only 15% of the Earth's ocean has been mapped! And coming back to navigation charts: even today there is still room for improvement. A new development is High Density bathymetric ENCs that can foster both commercial interests and safety of navigation. Hudson's mind would have boggled by this, but pioneers like him definitely contributed to the search for better navigation tools. The way of the pioneer is always rough.

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Bathymetric ENCs

In 2017, the Australian Hydrographic Office published its first Bathymetric ENCs for two ports, with more under development. Unlike those produced by several Port Authorities around the world, bathymetric ENCs produced by Hydrographic Offices are available both to ships' crew using ECDIS and to Marine Pilots' Portable Pilot Units.

Why is it so important that bathymetric ENCs reach also ECDIS on board? Managing the risks of ever decreasing safety margins to conduct vessels in confined waters requires the ship's crew to be on the same page with the marine pilot. This is the essence of Bridge Resource Management (BRM), whose ultimate aim is the prevention of accidents caused by actions of one person not challenged in due time or not challenged at all.

In this sense, Bathymetric ENCs produced by Hydrographic Offices support one of BRM's essential components: the possibility for anyone on the ship's bridge to monitor the navigation in confined waters against the same 'pilotage plan'. Other IHO Member States around the world may benefit from the Australian Hydrographic Office experience, which demonstrates how Bathymetric ENCs can foster both commercial interests and safety of navigation.

Antonio Di Lieto, senior instructor at CSMART
adilieto@carnival.com

ECDIS and ENCs Are Here. Now What?

The maritime world reaches a milestone in July 2018, when the schedule for transitioning SOLAS-class ships to Electronic Chart Display and Information Systems (ECDIS) using Electronic Navigational Charts (ENCs) is complete. Most national Hydrographic Offices have full suites of ENCs, and transitioned internal workflows to maintain ENCs first, ensuring they are up to date with the latest information. In the US, the National Oceanic and Atmospheric Administration (NOAA) provides ENCs, raster charts, and modern tile-based charts for free, updated weekly including changes to navigation aids, channel conditions, dangers, as well as more routine updates to shoreline and hydrography.

NOAA's National Charting Plan-the result of a multi-year planning effort to gather public input on the future of charting-provides a strategy to improve nautical chart coverage, products and distribution, so that mariners can take full advantage of the benefits of electronic navigation. The main focus of this strategy is improving ENCs and to lay out a new chart suite designed from the beginning for digital use. NOAA has made its last new large format paper chart. All new charts compiled under this plan will be available in digital versions, though a suite of paper charts will be maintained for backup, planning and context.

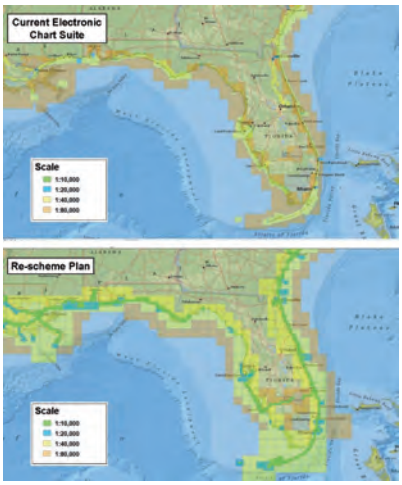
Electronic navigation systems are maturely in use across maritime sectors. Most large ships use ECDIS as the primary navigation tool. Commercial tugboats, ferries, fishing boats, and high-end recreational vessels use standalone or PC-based navigation systems, often with advanced capabilities not available in ECDIS systems. Electronic navigation is affordable and available through chart plotters and mobile apps to all vessels on the water.

The highest stakes and close-quarters navigation challenge is between the sea buoy and the berth. In these areas, ships must pass with mere metres to spare above the seafloor, from the edge of channels, from other ships, and under bridges and power lines. Larger ships are pushing all of these margins. The pilots guiding these ships employ specialised navigation systems called portable pilot units, which are optimised for these tight margins, and which use high-resolution, high-accuracy depth and water level information to precisely plan, monitor and execute the ship's movements.

These 'precision navigation' systems rely on data. NOAA, in partnership with the US Army Corps of Engineers, and guided by standards set by the International Hydrographic Organization, is developing a standardised set of services to support these users. We will provide large-scale high-resolution ENCs to complement the traditional ENCs; continuous tide, current and salinity models to complement the traditional station predictions; and real-time observations, and high-resolution nearshore wave models to complement traditional wave buoys. In a prototype project in the ports of Los Angeles and Long Beach, this combination of services, integrated through a dynamic under-keel management system and a portable pilot unit, has improved the ability of the pilots to manage risk. As a result, they have reached agreement with the shippers and Captain of the Port to increase the draft of the largest incoming ships by 1.3m, and increasing the value of the cargo by millions of dollars per transit.

These next-generation services for ports, distributed using S-100 based standards, are the leading edge of similar services that have much broader value to the navigation community, improving the safety and efficiency of ships at sea. I am proud of the international hydrographic community's decades-long drive to get us where we are, and am excited by what we can build on this strong foundation.

Rear Adm. Shepard M. Smith is director of NOAA's Office of Coast Survey and the US national representative to the International Hydrographic Organization (IHO).



Current electronic chart suite and re-scheme plan of the Florida and eastern Gulf Coast region.

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Fugro's Ultra-deepwater Surveys Support Seabed Mining Exploration

▲ *Echo Surveyor VII AUV.*

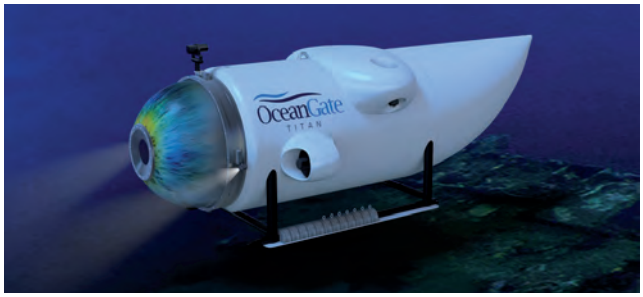
Fugro has commenced its first project supporting deep-sea polymetallic nodule mining under a contract awarded by seafloor mineral exploration company Nauru Ocean Resources Inc. (NORI). In the deepwaters of the eastern Pacific Ocean, Fugro's specialist marine geoscience team will perform detailed site characterisation surveys. The project, which began on 19 April, will advance NORI's polymetallic nodule project. Polymetallic nodules are potato-sized concretions enriched in nickel, copper and cobalt. These nodules also contain metals and non-metals important to 'green-tech' enterprises, such as electric vehicles and wind energy production. The site characterisation surveys will involve acquisition of high-resolution imagery and geophysical data, and sampling of minerals from the seafloor. The field work will be accomplished using the company's Echo Surveyor VII autonomous underwater vehicle (AUV) and specialised seafloor sampling equipment.

▶ ***https://bit.ly/2rOQpRi***

iXblue Equips Manned Submersible for New *Titanic* Survey Expedition

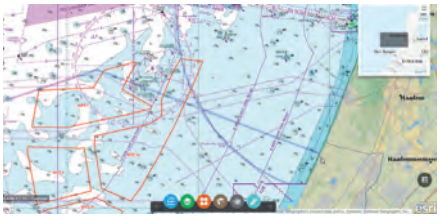
OceanGate, a provider of manned submersible services, and iXblue, a global company that provides innovative solutions for navigation, positioning and underwater imaging, are combining forces to conduct the first manned submersible expedition to the wreck of the RMS *Titanic* since 2005. iXblue's Phins 6000 inertial navigation system and Posidonia USBL positioning system will both be used for the accurate and reliable navigation and positioning of OceanGate's 'Titan', the newest addition to the company's fleet of deep-sea manned submersibles and the first privately owned manned submersible capable of reaching 'Titanic' depths.

▶ ***https://bit.ly/2GrdrCg***



▲ *OceanGate's Titan.*

Vattenfall Procures OceanWise Raster Charts XL



▲ *Raster Chart XL.*

Vattenfall, the Swedish energy group, has procured OceanWise Raster Charts XL (eXcluding Land) as a seamless Web Map Tile Service (WMTS) for Northern Europe. Based on standard nautical charts, and therefore with a familiar look and feel, Raster Charts XL are marine charts which have had all the land and other non-marine features removed. Meta-features such as scale bars, source data diagrams and title blocks have been removed meaning they no longer hide more useful information. Removing the land means Vattenfall can combine the WMTS with its own sources of land mapping data to give improved coverage in the coastal zone. Raster Charts XL have been developed by OceanWise in response to the increasing requirement for high-level, relevant and more accurate marine mapping data.

▶ ***https://bit.ly/2rO1eDk***

Change of Ownership at Geo Plus

▲ *The Geo focus vessel.*

On 17 April 2018, Patrick Defilet, former COO of the Dutch company Geo Plus B.V., took over the business from the founding owners. Geo Plus was founded in 1994 by Jan Loots and his wife Stijnie Veendorp. The company has a long and successful track record and will be celebrating its 25th anniversary in 2019. Back in 1994 Jan and Stijnie started a land survey company in the northern region of the Netherlands. Due to success, Geo Plus expanded quickly to 25 employees with activities throughout the world. The first hydrographic activities followed quickly by buying a small inland vessel. In 2007, Geo Plus started its investment programme for building dedicated survey vessels. By 2012, an impressive fleet of 7 specialised survey vessels had been established, with the 35-metre hybrid DP1 'Geo Focus' as flagship. In 2012, the management also decided to focus entirely on hydrography and sold the land survey activities. A strategic decision to stop executing their own hydrographic surveys followed in 2015.

▶ ***https://bit.ly/2La8C42***

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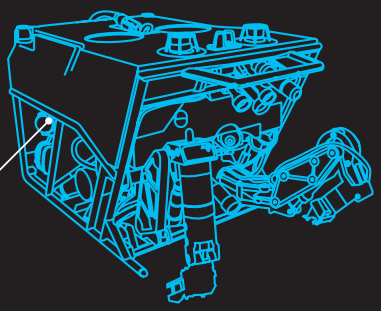

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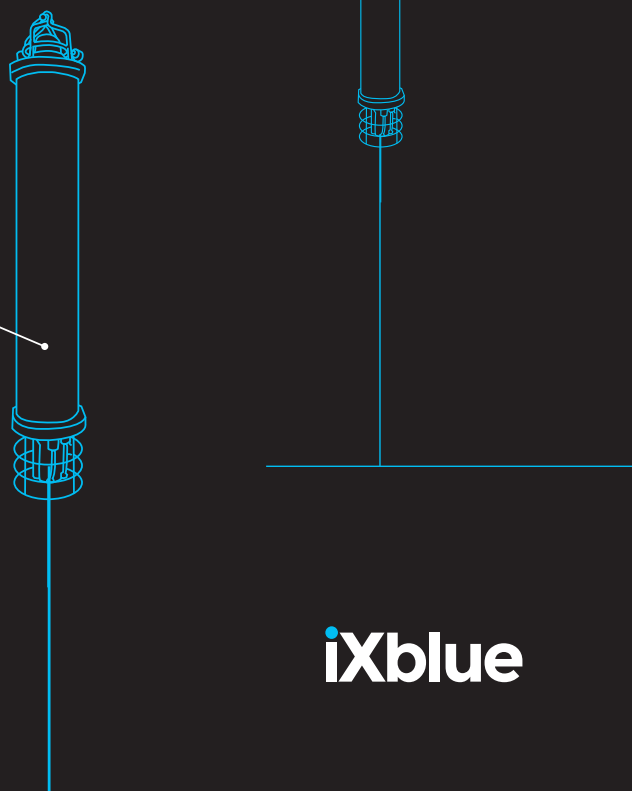
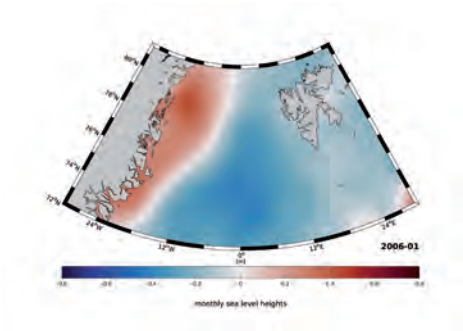


iXblue

Virtual Contact Lenses for Radar Satellites Improve Sea Level Measurements



▲ *The ocean east of Greenland.*

Radar satellites supply the data used to map sea levels and ocean currents. However, up until now, the radar's 'eyes' have been blind where the oceans are covered by ice. Researchers at the Technical University of Munich (TUM) have now developed a new analysis method to solve this problem. "The melting of the polar ice cap would have a drastic effect: sea level would rise by several metres around the world, impacting hundreds of millions of people who live close to coasts. This means one of the most important questions of our time is how climate change is affecting the polar regions", explained Dr Marcello Passaro of the TUM German Geodetic Research Institute.

▶ ***https://bit.ly/2rM5S4O***

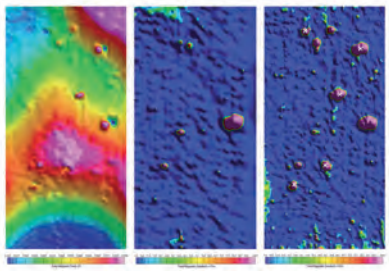
MacArtney Supplies System Solutions to German Geo Group

MacArtney Germany has effected the supply, installation and setting-to-work of several multibeam echo sounder systems as well as navigation equipment for hydrographic survey applications. The turnkey, customer-specific concept includes installation and training in hardware and software to support Geo Group, Germany, in mapping subsea areas. Being an internationally operating company providing solutions ranging from classic geoengineering services onshore to special tasks offshore, the Geo Group consists of 18 subsidiaries in Germany and Poland. The deliveries made by MacArtney have been distributed to four Geo subsidiaries. Geo Ingenieurservice Süd has taken delivery of Teledyne Reson SeaBat T50-P, SBG Ekinox2D, Valeport SVP, QINSy Survey. These products are applied on board a small vessel for surveys in small lakes and rivers.

▶ ***https://bit.ly/2wQhPv8***

▲ *Geo Group survey vessel.*

Marine Magnetics' Explorer Magnetometer Integrated with Gavia AUV



▲ *Total field, pre-seeded and post-seeded.*

Teledyne Gavia, manufacturer of the Gavia autonomous underwater vehicle (AUV), has announced the integration of Marine Magnetics' Explorer AUV magnetometer. The Explorer AUV is a high-accuracy omnidirectional sensor which is towed behind the vehicle, allowing it to operate outside the AUV's magnetic signature. The Explorer's exceptional accuracy and sensitivity, small size, low noise and minimal power requirements make it a highly valuable tool that is ideally suited for use with AUVs. Dynamic and static testing of the Gavia AUV was conducted at Marine Magnetics' facility in Canada and near Teledyne Gavia's manufacturing facility in Kopavogur, Iceland to validate that the Explorer could measure variations in the magnetic field, rather than the influence of the Gavia moving through the water column. The trial ensured that the data was accurate and free of heading error that might obscure small targets.

▶ ***https://bit.ly/2IQ4ibW***

Falcon ROV to Hunt Ocean Trackers

▲ *Dalhousie team with the newly delivered Falcon.*

A Saab Seaeye Falcon underwater robotic vehicle is helping to find lost aquatic animal tracking stations in oceans around the world. The Ocean Tracking Network (OTN) based at Canada's Dalhousie University will deploy the Falcon to recover acoustic tracking receivers missing from deployment sites on the seabed, principally in the waters of the Northwest Atlantic, the test hub of OTN and a hotspot for Atlantic ocean tracking research. OTN is the world's aquatic animal tracking network with over 2,000 acoustic tracking stations located across five oceans, spanning seven continents, and in freshwater systems that serve as highways to the oceans for species that migrate between fresh and salt waters.

▶ ***https://bit.ly/2Irw6UF***

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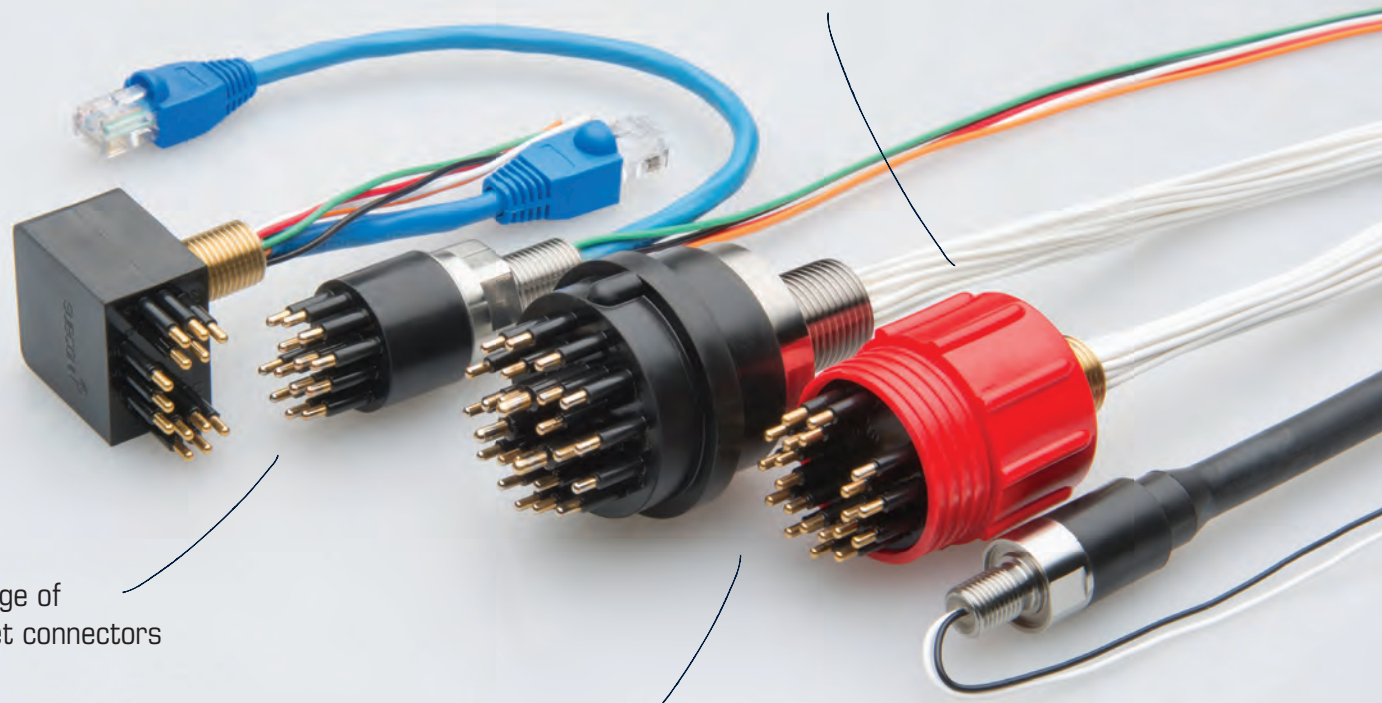

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New Partnership to Automate Offshore Platform Inspection

▲ *Seatooth Smart Clamp.*

WFS Technologies, the University of Aberdeen and OGIC have announced a joint technology project to design and build the world's first ExtremeEdge OLM (On-line Monitoring) system for offshore subsea and platform structures. At present, asset integrity and fatigue monitoring of North Sea offshore subsea structures is largely carried out 'manually' by divers or remotely operated vehicles (ROVs). This is not only hazardous and expensive, but also means that information on the integrity of the structure is not available in real-time. Furthermore, the quantity and quality of this data is insufficient to drive performance-enhancing big data analytic techniques. This can have an impact on production levels, or even lead to failure, due to sub-optimal predicative model correction and latency.

▶ ***https://bit.ly/2rMM6G5***

Satellite-derived Land/Seafloor Surface Models for Caribbean Disaster Recovery

TCarta, a global provider of marine geospatial products, has delivered pre- and post-disaster surface models for the Caribbean islands of Antigua and Barbuda for use in Hurricane Irma recovery efforts. The satellite-derived surface models contain seamless datasets of onshore elevation and offshore water-depth measurements for each island. The UK government commissioned the Hurricane Irma disaster mapping for Antigua and Barbuda as part of the Commonwealth Marine Economies Programme. TCarta won a competitive tender, which specifically requested end products derived from satellite imagery. By specifying satellite-derived data as the deliverable in its tender, the UK government acknowledged the speed and cost advantages this technology offers compared with traditional ship-borne surveying or airborne Lidar collection.

▶ ***https://bit.ly/2k4DyWM***

▲ *Land and shallow-water terrain model of Antigua.*

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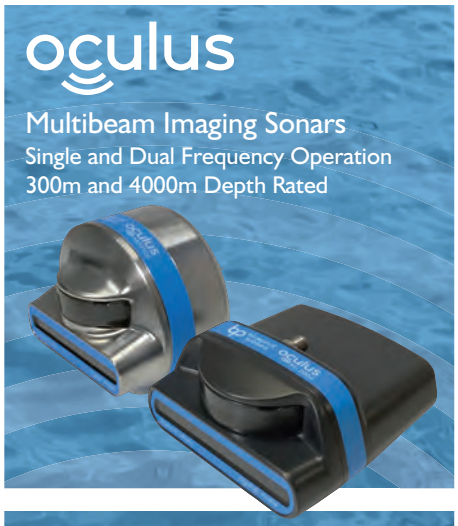

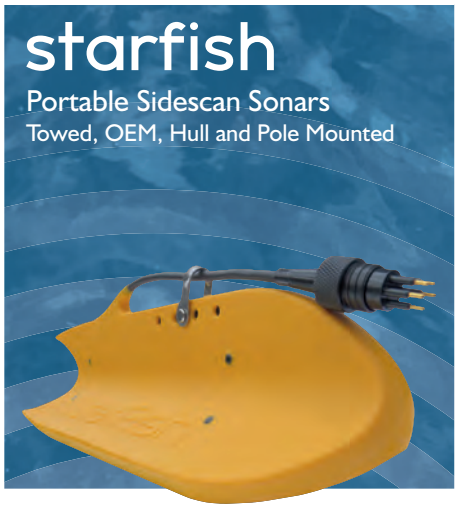

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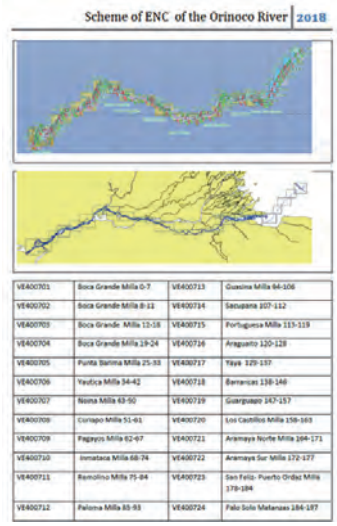
RTsys Uses Acoustical Detection to Characterise Nature of Surface Sediments

▲ *INSEA2.*

How can you study seafloor sediments simply, quickly and without taking samples? RTsys answers this question with acoustics. The French company, a specialist in underwater electronics and acoustics, has perfected INSEA (INvestigation of SEdiments by Acoustics), a sound velocity meter intended for studying sediments. INSEA is a portable sound velocity meter that can easily take measurements in situ in all types of sediments. It offers an alternative to sampling (coring, grab bucket, rake, etc.) that can be destructive, with a speed advantage as the analysis is performed in place and not in a laboratory. The first version of INSEA, created in partnership with the Maree company, is already five years old. INSEA2, released in 2016, has been considerably improved.

▶ ***https://bit.ly/2k1onOm***

ENCs of Orinoco River in Venezuela



▲ *Scheme of the ENC of the Orinoco River.*

The Service of Hydrography, Oceanography, Meteorology and Nautical Charting (SHN) of the Venezuelan Navy recently initiated a series of tasks aimed at guaranteeing the safety of navigation along Venezuela's main river navigation route. In an initial phase, 24 ENCs have been produced for the Boca Grande-Matanzas section (from mile 0 to mile 198) of the Orinoco River. This decision stemmed from the large volume of traffic of large vessels and the geostrategic significance of the waterway. Both of these factors are expected to increase in importance in the near future as the economic boom continues to stimulate the export of products and the movement of raw materials to all parts of the world. The SHN is keen to shoulder its responsibility for the timely publication, dissemination and maintenance of nautical cartography in order to safeguard the safety of navigation in the aquatic spaces of the Republic of Venezuela, which is a signatory to the International Convention for the Safety of Human Life at Sea (SOLAS).

▶ ***https://bit.ly/2Il8p6A***

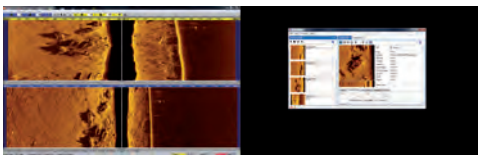
Riptide Autonomous Solutions and Draper Deliver Maritime Open Architecture Autonomy

▲ *Ripide Micro-UUV.*

Riptide Autonomous Solutions and Draper have agreed to implement maritime open architecture autonomy (MOAA) on all Riptide unmanned undersea vehicles (UUVs) delivered to the US government. Draper developed MOAA for the US government as an extensible open architecture framework for autonomous mission controllers for autonomous undersea vehicles (AUVs). MOAA capabilities have been demonstrated at-sea on multiple AUV classes with capabilities applicable to various undersea mission areas. This work represents millions of dollars of investment and decades of research and development.

▶ ***https://bit.ly/2IrvLks***

EdgeTech Releases New Side-scan Sonar Software for Search & Recovery



▲ *EdgeTech 4125-SAR system.*

EdgeTech, specialised in high-resolution sonar imaging systems and underwater technology, has launched a new side-scan sonar software package: Discover Blue. Discover Blue was developed specifically for police organisations, fire departments, dive teams and other groups that utilise side-scan sonar systems for search and recovery (SAR) efforts. Developed specifically for this community, the software offers a number of features that are only available with Discover Blue. Discover Blue side-scan sonar software offers the first ever Target Adaptive Software. This innovative software feature allows the sonar operator to select a target type from a list of common underwater targets. Then, it automatically configures the side-scan sonar system with the best settings to aid the operator in utilising the sonar to locate the target of interest in the most effective and efficient manner.

▶ ***https://bit.ly/2IHYkGr***

Airobotics Joins Israel's New Seaport Project Partnership

▲ *Airobotics drone mapping for the new seaport project.*

Airobotics, the Israeli startup that built the world's first fully automated drone, has announced it is partnering with Shapir-Ashtrom. The two companies will be working together to survey the construction of Haifa's new seaport, 'Gulf Port', intended to further develop Israel's coastline areas and increase maritime traffic and international commerce. The project includes construction of breakwaters and piers, as well as dredging and reclamation. Shapir-Ashtrom, a joint-venture, along with The Israel Ports Company, are building the Gulf Port, including dredging and reclamation and the construction of breakwaters and piers. The port will be 810 acres and be able to contain 1.1 million containers per year. Airobotics has applied its drone missions to assist in surveying reclamation areas, monitoring breakwater construction and stockpile measurements, which increases construction accuracy and accessibility, while reducing production costs, and adhering to project timelines.

▶ ***https://bit.ly/2LmmOGX***

Enhancing Safe Autonomous Navigation at Sea Using Deep Learning Techniques

▲ *ASV Global SIMVEE project.*

ASV Global (ASV) is leading a new £1.2million research project in partnership with BMT to enhance the safety and reliability of autonomous navigation. The project team will use deep learning machine vision systems trained with a unique combination of simulated and real-world data.

Partially funded by Innovate UK, the UK's innovation agency, this project will enhance situational awareness enabling the unmanned surface vehicle (USV) to operate in extreme and congested marine environments. The Synthetic Imagery training for Machine Vision in Extreme Environments (SIMVEE) project will build upon ASV's existing, COLREGs cognisant, autonomous collision avoidance and path planning capability. The project will use BMT's REMBRANDT simulator to train and validate ASV Global's vision algorithms to detect and classify objects at sea.

▶ ***https://bit.ly/2IDGrwL***

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The Role of Hydrographic Offices

Bathymetric ENCs in Confined Waters

Electronic charts with greater scale and bathymetric content than any Hydrographic Office's ENC (equivalent to a paper nautical chart) are not a novelty for many ports around the world. Such charts are normally produced by Port Authorities and are used by marine pilots on the Portable Pilot Units (PPU). The Australian Hydrographic Office (AHO) has experimented with, and now published, High Density (HD) Bathymetric Electronic Navigation Charts (bENCs) for two ports, with more under development. These ENCs – like any other official ones – are available both to ships' crew using ECDIS and to Marine Pilots' PPUs. Why are High Density Bathymetric ENCs so important for the conduct of vessels in confined waters? Why is it so important that these ENCs become available to both ECDIS and PPUs? Before answering these two questions, it is necessary to understand the background of the Australian approach.

In 2015, a cruise ship operator had to determine the safety margins of its 260m long vessels navigating within the 90m wide channel that leads to the Port of Cairns (Fig. 1).

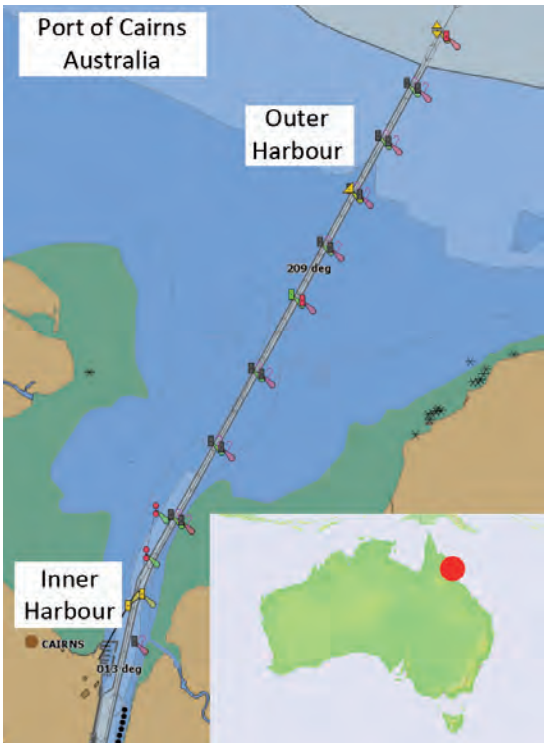


Figure 1: Port of Cairns - Harbour ENC AU5262X4.

A study was carried out at Smartship Australia, a ship simulator specialised in Port studies and training of marine pilots. During the study, ship captains and port pilots used a prototype of a High Density bathymetric Electronic Chart. The high density bathymetric content included 1m depth contour intervals and 50m spaced soundings based on survey data provided by the Port Authority.

The enhanced bathymetric content revealed significantly increased safety margins. With the same safety depth of 8m, the enhanced detail revealed a much wider navigable channel (Fig. 2) than the one perceived by looking only at the standard harbour ENC (Fig.3). Understanding of under-keel clearance is also improved. In fact, the standard ENC provides only an 8.3m maintained depth value that is associated to the dredged area that covers most of the outer harbour.

In a previous simulator based port study carried out in 2010, the lack of enhanced bathymetric content for the same turn between outer and inner harbour became one of the key factors in deciding that the same class of cruise ship could not enter the port with an adequate safety margin. The decision was reconsidered as a result of the 2015 study, and these larger vessels are now able to enter Cairns. This proves the commercial relevance of High Density bathymetric ENCs.

Proof of Concept

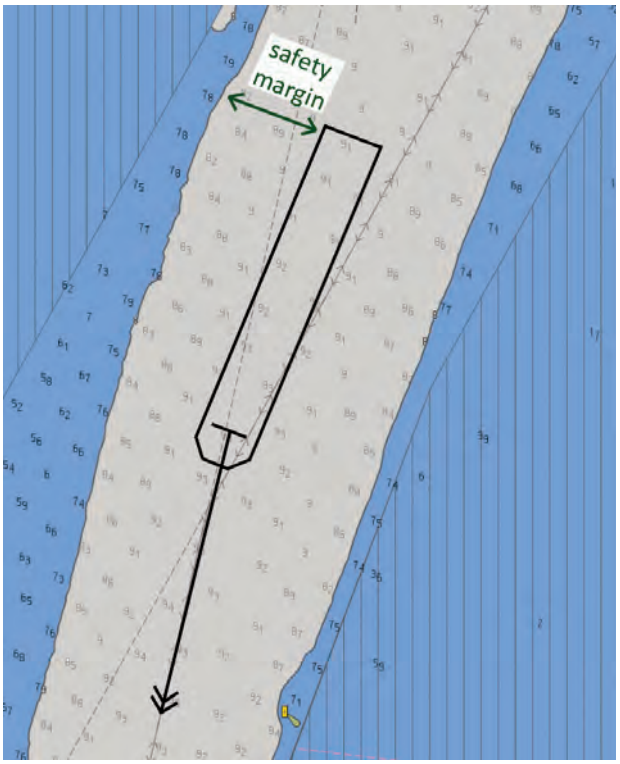
The AHO decided to use the Port of Cairns as proof of concept, and in 2017 two bENCs were published – one for the outer harbour and one for the inner harbour. They were both developed to meet specific Port Authority requirements.

The main features of these bENCs included:

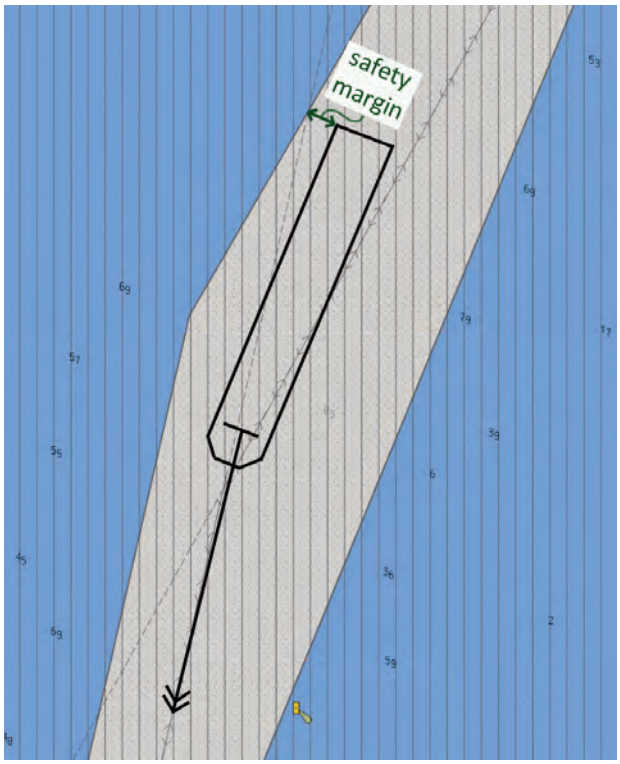
- navigation purpose "6"
- 1:2500 compilation scale
- coverage based on the availability of high density survey data
- depth contours at 1m interval, soundings with a 50m spacing, and essential Navaids

Navigation Purpose

The AHO idea is to create a new series of navigation purpose "6" bENC to overlay the exiting series of navigation purpose "5" harbour ENCs. The new bENCs comply with the existing IHO S-57 standard, including not exceeding the existing 5MB data limit. File size is managed by limiting bENC coverage to channels and manoeuvring areas, with the harbour ENC providing remaining coverage in non-critical areas. Long channels are broken into multiple adjacent bENCs, with areas aligned to the port's survey areas and survey programme. This also allows the AHO to update each ENC simply as



▲ *Figure 2: bENC AU6CNS01 (overlaid on the harbour ENC).*



▲ *Figure 3: Harbour ENC AU5262X4.*

new surveys are received. In the case of Cairns, two adjacent bENCs were enough to cover the outer and the inner harbour (Fig.4 and Fig.5).

Compilation Scale

An ENC compilation scale of 1:2500 corresponds to a display range (i.e. half ECDIS/PPU screen size) of 250m. For the user this means the possibility to zoom in without over-scale indication (vertical lines) to a level where a 260-metre-long ship covers about half of the screen size (Fig.2 and Fig.3). More in general, the compilation scale of a bathymetric ENC can be adopted as a compromise between ship sizes and safety margins for the area of interest.

Coverage

The geographic coverage of the two bathymetric ENCs in Cairns was defined on the availability of suitable survey data provided by the Port Authority. To simplify updating, each bENC is also aligned to the limits of different repeat survey programmes by the Port Authority. In general, the coverage of bathymetric ENCs should include depths that are as shallow as the minimum draft of the ships calling a Port. This operational requirement needs to be balanced with the capability of the Port Authority to keep up to date the high density bathymetric surveys of the selected area. Surveys must be of a sufficient standard to allow full replacement of the existing bathymetric data for each area, rather than modifying existing data.

Depth Contours and Soundings

The two Cairns bENCs included depth contours at 1m interval and spot soundings with a spacing of 50m (Fig.2). The availability of depth contours at 1m interval (and their relative depth areas) made it possible to visualise grounding areas (on both ECDIS and PPUs) that were consistent with the 8m safety contour setting on ECDIS. This was based on a ship's draft of 8m, a tidal height of 2m and the estimated reduction of underkeel clearance due to hull-seabed interactions throughout the channel.

The dredged area covering most of the standard harbour ENC was replaced in the two bENCs by high density depth contours, soundings and depth areas. In 2017, the AHO carried out further consultation with key stakeholders and concluded that levels of detail would be limited to high density bathymetry and any other essential aids to navigation which lies within the coverage of the bENCs.

Finally, the risk of potential clutter on users' displays (due to the high density bathymetric content) was managed by the AHO by encoding the SCAMIN filtering attribute within the ENCs. This embedded filtering attribute – that allows ECDIS and PPUs users to visualise information gradually as they zoom in – was adjusted on the basis of marine pilots' feedback during simulation.

Conclusions

So, why are bENCs so important for the conduct of vessels in confined waters?

The first conceptual innovation of High Density Bathymetric ENCs is about giving the possibility to visualise safety margins with higher resolution than a standard harbour ENC.

The second conceptual innovation of Bathymetric ENCs is about providing more detailed information on deep soundings within navigable areas, which is an important piece of information to anticipate the effects of hull-seabed interactions. This was not possible by looking only at harbour ENC's dredged areas that usually cover most of the confined waters with single maintained depth values.

These two concepts bring ENCs to exceed the mere equivalence to paper charts and to take full advantage of high accuracy electronic navigation systems to monitor real-time ship's position and heading when safety margins are tight.

Why is it so important that bathymetric ENCs become available to both ECDIS and PPUs users?

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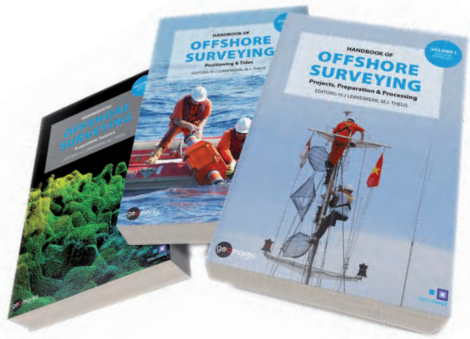

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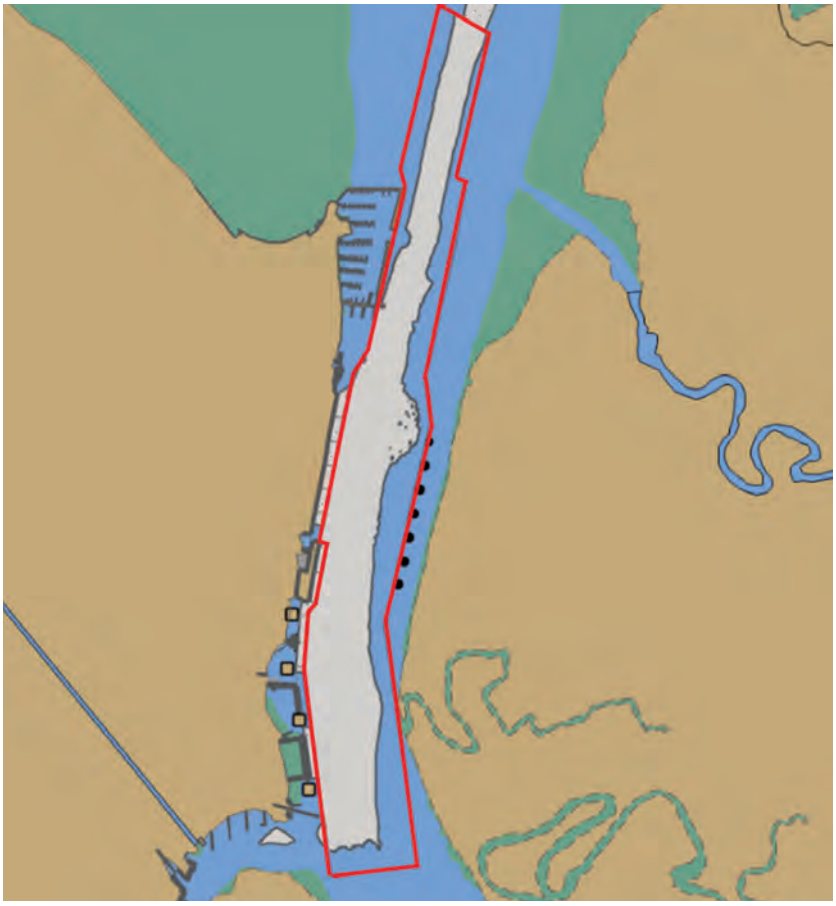
▲ *Figure 4: bENC AU6CNS01 (outer harbour).*



▲ *Figure 5: bENC AU6CNS02 (inner harbour).*

Because the risk of ever decreasing safety margins to conduct vessels in confined waters requires the ship's crew to be on the same page with the marine pilot, especially when safety margins are small. Sharing mental models is in fact the essence of Bridge Resource Management (BRM), whose ultimate aim is the prevention of accidents caused by intentions and/or actions not challenged in due time or not challenged at all. Bathymetric ENCs support one of BRM's essential components: the implementation of a 'pilotage plan' agreed between the ship's crew and the pilot.

In a recent paper of the IHO ENC Working Group (April 2018), the Australian Hydrographic Office has identified common pilotage plans as the justification for the production of High Density Bathymetric ENCs. This is a remarkable move towards the integration between Bridge Resource Management and electronic navigation in confined waters.

The Australian Hydrographic Office has succeeded in demonstrating that High Density Bathymetric ENCs can be created and maintained in S-57 format. The challenge ahead is managing new stakeholder requirements and re-prioritising charting activities by rationalising the existing paper chart portfolio and making as much use of cartographic automation as possible.

In order to manage stakeholder requirements, cartographers need to understand the demands of navigation in confined water, while users need to understand potential and constraints of existing IHO standards. In Australia, this mutual understanding was promoted during the numerous simulator-based training courses attended by marine pilots, harbour masters, ship's crew and AHO cartographers.

Other IHO Member States around the world may benefit from the Australian Hydrographic Office experience, which demonstrates how High Density Bathymetric ENCs can foster both commercial interests and safety of navigation.

Acknowledgements

In Australia, the idea of official electronic charts optimised for navigation in confined waters matured in 2015, but it dates back 15 years. Ravi Nijjer and Robert Ward worked relentlessly for the mutual understanding between key stakeholders, a critical factor for this achievement. ◀

Antonio Di Lieto is a senior instructor at CSMART, Carnival Corporation's Cruiseship Simulation Centre. He has sea-going experience as hydrographic surveyor (IHO cat A), Master of a survey ship and cruiseship officer. His experience as a simulator instructor matured at Smartship Australia, where he facilitated port development projects and Marine Pilots training courses.

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Mike Prince is the director National Charting Programme for the Australian Hydrographic Service. He served the Royal Australian Navy as hydrographic surveyor, navigator and commanding officer.

Alvaro Sanchez is the deputy director responsible for charting quality assurance, standards, and specifications at the Australian Hydrographic Office. Alvaro has more than 20 years of experience in navigation, hydrography and cartography from roles in the Uruguayan navy, the Uruguayan Hydrographic Office, and private industry and public service in Australia.

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Morphological Monitoring and Forecasting through Development of a Maintenance Management System

Proactive Dredging in the Dutch Wadden Sea

The navigation channels in the Dutch Wadden Sea require continuous maintenance due to unceasing sedimentation of sand and mud. In this article we describe the data management workflow and adopted technologies for a maintenance management system (MMS) used for morphological monitoring and forecasting of the various navigation channels. In 2016, the Dutch Department of Waterways and Public Works awarded a multiannual contract to contractor Gebroeders van der Lee to maintain the navigable waterways and harbours in the Dutch Wadden Sea, where HKV consultants supports the development, operation and maintenance of this MMS.

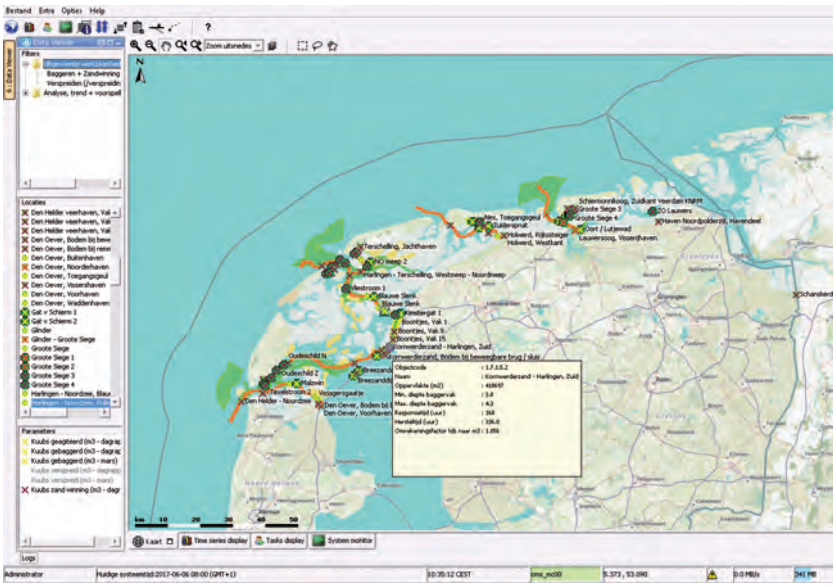
The challenge of working in these conditions is to find a balance between the strict limitations of the work in terms of ecology, but simultaneously the huge economic impact of improper maintenance of the channels. Therefore, it is of utmost importance to have continuous insight into the system, where adoption of the MMS results in the ability to pinpoint dredging activities, while reducing calamities and sharpening operational capabilities to reduce and optimise costs.

Study Area

The Dutch Wadden Sea has been on the UNESCO's World Heritage List since 2009 and is therefore a protected nature reserve. It is a highly dynamic system in terms of biodiversity and morphology due to tidal effects. The area is famous for its rich flora and fauna and there are multiple designated protected locations for mussel seed banks, shell production sites and seal reserves.

There is also economic activity in the region and multiple cables and pipelines are registered to be in place for data and telecom, electricity, gas and liquids, with a total length of nearly 850 kilometres. As numerous islands are also present, five of which are accessible for the general public, the region is also of great recreational value.

These islands are connected to the mainland by 11 harbours and 5 main navigation channels with a total length of 350 kilometres (see Figure 1). The channels are split into 100 dredge fields and 40 dumping locations, with each dredge field having a unique declared minimum and maximum bed level.

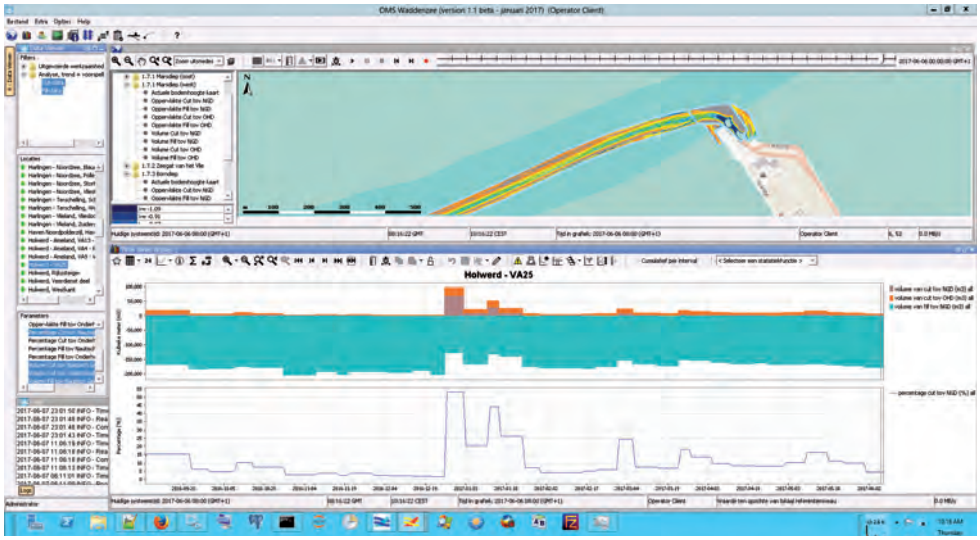


▲ *Figure 1: Geographical overview map of the MMS where location specific information is visible through tooltips.*

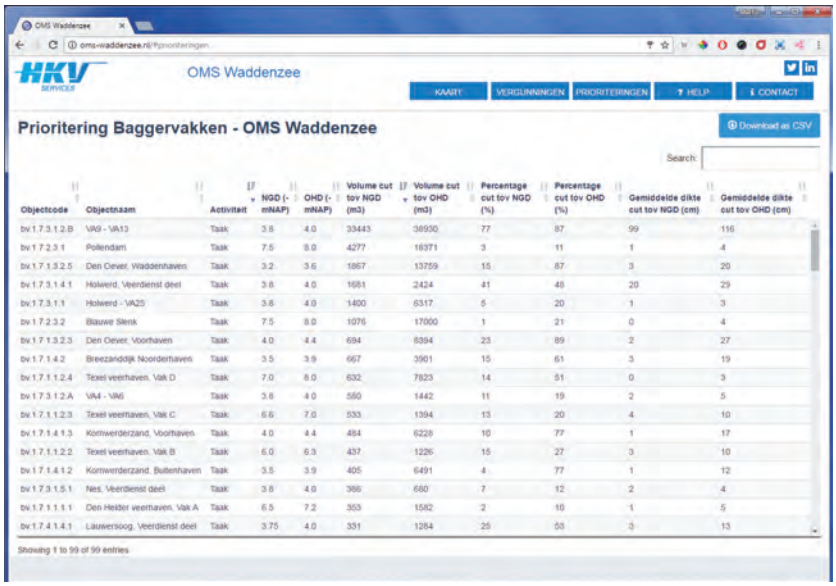
Materials

The vessels adopted by the contractor for its maintenance activities are a dredge vessel, trailing suction hopper dredger, plough vessel, water injection vessel and a survey vessel equipped with multibeam echo sounders.

While some surveys are conducted every other month, such as the dredge fields with little dynamics in the seabed changes, others require



▲ *Figure 2: Derivative results from the daily computed bed level used for creating the weekly dredging planning.*



▲ *Figure 3: Overview of the daily regenerated prioritisation in interactive tabular form sorted by volumes to dredge to comply with minimal required depths per location.*

a highly intensive weekly survey frequency as these dredge fields might contain significant shoaling. The multiple ferries active on the different navigation channels provide or will provide depth level measurements using single-beam echo sounders.
In parallel, the trailing suction hopper dredger is equipped with a Monitoring And Registration System (MARS) capable of automated measurement of dredged and dispersed volumes Tons Dry Solids (TDS) for every trip. Each of these numerical measurements are entered into the MMS servers in a standardised fashion so they can be processed automatically.

Monitoring of the Actual Bed Level

All multibeam echo sounder data presented to the MMS server are validated and have a spatial resolution of 1 by 1 metre. As the exact location of measurements is unknown from the textual description, all echo sounder data are processed and mapped to a custom-made tiling scheme overcoming spatial and temporal variances. The tile scheme follows the navigation channels including a minimal buffer of 50 metres. In total, 500 tiles are currently defined and updated daily (1 tile ~ 500x500 pixels x 4 byte (float32) = 1MB/day/tile). In the daily process of creating a complete coverage of the most actual bed level for all navigation channels we consider all provided echo sounder data in the last 30 days, since the process of data acquisition and passing all validation checks is, by contract, allowed to take a number of weeks. In other words, computation of the actual bed level is a daily process that retroactively considers changes in the last 30 days. Using the actual bed level several derivatives are computed (see Figure 2) such as the volume, percentage and average depth above and below the minimum and maximum declared bed level. This is the main input data for planning and monitoring the dredging activities and reports for the contractor's clients.

Forecasting of the Bed Level 10 days Ahead

Multiple approaches have been considered for forecasting.
Firstly, we tried to adopt a trend analysis of data reported by the previous contractor. These data could not be validated by its source and was aggregated to monthly values. For computation of speed of shoaling in cm/day this is insufficient. Since the data is based on monthly information it is hard to correlate the dredged volumes with wind directions.

Secondly, we tried to adopt an existing hydrodynamic sludge shoaling model (SOBEK 3D). This model was calibrated for January-March 2009, where the grid had a spatial resolution of 400 metres. Using this model we tried to find a sludge shoaling speed using the dynamic variables wind speed, wind direction and reported dredged volumes.
We were able to downscale the results to 200 by 200 metre spatial resolution, but this is still too coarse when comparing these with the measured spatial resolution of 1 metre from current multibeam echo sounders. The period of 3 months (90 data points) is too short to cover all wind directions and wind speed has no direct influence on the shoaling speed; it is mainly the direction of wind that is important.

Thirdly, we carried out the trend analyses again based on validated data collected within the first year of the current contractor where dredged and dispersed volumes of each trip were recorded and bed level measurements were available with a spatial resolution of 1 metre. The results showed that we still have insufficient data to create regressions for each wind direction. A southwesterly wind is the most dominant wind direction for shoaling, but the quality of the prediction and direction (increasing or decreasing shoaling trend by increasing wind power) still differs for the 100 analysed dredge locations.

Automatic Report Generation and Permit Monitoring

Multiple automatic report functionalities have been created to assist the contractors in fulfilling

their obliged duties regarding their clients. The following reports were reported through notification emails:

- Recently measured echo sounder data, including links to the raw data.
- Weekly overviews in chart and tabular format of the dredged and dispersed volumes for each location.
- Monthly overviews of all registered trips and automatic generation of CAD layout (A0) of raw echo sounder data.

Apart from the automatically generated reports and validity of permits, the collected dredged and dispersed volumes are also validated against currently known maximums mentioned in the permits, where a warning is provided if the dumping locations reach their maximum based on the permit allowed volume.

All dredge fields and dumping locations are subject to multiple permit licenses regarding the allowance, quality and quantity of dredging activities (both loading and dumping). Since all these permits are provided by a number of authoritative departments, where each permit has a different expiry date, it is important to provide warnings in time if a permit is subject to renewal.

Communication with Stakeholders

As all the data from multiple sources are processed, analysed, distributed and visualised from a centralised repository the system also becomes an important place for stakeholders other than the specialists hired by the contractor. We therefore set up a web-based interactive dashboard with multiple derived datasets used for viewing purposes.

The dashboard is currently very useful for:

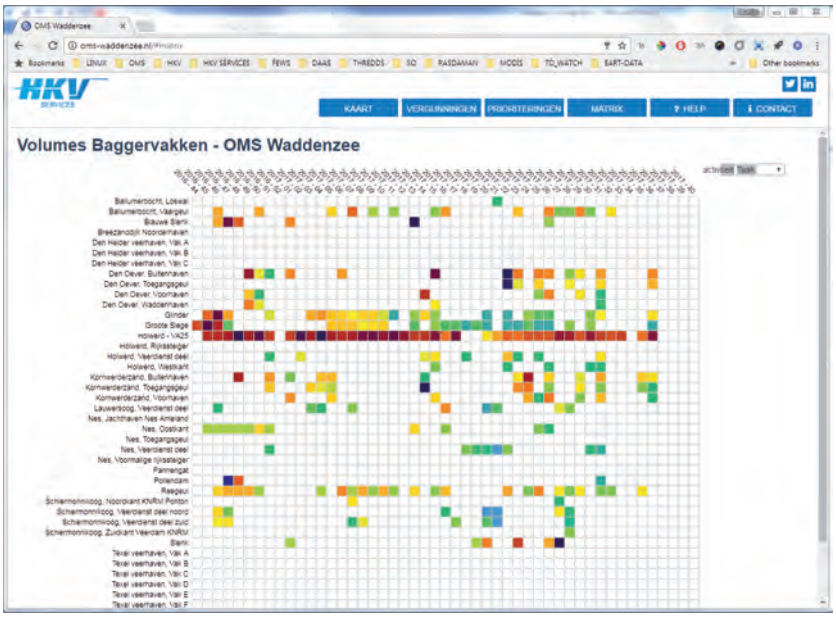
- Creating the weekly planning by daily recalculation of the priorities based on the newly collected bathymetrical information that is translated into volumes/percentages/ average thickness based on the minimum and maximum declared bed level depth of each dredge field (see Figure 3).
- The people on board of the dredge vessels to identity in detail where in the dredge field most detail should be given based on the interactive single metre spatial resolution map provided by means of an optimised web mapping service (WMS, Figure 4) for both the maximum and minimum declared bed level depth ('nautical guaranteed depth' and 'maintenance depth' respectively).
- The contractor's client to have quick insight into the weekly aggregated dredged and dispersed volumes for all locations as shown in Figure 5.

Conclusion

The developed Maintenance Management System provides capabilities to proactively pinpoint dredge activities, reducing both calamities and total dredged volumes in the Dutch Wadden Sea. Detailed tracking of permits, and the dredged and dispersed volumes sharpen operation capabilities and reduce and optimise costs. The MMS has been in operation for nearly two years and provides essential information for day-to-day activities on the dredge vessels, week-to-week activities such as planning and month-to-month activities such as detailed overviews of dredged and dispersed volumes.

The adopted method for the developed MMS presents capability of producing alerts and warnings before bottlenecks become critical, where the interactive dashboard is received with great interest by all actors within the project. Forecast information is still subject to further investigation but the confidence for the system is likely to increase year by year as more data becomes available. Future developments will focus on improved automatic report generation and the adoption of remote sensing imagery for turbid plume detection, as a proxy for shoaling. ◀

▲ *Figure 4: The most actual bed level subtracted the declared maximum bed levels depth visualised spatially in very high resolution accessible by hand-held devices such as smartphones.*



▲ *Figure 5: Interactive matrix overview within the dashboard presenting aggregated dredged volumes with dredge fields on the y-axis and weeks on the x-axis.*

Mattijn van Hoek graduated in the field of Geographical Information Management from Cranfield University in 2011. In 2016, he completed his PhD at the Earth Observation for Water Cycle department within the Institute of Remote Sensing and Digital Earth of the Chinese Academy of Sciences. At HKV Consultants, Van Hoek is a consultant in the advisory group products and services. He is involved in a broad range of projects relating to data and information for operational water management. He implements early-warning, maintenance management, decision support and water information systems for governments and contractors. In addition, he is involved in research on satellite-based drought and evapotranspiration and the optimisation of presenting web-based geographical information.
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Historical Overview

Hydrographic education in Hamburg started in 1985 at the Hamburg University of Applied Science (HUAS) with three additional semesters of Hydrography and one practical semester to the existing surveying programme of six semesters. After completing the five years, the students received a diploma in 'Vermessungswesen und Hydrographie' (Surveying Engineering and Hydrography). In 1990, the programme was first recognised by the FIG/IHO/ICA International Board on

First Semester *30 CP*	**Tutorial Land Surveying**	**Engineering Mathematics** *2.5 CP*	**Software and Interface Technology** Software and Interface Technology *5 CP*	**GI Science** Introduction into GI Science *2.5 CP*	**Basics of Hydrography** Determination of Positions and Water Depth *1.5 CP* Practical Course 1 *1 CP*	**Hydrographic Data Acquisition and Processing** Underwater Acoustics *3 CP* Hydrographic Data Processing *2.5 CP* Practical Course 2 *1 CP*	**Marine Environment** Marine Meteorology *3 CP* Legal Aspects *2 CP*	**GNSS** GNSS *2.5 CP*	**Project Management** Project Management – Lecture *2.5 CP*
Second Semester *30 CP*	**Terrestrial Laser Scanning 1** Terrestrial Laser Scanning 1 *2.5 CP*	**Integrated Navigation** Integrated Navigation *5 CP*	**Higher Geodesy** Higher Geodesy *5 CP*	**Spatial Data Analysis** Geostatistics *2.5 CP* Digital Elevation Models *2.5 CP*	**Advanced Hydrography** Advanced Hydrography *3 CP* Practical Course 3 *2 CP*	**[Q]Studies** [Q]Studies 1 *2.5 CP* [Q]Studies 2 *2.5 CP*			Project Management – Seminar *2.5 CP*
Third Semester *30 CP*	**Nautical Charting** Nautical Charting *2.5 CP*	**Navigation in Hydrography** Nautical Science *1.5 CP* Electronic Chart Display and Information System *1 CP*	**Oceanography** Physical Oceanography and Tides *3 CP* Oceanographic Data Processing *2 CP*	**Marine Geology/ Geophysics** Geology/ Geomorphology *1CP* Seismics *2 CP* Magnetics and Gravimetry *2 CP*	**Hydrographic Practice** Supplementary Field Training/ Practical Course *5 CP* Quality Management *2.5 CP*	**LIDAR and Remote Sensing** LIDAR and Remote Sensing *2.5 CP*	**Interdisciplinary Project** Interdisciplinary Project *5 CP*		
Fourth Semester *30 CP*	**Master Thesis** Master Thesis and final examination *30 CP*								

▲ *Figure 1: Programme structure.*

▲ *Figure 2: Students during practical courses and the final field training.*

Standard of Competence for Hydrographic Surveyors and Nautical Cartographers (IBCS) as a Category A programme with 'Specialisation in Nautical Charting'. In 2000, a new curriculum was established introducing the 'Hydrography' Master's programme that is taught in English. The MSc degree could be completed in a total of five years (including the Bachelor degree).

In January 2006, HafenCity University (HCU) was founded by the Free and Hanseatic City of Hamburg, merging four departments from three state-owned universities (HUAS, Technical University Hamburg-Harburg, and University of Fine Arts). HCU brings all the areas of study and research needed for the 'built environment' together under one roof. Apart from an MSc in Geodesy and Geoinformatics (of which hydrography is a specializations) the following programmes are also offered at HCU: Architecture, Civil Engineering, Urban Planning, Metropolitan Culture, Urban Design, and Resource Efficiency in Architecture and Planning (REAP). HCU aims to improve interdisciplinary innovation in teaching, research and development of all building and planning related disciplines. In 2014, the HCU moved to its new building in Hamburg. In January 2018, the university had a total of 2397 students, 50 professors and 112 research and teaching associates.

Programme Structure

The MSc in Geodesy and Geoinformatics offers three specialisations: Geodetic Measurement Technology, Geographical Information Technology and Hydrography. The courses are taught in English and as modules (Figure 1). They consist of compulsory and optional modules in the first three semesters followed by a Master's thesis in the final fourth semester. The modules of each semester add up to 30 European credit transfer system points (ECTS), with an average 27 study hours each, resulting in an overall workload for the students of 120 ECTS for the entire two-year programme.

The interdisciplinary approach of the HCU is reflected in the programme structure. Some courses are taught together with the other specialisations of the Geodesy and Geoinformatics programme (e.g. Terrestrial Laser Scanning, Geo-Information Science, or Integrated Navigation). In the same way, all students of the Master's programme must enrol in an introductory lecture on Hydrography in the first semester to gain a basic understanding of Hydrography.

Interdisciplinary and transdisciplinary topics are also an option offered in the Interdisciplinary Project in the third semester at the interface of various education programmes. Within these modules, the students of different programmes work together to gain an insight into the research methods of other disciplines and improve their communication skills within an interdisciplinary team. The Project Management lecture, as part of the BASICS course, conveys competencies and soft skills that enable students to use and critically examine classical project management instruments.

Practical Exercises

The hydrographic modules include exercises and practical courses (Figure 2), which give students the opportunity to apply the previously gained theoretical knowledge within a practical environment. In the third semester, the final

field project (Supplementary Field Training) takes place, where students carry out complex hydrographic projects in small groups. The individual project tasks vary slightly from year to year, but always include the following components: project planning, preparation, data-acquisition, processing and evaluation of the system performance.

Most of the systems and vessels currently used for the practical exercises belong to government authorities or institutes. However, a new survey vessel is under construction (Figure 3). The vessel will have a length of about 8m and a width of 2.5m so that it can be trailered to waters of interest. The vessel will be optimised for shallow-water applications and will be equipped with a state of the art multibeam and single-beam echo sounder, a sub-bottom profiler, side-scan sonar, magnetometer, inertial navigation system and GNSS positioning. These systems will be modular so that they can be easily installed and exchanged depending on the task of a practical training or research topic. Borrowed equipment for detailed investigation or specific tasks can also be easily integrated into the vessel system. There will be space for up to four students in the cabin. In addition to practical training sessions for the students, the survey vessel will also be used for research purposes.

Further to the new survey vessel with its high-end hydrographic equipment, some low-cost systems (e.g. single frequency single beam echo sounders, fishfinders) are owned by the HCU. The university also owns an OpenROV, which is a small scale, open source ROV assembled by students and used for various projects.

Projects and Research

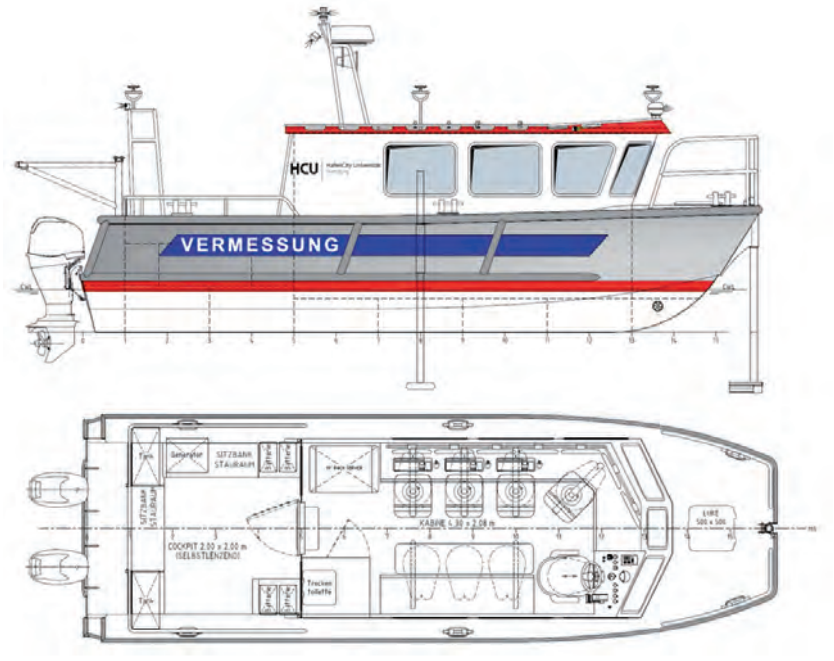
HCU closely cooperates with different institutes and authorities dealing with Hydrography or Bathymetry, such as the Hydrographic Agency of Germany (BSH), the Alfred Wegener Institute (AWI), the Hamburg Port Authority (HPA) and various companies. The students have the opportunity to get internships or write their thesis in cooperation with these partners.
As an example of such a partner project, HCU, in collaboration with the German newspaper WELT, developed dynamic and interactive 3D views and videos of the River Elbe for public information purposes in news media. These have been integrated into a multimedia special that aims to give people better insight into the complex topic of the fairway adjustment of the Elbe.
Recently, HCU has been contracted by the BGR (Bundesanstalt für Geowissenschaften und Rohstoffe / Federal Institute for Geoscience and Natural Resources) in the INDEX2017 (Indian Ocean Exploration) project. The project deals with marine resource assessment in the German licence area in the Indian Ocean. In addition to supporting the BGR during data-acquisition on the SO259 INDEX2017 cruise of the German research vessel *Sonne*, the HCU focuses on processing, analysing and investigating the data collected with the deep-towed bathymetry sled HOMESIDE and the ship-based multibeam echo sounder data.

Entry Requirements and Statistics

Applicants for the Master's course must have completed a Bachelor's or Diploma degree in Hydrography, Geodesy and Geoinformatics, Geomatics, or a related geo-scientific technical or engineering-oriented degree programme. A satisfactory score on the Bachelor's examination is required. Applicants whose first language is not English must provide evidence of their English language ability.
The programme starts every October. The number of students is limited to a total of 16. The number of first-year students within the Hydrography specialisation varied between eight and fifteen over the last few years. A total of 42 students from 21 different countries (in October 2016) are enrolled in the programme.

Further reading

River Elbe in 3D: http://www.welt.de/lesestueck/2016/elbvertiefung. ◂



▲ *Figure 3: Draft of HCU's planned survey vessel.*

Prof. Dr.-Ing. Harald Sternberg was trained as a surveyor by the German Army (Bundeswehr). He did his doctorate on surveying in 2001 and has been lecturing Geodesy and Hydrography at the HafenCity University since 2001. He has been vice president for Studies and Teaching at HafenCity University since 2009.
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Tanja Dufek completed her Master's in Geomatics at HafenCity University in 2012 and has been employed as a Student Assistant at the Alfred Wegener Institute for Polar and Marine Research. After a short period with Fugro OSAE she became a research and teaching associate at HafenCity University in 2014.
✉ tanja.dufek@hcu-hamburg.de

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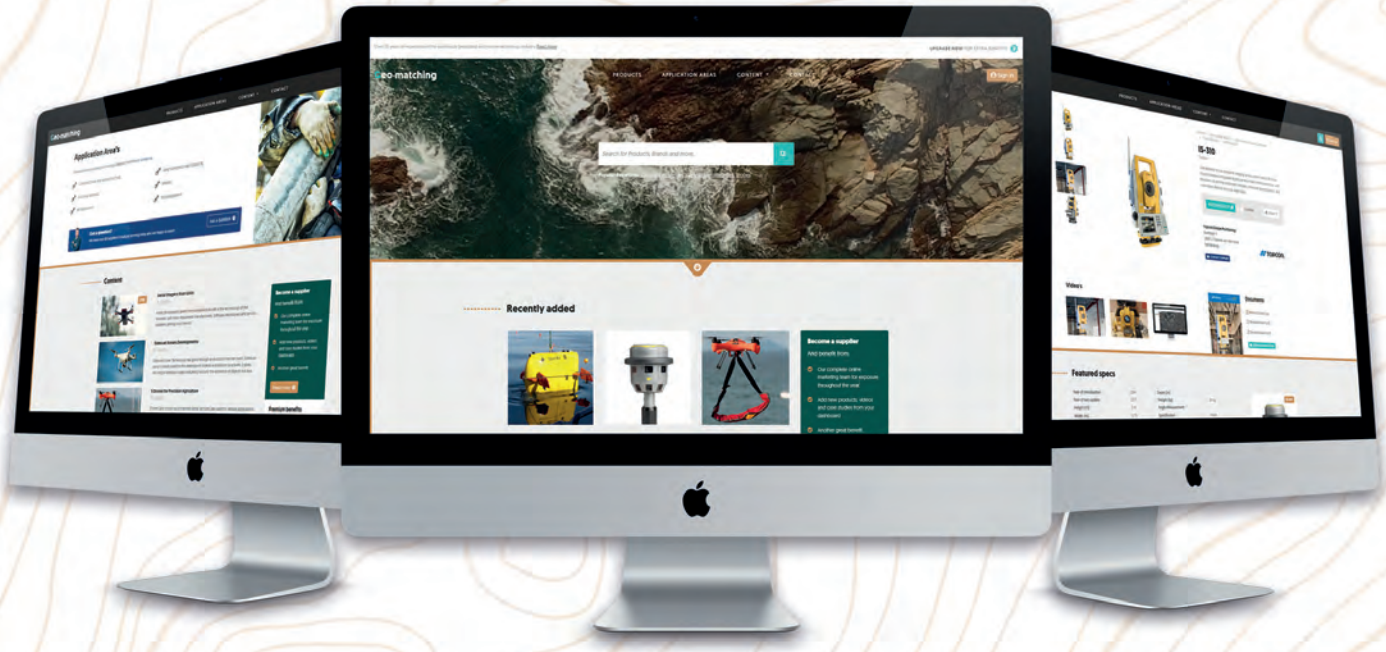

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ENC Production to the Max

Port of Rotterdam – Innovative Hydrography

The Port of Rotterdam is a leading global port and by far the largest seaport in Europe. The port is situated in the Rhine delta and with its direct connection to Europe's largest industrial region, the Ruhr area, it is a key entry point to the European market. Understanding the depths throughout the 40km of the port's waterways is critical to the day-to-day running of the port. Because the Netherlands Hydrographic Office only produces Electronic Navigation Charts (ENCs) for harbour usage, the port investigated the possibility of producing 'Berthing' ENCs containing high density depth data to support decision-making within the port.

The Port of Rotterdam started a pilot project to produce S-57 ENCs of the area covered by the port more than ten years ago. The goal of this project was to produce daily high density ENC updates that incorporated daily hydrographic surveys of the area. This product was to contribute to efficient port planning by taking advantages of accurate depth data and available 'over-depth' in the port's basins and fairways, which minimise under-keel clearance (UKC) requirements. The 'over-depth' is the vertical distance between maintenance and actual dredged depths when the actual bottom is deeper than the maintenance depth.

It took nearly three years to take the high density ENC into production due to many conversion tools that had to be developed and performance problems in creating depth areas at a contour interval of only 10cm.

In 2013, the port partnered with Esri to implement PortMaps. PortMaps, built by using the ArcGIS platform, is not only an asset management system, but also provides the framework for hydrographic production. The core element of PortMaps is the ENC production module built around QPS Qarto (Figure 1). PortMaps went live in 2015. Nowadays, harbour masters, asset managers and marine pilots have access to the data needed via Esri Maritime Chart Server (MCS). MCS provides the port with the most recent ENCs available, including ENCs created with depth information surveyed that same day. The port operates a fleet of dredgers to keep the port open all year and for safe navigation. In addition, two survey vessels, equipped with the latest multibeam echo sounder systems, survey the port. It is not uncommon for three surveys to be conducted per day.

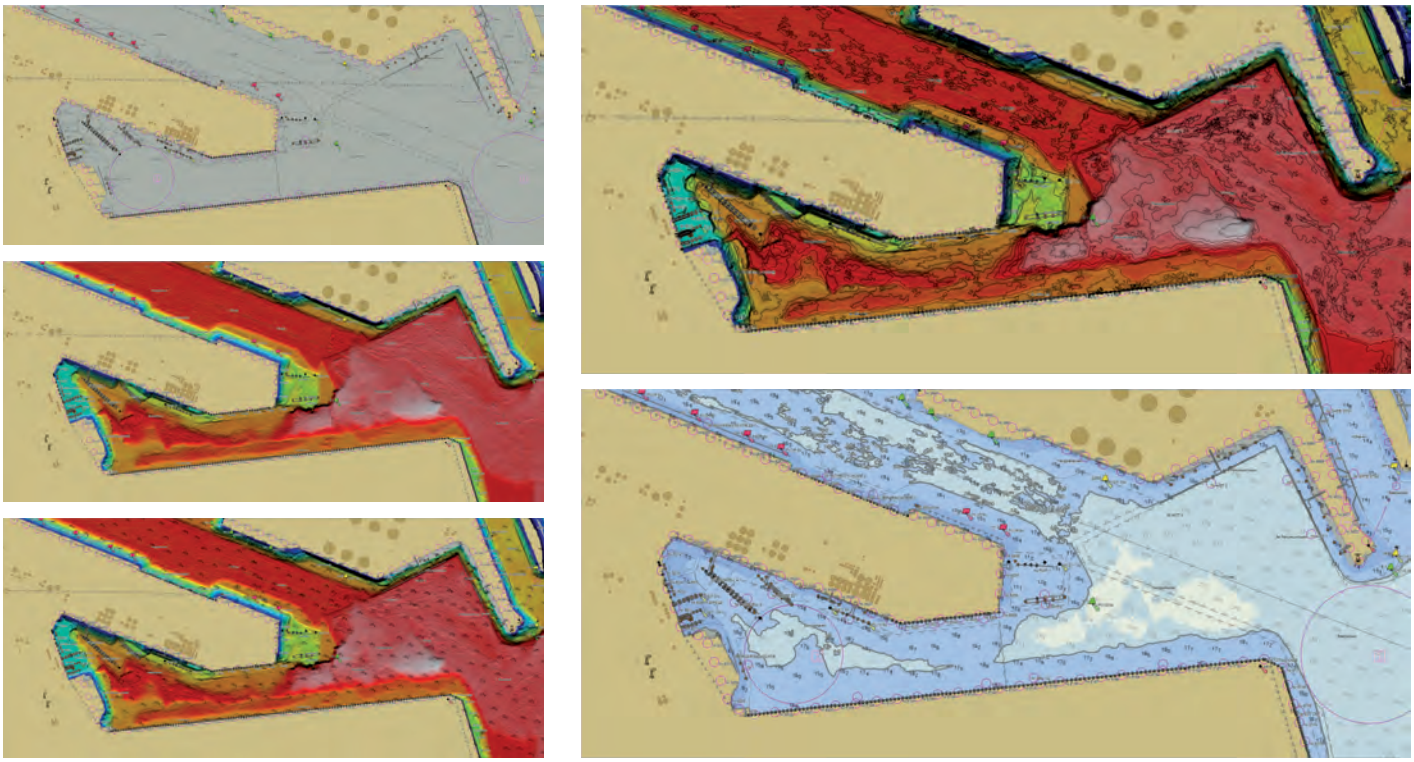
ENCs are published to a wide variety of users in the Port of Rotterdam

The Hydrographic Survey Service

Hydrographic surveys of the port are conducted daily according to a survey plan generated from

▲ *Figure 1: QPS Qarto ENC production utility.*

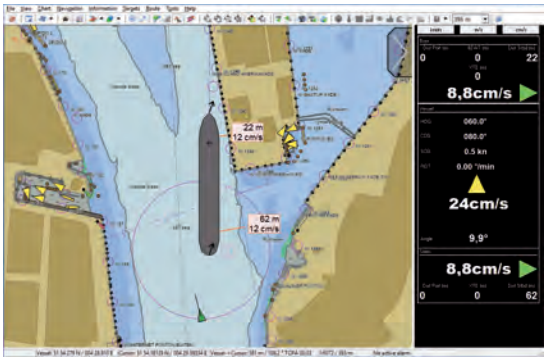
▲ *Figure 2: Survey vessel of the Port of Rotterdam.*



▲ *Figure 3: The steps of ENC production with QPS Qarto.*

siltation rates. The port operates two survey vessels equipped with the latest multibeam echo sounder systems and with the help of QPS QINSy (Figure 2).

▲ *Figure 4: Cruise* vessel Ovation *of the Seas arrives in Rotterdam.*



▲ *Figure 5: Arrival of cruise* vessel Ovation *of the Seas shown in QPS Qastor.*

The multibeam surveys contain overlapping tracks to distinguish seabed objects from unwanted noise/spurious soundings. The survey data is processed onboard the vessels on the same day to a 1x1 metre grid. On slopes of bottom protection rock dump areas, a mean of 0.5x0.5 metre grid is created to maintain detail of the seabed. Once the survey has been fully processed it is sent to the Data Management department as a clean digital terrain model (DTM). The survey vessels are connected to the Port of Rotterdam local network by high speed connections. The surveys are copied to the network drive which is monitored by the PortMaps data team. The Data Management office converts the DTM from an ASCII file into a GeoTiff containing two bands: depths and date of survey. After a quick visual inspection, the GeoTiff is registered with the ArcGIS BIS.

The port maintains a compete bathymetric surface model for its jurisdiction using the ArcGIS for Maritime solution. When new surveys are registered with the BIS they are overlaid onto the existing data into a seamless bathymetric surface based on a set of filters and rules. The ArcGIS for Maritime solution uses ArcGIS mosaic dataset functionality to combine the individual surveys into a seamless surface based on the rule 'most recent survey data on top'. The Port of Rotterdam's surface model is updated daily with the latest surveys to ensure the most up-to-date data is included in the port ENCs.

The survey data recorded by the port's survey vessels are not only used to produce ENCs but are also used by the port's dredging team. Their task is to analyse the survey data against a port design model. Products like surface difference charts and volume reports are generated to monitor the siltation of the port. This information is used to instruct the dredging vessels where the maintenance dredging is required. This process will guarantee the port's accessibility 24/7.

ENC Production and Updates

The Port of Rotterdam ENC and IENC (Inland ENC) production is almost close to perfection using the latest versions of ArcGIS, QINSy Processing and Qarto. Thanks to a joint operation by Esri, QPS and the Port of Rotterdam the ENC production process is improved by the following steps (Figure 3):

- ENC and IENC production from the ArcGIS product library
- The ArcGIS S-57 validation utility
- The QINSy Processing generalise DTM utility
- Qarto depth contours and depth areas have quality and performance improvements

- Qarto date-of-survey areas (M_SREL) auto populated from DTM metadata
- The Qarto S-58 validation utility

When an ENC update is required, the base ENCs can be exported from the Nautical Information Server (NIS) using the Nautical S-57 tools. The Nautical S-57 tools use an ENC cell coverage layer to select and batch export ENC cells that need to be updated. The complete port area can be exported as ENCs in less than an hour. At this stage of production, the exported ENCs do not include bathymetric information. To complete the S-57 ENC Qarto is used.

The Qarto workflow is completed within just a few mouse clicks. From the Bathymetric Information Server (BIS) Qarto receives a 5x5 metres sounding grid based on the shallowest depths including the date of the survey, as well as features from the NIS. With this information Qarto creates the depth contours at 10cm intervals (for depths less than 25m), depth areas and spot soundings. Finally, it takes the GIS exported ENC (base cell) and integrates this with the depth model.
In other words, a new ENC set is produced, populated with the most up-to-date nautical information and the latest hydrographic data. Once the ENCs have been made available they are published to a wide variety of different users in the Port of Rotterdam.

Maximise Port Accessibility and Goods Throughput

The aim of all ports is to increase the throughput of goods by maximising the accessibility for vessels under all circumstances. The two principal ENC users at the Port of Rotterdam are the Port Authority and Marine Pilots group (Loodswezen). Both groups use the information in different ways to assist in safe navigation of ships with marginal UKC. The use of high density ENCs or bENCs (Bathymetric ENC) by marine pilots is a critical factor in this part of the operation. The bENCs show exactly where it is safe and where it is not safe for navigation, taking the vessel's draft and the real-time tide level into account.
Any vessel that is limited to the fairway by its draft must call into the Port Authority at least 48 hours beforehand. When the vessel calls in, the Harbour Coordination Centre (HCC) checks the fairway and berth depths using MCS. In the MCS user interface the HCC officer can enter the vessel's draft, UKC and tide level. The safety contour will be derived from this information and shown automatically in MCS. During this time, the pilot will update his Portable Pilot Unit (PPU) with the same ENCs and MCS to prepare the vessel's transit to the berthing location (Figure 4 and 5).

The Port of Rotterdam has produced almost 300 usage band 5 (Harbour) and 6 (Berthing) ENCs. The usage band 6 cells all have depth contours with an interval of 10cm to give it a bENC or high density ENC character. Based on the latest surveys the new editions of the cells are selected and produced overnight. In other words, what was surveyed yesterday is available as a bENC today. The bENCs are in use by pilots, harbour masters and potentially even captains (with pilot exemption) of the ferry services that have daily schedules to and from Rotterdam.

Conclusion

QPS and the Port of Rotterdam have been hydrographic partners for many years. The delivery of hydrographic data is critical for the port operations. The introduction of PortMaps enables the Port of Rotterdam to produce a wide variety of information products in less than 48 hours. By combining the GIS activities of all asset management departments of the Port into PortMaps, errors are significantly reduced and data is synchronised.

Future Developments

The success of the PortMaps project and the easy accessibility of information products has meant that the user group is still growing. In fact, the demand for other information products is growing. As the port has reached the initial operating capability, the next phase of the project is to optimise the automation and streamline the workflow. Web services can be introduced to serve clients. Shipping companies and agents will be able to reduce turn-around times if they can access the latest depth information.
Due to the legislation in some countries the method used by the Port of Rotterdam is not always accepted. In these countries, marine pilots are obliged to use the official ENCs produced by the country's Hydrographic Office, although a bathy overlay ENC in combination with the official ENC is allowed instead of a complete chart. For the next version of Qarto, it will be possible to generate bathy overlay ENCs (Figure 6).

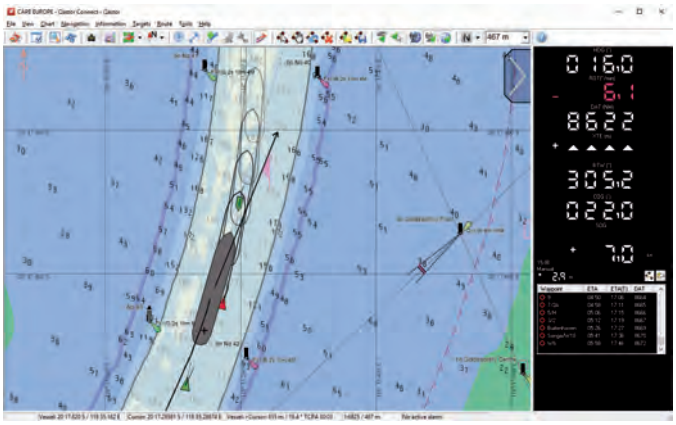


Figure 6: bENC overlay, containing 10cm contours, on Primar chart in QPS Qastor.

Further reading:
- 2015 US Hydro Proceedings. The Port of Rotterdam: A Modern Hydrographic Workflow. By Jeroen van Reenen, Port of Rotterdam, Rotterdam, The Netherlands. Co-author Caitlyn Raines, Esri, Redlands, CA.

Jeroen van Reenen: Jeroen obtained his BSc Hydrographer at the Nautical College of Amsterdam in 1991. Before joining the Port of Rotterdam in 1999, Jeroen worked at Royal Boskalis Dredging Company for seven years on various international projects. He started to work at the Port as hydrographer. Later he became asset manager for the Data Management department. He recently left the Port of Rotterdam to start his own company, HydrographX.

Frans Nijsen obtained his BSc Hydrographer at the Nautical College of Amsterdam in 2003. After his graduation, he joined QPS as a software support engineer, focusing on Qastor and Portable Pilot Units. Later he became a port consultant and hydrographer at Royal HaskoningDHV and account manager at Caris. In 2014, he returned to QPS to join the Marketing and Sales department.

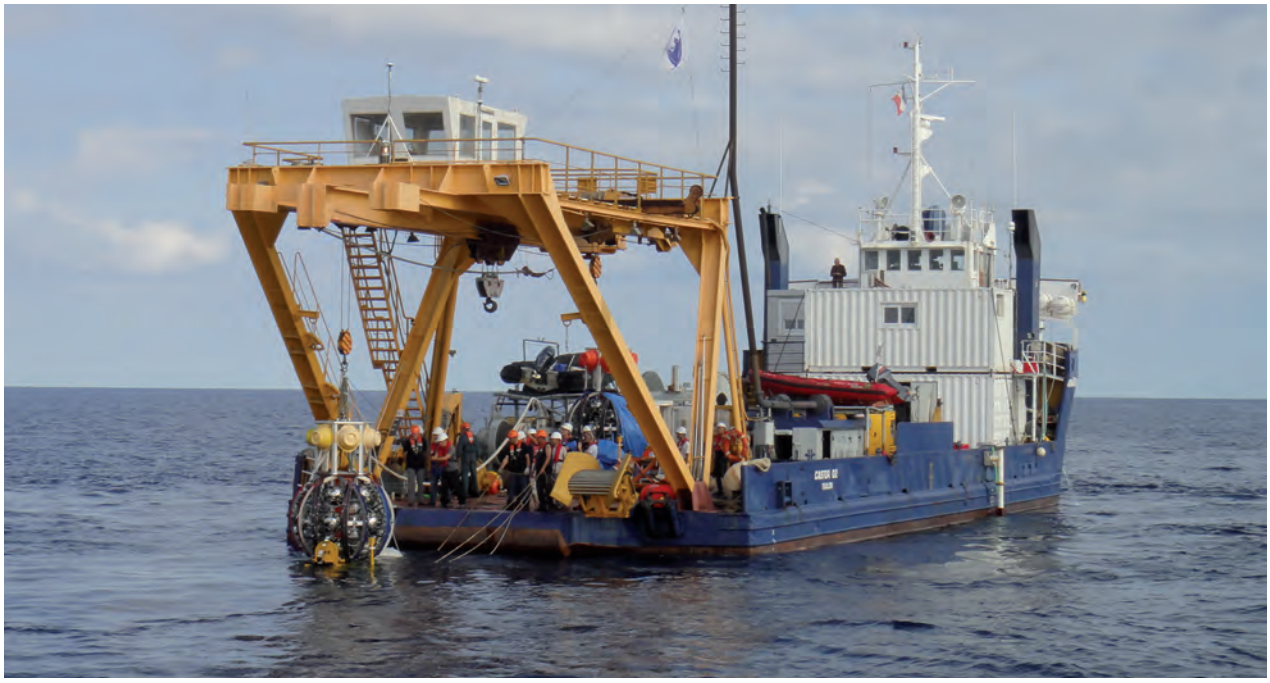
YANN CASAMAJOU, PRODUCT MANAGER, IXBLUE

A **Submerged Telescope** to Listen to the Universe

iXblue, a global company that provides innovative solutions devoted to navigation, positioning and underwater imaging, recently took part in the deployment of a major submerged telescope off the coast of Toulon (France), to observe particles from space that are quasi-undetectable in terrestrial environments. The European project KM3NeT (Kilometer Cube Neutrino Telescope), in which iXblue has been involved for many years, brings together institutes of physics, astronomy and oceanography from all over Europe and aims to deploy networks of sensors at several sites in the Mediterranean off the coasts of France, Italy and Greece.

These networks of photosensitive underwater sensors come together to form telescopes that observe space particles named neutrinos. These elementary particles are at the heart of the research being conducted within the framework of some of the largest experiments in fundamental physics on Earth. While the heavens have always been observed with the help of photons emitted by celestial bodies, the intrinsic properties of neutrinos make them excellent indicators of the most energetic events in the cosmos. However, those particles are difficult to detect and the Earth is thus used as a target to observe them. When a neutrino passes through the Earth, there is a chance that it will interact with one of its atoms. When such a collision occurs, another elementary particle – a muon – is generated, following a trajectory based on that of the neutrino. When it exits the Earth's crust, this muon will interact with water and generate a cone of bluish light known as Cherenkov light. Captured by a telescope made up of a network of photo-multiplier tubes positioned precisely underwater to avoid any external light pollution, this light makes it possible to precisely reconstruct the course of the particle and determine the direction of the source of the neutrino. It thus becomes detectable thanks to the placing of networks of Cherenkov light sensors in the depths of the sea.

It was to deploy these complex networks of photo-multiplier tubes that iXblue was contacted



▲ *Deployment of the optical module cells from the Castor Ship. (Courtesy: CNRS)*

in 2014 by the Marseille Particle Physics Center (CPPM), which is responsible for the installation and operation of the telescope in French territorial waters, on a site off the coast of Toulon, at a depth of 2,500 metres. Implementing this telescope, consisting of tens of lines themselves made up of 18 optical module cells, requires a high degree of precision at every step in its deployment. High-quality positioning being needed and GPS being unreachable undersea, it was iXblue's range of positioning products that was chosen for this mission. Built on several decades of experience, iXblue's offer includes top-of-the-range positioning equipment such as the Posidonia and Ramses systems. In the call for tenders launched by the CPPM in 2014, it was Ramses, iXblue's LBL (long baseline) positioning system that was selected for the monitoring of devices and the location of the underwater structures.
iXblue was duly called upon by the CPPM in September 2017 for deploying and calibrating the reference beacons. Unusually, Ramses was installed on the vessel and not on the device to be positioned, though the principle of positioning remains similar, with vehicles and structures being located using distances to the reference beacons. Ramses was thus coupled to iXblue's Hydrins inertial navigation system, itself connected to a GPS, so that its position could be known precisely at any time. During the course of this mission, the calibration of the reference beacons was performed by Ramses, which constantly measured the distance to the subsea beacons and integrated it into its Kalman filter to determine its exact position in real-time. Thanks to the outstanding autonomy of the beacons, with their position now known, these can subsequently be used to position vehicles in the field for several years, without any further intervention being required.

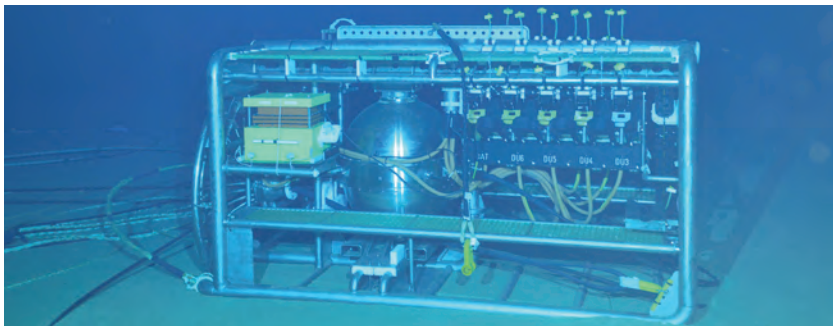
A second mission was organised for the installation of the first line of detectors and its associated infrastructure. During this mission, navigation for vehicles within the field was provided thanks to a beacon mounted on the vehicle which responded to queries from Ramses, whilst re-querying all the surrounding reference beacons. The indirect distances measured ultimately enabled Ramses to triangulate the position of the device in the field. The installation of the tens of lines of the telescope was carried out using beacons from iXblue's Oceano range, which not only enable the lines to be positioned by Ramses during deployment, but which are also used in their handling, from lifting to their release down to a depth of 2,500 metres. However, due to extreme weather conditions, the Manager of Operations had to postpone the lowering into the water of the first line and of the CNRS's oceanographic acquisition module.

A third mission was organised and lasted several days with two vessels working at a distance of just a few tens of metres from each other with equipment connected below the surface, a deep casting winch deployed and a ROV operating at the same time at a depth of 2,500 metres below the surface. A painstaking operation which put all the know-how of the respective captains and crews to the test. Under such conditions, positioning the equipment on the seabed is of crucial importance. Ramses thus provided invaluable assistance by enabling the line of detectors to be deployed into its exact position within a 'target box' of just 3 metres radius in size. Evaluated based on data recorded during the mission, then reprocessed after operations were complete, the positioning accuracy of the line during the deployment was brought to within barely 10 to 30cm.

The release phase of the first line then followed, with all the sensors being rolled out on the seabed and positioned on the line. Then came the connection to the junction box of the seabed infrastructure by the ROV. Contact is then established with the station on land to coordinate the powering up of the line and the sensors are ready to record their first neutrinos.

So, on Friday 22 September 2017 at 10:20pm local time, just 20 minutes after the first optical sensors were connected, the system was already detecting its first signs of cosmic muons. The heavens had been heard from the depths of the abyss: a whole host of know-how deployed to listen to the universe. ◀

▲ *Ramses LBL subsea positioning system. (Courtesy: iXblue)*



▲ *Junction box installed on the seabed. (Courtesy: Ifremer)*

The Shape of the Future of ECDIS

The 1st of July 2018 turns out to be a historic date for chart navigation at sea. On exactly this day ECDIS carriage requirement will be mandated for any new and existing vessel of relevant size on international voyages. This date, however, will not gain any particular reaction from those who are affected and this is due to the applicability and implicitness of technology. It is fair to say that this date marks symbolically that ship navigation has accomplished the principal shift from analogue paper charts to the era of digital chart navigation. I was one of those who wrongly predicted the decline of paper charts ten years earlier. But now, after some delay, it is really happening. Sales of paper charts are in rapid decline and no longer even popular as a backup solution. I was recently told by a chart data and ECDIS vendor, that even the fall-back for the regular ECDIS double installation backup is no longer in paper on many ships. Younger mariners belonging to the digital generation, carry their private navigation app running on a tablet as a digital 'take me home' chart if all the professional bridge requirements fail. This actually tells us two things: firstly ECDIS has been tested as being robust and reliable, and, secondly, those mariners who are familiarised with digital chart technology don't want to abstain from the obvious advantages – not even in an emergency case.

▲ *Mathias Jonas.*

So, all said and done with ECDIS? I don't think so. Actually, some (rather remote) areas are not fully covered with ENCs in appropriate scales; there are still problems with geographic overlapping and the quality of the underlying survey data needs improvement in many areas. These problems are the subject of various coordination efforts within the framework of the IHO activities. Many regional projects for resurveying by means of modern equipment are underway and ENC producing coastal states are constantly striving for improvements of the production workflow, quality assurance and update regime. But looking to comparable mobile navigation systems ashore it is obvious that ECDIS, as a concept, is no longer as modern as it used to be. It was once the very first of its kind, it is now lagging behind any modern car navigation device in the design of the user interface and functionality. Now would you like some evidence in favour? Well, as the term 'Electronic Navigational Charts' suggests, the now thirty-year-old ECDIS concept has basically converted the chart paradigm into the digital sphere, almost only by digital treatment of the information provided on paper beforehand. This judgment applies to many details such as the scale concept, the geographic coverage of cells, the steps of depth contours, the symbolisation etc., which finally imitated more or less the look and feel of a paper chart on a computer screen.

There were comprehensive reasons for keeping similarity in visual content provision for the interim period of parallel use of both media paper and display, but noting the contemporary user's requests it is clear that ECDIS needs another step in the way of transformation. What appears to be the predominant need from the users is for dense bathymetry and real-time application of tide water level. The concept to shape ENC cells mainly according to the corresponding paper charts should be revisited showing a regular grid. Amending text-oriented navigational information, which is still delivered by printed (or pdf) sailing directions, should be naturally embedded into the traceable database of the ECDIS device. Information overload on display? Well, automated interpreters should trace all information continuously, evaluate for the specific situation of the individual vessel and display the relevant information only. If it eventually comes to guided or fully autonomous vessel operation there will be a much lesser need for information getting displayed visually. Instead, the highly automated surveillance mechanism should gain access to supplementing marine information provided by neighbouring domains such as meteorology and oceanography. Future ECDIS will have to manage the full set of our maritime knowledge to create the biggest, most up-to-date, most detailed image – not necessarily visually but ready for automatic processing. This goal has to be addressed in two ways: technically by standardisation and intellectually by closer collaboration of all contributors affected: IGOs such as IMO, IHO and IALA along with their Member States, industry, science and academia. The IHO is targeting this ambition in all fields of standardisation, capacity building, education and cooperation activities. It will be exciting to see how the implementation of IMO's e-navigation strategy will impact the shape of future ECDIS devices. ◀

Hydrographic Society Benelux

Workshop and Annual General Meeting

Theme for the HSB meeting on Friday 20 April was the relationship between HSB and the International Federation of Hydrographic Societies. Special guest, IFHS chairman Holger Klindt, was invited for his view on the added value of international cooperation. Since its birth in 2004, in Galway, the IFHS aims to be a facilitator of international traffic between hydrographic surveyors, either individual or corporate. Currently nine national or regional hydrographic societies are member of IFHS. Because the tangible benefits of membership are limited, consisting of allocation of the Hydro conferences from year to year, the annual IFHS Student Award and attempts to start the IFHS Newsletter, it would appear at first glance that there is scope for more and other initiatives. Exchange of knowledge, best practises, particular survey conditions and/or results could all be part of the game. Personal certification is also being discussed.

The most important aspect of the international platform is to just be there, with a standing invitation to have members develop something new and exciting, which can be relayed and transferred to all those interested over the world. The success of Hydro17, as reiterated by its organiser Floor de Haan, shows that an international approach towards our common professional skill is as important as ever. The continued presence of *Hydro International* is another example of the same. Perhaps an effort could be made to get other periodicals published by IFHS members – Tidings, Hydrographische Nachrichten – to the complete IFHS membership. The discussion following on from the introductions by Holger and Floor were quite open minded, keeping clear of the vigorous debate that was expected. The outcome seems to be that IFHS is recognised as the body for international communication on commercial aspects of hydrography.

▲ *Holger Klindt.*

◀ *Daan van der Heide was awarded for his work on 'Shallowest point determination using water column imaging'.*

Former Hydro06 organiser Wim van Wieren demonstrated an app with which the audience could use their phones to vote. Answers from the audience to quantitative questions were directly shown on the beamer. The afternoon continued with the announcement of the winner and runner-up of the HSB thesis award for 2017. Four students from Terschelling's MIWB had been short-listed and invited to give a short presentation on their theses. As one of the students was abroad, three presenters took to the floor, ready to read their entire papers if so required. The Educational Fund committee was represented by IJves Wesselman. He awarded two cheques; one amounting to €500 for the winner Mr Daan van der Heide, for his work on 'Shallowest point determination using water column imaging'; and one amounting to €200 for the runner-up, Ms Dzjamilja Tjeerde, who was not there to accept the award. Our congratulations to both! Daan has also been put forward to enter the IFHS Student Award scheme for 2017.
After the coffee/tea break the audience reconvened to the Annual General Meeting, a report of which will follow after the Dutch spring holiday.

Rob van Ree, 24 April 2018 ◀

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'Unofficial Charts' on the Horizon?

In the article entitled 'How Blockchain Will Have an Impact on Navigation' published in the issue of *Hydro International* dated March/April 2018, Gert Büttgenbach explains how the new blockchain technology could be potentially beneficial for the production and distribution of nautical charts. I believe that encouraging the community to think about the impact of new technologies is always a good thing, especially in an environment that is often considered, whether rightly or wrongly, as rather conservative.

One of the conclusions of the article indicates that the new technological environment calls for reconsidering the 'exclusive domain of national Hydrographic Offices' (HOs) and suggests that the private sector could in future produce 'unofficial charts' that would be superior to 'official' charts produced by the HOs. It seems to me that these views reflect a misunderstanding of the situation.

The question as to which organisations should be entrusted with the production of nautical charts as a key enabler of safe navigation is the subject of recurrent debate. As a matter of fact, this was originally an activity run mostly by private chartmakers and chart information was considered a trade secret. France was the first country to establish a national Hydrographic Office in 1720. The rationale behind this initiative was that more warships were being lost at sea because of lack of access to charts than in combat. The benefit of assigning a dedicated public organisation to the task of collecting all available information, compiling it and making it available through 'official' nautical charts was progressively recognised and all maritime nations followed the lead of France more or less rapidly. Some private chartmaking continued into the 20th century but it was generally focussed on the specific needs of the leisure market. The obligation for ships to carry adequate and up-to-date nautical charts and publications was introduced in the International Convention for the Safety of Life at Sea (SOLAS) of 1974 (regulation V/20) but the provisions related to the production of adequate nautical charts and publications were left at the discretion of the Contracting Governments.

In the late 1980s, the advent of the digital era created a new opportunity for private entrepreneurs who were keen to develop electronic chart systems (ECS) and proposed digital nautical charts generally obtained simply through digitising the paper charts produced by HOs. When the progress of ECS technology led to the consideration of using such systems not only as navigation aids complementing paper charts but as meeting as such the SOLAS chart carriage requirement, the International Maritime Organization adopted Performance Standards for Electronic Chart Display and Information Systems (ECDIS) in 1995. Considering the liability aspects, the Performance Standards included a provision that the associated Electronic Navigational Charts (ENCs) had to be issued 'on the authority of government-authorised hydrographic offices'. This provision was refined in the amendments to the SOLAS Convention that were adopted in 2000 and entered into force on 1 July 2002. These amendments include a definition of a nautical chart or publication as 'a special-purpose map or book, or a specially compiled database from which such a map or book is derived, that is issued officially by or on the authority of a Government, authorised Hydrographic Office or other relevant government institution and is designed to meet the requirements of marine navigation.' (regulation V/2.2). They include also the requirement that 'Contracting Governments undertake to arrange for the collection and compilation of hydrographic data and the publication, dissemination and keeping up to date of all nautical information necessary for safe navigation.' (regulation V/9).

Now it is up to each Contracting Government to decide which arrangements best suit its circumstances. The requirement is solely that nautical charts and publications should be produced on the authority of a Government and this is justified by the liability issue, noting the extent and cost of the damages that could be caused by a ship's grounding due to a charting error. As explained in Publication M-2 of the International Hydrographic Organization on 'The need for hydrographic services', 'Coastal States can satisfy their hydrographic needs and obligations through a variety of arrangements (…). The use of bilateral arrangements with established Hydrographic Services and the use of commercial contract support are alternatives to establishing a full in-country Hydrographic Service.' The reality is that a number of HOs do outsource production activities to the private sector. Therefore, one should not oppose HOs versus the private sector and 'official' versus 'unofficial' charts but encourage both sides to imagine together the most efficient ways to improve future 'official' charts for which governments continue to accept full responsibility.

In that perspective, it is worth noting that HOs are evolving from a traditional chart-centric model to a data-centric model in order to address the variety of hydrographic requirements associated with all human activities that take place in, on or under the sea and support the sustainable development of the oceans. This means that delivering a portfolio of nautical charts covering the waters of a country is no longer an end in itself but one of the many applications of a national marine spatial data infrastructure that must be considered as a public good. The private sector can and should play a major role in developing tools to manage efficiently the MSDI as well as in inventing and developing a variety of value-added products and services derived from that infrastructure. But as long as shipping remains a significant component of the world trade infrastructure, there will continue to be a substantiated need for 'official' nautical charts. ◀

▲ *Gilles Bessero.*


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