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THE GLOBAL MAGAZINE FOR HYDROGRAPHY
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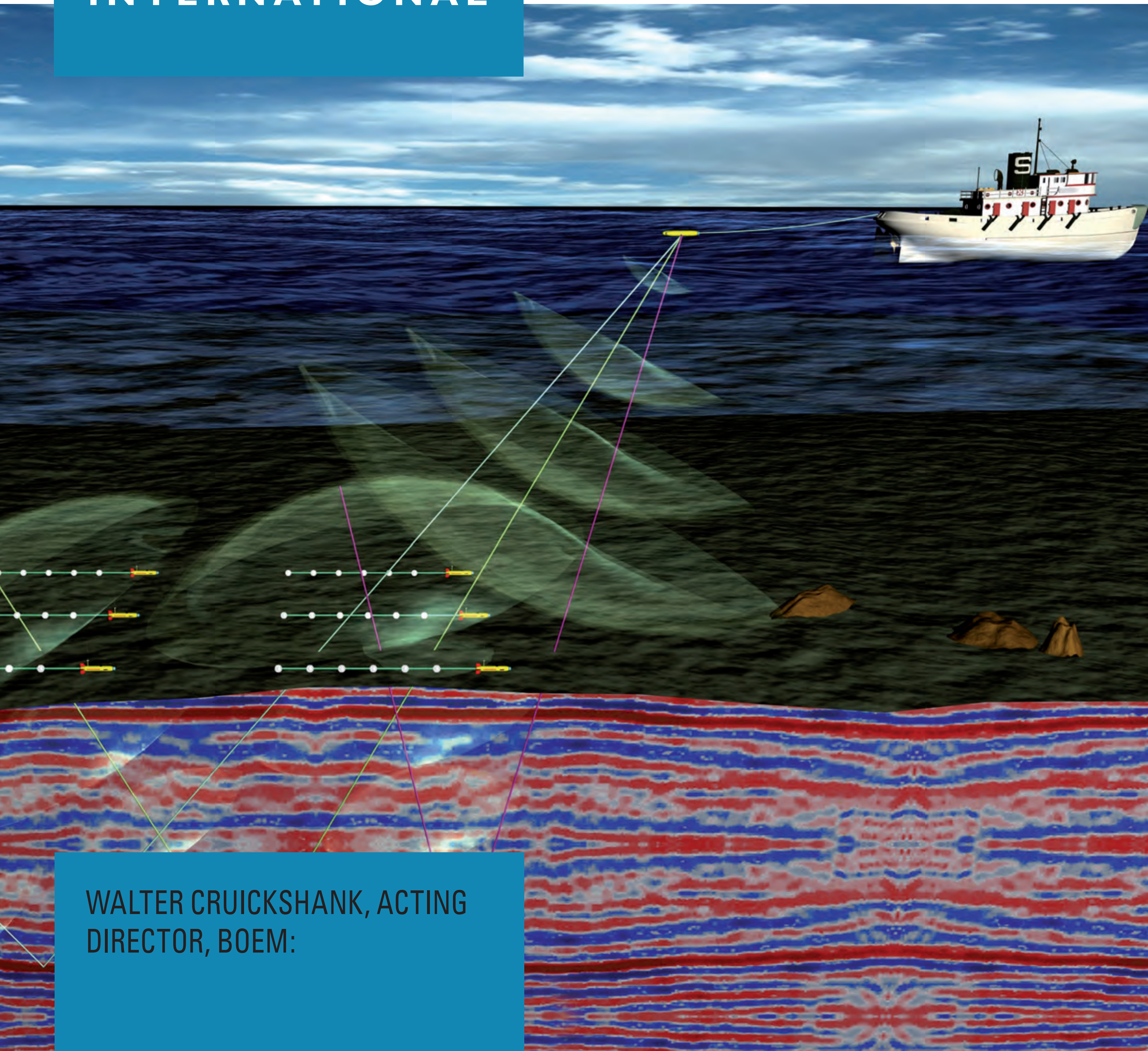
geomares PUBLISHING

MAY/JUNE 2017 | VOLUME 21 NUMBER 3



WALTER CRUICKSHANK, ACTING DIRECTOR, BOEM:

How to Sustainably Use and Protect Oceans and Coasts

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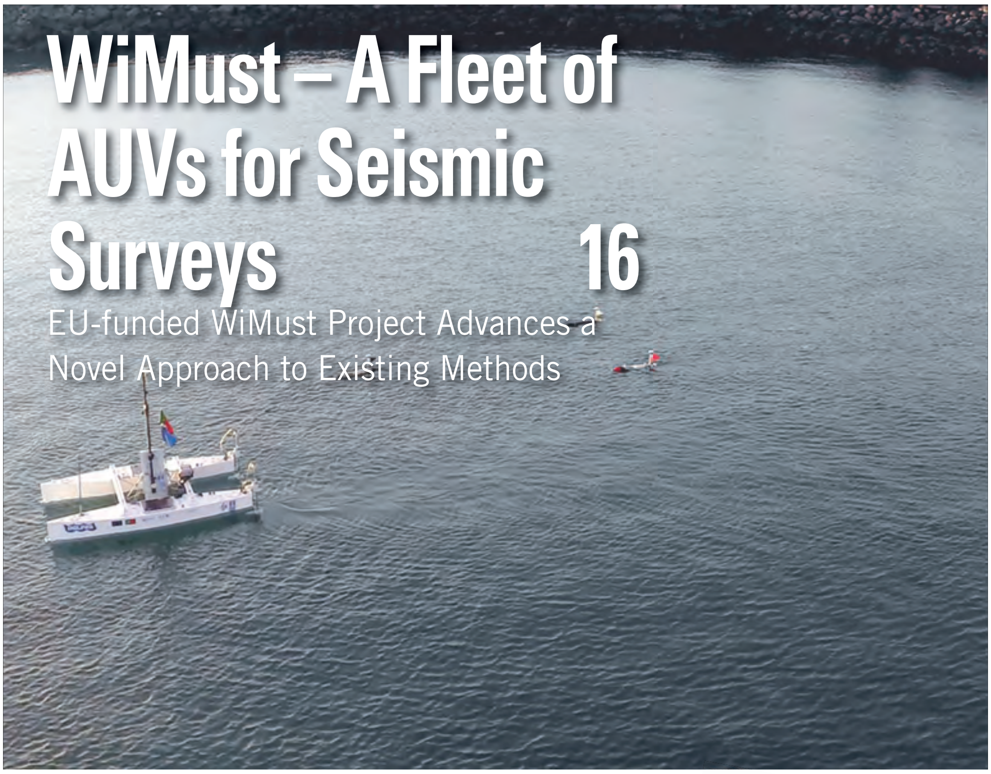

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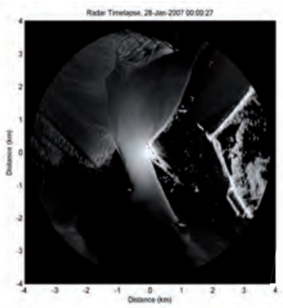

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The WiMUST system - an artist's rendering. The project aims to design and test a system of cooperating autonomous underwater vehicles (AUVs) that would simplify seismic surveying and offer significant advantages over modern streamer-towing operations. See also the article from page 16. Image courtesy: WiMUST consortium.

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Hydro INTERNATIONAL

Hydro International is an independent international magazine published 6 times a year by Geomares Publishing. 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.

geomares PUBLISHING

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Transition of an Era

For the future of hydrography it is necessary to think differently and of course adjust the business to that new way of thinking. That not only applies to hydrography, but to many fields close to hydrography and fields that hydrography delivers data to. A few weeks ago I visited the Port of Rotterdam and after a little tour on the water, the CEO of the Port of Rotterdam, Mr Allard Castelein, gave us a presentation on the future of the port's business and what is needed for sustainable future growth in a world where some countries can build ports the size of Rotterdam in a decade (whereas it took Rotterdam 70 years!). In the Port of Rotterdam one speaks of a transition of an era, not of an era of transition.

Things will really change. Think of a biobased & circular economy, and major developments in the energy sector – (American shale gas, low oil price, solar and wind energy, etc.). How does all this come together for a Port Authority that strives to keep its position amongst the major ports of the world. In Rotterdam it is all about digitalising and energy transitioning – facilitate existing businesses and stimulate new businesses, with an overarching goal: a stronger position amongst competing ports, for the better of society and business alike.

Digitalising in the Port of Rotterdam means setting up an efficient system for information exchange between ships. Give ships the opportunity to manage their most efficient and optimised route through the logistics chain of the port and develop smart mooring posts all over the port sending their availability and cost to the ship. The whole transition for the Port of Rotterdam was thought over in a period when the offshore industry was in crisis. It was very necessary for the Port Authority to change its mindset immediately! The same of course applies to hydrography. An ongoing discussion that needs to be taken to the tables of those shaping our business.

Maybe in Monaco as well? From September on, a new trio will head the International Hydrographic Organization. The new Secretary-General is Dr Mathias Jonas (now Chief Hydrographer of Germany) and he will be assisted by the experienced and re-elected director Mustafa Iptes and the new director, Captain Abraham Kampfer from South Africa. *Hydro International* congratulates the trio and wish them all the wisdom they will need to reshape the future of hydrography, a job that had already been taken on by leaving Secretary-General Robert Ward and his team – who I would also like to thank for the great work they've done in the last few years! In Monaco, but also on the desks and in the minds of thought leaders, researchers and entrepreneurs in hydrography, it's also the transition of an era. It is good to take a look at examples nearby, like that of the Port of Rotterdam, as well as other examples over the world and in other businesses to get as many ideas to rethink and reshape as possible.

Durk Haarsma durk.haarsma@geomares.nl

The Difference One Year Makes

In June 2016, the IHO/IOC GEBCO Guiding Committee and the Nippon Foundation hosted F-FOFM, the Forum for Future Ocean Floor Mapping in Monaco. Over three days, some 170 ocean mapping stakeholders were encouraged to collaborate and complete the mapping of the world's oceans below the traditional limits of hydrographic surveys (~150m).

FOFM, featured in Newsweek and Economist articles, energised the community by setting a 2030 date for completion of a 100m grid of the oceans. In the year since, a number of advances indicate the possibility of success.
My previous Insider's View (January 2016) proposed using a mother ship with 50 HUGIN AUVs to complete the unmapped 88% of the oceans. While eliciting little response, it coincided with Sea Trepid International's purchase of 6 HUGIN 6000s. Now, together with Ocean Infinity, and under the aegis of Swire Seabed, they will vastly increase the economics of seafloor mapping by using their new mission dedicated vessel *Seabed Constructor* as the host surface vessel (HSV), controlling six unmanned surface vessels (USVs), each in contact with its own HUGIN 6000. This combination is under contract for the next six years, almost 50% of the time remaining until 2030.

In space, a few of the world's 1,810 billionaires have already set impressive goals for galactic exploration. In light of the far more tangible returns from mapping our oceans, it might be rewarding for another billionaire to fund the work of such a HSV-USV combination. Recently, Ocean Infinity has even acquired two more HUGINs. I frankly consider a grid for the oceans, similar to those existing for our fellow planets, to be nearly on a par with the initial decoding of the human genome.

A month before that last column, Shell's USD7m Ocean Discovery XPRIZE initiated a competition to refine autonomous technologies to better map the mostly deep seafloor. At present 21 semi-finalists are developing similar autonomous techniques.

March's THSOA HYDRO-2017 meeting in Galveston, USA, showcased the standardisation and simplification of multibeam acquisition and analysis and the widespread movement towards autonomous data acquisition by unmanned surface vehicles and UAVs. A strong take-home message was delivered by CCOM's John Hughes-Clark who showed that troublesome outliers on MB swaths result from near surface oceanography and not the equipment. The solution is either a more narrow swath, instantaneous measurements of these effects in the upper layers, or as we are seeing, AUVs operating well below these phenomena.

Another outcome of FOFM has been wholesale release of existing datasets. Examples are the EMODNet, BOEM's Gulf of Mexico grid, the MH370 search area, localised grids like that for the Baltic Sea, and likely future contributions of offshore oil and seabed mineral surveys. However, inshore areas still face the political hurtle of grids as fine as 100m. I for one, have expanded the compilation of our 100m grid for the Red Sea (*Hydro International* Nov-Dec 2014) to the Persian Gulf and Indian Ocean down to the Equator. This will use all available sources for the shallow offshore of 19 countries comprising ~2% of the Earth and its shallower seas.

The MH370 search showed that the oceans are poorly mapped. An article by GEBCO's Karen Marks and Walter Smith in AGU's monthly Eos, caught the attention of multiple media outlets. emphasising to air travellers that a ditching at sea would probably be in a poorly mapped area.

Hydrography Training for 5 Angolan Officers

In an effort to contribute to hydrographic capacity building and consequently to the safety of navigation in Angola, the Portuguese Navy invited the Inter-ministerial Commission for the Delimitation and Demarcation of Maritime Areas of Angola to send up to five students to the Hydrographic Technical Course. The Portuguese Navy also offered to support the costs related to tuition fees, food and accommodation.

▸ *bit.ly/2qvxDPx*

▲ *Portuguese hydrographic course with the Angolan officers in the classroom.*

Most Shared

Most shared during the last month from www.hydro-international.com

1. Hydrography Training for 5 Angolan Officers - bit.ly/2qvxDPx
2. Bathymetry from Space - bit.ly/2qvL5Tt
3. Candidates Presenting for IHO Office - bit.ly/2qvMN7A
4. EdgeTech and Esri Cooperating for Data to ENC Solution - bit.ly/2qvxfRd
5. Coast Survey's Certification Programme in Nautical Cartography Approved - bit.ly/2qvwho7

Coast Survey's Certification Programme in Nautical Cartography Approved

The International Board on Standards and Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC) recognised and approved Coast Survey's certification programme in cartography (CAT-B) at its 40th meeting in Wellington, New Zealand. Capt. Andy Armstrong (NOAA, ret.), co-director of the Centre for Coastal & Ocean Mapping/Joint Hydrographic Centre at the University of New Hampshire, presented the programme at the meeting.

▸ *bit.ly/2qvwho7*

▲ *Capt. Andy Armstrong (left) with IBSC chair Adam Greenland at the 40th meeting of the IBSC in Wellington, New Zealand.*

Wave Sensor Deployments around the Globe

SeaView's SVS-603 Wave Height Sensor is enabling wave measurements on a wide range of buoy hulls worldwide. The SVS-603 is bringing wave measurements to a variety of platforms for which such measurements would have been impractical before the complete algorithms, small form factor and very low power consumption offered by the SVS-603.

▸ *bit.ly/2qvt0EZ*

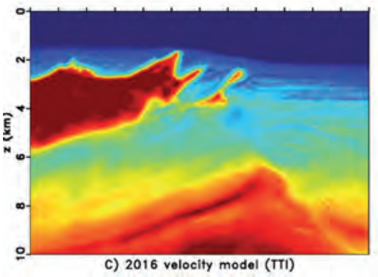
Integrated Vessel Concept for New-build Research Ship

▲ *Artist's impression of Germany's research vessel* Atair II.

A double digit multi-million Euro contract was signed by Kongsberg Maritime and Fassmer Werft on 4 April 2017, following the German Federal Maritime and Hydrographic Agency's (BSH) approval of Kongsberg to deliver a technical solution based on its Integrated Vessel Concepts for the new-build research vessel *Atair II*, which will be built at the Fassmer yard in Berne. Kongsberg's Integrated Research Vessel concept will unite operational hydrographic and energy functions on board, facilitating seamless information sharing, enhanced efficiency and long-term life cycle benefits.

▸ *bit.ly/2qvPtBU*

Advances in Deep-sea Seismic Imaging Technology



▲ *BP seismic survey data after analysis.*

BP has announced a breakthrough in seismic imaging that has identified more than 200 million barrels of additional resources at BP's Atlantis field in the deepwater Gulf of Mexico. The innovation has enabled BP to enhance the clarity of images that it collects during seismic surveys, particularly areas below the Earth's surface that complex salt structures previously obscured or distorted. The sharper seismic images mean that BP can drill new development wells in deepwater reservoirs with higher confidence and accuracy. As a result, BP is deploying this technique to fields elsewhere in the Gulf of Mexico as well as in Azerbaijan, Angola and Trinidad and Tobago.

▸ *bit.ly/2qvBMTy*

Two Additional HUGIN 6000 AUVs for Ocean Infinity

Ocean Infinity has purchased two more autonomous underwater vehicles (AUVs) from Kongsberg Maritime. This will increase Ocean Infinity's fleet of HUGIN 6000 AUVs from six to eight vehicles. The AUVs will be used worldwide to collect high-resolution seabed data for clients. The fleet of AUVs will be operated simultaneously, each AUV programmed with an independent mission plan. Independence allows the systems to cover huge swaths of seabed quickly and accurately. Each AUV can reach depths of 6,000 metres and has an approximate endurance of 48 hours.

▸ *bit.ly/2qvupeK*

Teaming up for Cheaper Energy from Ocean Tides

Oceanographers at Bangor University's School of Ocean Sciences are launching a major project to study tidal turbulence at the Menai Strait in Wales. The oceanographers have been awarded two major grants totalling GBP230,000 for their research, which is aimed at helping to improve the design and operation of tidal energy capture devices.

▸ *bit.ly/2qvnS3U*

▲ *Oceanographers at Bangor University's School of Ocean Sciences will focus on the collection of novel turbulence data in the Menai Strait, using Nortek's Doppler technology. Image courtesy: David Roberts.*

Contribution to Digital Preservation Recognised

Deep Ocean Engineering has received a letter from the Historic Hawaii Foundation in recognition of its outstanding efforts during the USS *Arizona* Digital Preservation Project. The efforts of all contributors, including Deep Ocean Engineering, will be acknowledged with the Preservation Commendation Award at the Historic Hawaii Foundation's 2017 Preservation Honour Awards Ceremony. The event will be held in Honolulu, Hawaii, on 19 May 2017.

▸ *bit.ly/2qv0hOX*

▲ *Deep Ocean Engineering Phantom H-1750 at USS* Arizona *Digital Preservation Project.*

Close Connection between Deep Currents and Climate

The Labrador Sea in the north western Atlantic is one of the key regions of the global ocean circulation. The GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, has been operating an array of oceanographic observatories there since 1997. It monitors the currents from the surface to the seabed. GEOMAR oceanographers recently published an analysis of their data obtained from 1997 to 2014 in the 'Journal of Geophysical Research Oceans'. It shows a close connection between deep currents and climate variabilities on different time scales.

▸ *bit.ly/2qIAJfI*

Autonomous Vessel Mission Control Centre for ASV Global

▲ *ASV Global Mission Control Centre.*

Mark Garnier MP and UK Parliamentary Under Secretary of State, has opened a Mission Control Centre developed by ASV Global at its headquarters in Portchester, UK. This centre is the hub for the company's ongoing development of its ASView® autonomous vessel control system. The centre will be capable of operating and monitoring the company's fleet of autonomous surface vehicles (ASVs) all over the world using satellite communication links and it can also be used for operator training and simulation exercises.

▸ ***bit.ly/2qlGqdw***

Using UAS for Marine Samples

For the first time, a team of scientists from GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, has successfully used a drone to collect marine air and water samples. The objective of the study is to better understand the role of coastal waters as a source of reactive trace gases, which are important for chemical processes in the atmosphere and the climate. The 'LASSO' project is funded by the Kiel Cluster of Excellence 'The Future Ocean'.

▲ *Drone experiment of the beach of the island of Sylt. Image courtesy: B. Quack, GEOMAR.*

▸ ***bit.ly/2qlTgrU***

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CEE HydroSystems - CEE JET	bit.ly/2qJ9mpr
DutchWorkboats - Survey Cat 11.00	bit.ly/2qJ9sNP
Swede Ship Marine - 11 m Hydrographic Survey Vessel	bit.ly/2qJ73Th

Business Person of the Year 2017 Award for Mike Osborne

▲ *Dr Michael Osborne wins AMSI Council Business Person of the Year 2017 Award.*

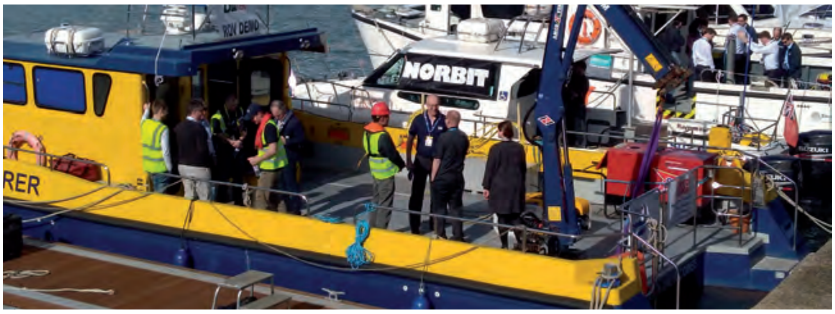
The annual AMSI Council Business Person of the Year award was presented to Dr Michael Osborne, managing director of OceanWise Limited, on 5 April 2017. The presentation was made by Mr Terry Sloane, chairman of the AMSI Council of the Society of Maritime Industries, during the Ocean Business Gala Dinner. The award is designed to recognise the individual who, in the opinion of the adjudicating panel, has made a significant contribution to the business of marine science and technology in the UK.

▸ ***bit.ly/2qIDRId***

Contacts Matter at Ocean Business 2017

This edition of Ocean Business was the time to celebrate the 10th anniversary of the event and the organisers made an effort to bring the people who started Ocean Business together. On Wednesday 5 April, they enjoyed the cake and tea that was served. It's an example of how people and contacts matter at Ocean Business – and this edition that took place from 4-6 April 2017 in Southampton, UK, was no exception.

▲ *Figure 1: Cake cutting to celebrate 10 years of Ocean Business.*



▲ *Figure 2: Well-attended on-water boat demos to see equipment and software in action.*

The tradeshow attracted more than 340 exhibitors in the two areas – add to this 180 hours of training and demonstrations in classrooms, in a test tank, on the water and on board of survey vessels. They were very well attended with people having to stand in the classrooms in many of the sessions and the dockside demonstrations also attracting many to the viewing area. These sessions were used to present new products and to explain their use in daily life. Product launches and updates were scheduled on many stands, including Teledyne CARIS HIPS and SIPS Essential, the Eelume snake-like AUV/ROV at the Kongsberg stand, and Planet Ocean launching the new ecoSUB Robotics micro AUVs. These launches were a good incentive to invite new and existing customers and to provide updates!

▲ *Figure 3: The matchmaking event brought businesses and professionals together.*

Matchmaking

Host of the event, the National Oceanography Centre, also provided part of the lecture programme. This brought science closer to the business and enabled the sharing of innovations and insights of the research performed at the Centre. As a business event, in addition to traditional formats like the stands, lectures and workshops, it was possible to participate in a matchmaking event where professionals were linked and were able to get to know each other during short sessions – and to find out if they could help each other. These sessions were also well attended and participants indicated that they had interesting conversations.

Meeting Up

In a way, the most important at Ocean Business is meeting people, talking with them. And this was certainly a great success! The traditional buzzing welcome party in the Pitcher & Piano bar was well attended – and it was a good place to see all the professionals again! The Wine Trail with no less than 24 stations proved to be another appreciated attraction that gave the visitors an incentive to have a casual chat. The traditional Gala Dinner included entertainment and the presentation of the AMSI Business Person of the Year award, presented to Dr Mike Osborne (OceanWise).

Is the breaking up of the stand and going home the end of the event? No – that's when the real work starts! After the show, most exhibitors and visitors had to dedicate quite some time to the follow up. Ultimately, that is what will make your participation a success!

More information
www.oceanbusiness.com

First Assembly of the International Hydrographic Organization (IHO)

People Pass, Institutions Remain

The first Assembly of the International Hydrographic Organization was held in the Auditorium Rainer III of Monaco, from 23 to 28 April 2017. I have entitled my report after a quotation by Jean Monnet, French politician and one of the European Community's founders: Les hommes passent, les institutions demeurent. The director Gilles Bessero mentioned it in his farewell speech at the end of the Assembly.

Figure 1: The newly elected Secretariat. From left to right: Mustafa Iptes (director), Mathias Jonas (Secretary-General) and Abri Kampfer (director).

Figure 2: His Serene Highness Prince Albert II of Monaco with the IHO Secretariat and representatives of observing organisations.

Jean Monnet's sentence is perfectly applicable to the IHO, an organization founded in 1919 that has, since then, not stopped growing in number of Member States and continues to ensure that all the world's seas, oceans and navigable waters are surveyed and charted.

In his opening speech, the Sovereign Prince of Monaco, Albert II, reminded us of the history of the IHO starting from the Maritime International Conference held in Washington in 1899 followed by the conferences in St. Petersburg (1908 and 1912). As known to all, the Hydrographic Organization was eventually created at the London Conference of 1919. The Principality, said the Prince, is glad to see that the IHO is now implementing the substantial changes to its Convention decided during the Extraordinary Conference of 2005. The Prince also mentioned the growth in number of Member States (from 41 in 1970 to the present 87) and welcomed the recent adhesion of Georgia, Viet Nam, Brunei Darussalam, Malta and Vanuatu. From now on, the adhesion of new members will be much easier and speedier thanks to the special clause included in the IHO Convention. The Prince reminded everyone of his commitment to the preservation of the environment and especially the seas and oceans. His Serene Highness Prince Albert II of Monaco presented the Prince Albert Ist Medal for Hydrography 2017 to Mr Juha Korhonen (Finland) for his active and continuous contribution to the work of the IHO from 1980 until his retirement in 2014 and for his success in maximising hydrographic capacity within the Nordic and the Baltic Sea region. On his part, the IHO Secretary-General (Robert Ward) mentioned the forthcoming UN Ocean Conference in June 2017, where the IHO Secretariat will represent the IHO. In that regard, he added, we all look forward to supporting You, Serene Highness, in Your efforts at the Conference, where we hope that hydrography and the measurement of the depth and shape of the seafloor will be further recognised for the fundamental role that it plays in the sustainable use of the world's seas, oceans and navigable waterways.
The speeches by Mr. Kitack Lim, Secretary-General of the International Maritime Organization, Dr Petteri Taalas, Secretary-General of the World Meteorological Organization and Mr Michael Lodge, Secretary-General of the International Seabed Authority manifested keen interest in the IHO activities and the spirit of cooperation.
Dr Parry Oei, Hydrographer of Singapore, chaired the Assembly with outstanding professionalism. Dr Oei is well known and respected in the hydrographic environment for his active participation in all the IHO fora and activities. Captain Brian Connon (US Navy) was elected vice chairman.

▸ ***bit.ly/2qlK51D***

Hydro International Interviews Dr Walter Cruickshank, Acting Director, BOEM

"How to Sustainably Use and Protect Ocean And Coasts"

During the recent Offshore Technology Conference in Houston, Texas, USA, the Executive Order on Implementing an America-First Offshore Energy Strategy was signed to support offshore science development. In the context of the highly dynamic offshore energy sector, *Hydro International* interviewed Dr Walter Cruickshank, acting director of the Bureau of Ocean Energy Management (BOEM), about accelerating authorisations for seismic surveying, marine geospatial data, environmental monitoring and the potential of marine renewable energy.

What is the role of maritime geospatial data for BOEM?

BOEM uses maritime geospatial data for a variety of needs. For example, by identifying ocean areas used for various purposes, BOEM's efforts to understand and deconflict various uses lead to better planning and stewardship of Outer Continental Shelf (OCS) resources across all of our programmes, including oil and gas development, renewable energy development and sand extraction for beach replenishment and coastal restoration. In a second example, maritime geospatial data is used to help with National Environmental Policy Act (NEPA) analyses related to the leasing of areas for such resources. Thirdly, geospatial data are used to define the National Baseline along the coastline of the USA. In turn, the digital baseline is used to generate official offshore boundaries, such as the Submerged Lands Act boundary – which divides Federal and State waters – and the Outer Continental Shelf Lands Act (OCSLA) Section 8(g) zone boundary. This pertains to the distribution of revenues gained from offshore leasing.

Marine planning provides a public process to better determine how the ocean and coasts are sustainably used and protected

How is BOEM receiving geospatial data for its work? Does the organisation have its own hydrographic service?

No, BOEM does not have its own hydrographic service or the ability to directly collect geospatial data. Instead, BOEM contracts out to the private sector or other Federal agencies to collect such data. For example, we have provided funds to universities and private companies to collect hydrographic data (salinity, temperature, currents) on the OCS. The industries that we regulate also collect geophysical data, which BOEM has access to and makes available to the public through the National Archive of Marine Seismic Surveys data portal hosted by the U.S. Geological Survey after the proprietary term expires. At BOEM, we also use public geospatial data that is becoming more readily available through data portals. We then use this geospatial data in our decision-making processes.

In the coming years, where do you expect to find the biggest potential for offshore oil & gas? And how will this be established?

Approximately every five years, we compile an assessment of the undiscovered oil and gas resource potential of all 26 of the OCS planning areas. We use our understanding of known oil and gas fields and accumulations, both on the OCS and from analogous areas around the world, to inform our estimates of the size and location of yet-to-be-found resources. Based on our latest assessment completed in 2016, we project that the Gulf of Mexico still holds the largest potential for offshore oil and gas discoveries in the future. That's the location of over 50% of the projected undiscovered oil and over 40% of the projected undiscovered gas on the OCS. More specifically, we project that approximately 95% of the undiscovered oil resource in the Gulf of Mexico will be in a relatively deep water environment where oil production is currently at an all-time high. Also, we see the Arctic Alaska OCS as holding significant potential with nearly 30% of the undiscovered resources on the OCS located within the Chukchi Sea and Beaufort Sea planning areas.

How will the Executive Order on Implementing an America-First Offshore Energy Strategy affect the way seismic data will be collected and used in the future?

The Executive Order will not affect the way seismic data is collected or used on the OCS. However, implementation of this Executive Order will affect the seismic permit application approval process because it directs the Secretary of Interior and Secretary of Commerce to expedite all stages of consideration of Incidental Take Authorization requests, including Incidental Harassment Authorizations and Letters of Authorization and seismic survey permit applications. The Department of Commerce – via the National Marine Fisheries Service (NMFS) – has the responsibility for reviewing and authorising Incidental Take Authorization requests and Incidental Harassment Authorizations prior to BOEM-approved seismic activities occurring. In order to comply with the Executive Order and corresponding Secretary's Order, BOEM and

NMFS will work together to establish and implement a plan leading to a more expeditious approach to approving these authorisations, thus reducing the time needed to review permits for seismic activities on the OCS.

What is the biggest challenge in collecting the maritime geospatial information and making it available?

While there are many challenges to making geospatial data available, formatting and download space can be especially difficult at times. Many data products come in formats that the general public or other stakeholders cannot easily input into available GIS software, and such data can be voluminous. Therefore, we and our contractors often need to reformat the data, parse it into smaller packets, and find a public-facing server on which data can be accessed, along with all the necessary security protocols that agencies are required to implement to protect data from unauthorised access.

Does BOEM's marine geospatial (hydrographic and oceanographic) data have a wider use?

Absolutely. Most of BOEM's marine geospatial data that is not restricted from public use is made available or linked through our website and MarineCadastre.gov. In addition, the data must be archived at NOAA's National Centers for Environmental Information (NCEI), which is accessible to the public. BOEM's geospatial data and other agency data layers are used for marine planning efforts. In practical terms, marine planning provides a public process to better determine how the ocean and coasts are sustainably used and protected – both now and for future generations. In addition to MarineCadastre.gov, other marine spatial planning portals such as the Mid-Atlantic Regional Council on the Ocean (MARCO) Portal, North East (NE) Data Portal and West Coast Governors Portal all directly link to geospatial data served by BOEM.

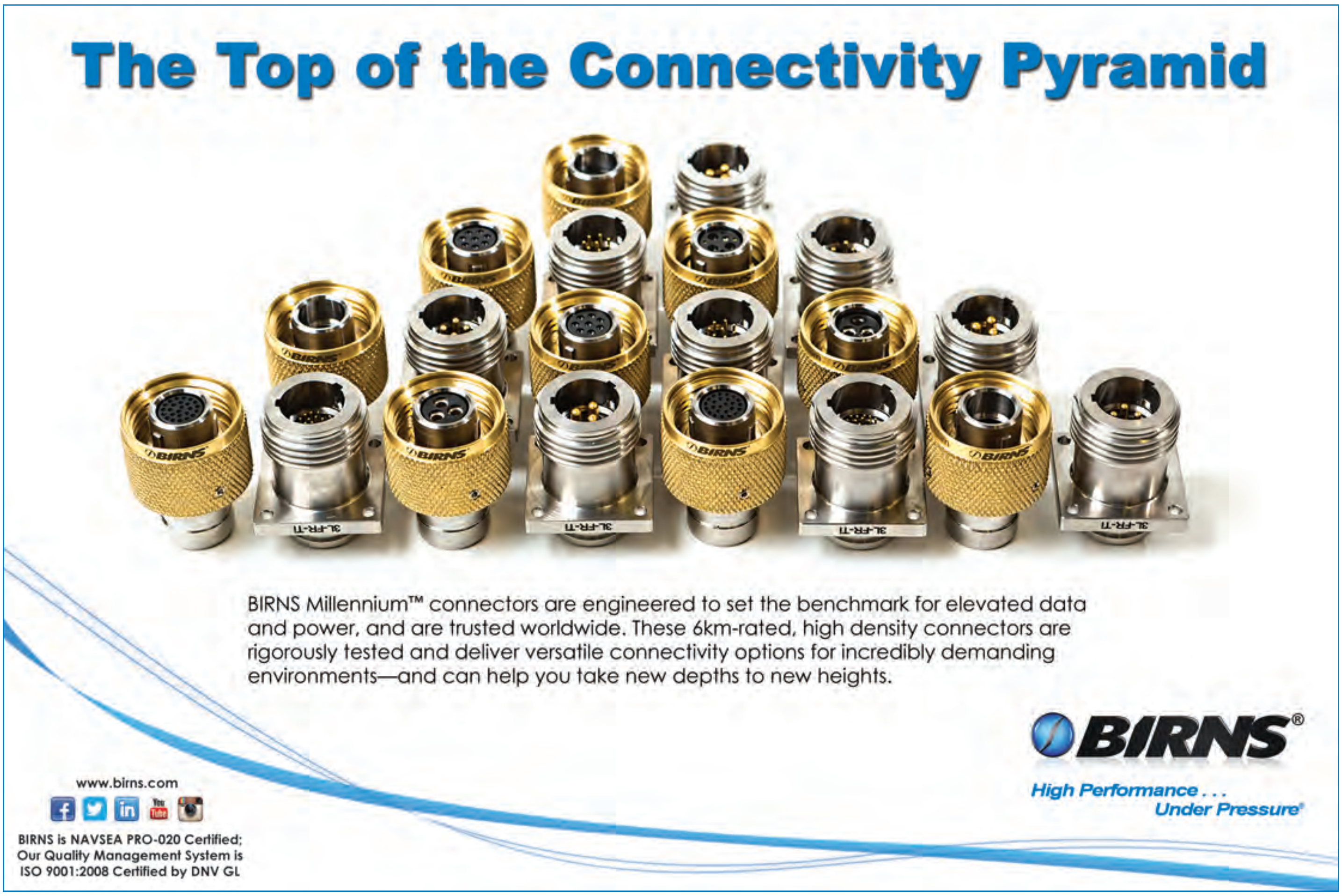
▲ *Figure 1: Dr Walter Cruickshank, acting director, Bureau of Ocean Energy Management.*

BOEM is the initiator of the Environmental Studies Programme. What is the focus of this research programme?

BOEM's Environmental Studies Program (ESP) is mandated by Section 20 of the OCS Lands Act to conduct studies that will provide the information needed to assess and manage impacts on the human, marine and coastal environments from offshore energy and marine mineral development. Section 20 specifically calls for studies addressing impacts on marine biota, which may result from chronic, low-level pollution or from large spills associated with OCS production. Section 20 also calls for studies to monitor human, marine and coastal environments. These studies provide time-series and data-trend information for identifying significant changes in the quality and productivity of those environments and identify the causes of any changes. The ESP has provided over USD1 billion for research to this end since its inception in 1973.

Is BOEM collecting oceanographic environmental data on its own, or which other organisations are involved in collecting and/or managing this data?

BOEM's ESP uses contracts, cooperative agreements and interagency agreements to collect oceanographic environmental data by engaging the private sector, universities and other Federal and State agencies. BOEM scientists manage a diverse portfolio of sciences to inform BOEM decisions. Many areas of intense study are designed and developed by BOEM scientists that feed our National Environmental Policy Act (NEPA) and consultation processes. Such areas of study include physical oceanography, atmospheric sciences, biology, protected species, social sciences and economics, submerged cultural resources and environmental fates and effects. BOEM is a leading contributor to the growing body of scientific knowledge about the nation's marine and coastal environment, and we partner with several Federal agencies (e.g.



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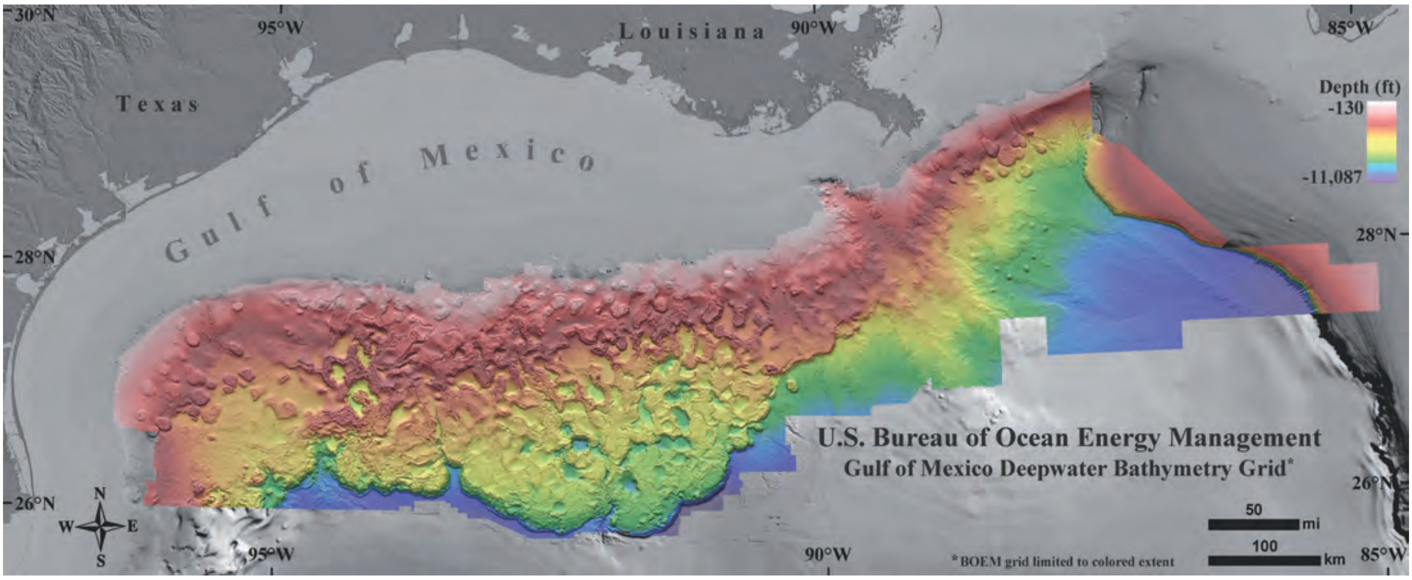


▲ *Figure 2: BOEM's Gulf of Mexico Deepwater Bathymetry Grid.*

National Oceanic and Atmospheric Administration, U.S. Fish and Wildlife Service), and State and local governments, as well as other stakeholders (e.g. universities, tribal partners) to achieve this goal. All BOEM ESP study products and data are managed in ESPIS (https://marinecadastre.gov/espis/#/). This geospatial data viewer enables users to discover all ESP studies ever conducted and provides web links back to other agency websites where data can be found.

The emphasis of the Executive Order on Implementing an America-First Offshore Energy Strategy is on hydrocarbon energy sources. What is the potential of tidal and wave energy for the United States?

At this time, offshore wind technology is more commercially viable than offshore wave and current technology. In fact, offshore wind energy offers significant benefits for the USA. Using existing technology, there is a technical potential of over 2,000GW of offshore wind resource capacity accessible in US waters. This is equivalent to an energy output of 7,200 terawatt-hours per year – nearly double the total electric generation of the USA in 2015. We are on our way toward achieving such potential. To date, we have awarded 12 offshore wind renewable energy leases, soon to be 13, with over 15GW of capacity: enough to power over five million homes. These leases will serve as a strong foundation to develop an offshore wind industry in the USA.

With regard to wave and current energy, if an interested party submits an application for an ocean wave or current project, BOEM will determine whether such a proposal has promise. If so, we could decide to move forward with processing the application.

The coastal states see various ways of developing renewable energy, yet some (like Texas and Louisiana) don't seem to have any plans developed for renewable or wave and tidal energy generation. Will they be encouraged to do so?

At BOEM, we manage offshore energy and marine mineral resources in an environmentally and economically responsible manner. This includes providing responsible access to offshore renewable energy resources, and were BOEM to be approached by an interested state or potential developer, we would work closely with our diverse stakeholders to evaluate future potential projects.

How is BOEM working with similar organisations in neighbouring countries on efforts for maritime geospatial and environmental data?

We work with our counterparts in Mexico and Canada and through multilateral efforts such as the International Offshore Petroleum Environmental Regulators to exchange information regarding environmental issues associated with offshore oil and gas. For example, regarding Mexico, BOEM signed a Letter of Intent with the Agency for Safety, Energy and Environment (ASEA) in October 2016 to strengthen cooperation, coordination and information-sharing on environmental matters related to offshore hydrocarbon activities in the Gulf of Mexico. BOEM and ASEA are in the process of identifying areas that would be particularly appropriate for greater coordination. In March 2017, BOEM and ASEA participated in the Gulf of Mexico Workshop on International Research. The workshop identified knowledge gaps regarding marine ecosystem science, prioritised relevant research needs and intensified relationships between individuals and organisations working on marine science issues in the Gulf of Mexico. ◂

As deputy director, and currently acting director, of BOEM, Dr **Walter Cruickshank** oversees the administration of programmes that manage the development of the USA's offshore resources in an environmentally and economically responsible way. These programmes include leasing, plan administration, environmental studies, analysis of the National Environmental Policy Act, resource evaluation, economic analysis and the Renewable Energy Program. Prior to becoming the deputy director of BOEM upon its establishment in October 2011, Dr Cruickshank had served as deputy director of the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) and the former Minerals Management Service (MMS) since 2002. Dr Cruickshank has worked in the Department of the Interior for more than 30 years. He earned a bachelor of arts in geological sciences from Cornell University and a doctorate in mineral economics from the Pennsylvania State University.

EU-funded WiMust Project Advances a Novel Approach to Existing Methods

WiMust – A Fleet of AUVs for Seismic Surveys

The ongoing WiMUST (Widely scalable Mobile Underwater Sonar Technology) project aims to design and test a system of cooperating autonomous underwater vehicles (AUVs) that would simplify seismic surveying and offer significant advantages over modern streamer-towing operations.

Seismic surveys are a crucial part of offshore exploration, producing detailed imagery of sub-bottom rock formations that enables the location and evaluation of oil and gas deposits. Other commercial, scientific and military uses include assessments of the seabed for offshore construction, installations of renewable energy infrastructure, academic studies of the geology, civil engineering projects in shallow coastal zones, etc.

Traditionally, seismic acoustic surveys are performed with a vessel that tows a powerful acoustic source (an airgun array) and one or multiple streamers - an array of hydrophones on a system of long cables. Acoustic waves from the source bounce off the sub-bottom structures and travel back to the sea surface, where the reflections are captured by the hydrophones. Post-processing of the acquired sound propagation data reveals the details about the structures beneath the seafloor.

Objectives of the survey and the subsurface complexity in the target area define the particular configuration of the data-acquisition solution. Developed over the past 50 years, contemporary methods range from 2D surveys with single-vessel narrow-azimuth passes to sophisticated wide-azimuth multi-vessel 3D surveys, and the choice of a particular survey scenario is based on balancing the required image quality with available time and cost resources while minimising risks.

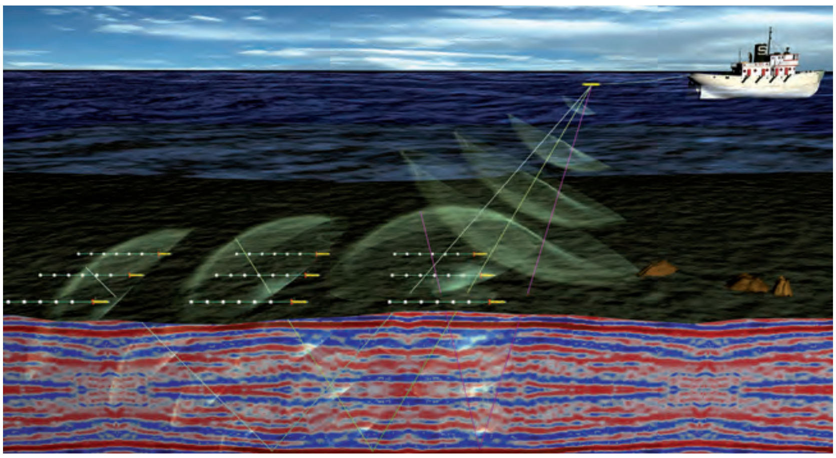
Modern Seismic Surveys: The Scale

As modern technology allows the capture and processing of bigger and bigger data volumes, a large 3D survey would, for example, involve a specialised vessel that tows up to 10 parallel streamers 4 to 12km in length, each containing over 300 receivers paired with accelerometers, depth and other sensors. With 17.6 square kilometres covered by its spread, one such system is, in fact, the largest man-made moving structure on Earth.

Towing such a large object may yield faster production rates, but obviously comes at a cost. Even manoeuvring a big streamer array requires significant space and time - a 10km streamer might require up to 8 hours to turn.

While being extraordinarily well engineered solutions, the streamers present limitations that need to be overcome in order to further improve seismic acquisition quality and efficiency.

Overall, seismic surveys are highly complex operations - and increasing demand drives



▲ *Figure 1: The WiMUST system - an artist's rendering. All images with this article, image courtesy: WiMUST consortium.*

▲ *Figure 2: EvoLogics modem board with the chip-scale atomic clock.*

exploration into more and more challenging environments that require extremely sophisticated approaches. For example, 'looking under the edges' of acoustically opaque structures like salt domes or dense basalts might require a costly multi-vessel survey with additional source and/or streamer-towing ships (Gisiner, 2016).

Large streamer spreads are subjected to lateral drift (so-called feathering) that requires efforts to mitigate, and are exposed to significant forces that lead to risky deployment and recovery. Other setbacks include swell and turbulent flow noise that affects seismic data, inflexible source-receiver geometry, inability to operate in obstructed areas, and extensive barnacle fouling in certain areas.

Modern industry tends toward longer streamers, higher streamer counts, tighter streamer spacing. But towing such a large recording system may not be the ultimate solution in terms of the ratio of data quality to cost. Is bigger necessarily better?

WiMUST Project: The Concept

The EU-funded WiMUST project aims to fundamentally improve existing methods for geophysical acoustic surveys by 'cutting the cable' and decoupling the acoustic source from the system of receivers. The main novelty of the WiMUST system is using marine robots to capture seismic data instead of conventional streamers.

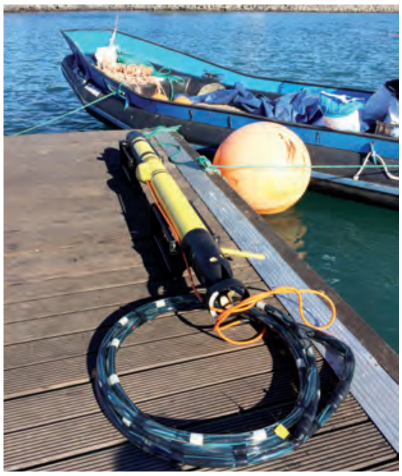
Discarding complex kilometre-scale structures, the 9 project collaborators advance an innovative concept where short streamers of small aperture are towed by autonomous underwater vehicles (AUVs) that work together in a cooperative formation.

The AUVs act as sensing and communication nodes of a reconfigurable mobile acoustic network, and the whole system behaves as a distributed sensor array for recording data, obtained by illuminating the seabed and the sub-bottom with strong acoustic waves from a source(s) installed on-board a support vessel (Figure 1).

Project Partners

The 36-month WiMUST initiative started on 1 February 2015 and brings together a group of research institutions, geophysical surveying companies and SMEs with expertise in autonomous systems, marine robotics, communication, navigation and cooperative control.

▲ *Figure 3: IST MEDUSA AUV at Sines trials, 2016.*



▲ *Figure 4: Graaltech Folaga AUV at Sines trials, 2016.*

The four academic partners are:

- the Interuniversity Centre on Integrated Systems for the Marine Environment - ISME (Project coordinator) - Italy
- Instituto Superior Tecnico - IST - Portugal
- Centre for Technological Research of the Algarve - CINTAL - Portugal
- University of Hertfordshire - United Kingdom

The five industrial partners are:

- EvoLogics GmbH - Germany
- Graal Tech S.r.l. - Italy
- CGG - France
- Geo Marine Survey Systems B.V. - The Netherlands
- GeoSurveys - Consultores em Geofisica, Lda. - Portugal

WiMUST System: Current Status

In 2015, the end-user partners laid out the WiMUST groundwork by defining the requirements for the system and a reference scenario to validate its performance - a 3D geotechnical seismic survey. Based on the end-user objectives, the WiMUST consortium established system specifications and outlined the roadmap for further theoretical and experimental studies in distributed sensing, cooperative control, underwater communication and group navigation. The goal is to design and test a system capable of executing a compact geotechnical survey, that could eventually be scaled to performing large 3D kilometre-sized operations.

Research in Distributed Sensing

The AUVs bring the benefits of mobility and allow for the departure from the traditional geometry of seismic receiving arrays by employing vertical and horizontal configurations. Within the WiMUST framework, the system of receivers is viewed as a distributed sensor array (DSA), free to adopt any geometry. To maximise the information content extracted from the acoustic signals, the WiMUST research efforts in determining the criteria for optimal DSA geometry follow the low field coherence approach, i.e. the sensors for seismic data-acquisition should be placed where the acoustic field is the most diverse.

Research in Cooperative Navigation and Control

Cooperative navigation and control of the AUV team is crucial for WiMUST system performance, as acquisition of seismic data with the distributed sensor array would require each receiver to be correctly placed for the desired source-receiver geometry of the mission.

WiMUST partners work on cooperative navigation and control algorithms that will accurately steer the vehicles so that all the AUVs and the towed streamers avoid collisions and maintain the specific geometry relative to the acoustic source(s). Several algorithms were investigated - the cooperative path following, where a pre-defined path is set for the formation, and the target/trajectory tracking, that imposes 'time and place' rules - a timing law and prescribed waypoints for each vehicle to follow. A hybrid approach that combines the benefits of the two seems more appropriate for the WiMUST system and is the subject of further investigation (Indivieri et. al, 2016).

Research for Mission Planning

Efforts in mission planning for the WiMUST system are focused on an efficient planner that will generate waypoints, based on the required vehicle formation for optimal sensor array geometry, and ensure collision-free AUV streamer motions. The paths generated by the planner will be used by the navigation system to guide the vehicles along the mission phases.

Research for the Communication System

Communication architecture of WiMUST must ensure that positions of each AUV in the formation are known with centimetre-scale accuracy, and that the internal clocks of the vehicles are precisely synchronised. This is crucial to ensure that the acquired seismic data is assigned temporal and spatial tags that are consistent across the formation, as well as to derive relative positions of the vehicles for navigation and control.

The AUVs are equipped with EvoLogics underwater acoustic modems, capable of measuring distances with high accuracy even when operating in dynamic, reverberant underwater acoustic channels thanks to the adaptive spread-spectrum technology. To accurately synchronise the nodes of the distributed underwater acoustic network, the team implemented a novel integration of a chip-scale atomic clock into the modems - so the internal clocks of the sensor network nodes are synchronised with GPS on the surface pre-mission (the so-called disciplining procedure), and maintain the desired high precision when submerged (Figure 2).

Ongoing research involves implementing and testing short- and long-range communication protocols for AUV navigation and control, inter-vehicle service data exchange, as well as transmissions of seismic data samples to the support vessel for quality monitoring.

Experimental Trials

In 2015 and early 2016 in Lisbon, preliminary tests of 2 IST's MEDUSA class AUVs towing 13m streamer dummies from Geo Marine delivered valuable data for dynamic modelling of the AUV streamer system, and in March 2016 Graal Tech and ISME carried out similar preliminary tests of Graal Tech Folaga AUV towing the Geo Marine dummy in the area of La Spezia, Italy.

The first larger-scale experimental trials took place in Sines, Portugal, in November 2016. Project partners used IST's MEDUSA AUVs, Folaga AUVs from Graal Tech and Geo Marine streamers. A catamaran from IST served as a support vessel for AUV tracking. Key challenges of the trials were to validate the atomic clock disciplining to ensure synchronised AUV timekeeping, perform synchronous clock, one-way-travel-time positioning of the vehicles, as well as testing algorithms for cooperative behaviour of the AUV swarm (Figure 3 and 4).

The trial objectives were achieved, and WiMUST partners are planning the next round of field experiments for July 2017 to experimentally verify further advances. The next step would be performing a small-scale seismic survey using a sparker acoustic source, and comparing the results with pre-existing surveys of the area (Figure 5).

Future Prospects

A robotic receiving antenna that changes its geometry is a step away from the classical ship-towed streamer solution and holds a lot of potential for significant improvement of ocean surveying.

▲ *Figure 5: The AUV formation at Sines trials, 2016.*

Compared to streamer-towing, a robotic swarm system would greatly simplify marine operations from deployment to recovery - cutting the cables between the ship and seismic receivers would cut both time and cost of a survey operation. Such systems could be deployed from vessels of opportunity and work safely and efficiently in congested areas.

Using AUVs would significantly reduce risks that skyrocket project costs: where a towed system is often a survey's single point of failure, the failure of one AUV would not compromise operation of the swarm. This is important, as whilst the geophysical survey is a fraction of a large construction project's budget, survey delays can cause tremendous penalties incurred due to standby rates of construction equipment chartered in advance.

Offering an advantage in data quality, distributed receivers of acoustic signals could be excited from different angles, which would improve the seabed and sub-bottom resolution as well as maximise the extracted information content.

Optimising the shape of the robotic receiver formation to the specifics of a particular survey scenario is a big leap for the seismic surveying technology, and design and implementation of such systems is a challenging task that calls for significant research and experimental efforts. Forthcoming research aims to reinforce the advantages perceived today. The WiMUST project's goal is to pave the wave for further advances and achieve results that could be scaled to 3D survey missions for exploration and development of large target dimensions.

Acknowledgements

The work of the WiMUST project collaborators received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 645141.

Special thanks are due to Giovanni Indiveri (ISME), Jonathan Grimsdale (CGG), Henrique Duarte (GeoSurveys) and Luís Sebastião (IST) for their kind assistance. ◀

More information

- Robert C. Gisiner (2016). Sound and Marine Seismic Surveys - Acoustics Today, Winter 2016, Volume 12, issue 4; Acoustical Society of America, pp 10-17.

- Giovanni Indiveri, Gianluca Antonelli, Filippo Arrichiello, Andrea Caffaz, Andrea Caiti, Giuseppe Casalino, Nicola Catenacci Volpi, Ivan Bielic de Jong, Daniela De Palma, Henrique Duarte, Joao Pedro Gomes, Jonathan Grimsdale, Sergio Jesus, Konstantin Kebkal, Elbert Kelholt, Antonio Pascoal, Daniel Polani, Lorenzo Pollini, Enrico Simetti and Alessio Turetta, Overview and first year progress of the Widely scalable Mobile Underwater Sonar Technology H2020 project, 10th IFAC Conference on Control Applications in Marine SystemsCAMS 2016 Trondheim, Norway, 13-16 September 2016, IFAC-PapersOnLine, Volume 49, Issue 23, 2016, Pages 430-433, ISSN 2405-8963, DOI: 10.1016/j.ifacol.2016.10.442

- WiMUST official page http://wimust.isme.unige.it/index.php/publications

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Filling in The White Ribbon

Radar-based Nearshore Hydrographic Monitoring

Shore-based marine radar techniques have recently proved to be an excellent tool for monitoring erosion and accretion in the dynamic nearshore area through repeated and automated large-area surveys. The ability to routinely survey intertidal areas has always been logistically challenging and expensive due to the limitations imposed by the tides, weather and access. Advances in remote sensing techniques and the development of new data-processing algorithms have made the surveying of these areas much more cost-effective.

There is a global need for greater awareness of the sedimentary dynamics of intertidal regions. These seldom surveyed areas are host to a variety of vital coastal resources, both social and physical. In particular, intertidal zones often serve as a crucial buffer zone between high energy waves, tides and currents and coastal developments such as ports, harbours and residential areas. In many locations the integrity of these buffer zones is being severely degraded. The results of mismanagement of coastal areas can be expensive and damaging to people, environments and businesses operating in coastal areas. Unmonitored sedimentation can lead to costly increased dredging requirements and erosion can increase the risk of flooding and damage to coastal defences.

High traffic subtidal areas such as shipping channels, harbours and anchorages are generally routinely surveyed and dredging routines are well established by port authorities and coastal managers. However, the adjacent intertidal regions are often woefully under-surveyed. Frequently, trends of sediment migration, local hydrodynamics and patterns of seasonal change are known only anecdotally and vary significantly in their extent over inter- and intra-annual timescales.

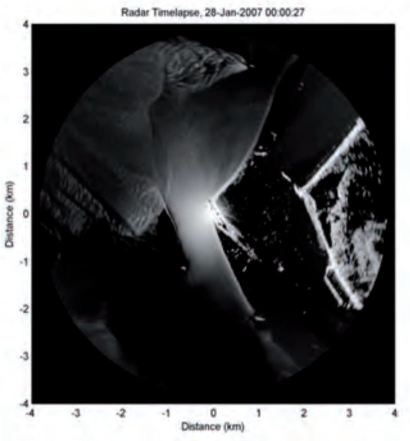
Rapidly Deployable Remote Sensing Survey Platform

The rapidly deployable radar survey platform (Figure 1), developed by Marlan Maritime Technologies Ltd provides the ability to cost-effectively monitor long-term changes in these areas without anyone getting their feet wet or their boats grounded. The radar-based system provides advanced warning of adverse sedimentary activity, volumetric information on sediment movements (especially useful for monitoring beach nourishment schemes) and broad-scale indications of beach system health, delivering a wealth of previously difficult-to-gather information to coastal managers.

Marine Radar-based Hydrographic Monitoring

Marine radar has been used as an oceanographic tool now for several decades. However, its popularity has increased due to recent advances in computing power, data storage, video digitisation and new data-processing algorithms. Researchers in the 1980s determined that radar is capable of imaging ocean waves and could be used to infer water depths and near-surface currents through linear wave theory. These 'wave inversion'

▲ *Figure 1: The Rapidly Deployable Radar Survey Platform in place at a new deployment in the northwest UK, tasked with monitoring winter storm erosion rates and sediment migration (Image courtesy: Cai Bird).*



▲ *Figure 2: A 10-minute time-exposure image created using marine radar data, one of many hundreds used to generate nearshore survey data.*

▲ *Figure 3: Study site location: Dee estuary UK showing area surveyed by a single radar system. Map data from www.OpenSeaMap.org.*

techniques were developed over the next few decades and commercialised, but can still struggle to resolve the fine detail needed to monitor the high spatial variability typical of intertidal zones.

This shortcoming led to the development of the temporal radar waterline method by researchers at the National Oceanography Centre, the University of Liverpool and Marlan Maritime Technologies Ltd. in a three-year project funded by the Centre for Global Eco-Innovation and the European Regional Development Fund. This technology and enable its deployment commercially, the results were compared to an airborne Lidar survey. Figure 4 shows the radar-derived elevations over the same area covered by a Lidar survey flown at the same time. Figure 5 illustrates the Lidar elevations. It is clear that the radar system is able to derive the major features of the topography including complex channels and bedforms.

The radar-derived elevations were for the most part within +/- 20cm of the Lidar results and areas of poorer accuracy were observed in a series of linear

Cost-effectively monitoring long-term changes without anyone getting their feet wet or their boats grounded

technique uses the radar-imaged sea surface (Figure 2) and an accurate record of tidal elevations as an altimeter to measure tidally-driven water level elevations at each pixel in a radar scan with a maximum radial working range of 4km (Bell et al., 2016); the effective range can be extended by using larger, more powerful antenna and mounting the scanner higher to alleviate shadowing. The new approach differs from more traditional waterline-based methods by altering the procedure from that of detecting precise waterlines in individual images, to associating the temporal pattern of wetting and drying at each pixel with a known tidal record.

Surveys in a Complex Estuary Environment

The developed technique is able to monitor extremely complex geomorphological environments. Initial research and development was carried out using a three-year dataset collected from the Dee estuary, northwest UK. This estuary has a tidal range in excess of ten metres on high spring tides and a very complex morphology with large areas of intertidal sandflats, subtidal channels, mudbanks, saltmarshes and rocky areas. Figure 3 shows the location of the study site, the radial area highlighted shows the extent of the radar survey from its position on Hilbre Island in the estuary mouth. This 2.5m radar antenna derived intertidal topography within a 4km radial range with a gridded 3m spatial resolution.

Comparison with Airborne Lidar

This technique is still at a relatively early stage of development and in order to validate the

features at longer ranges, indicative of intermittent shadowing reducing the signal to noise ratio from these areas. Elevations derived by the radar represent the mean elevation over two weeks, while the Lidar is a snapshot in time so there will inherently be some differences.

While the absolute accuracy of this method is currently lower than modern Lidar, differences in elevation are consistent between surveys as shown by a stability analysis (in Bell et al. 2016). This stability means that observed changes over time are a good reflection of actual morphological change being observed by the radar, allowing moving sedimentary features to be detected and areas of erosion and accretion detected with high sensitivity.

Monitoring Dynamic Geomorphology

Significant changes in the morphology of the Dee estuary were detected over three years of continuous radar observation. Multiple intertidal bars with wavelengths of the order of 100-200m and crest lengths in excess of 200m were observed migrating onshore from the nearshore zone and welding onto the beach over a course of several seasons. Bedforms were observed to flatten in winter during the stormy season and recover during spring and summer (Bird et al. In press). Video 1 shows this phenomenon on a beach at the mouth of the Dee estuary.

While in the demonstrated case this movement was very benign, similar large scale migrations of sediment can cause great disruption to operations in coastal environments if undetected. Examples of this kind of disruption include:

More information

- P.S. Bell, C.O.Bird & A.J.Plater (2016) A temporal waterline approach to mapping intertidal areas using X-band marine radar. Coastal Engineering, 107, p.84-101. http://dx.doi.org/10.1016/j.coastaleng.2015.09.009

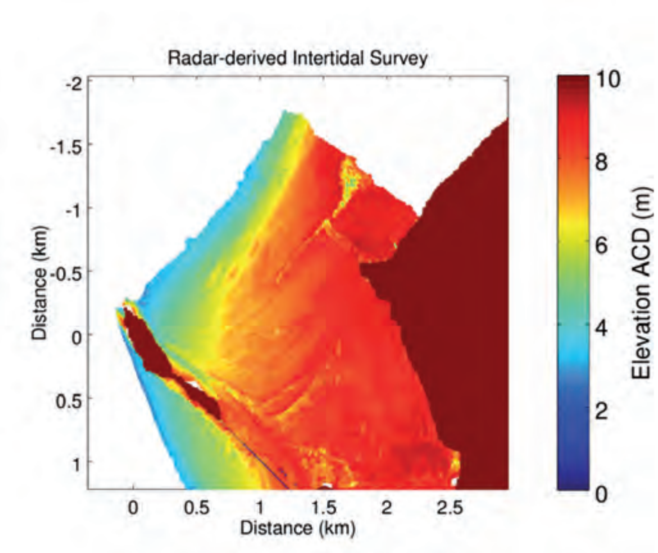
- P.S. Bell & J.C. Osler (2011) Mapping bathymetry using X-band marine radar data recorded from a moving vessel. Ocean Dynamics 61: 2141. doi: http://dx.doi.org/10.1007/s10236-011-0478-4

- P.S. Bell, (2009) Coastal mapping around shore parallel breakwaters. Hydro International, 13 (1). 18-21.

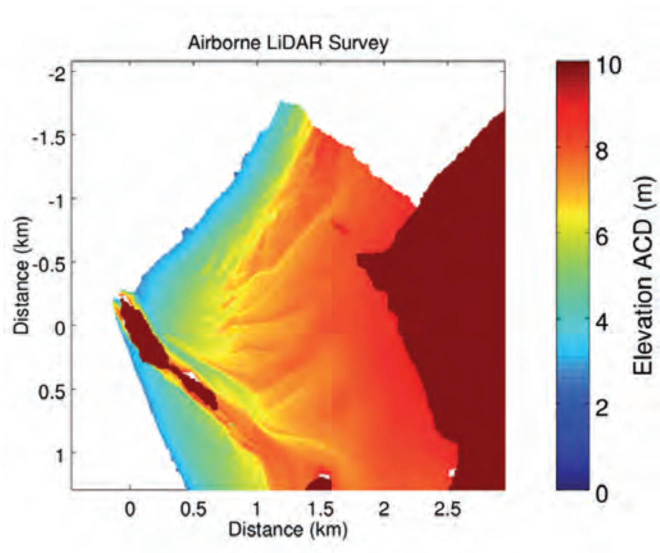
- C.O. Bird, P.S. Bell & A.J. Plater (2017, In Press). Application of Marine Radar to Monitoring Seasonal and Event-based Changes in Intertidal Morphology. Geomorphology.

- http://marlan-tech.co.uk/hydrographic-coastal-monitoring/ or by contacting any of the authors directly.

Video
- Intertidal Bar Migration http://bit.ly/2qHEKkw



▲ *Figure 4: Radar-derived elevations over a section of beach adjacent to Hilbre Island where the Lidar survey overlapped with the radar observations.*



▲ *Figure 5: Lidar measured topography over the same location as imaged by the radar.*

A potent force multiplier in long-term survey campaigns

exposure of sea defence foundations, blocking of cooling water pipes at power stations, blocking of channels at smaller ports, harbours and marinas, in addition to potentially rapid infilling of navigation channels at deepwater ports.

In addition to direct observation of migrating sediment, this technology is also able to provide an overall indication of 'beach health' by tracking volumetric change throughout seasonal cycles (Bird et al. In Press).

Limitations

There are some limitations for this type of survey. The radar must pick up sufficient signal from the sea surface to create an effective image, so tidal areas that are very well sheltered, such as up-river saltmarshes and mudflats, may not be best suited to this technology. Experiments are underway with different radar antennas and sensors to try and survey these problematic areas. Some locations have a very small tidal range combined with steep gradients at the beach, and therefore the area exposed by the rising and falling tide would be relatively narrow and thus a multibeam survey would likely be more applicable as the survey vessel is not time-limited by the tide.

Conclusion

This technology is a potent force multiplier in long-term survey campaigns, as it can be used to monitor the wider area around regularly surveyed channels or to highlight potentially dynamic regions that require further investigation. It has great potential to be used in combination with autonomous surface/underwater/airborne vehicles as it may not be economical for the vehicles to survey large areas continuously, but they could be used to fill in the areas where the radar is shadowed for example. While it is possible using existing technology to monitor the changing morphology of beaches, sandbanks and nearshore zones, the cost of repeated Lidar or manual in-situ surveys is extremely high in comparison to a radar deployment.

The use of marine radar makes the collected dataset extremely versatile. A single sensor can cost-effectively produce a wealth of hydrographic information with the application of the correct data-processing algorithms, including subtidal bathymetry down to water depths of 30-50m, intertidal topography, near-surface current directions and magnitudes, and wave statistics. The radar can also continue to be used as a vessel detection tool through interface with VTS (Vessel Traffic Service) systems, and remains an effective imaging tool that can be used to increase situational awareness in a maritime environment.

Acknowledgements

Thanks are extended to the Marlan Maritime Technologies, the Centre for Global Eco-Innovation, ERDF, the National Oceanography Centre, NERC and the University of Liverpool for funding and supporting this project over the last few years. ◀

Dr Cai Bird has worked with Marlan Maritime Technologies since its foundation in 2013. His research focuses on developing and applying novel algorithms to remote sensing data in order to develop new products and services for the hydrographic survey industry. Cai completed his PhD in 2016 at the University of Liverpool and National Oceanography Centre whilst working with Marlan and continues to work closely with these and other academic institutions.

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Dr Paul Bell is associate head of Ocean Technology & Engineering at the UK's National Oceanography Centre. He specialises in the development of marine radar remote sensing methods and earned a BSc in Physics & Electronics from St Andrews University, Scotland in 1992 and a PhD from Bangor University, North Wales in 2005.

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Esmeralda and *São Pedro*

The Search for **Vasco da Gama's Lost Ships**

Two Portuguese ships from Vasco da Gama's second voyage to India, left behind in the Gulf of Aden to disrupt maritime trade through the Red Sea, were wrecked during a storm in 1503 on the coast of Al Hallaniyah Island, Oman. The remains of at least one of the ships was found in 1998, prompting a search for the second ship that was undertaken in 2013. The geophysical survey was complicated by environmental conditions but succeeded in locating all cultural heritage material in the bay.

The Portuguese ships that were the target of this research, and the ensuing searches, are two of the most interesting and early European ship losses to have occurred in Oman and the greater Western Indian Ocean. The two ships, *Esmeralda* and *São Pedro*, were commanded by da Gama's maternal uncles, Vicente and Brás Sodré. Extensive archival research identified two potential locations for the wreck

▲ *Figure 1: The bay where the Portuguese ships were lost.*

▲ *Figure 2: Searching with the magnetometer in shallow water close to the shore.*

▲ *Figure 3: Diver with the almost completely buried anchor.*

site, which were searched by a small team in May 1998. Nothing was found at the first location on the western side of the island so the team then moved to the eastern bay and almost immediately found more than 20 stone cannonballs in shallow water close to the shore. During a second more extensive expedition that same year the team located more stone shot, a lead sounding weight and other artefacts suggesting that at least a one of the shipwrecks had been found. Work was suspended because of logistical difficulties, but was restarted in 2013 as a collaborative project with Oman's Ministry of Heritage and Culture (MHC). One of the aims of the current work was to undertake a detailed geophysical survey to locate the remains of any ships lost in the bay and to learn more about the wreck site located earlier.

Ghubbat ar Rahib Bay

The bay where the wreck material was found provides natural shelter from the southeastern monsoon making it an anchorage that has been used for centuries. It was known that the steamship *City of Winchester* was scuttled in the bay in 1914 and the cargo ship *Al Quasmi* was wrecked on the western shore in 1999. These two ships are large and made of steel and thus easy to locate, but the Portuguese ships were small vessels made of wood, a material which does not survive well underwater.

Historical accounts suggested that one of the Portuguese vessels was wrecked very close to shore whilst the second vessel may have sunk in deeper water. Any vessel on the shore would be destroyed but some structure may remain if the ship sank in deep water and was quickly covered by sediment. The iron anchors used by the ships and the tons of ballast stones they carried might also mark where the hull sank. It was known from the historical accounts that the surviving crew salvaged as much of the wrecks as they could, and with the eroding effects of the sea there may be little remaining of either ship. The geophysical survey would therefore need to be of high quality in order to detect the smallest objects on the seabed.

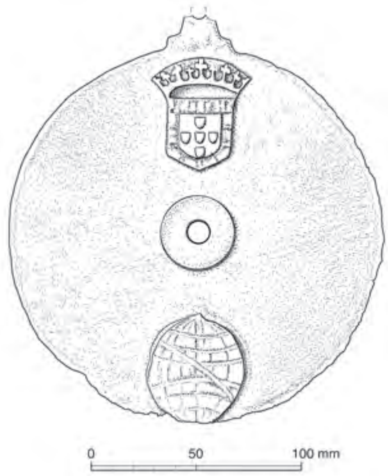
Logistics

The survey was challenging because of the remote location of the island off the southern coast of Oman, the shallow depth of the water inshore and the difficulty of detecting such ancient shipwrecks. Because of the shallow water the survey vessel needed to be small yet large enough to support the survey equipment and operators. A Geometrics G882 caesium magnetometer with a Tritech altimeter was used to detect iron objects. Only a small amount of iron was expected to survive so the highest quality magnetometer was needed for detecting the smallest magnetic anomalies. Wooden shipwrecks often erode away leaving only a 'ghost' of the wreck on the seabed so a high-resolution Edgetech 4125 Dual Frequency (400/900kHz) side-scan sonar was used. Positioning was provided by a C-Nav 3050 GNSS and bathymetry was measured using a simple Garmin fish-finder.

Smallest Targets

The sonar survey was run at a slow speed and short range in order to detect the smallest possible targets. The side-scan tow fish was maintained at an altitude of 6m above the

▲ *Figure 4: 175mm diameter copper-alloy disc marked with the Portuguese royal coat of arms and esfera armilar.*



▲ *Figure 5: Copper disc, possibly a navigation instrument.*

seabed except in areas where the topography changed rapidly and the altitude was increased to avoid collisions. The survey objective was to detect any iron objects larger than 500kg requiring the magnetometer tow fish to be towed just 6m off the seabed and with a 15m separation between adjacent survey lines. Tow speed was maintained at 4 knots but was varied to keep the tow fish at the correct altitude above the seabed. The weather conditions for the survey were ideal with a flat calm sea and minimal current. In the shallow areas the clear water allowed a spotter in the bow of the boat to see any rocks near the surface so they could be avoided.

Results

The side-scan sonar revealed that the seabed in the bay was a wide expanse of featureless sand with only a few targets visible. Of the 310 separate targets detected during the survey, 17 were repeatable, 198 were classified as poor and 95 were caused by marine life – depressions made by large stingrays.

Problems were experienced when processing the magnetometer data as there was a large magnetic field gradient across the whole survey area. The gradient was most extreme closer to shore with the background field changing up to 3.5nT over just 1 metre distance in places. The large size and wide area of the magnetic anomalies indicated they were caused by underlying geology. This background magnetic 'noise' was so large that it masked any effects from iron shipwreck material on the seabed. Unfortunately, the area corresponded with the location of the inshore wreck site so it effectively hid any iron objects that may exist there.

Investigating Targets

Each significant target detected by the side-scan sonar and magnetometer was investigated by divers. An Aquascan DX200 diver held magnetometer was essential for locating iron targets found using the towed magnetometer as all but two of them were deeply buried in the seabed. Close to shore the divers found that even the isolated targets were highly magnetic rocks that produced similar readings to those caused by man-made iron objects.

In the deeper waters of the bay, one small sonar and magnetometer target was identified as the fluke of a large iron anchor almost completely buried in the seabed. The anchor was found to be identical to one on the nearby *City of Winchester* wreck. One other target was the remains of a small steamboat partly buried in the seabed. No identifying marks were found on either the engine or boiler, however this tiny wreck is believed to be a pinnace from the *City of Winchester*.

Conclusions

The results showed that the bay did not contain the remains of many shipwrecks. The iron anchor that was lost in 1914 was buried under more than a metre of sediment indicating that any wrecks older than that date would by now also be completely buried. The inshore magnetometer survey did not detect any targets because of the background noise from magnetic rocks, but the area was carefully searched by divers carrying metal detectors and no shipwrecks other than the first wreck were found.

It is proposed that the wreck found in the shallows is the *Esmeralda* and that the *São Pedro* was washed on the shore before being broken up. The *Esmeralda* was found in an area where the rock ledge along the foreshore is wide with deep gullies, which acted as a trap for the ship and its contents. Had the *Esmeralda* been wrecked at any other point along the shore she too would have simply been washed up on the shore. Work continued on the wreck site in 2014 and 2015, which resulted in the archaeological excavation of more than 2,800 artefacts, including the ship's bell, navigation instruments, rare gold and silver coins, pottery, beads and armaments consistent with the military mission of the Sodré ships.

Acknowledgements

This project was funded by Oman's MHC and by grants to David Mearns from the National Geographic Society and Waitt Foundation.

More information

- The Esmeralda Shipwreck, http://esmeraldashipwreck.com
- David L. Mearns, David Parham, Bruno Frohlich, A Portuguese East Indiaman from the 1502–1503 Fleet of Vasco da Gama off Al Hallaniyah Island, Oman: an interim report, http://onlinelibrary.wiley.com/doi/10.1111/1095-9270.12175/abstract
- https://www.youtube.com/channel/UCHVM7I8t9CVd7enLH4byUTg/feed

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David L. Mearns is an expert in the research, location and filming of shipwrecks. During the course of his 30-year career he has led the research and discovery of 24 important deepwater shipwrecks including MV *Lucona*, MV *Derbsyhire*, HMS *Hood*, HMAS *Sydney*, KTB *Kormoran* and AHS *Centaur*.
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Improvements to Shallow-water Surveying

Rapidly Identifying Patterns and Problems in Multibeam Datasets

The Naval Oceanographic Office (NAVOCEANO) utilises a diverse suite of survey assets to collect high-resolution oceanographic and hydrographic data in shallow-water areas all over the globe. These assets maintain a high operation tempo, resulting in extremely large data volumes. The success of these data collection efforts depends on the quality of collection systems and the ability of personnel to rapidly identify and correct errors.

The collection systems employed by NAVOCEANO are considered to be of the best in the industry, and the survey travel personnel employed by NAVOCEANO are both hardworking and innovative. Even with a combination of adequate equipment and a professional workforce, raw and processed data quality cannot be guaranteed in all instances because:

1. Most NAVOCEANO surveys are multidisciplinary in nature, with one particular data type being the primary data collection focus. Optimising the survey manning complements by completely staffing with full-time hydrographic surveyors (in the case of a primary hydrographic collection) would be preferred but is not realistic for NAVOCEANO survey requirements.
2. Surveying duties for seagoing personnel account for only a small portion of their overall employment responsibilities. The duties required on survey missions are complex and often differ significantly with respect to the duties required while in-house at NAVOCEANO. While the majority of the employees in the Hydrographic Department at NAVOCEANO are survey travellers, most focus neither on data collection nor on data processing on a daily basis while in-house. Maintaining expertise and proficiency with survey collection and processing is inherently challenging.
3. Responsibilities of the survey party members typically end once the survey mission has concluded. Surveyors resume their in-house responsibilities immediately upon return to the office with no additional opportunity to finalise datasets prior to in-house production efforts. Survey datasets may not be ready for in-house production efforts once the crew disembarks the survey vessel.

Because of these nuances of the NAVOCEANO survey structure, the Hydrographic Department observed recurrent problems with survey datasets, including deviations from the Survey Technical Specification documents, incorrect configuration biases, incorrect installation and runtime parameters for the multibeam sonar systems, and data cleanliness issues. Each of these factors was having a direct influence on hydrographic product delivery timelines, as in-house resources were required to address the issues (which in a handful of cases were unresolvable and required re-collection).

Monitoring Datasets

To serve in a more proactive capacity and to ensure Subject Matter Expert (SME) oversight

Module Name	Description
proc_detect	finds files that have no manually- or filter- invalidated beam flags (suggesting they have never been unloaded to)
ppp_detect	determines what navigation service level(s) each file has
params_detect	finds discrepancies between parameter values reported in the SPSS and those found in sensor and process parameters
att_detect	finds ping ranges for which roll, pitch, and heave values equal 99.00 (suggesting an attitude problem)
ds_detect	finds what dual swath statuses apply to each file
ping_detect	displays ping flags for all files, the ping range for each flag, and the time range for each flag
speed_detect	displays minimum, maximum, mean, STD, and variance regarding vessel speed for each file
cov_detect	determines minimum coverages and slopes for each file and suggests appropriate line split distances
pen_detect	finds what penetration filter settings (if any) apply to each file
spike_detect	finds what spike filter settings apply to each file
source_detect	finds what sea surface sound velocity source(s) applies to each file
acta_detect	finds across track angle settings (both port and starboard) for each file
mode_detect	finds what depth mode settings apply to each file
erat_detect	finds whether each file has errors attributed to it in real-time and in post-time
fdes_detect	finds all features, selected soundings, and designated soundings in each file and reports the ping number, depth, and location of each
tide_detect	finds the tide and delayed heave status of all files
sctr_detect	finds files for which Sector Tracking is enabled (an undesirable condition)
secinfo_detect	displays sector specific information (center frequency, pulse type, pulse length) for all files
position_detect	finds ping ranges for which navigation is flagged as bad
trunc_detect	finds files that may have been truncated and estimates the length of what may have been lost
history_detect	finds and summarizes all history records in a file
beam_detect	counts the unrejected, rejected, and dropped beams
svp_detect	counts, names, and determines the number of points in each SVP in a file
svp_retrieve	retrieves SVPs from a file into a new directory
nav_detect	displays navigation service levels for all files, the ping range for each service level, and the time range for each service level

▲ *Figure 1: Sample of NAVOCEANO's Data Detective Services Suite (D2S2) of software used to monitor the collection of shallow-water hydrographic data.*

▲ *Figure 2: The current list of GSF corrections or attributions that can be accomplished by the DCS2 suite.*

on all hydrographic operations, the Hydrographic Department has developed tools and methods, leveraging NAVOCEANO's commercial C/Ku Band data transfer capability, to provide SMEs the ability to monitor data during collection and to rapidly identify anomalies and troubleshoot issues to support the forward-deployed survey crew. The current capacity for data transfer of approximately 25 GB per day supports SME visibility on a representative sample of multibeam sonar Generic Sensor Format (GSF) data files.

To enable thorough and timely monitoring of those datasets, three general assumptions were made about multibeam data quality issues: (1) most data are of good quality, (2) most issues occur in patterns, and (3) most cases of operator error are easily introduced. Each of these assumptions led to specific design choices for the NAVOCEANO monitoring strategy. Along with these assumptions, other ground rules were established to promote the efficiency of data monitoring.

Focus on the problem areas: If most NAVOCEANO data are of good quality, data volume would not necessarily have as much significance as if data quality were indiscriminant throughout all datasets. Monitoring tools that rapidly identify and highlight issues virtually convert a large, amorphous dataset into a small, meaningful one.

It is not sensible to employ tools that are more tedious to use

Illuminate the trends: If patterns are present with most data issues, identification would become markedly easier, and fewer anomalies would go undetected. Output information from monitoring tools is organised to optimise efficacy of human review methods, making trends stand out more.

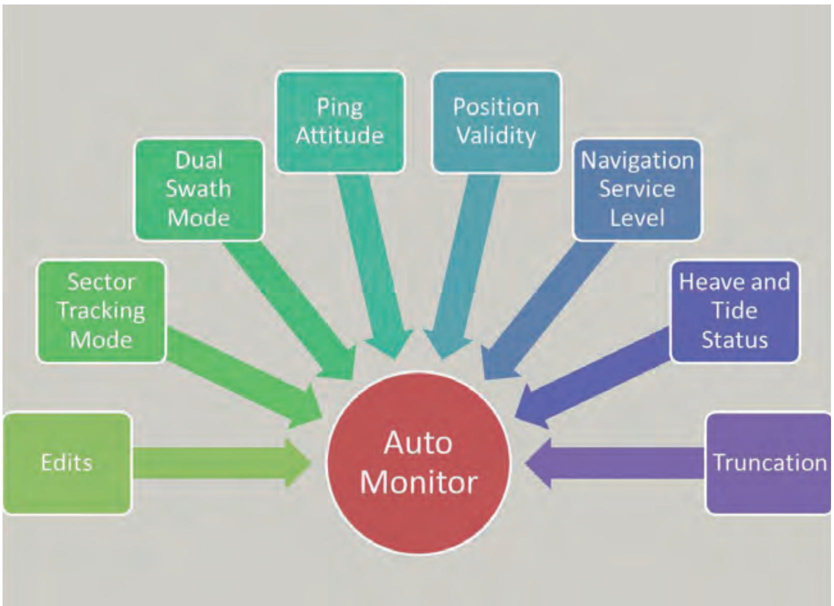
Automate wherever possible: If most operator error is simple to introduce, methods of mitigating and correcting it should minimise the introduction of further operator error. It is not sensible to employ tools that are more tedious to use or that require more human intervention than the erroneously configured systems they are attempting to examine.

Data Detective Services Suite

The first tools created for this monitoring effort were the Data Detective Services Suite (D2S2), a growing series of command line-based C programs to examine the contents of GSF files. Although several commercially available programs are able to examine GSF files, none were found that quickly and simply dissected those files to separate the problematic files and file portions (or files with particular selected parameters) from the files that do not meet those criteria. From early 2012 to the time of this writing, 29 modules were developed as part of D2S2 and address the areas of runtime parameters, ping and beam statuses, vessel speed, editing status, and waveform information, among others. The report formats are simple and text-based to maximise their universality and minimise the effort required to maintain the programs. D2S2 is currently employed on all Linux workstations used by the Hydrographic Department, both in-house and aboard NAVOCEANO vessels. A sample of the current list of programs is shown in Figure 1.

Data Correction Services Suite

The same considerations that led to the creation of D2S2 were later extended to include not only viewing multibeam GSF data but also performing basic corrections or attributions to those files when the situation merited it. Because of the sequential file structure of GSF data, several programs were created as part of the Data Corrective Services Suite (DCS2) by making small modifications to existing D2S2 programs. What's more, the algorithms at the



▲ *Figure 3: 'Auto Monitor' consolidates the most frequently used monitoring tools, thus reducing the time required for issues to be discovered and resolved.*

heart of DCS2 programs can often be easily adjusted to detect and modify another GSF parameter or condition. Example functions of DCS2 include removal of vertical correctors, removal of erroneous out-of-sequence data records, attribution of vertical datum information, and removal of specific types of beam edits, among others. As of this writing, there are seven DCS2 modules, each of which is mentioned in Figure 2. Like D2S2, DCS2 is employed on all Hydrographic Department Linux workstations.

Auto Monitor

The latest evolution of the monitoring effort has led to the consolidation of the most frequently used D2S2 tools into a single program with a unified output called 'Auto Monitor'. Complementary to this development of Auto Monitor was the generation of a standard workbook, formatted to specifically receive this unified output and highlight those areas that deviate from Survey Technical Specification requirements, common settings, or pre-established thresholds. This method of organising the data allows monitoring personnel to see patterns that can aid in discovering the nature of a particular problem and considering potential solutions. While the original D2S2 programs addressed the challenge of analysing vast datasets, Auto Monitor further reduces the time required for issues to be discovered and resolved. The most individual D2S2 components used to derive the consolidated output from the Auto Monitor program are shown in Figure 3.

The Hydrographic Department has been successfully employing these methods to assure the quality of our shallow-water survey missions. Future development for these monitoring efforts will focus on an increased level of automation and linking common problematic data symptoms to known and established solutions.

Acknowledgements

The views expressed in this document are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defence, nor the US Government.

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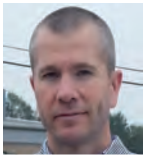

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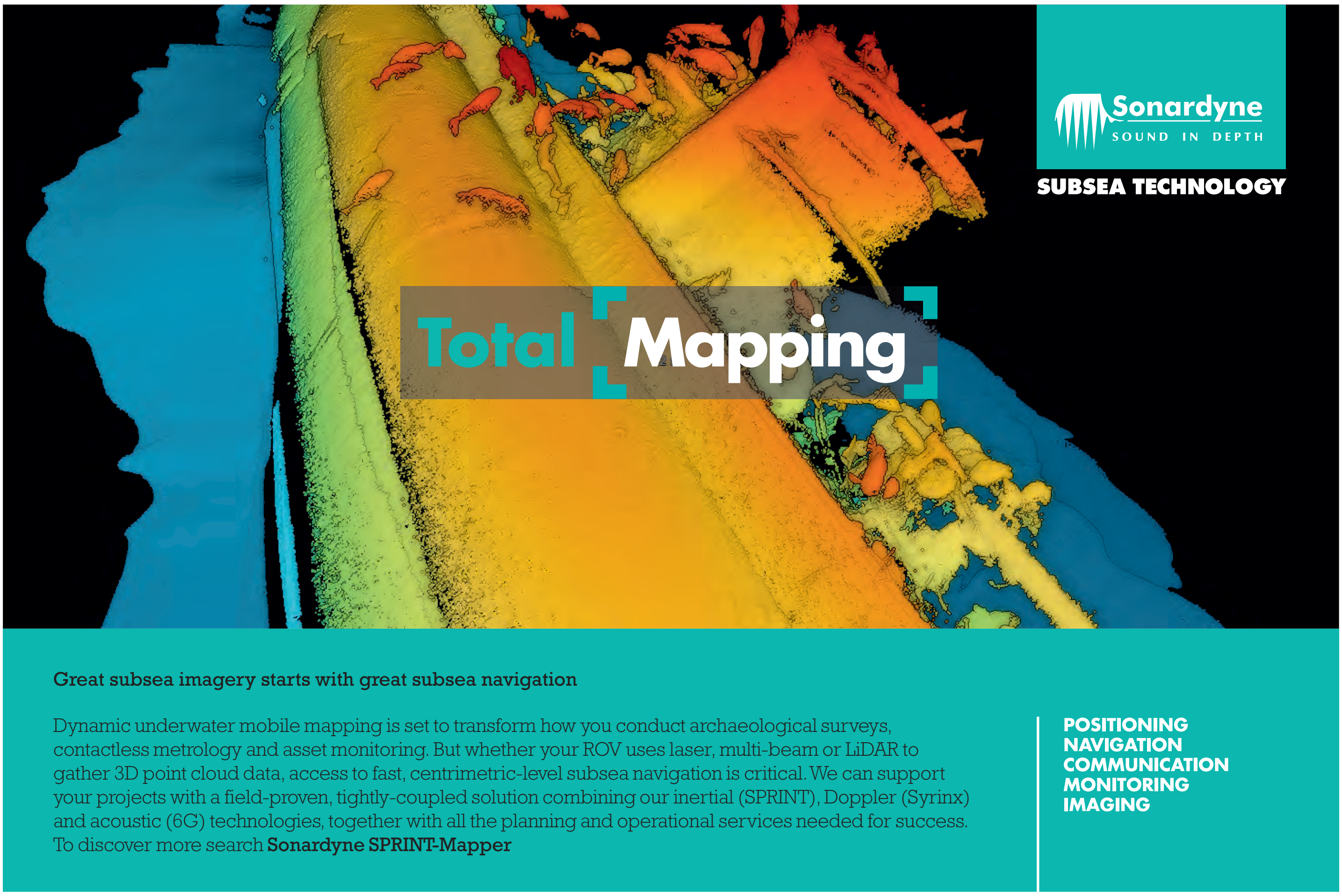
AANDERAA
...AND MANY MORE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A Life-Changing Voyage

On New Year's Day 1916, S. Davis Winship, a young Coast and Geodetic Survey (C&GS) officer, began a life-changing voyage, one that would take him far from his New England roots to a life in an exotic tropical land. Much of what follows is in Winship's own words.

Prior to embarking for the Philippine Islands, he had been in the C&GS for two years and had worked off the rocky shores of New England, the comparatively calm waters of Chesapeake Bay and the sounds of North Carolina, and in the deep, but pinnacle-studded, waters of Alaska's Inside Passage. He arrived in Manila on 1 February and was assigned to the C&GS ship *Fathomer*. The ship sailed 6 March for its working grounds on the south shore of Mindanao Island. Here Winship received his baptism of fire. As he relates: "What looked like an easy job for me was the ascent of a 2,300 foot mountain, with a Moro guide, and two cargodores or porters to carry food and tools. It turned out to be more than it looked, for there was no trail and it took us eight hours to cut our way through the jungle to the summit, an hour to do the necessary work and three and one half hours to fall back down the mountain. The ship looked pretty good when we finally reached her that night at nine o'clock." This was but the beginning.

The next day he "was landed on the beach with ten days supplies, six men and the necessary tools to build an eighty foot high scaffold. I hired four Moros to assist and we were soon busy getting out lumber and building the signal. It was hard work, because all the timber which grows near the water is swamp hard wood and very heavy, whereas in fact, it will not float…."

This was followed by a ten-day trip to a mountain five or six miles inland and 3,500 feet high, to build and occupy a triangulation station. "This trip was to take him into the heart of the Manoboe Country, a country whose people were little known, and whose attitude to outsiders, with whom they have practically no dealings, was absolutely unknown. He hired six Moro cargadores and an old Manoeboe guide who proved invaluable when encountering other Manoboes, and as an interpreter: "Speaking to the natives here is quite a stunt. On this trip I took, as usual, six men from the ship. They are Tagalogs, or "Manila Man". When I wish to talk to a Manoboe, I called one of these Tagalogs, and in a mixture of English, Spanish, Tagalog, and Profanity, explained my wants to him. He passed it on to a Moro who understood Tagalog, who in turn passed it on to a Moro who understood more Manoboe, he giving it to the old man …. who finally gave my message, or something like it to the person with whom I wished to talk. The answer came back the same way."

Winship managed to procure some Manoeboe cargadores in an unorthodox, and by today's standards, perhaps unacceptable manner: "After I had filled these savages with rice, we started the talk fest, consuming many cigarettes meanwhile. These cigarettes, by the way, I buy for the purpose for fifteen cents gold per hundred, and they are a great 'Open Sesame' to conversation. Finally they decided to go, and though we were still overloaded we started, intending to capture others on the way. Half an hour later my savages dropped their loads with a yell and dove into the bushes. After a few minutes struggle they

▲ *Figure 1: S. Davis Winship in the 1930s.*

▲ *Figure 2: The Coast and Geodetic Survey Ship* Fathomer.

Figure 3: Native help on the outlying islands.

emerged again bearing another struggling Manoboe of about their own size and of similar appearance except that he was naked and was armed with bow and arrows. They announced that he was going to be a cargodore whether he wanted to or not, but he seemed to think it a great lark, and soon made himself a pack and away we went. The Manoboes singing and shouting like boys out of school. An hour later they corralled two more by the same tactics and we were now more practically loaded."

Although a short airline distance, the trail to the mountain was quite circuitous and it took two days just to reach the foot of the mountain. Along the way, Winship encountered a friendly datu (chief) who directed his son to accompany Winship as a bodyguard. This was fortunate as, "Again we started, and the trail now became difficult. Up a hill, steep as the side of a home and down the other side, across a mountain torrent and along the face of a steep vine covered cliff where there was the barest toe hold which must be helped out by clinging to the vines. And here the datu's son came in. Always at my back, with his spear pointing out which vines I was to trust, for some are tough as steel while others are tender as paper. Time and again did that spear correct my ignorant choice, or kept me from grasping some poisonous vine which would have made my hands sore for forty-eight hours, and when I waded across a rushing stream he waded below me."

To climb the mountain itself took another half day. Winship remarked, "Up we went, and how I envied the natives their bare feet. Twenty of them climbing … with fifty or sixty pounds on their backs, while I struggled for every foothold. Many times did my nurse hold on by his eyebrows in order to help me to a better foothold. Finally we reached the top and got our breath, and we were in a dim fog. Except an hour or two in the morning these hills are cloud capped continually at this time of year, which makes it very difficult to do our work. We stayed up there three days, and each night as I lay in my hammock, I thought how much safer I was there unarmed with twenty savages, than the average man in a large city who is exposed to all kinds of accidents and violence."

Two months later Winship wrote: "I have twice returned to that same mountain, and the friendship of the Manoboes whom I described, has been invaluable, as they have passed the word along, and now, though twenty five miles from Sangay, the Manoboes here know that I am a friend of Datuadil, and are doing everything possible to make it easy and pleasant for me. I have almost daily gifts of corn, chicken, eggs, papaya, bananas, or plantain and I never lack cargodores and guides."

It wasn't all that easy though. Winship allowed himself a complaint in a letter home: "… Bees are very thick and I have had so many encounters with them that I am becoming callous. Centipedes and scorpions, which I used to think were deadly poison, give me no more than a passing shudder. Their sting is excruciatingly painful, but for a person in good health, they are by no means dangerous. Then there are leeches, small blood suckers, about an inch long, which get into your shoes, and if there is a hole in your sock they always find it and make a troublesome sore, but I manage to keep them out most of the time."

Such was the work of the C&GS officer in the Philippine Islands in the early twentieth century. Because of the transfer of C&GS officers to the armed services during World War I, replacements were not sent to the islands and Winship's tour was extended. This was fortunate for him as he was given command of the *Fathomer* in 1917 after only three years total service. He survived the worldwide influenza epidemic of 1918 but wrote of crews of the *Pathfinder* and *Romblon* being tied up with their whole crews sick. He also mentioned a small village of fifty that he visited and, when coming back a month later, only five individuals had survived. Davis Winship remained in the Philippine Islands and resigned in 1920. His superior officer noted, "As he was a very competent individual, this was unfortunate for the C&GS". By this time Davis Winship had decided to make the Philippine Islands his home. He married a beautiful Filipino woman and had three children. He went into business and by 1930 was the president and general manager of the Eastern Isles Import Corporation, a large manufacturer of hand embroideries. He made three-quarters of a million nightgowns, and half a million baby dresses that year. Winship was quite prosperous and made many trips to the United States. In 1936, he was the first customer in the world to buy an around-the-world airline ticket for the then princely sum of $2,308.33. As one leg of this trip was to take the Zeppelin Hindenburg across the Atlantic, this trip was never completed as the Hindenburg had crashed and burned while docking at Lakehurst, New Jersey on 6 May 1937.

By this time, ominous signs were clouding the future. That Winship understood the world situation is shown in the following written in November,1937: "We are all somewhat nervous over the Japanese invasion in China. So many of the news dispatches seem to convey the impression that this is just one of those accidental little skirmishes that don't amount to much. It is a major war, part of the deliberate Japanese plan to dominate everything from the 180th meridian to Suez. They never will stop going until some combination of nations literally blows them out of the water, sinks every naval vessel they have."

Although he believed that "The Lord takes care of fools, drunkards, and ex-Coast Survey officers", he was a poor prognosticator and wrote on 25 November 1941, "… officially the Japanese will do everything possible to avoid armed conflict with the US". Pearl Harbour was attacked two weeks later and Manila bombed a few hours later on December 8. Manila was occupied by Japanese forces on 2 January 1942. S. Davis Winship was not heard of for over three years as he was incarcerated at Santo Tomas and then Los Banos prison camps. He was liberated from Los Banos on 23 February 1942, in a famous military raid. He was one of the last ones out. His health was broken and he returned to the US for two years, returning to the Philippines in 1947. However, his lifelong voyage to the Philippines came to an end as his body was too decimated to continue on. He died on 24 December 1947. A friend writing of his passing to his relatives in the United States, referred to him as 'Cap', probably a name he retained from his days as captain of the C&GS Steamer *Fathomer*.

Acknowledgements

Thanks to Mr. David Record and the family of S. David Winship for providing me with an account of Winship's life.

▲ *Figure 4: Signal building crew on the way to a mountain peak.*

Real-time Current and Wave Data from HF Radar WERA®

Valuable Met-ocean Data for the Port of Rotterdam

To fulfill its mission to "continually improve the Port of Rotterdam and to make it the safest, most efficient and most sustainable port in the world", Rijkswaterstaat, part of the Ministry of Infrastructure and Environment, decided in 2014 to improve the quality and reliability of the ocean current forecasting. The forecasting is based on a hydrodynamic model operated by Rijkswaterstaat. A transition is currently being prepared, in which the operational 2D model will be replaced by a new fully 3D model, created together with Deltares consultants.

Rijkswaterstaat has chosen HF radar technology as additional real-time data input. The shore-based HF radar system provides reliable data of ocean surface currents as well as wave height and wave direction over long distances (in this case more than 60km offshore) with outstanding spatial and temporal resolution for vessel traffic service, search-and-rescue and environmental protection applications. Due to the fact that there are no in-water system components, this technology offers a very good price-to-performance ratio compared to other ocean sensing instruments. It is easy to install and maintain. In contrast to single-point measurements, e. g. using buoys, an HF ocean radar system gives access to spatial data with the comfort of land-based instruments.

Largest Seaport of Europe

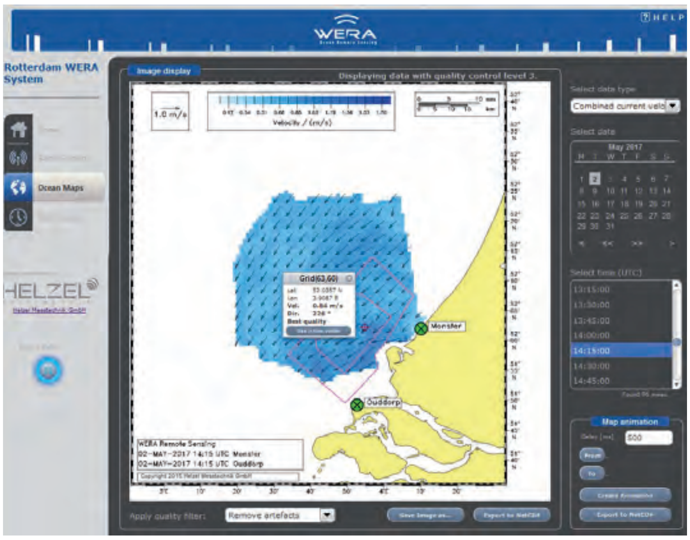
The Port of Rotterdam in the Netherlands is Europe's largest seaport and the sixth biggest port in the world. With its outstanding accessibility, it connects around 30,000 sea-going vessels with more than 100,000 inland vessels annually. To maintain and sustain the huge amount of nearly half a billion tons cargo per year to and from Central and Northern European fairways, ship traffic has to be safe and efficient.

Using modern patrol boats and a high-tech traffic control system, the Harbour Division supervises shipping traffic day and night. As an official emergency service, the Harbour Master's Division, together with different aid agencies, is in charge of safeguarding coordination, safety of shipping traffic, and monitoring of surrounding areas.

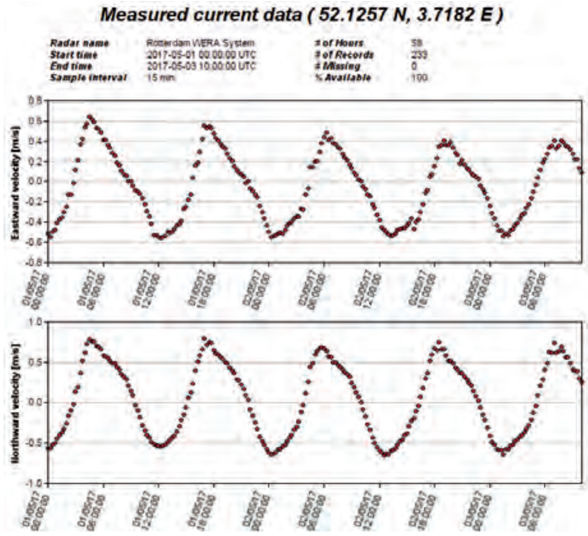
▲ *Figure 1: WERA ocean radar receive antenna array at the public beach of Monster with the Port of Rotterdam in the background. The systems have been operational since autumn 2015.*

High-resolution Current Maps

The EU tender 'HF-Radar system Maasmond' has been awarded to the German company HELZEL Messtechnik GmbH supported by the Dutch partner companies OCN and Radac. The ocean radar system WERA® manufactured by HELZEL delivers high-quality ocean current maps covering hundreds of kilometres offshore and maps of significant wave height within 50% and directional wave spectra within 30% of the current mapping coverage. The high-resolution current maps even show sub-mesoscale surface current structures. Various comparisons between surface currents measured by WERA® systems and sub-surface currents measured by acoustic Doppler profilers as well as drifters have shown a correlation of better than 0.9. A combination of the real-time WERA® measurements with numerical ocean models



▲ *Figure 2: WERA Data Manager and Viewer enables the access of data archive, the export of maps and data and the generation of time series as shown in Figure 3.*



▲ *Figure 3: WERA time series for measured current data 1 – 3 May 2017.*

offer promising opportunities to improve the accuracy of oil spill drift prediction as well as improving search-and-rescue operations.

WERA Radar Principle

A pair of WERA® ocean radar stations has been monitoring the surface currents (speed and direction) at the entrance of the Port of Rotterdam at Hoek van Holland since October 2015. This installation is the first permanent one in the Netherlands. First temporary experiments were already carried out in 1988 and 1996.
Each station consists of one transmit antenna system using less than 30 Watts of transmitted power, 12 receive antenna elements (Figure 1), and the necessary electronic equipment. The operating frequency is 16MHz providing a range of up to 60km.
The radar signals from the transmit antennas are backscattered by the ocean surface and then measured by the receive antennas. These HF radar systems use linear antenna arrays and apply beam-forming techniques to derive current data with highest spatial accuracy of typically ± 1° and high temporal resolution of up to 5 minutes.
Four measurement cycles within one hour are combined from both radar stations in order to produce current vector maps (Figure 2 and 3). The coverage area extends beyond Hoek van Holland to the west and northwest directions occupying an overall area of 60 x 40km². The range resolution depends on the allocated radio bandwidth, in this case a grid cell size of 1 x 1km² is used.
In the near future, the measurements will be assimilated into the envisaged new 3D ocean current model to improve marine oceanographic prediction. The radar system also provides met-ocean data for parts of the fairway at Hoek van Holland.
This information will be available to the pilots and navigation officers of incoming and outgoing vessels as well as to the general public via websites (www.hfradar.nl). Deep draught ships, sailing through the narrow dredged shipping lane consisting of the Euro and Maas channel towards the Port of Rotterdam get the precise ocean current information in time to navigate safely towards their destination.

Hydrodynamic Operational Forecasting System

The radar systems will become an integrated part of an improved hydrodynamic operational forecasting system which is currently under development for navigation to the port. The operational forecasting requires the highest availability and accuracy of the radar data. Furthermore, there is a strong focus on the online quality control procedures. For two defined areas, the requested data availability is 90% and 95%.
The acquired current data from the WERA® radar system are presently compared with other data sources and model results. The analysis shows the level of current complexity in the estuary and how much of that can be observed on the surface. Figure 4 shows a satellite result versus HF radar. The satellite shows the murky outflow of the river at low tide. There is a distinct boundary line in the satellite picture just north of the inlet, which is the edge of the plume of river water. At this boundary the HF radar clearly shows the change in flow direction. Inside the plume the flow is offshore and just north of it the usual along shore flow is being blocked and diverted due to this river outflow. Scientific publications with results are expected for presentations during upcoming conferences and workshops.
The reported data availability for current vectors has been more than 98% since October 2015. This reliability is not just based on the high quality standard of the radar, but is also a result of the excellent cooperation with the local partner companies OCN and Radac who take care of preventive maintenance by keeping contact with the data users and with third parties involved. ◀

More information

- www.hfradar.nl
- www.helzel.com
- www.portofrotterdam.com
- Mal Heron, 2016. HF Radar for Port Management: Case study in the Port of Rotterdam. IEEE Proceedings, IEEE Oceans Shanghai.

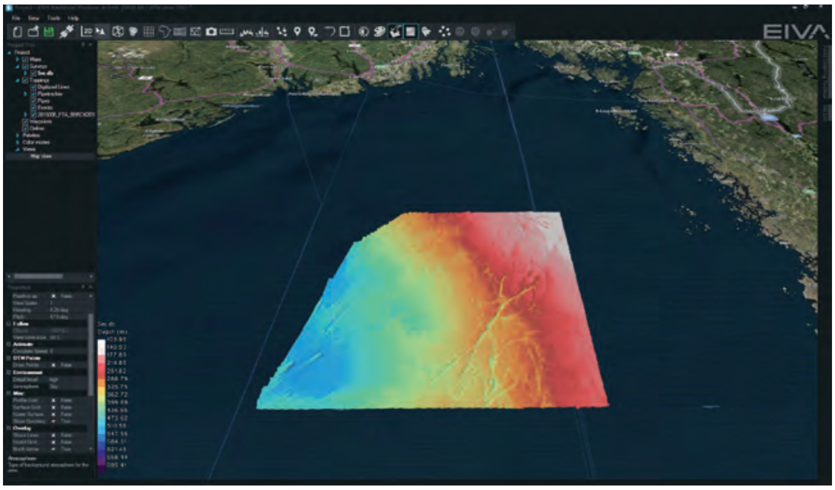
▲ *Figure 4: Satellite result versus WERA HF radar data. Image courtesy: Deltares.*

EIVA and Clinton Surveys

Cooperation and Customisation for **Better Technology**:

When choosing a single supplier, Clinton found that the customisation possibilities that EIVA offered made for a great partnership – and together, Clinton and EIVA developed the tools necessary to meet Clinton's unique challenges.

For a long time, Clinton, a Swedish surveying firm, has been using several different suppliers and platforms to perform its varied surveying work. And for just as long, this had been considered the ideal tack. However, the firm was realising that using multiple suppliers was causing more problems than it solved in the form of high maintenance fees, scattered knowledge, different support teams and support cases, and transition issues. Continuing to use multiple suppliers was not a viable plan; Clinton would need to streamline and standardise to be even more efficient and innovative in the future. Choosing a single supplier is a leap of faith not to be undertaken lightly, since although the benefits can be great, a company will be 'confined' to only the software, solutions, and procedures offered by that supplier. Clinton is a large company with a turnover of 90 million SEK that handles many varied and complex projects, from very large-scale surveys on the ocean to working with extremely shallow depths with complex water columns, and, from experience, no supplier perfectly met all needs out-of-the-box. Moreover, the survey field is constantly evolving, and so the solutions must also constantly evolve – which required a dynamic relationship with the supplier.



▲ *Figure 1: Clinton's survey of the Bratten area using EIVA NaviSuite.*

▲ *Figure 2: Clinton's survey vessel* Northern Wind.

Solution

After evaluation, Clinton chose EIVA as its new single supplier. Clinton was undergoing a rapid expansion in the types of projects they were tackling, and this meant new requirements and new challenges regularly occurring. EIVA's consistent assistance in making sure deadlines were met was a mark in its favour.

EIVA also had a strong software suite in NaviSuite that covers all stages of an offshore/shallow water survey – and furthermore, based on their experience with EIVA's custom development in the past, Clinton also knew that EIVA could show the same flexibility and dedication in helping to fulfil any unmet needs for Clinton's projects.

Customised Solution Development

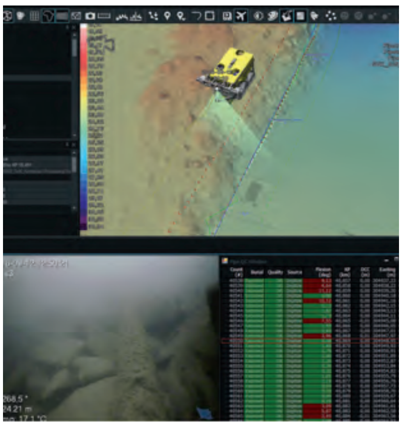
During the single supplier decision process, Clinton reached out to EIVA to again explore the possibility of custom developments. With Clinton supplying the requirements and EIVA supplying the development, new custom surfaces were rapidly added to EIVA NaviModel to combat specific challenges that Clinton was facing. Different clients have different requirements for the data to be delivered, and Clinton was working on a project where they needed to provide information about uncertainty in the data. EIVA's existing tool at the time covered difference, variance and standard deviation in each cell, but it was not exactly what Clinton was looking for. However, with the new custom surfaces, Clinton could design their own formula and solve the task. Other projects undertaken together before and since include tools for squat tables, gap-finding, filtering, and more.
A more recently developed tool was a new refraction slide tool, which has saved Clinton a lot of time and effort, and thus saved the end client substantial costs. It has also improved the end product. One of the trickiest scenarios in surveying can be ray bending, or working with the path that a sound wave travels from the vessel to the seabed and back again. Based on, among other things, temperature and salinity, the route bends using Snell's law, or the law of refraction. To do this, you need to ensure that you have measured a sufficient number of sound velocity profiles. If a sufficient number is not reached, a new survey will often need to be made as the profiles change over time. The refraction tool makes avoiding this scenario much simpler, since it gives methods to manipulate the profile to determine if it can be successfully used.

▲ *Figure 3: Surveying on the lake.*

The refraction tool is particularly useful for Clinton when dealing with complex water columns (perhaps caused by a strong layering of freshwater and salt water), strong thermal layers in sunny weather, or even just when it is not possible to get sufficient spatial coverage of the sound velocity sampling. Recently, the tool was used for a complex Norwegian river survey where the water was extremely shallow and the water column unstable – the successful completion of which 'would not have been possible without EIVA's effort'.

Result

Armed with these new tools, Clinton has used NaviSuite for all its projects since the collaboration started, including its recent project surveying the Bratten area in Skagerrack – a survey project over a much larger and deeper area than most in Scandinavian waters. The assignment involved charting a 1206km^2 area, and in the process, charting the deepest point in Swedish waters at 560m. This was done quickly and accurately despite bad weather and deep water.
EIVA makes sure that as Clinton's projects evolve and progress, the software does too, so that needs are promptly met both now and in the future. In the words of Clinton's survey manager Anders Wikmar, "We used NaviSuite for all our hydrographic and offshore projects during 2016, and will do the same in the future. This decision has created a smooth processing workflow and increased competence for our personnel by using only one standardised software flow. The client will benefit from higher quality and more cost-effective operations in the coming projects." ◀

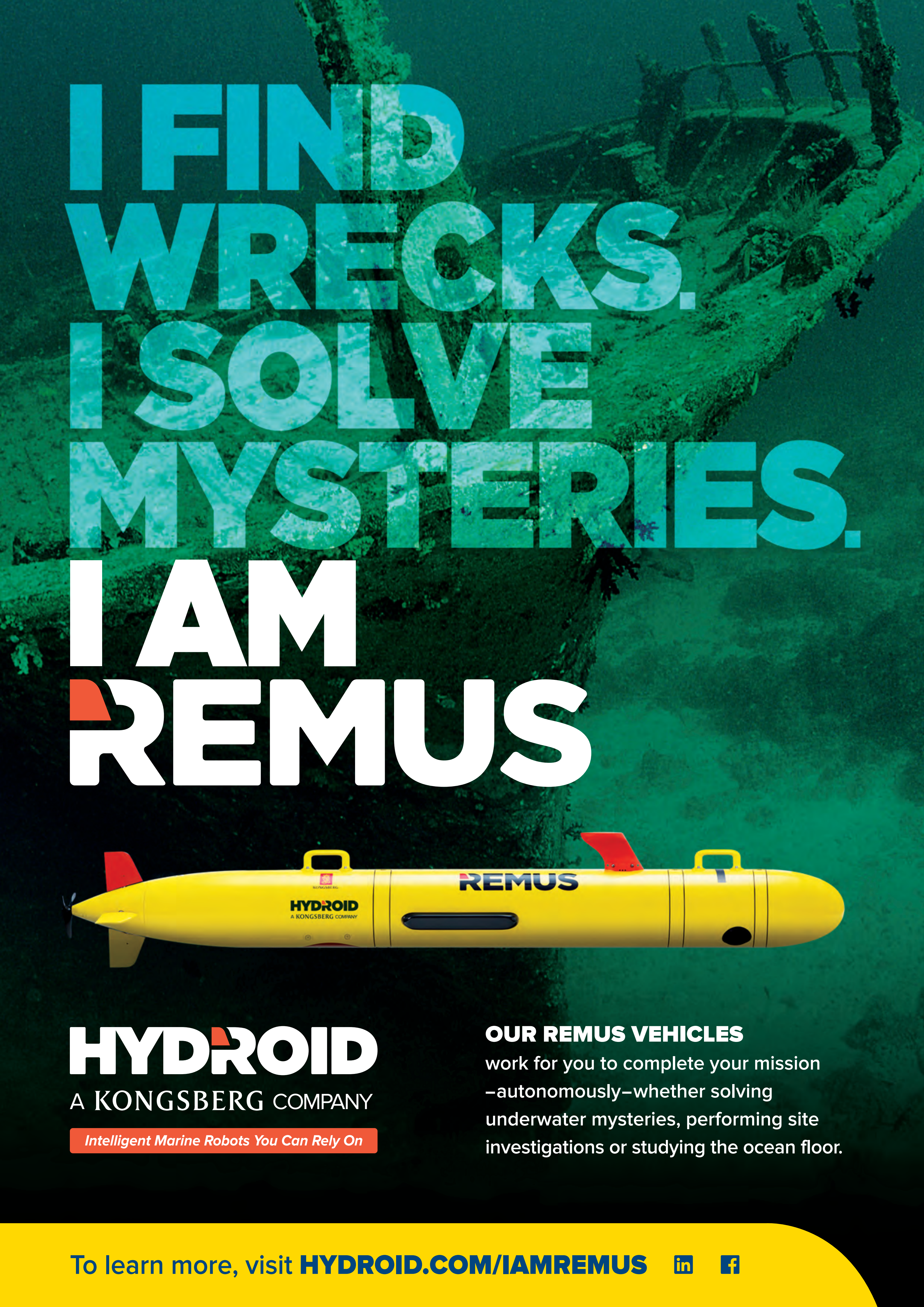


▲ *Figure 4: Cable tracking in EIVA.*

▲ *Figure 5: Clinton surveyors when the mission was completed.*

More information

- bit.ly/hyd-eivaclinton Article on Hydro International's website including a video.
- bit.ly/eiva-clinton-custommade-case The case study
- www.eiva.com
- www.clinton.se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IHO Encouraging Crowdsourced Bathymetry

At the 5th Extraordinary International Hydrographic Conference, held in Monaco in October 2014, the International Hydrographic Organization (IHO) agreed on the need to explore sources of bathymetric data outside traditional observations - particularly in support of defining a baseline global bathymetric dataset for the many non-navigational uses for depth data that are now emerging. This resulted in the establishment of a Crowdsourced Bathymetry Working Group that was tasked to provide guidance on how the IHO could encourage and promote crowdsourcing by vessels and craft using standard, fitted equipment.

The IHO has a long history of encouraging the collection of crowdsourced bathymetry. The General Bathymetric Chart of the Oceans (GEBCO) project was initiated in 1903 by Prince Albert I of Monaco to provide the most authoritative, publicly-available bathymetry of the world's oceans. Over the years, the GEBCO project, now jointly overseen by the IHO and the Intergovernmental Oceanographic Commission of UNESCO, has obtained depth measurements collected by vessels as they journeyed across the oceans. These 'passage soundings' have enabled the creation of progressively more-detailed seafloor maps and digital data grids. More recently, systematic surveys have also been used to improve these maps and grids.
Unfortunately, notwithstanding the efforts in collecting data since 1903, less than fifteen percent of the world's ocean depths have been directly measured; the rest of the data used to compile the maps of the seafloor are estimated. These estimates are largely derived from satellite gravity measurements, which can miss significant features and provide only coarse-resolution depictions of the largest seamounts, ridges and submarine canyons. Progress in mapping the world's coastal waters is only marginally better. IHO figures indicate that about fifty percent of the world's coastal waters less than 200m deep remain unsurveyed.
While the hydrographic and scientific community lament this lack of real data, the world's interest in seas, oceans and waterways continues to increase. The concept of a 'blue economy' is firmly established, along with an ever-growing public awareness of mankind's dependence upon, and vulnerability to the sea. Several high-level global initiatives are now in place that seek to address ocean issues, including the goals associated with the United Nations 2030 Agenda for Sustainable Development, the Paris Agreement under the United Nations Framework Convention on Climate Change, and the Sendai Framework for Disaster Risk Reduction 2015-2030.
International shipping regulations oblige all commercial vessels to be equipped with certified echo sounders and satellite-based navigation systems. As a result, the world's commercial fleet represents a significant, and as yet largely untapped, source of potential depth measurements. While crowdsourced data may not meet the accuracy requirements for charting areas of critical under-keel clearance, it still holds significant potential for other uses. If vessels collect and contribute depth information while on passage, their data can be used to help identify uncharted features, to assist in verifying charted information, and help to confirm that existing charts are appropriate for the latest traffic patterns. Crowdsourced bathymetry can also provide vital information to support national and regional development activities, and scientific studies in areas where little or no other data exists. Crowdsourcing can be a valuable and efficient way to determine where rigorous hydrographic surveys need to take place.
The IHO Crowdsourced Bathymetry Working Group, comprising representatives from national Hydrographic Offices, academia, and industry has developed the first draft of a guidance document that sets out the key issues regarding crowdsourcing - both from a collector's and a user's perspective. The guidance document is intended to provide general advice and information for those considering collecting or using crowdsourced bathymetry. It is not intended to be either prescriptive or authoritative, but rather to alert those with an interest in crowdsourcing of the relevant considerations to take into account.
The draft guidance document on crowdsourced bathymetry is now available on the IHO website at: https://www.iho.int/srv1/index.php?option=com_content&view=article&id=635&Itemid=988&lang=en. The IHO Crowdsourced Bathymetry Working Group would welcome comments and feedback on this first draft, which can be forwarded to the chair of the working group at: Jennifer.Jencks@noaa.gov.

Diagram showing the extent of publicly available bathymetric data for the ocean.

Hydrographic Society Benelux

Unmanned Systems and Data Analysis Workshop

During TUS Expo, the international conference and trade show focussing on Unmanned Systems, that took place in the World Forum in The Hague on 19-21 April 2017, the Hydrographic Society Benelux organised a workshop with the theme 'UUVs and data analyses' on 20 April.

After a visit to the show and a lunch, the delegates learned about the possibilities of the SAAB SeaEye Sabertooth as an unmanned and even partly autonomous survey vehicle as it can work as AUV and ROV. This contribution was followed by a forward-looking presentation by Mike Loonstijn (TU Delft) on autonomous shipping. It was certainly interesting to see where this will lead and which requirements are necessary. Atle Gran (Kongsberg) then discussed AUV risk management and future AUV developments. After a break, John van de Marel (QPS) continued on the software side of the business, focussing on data acquisition and processing. Niels van der Vaart (Esri) concluded the workshop with his vision on spatial data analysis, visualisation and data management, which is getting more important, also in hydrography, as we are collecting and mapping more data. The networking reception gave the participants an opportunity to discuss the developments that were presented during the lectures as well as other matters.

▲ *The presenters of the workshop.*

Newest Hydrographic Techniques in the Region

The next workshop is scheduled for 20 June 2017 from noon at the Waternet venue in Amsterdam (the Netherlands), the day before World Hydrography Day. The Hydrographic Society Benelux, Platform Baggernet and Waternet will update the delegates on the newest hydrographic technique developments. What are you using? How can you best map water depths and the structure of the bottom? Some techniques will be demonstrated outdoors. This workshop will focus on the World Hydrography Day theme 'Mapping our Seas, Oceans and Waterways – More Important Than Ever'. The goal is to learn from each other so expect the afternoon to be interactive!

More information and booking on www.hydrographicsocietybenelux.eu.

MAY

UDT
Bremen, DE
→ 30 May-1 June
www.udt-global.com

JUNE

EWEA Offshore
London, UK
→ 6-8 June
ewea.org/events/ewea-offshore

IMCA Marine Seminar
Stavanger, NO
→ 14-15 June
www.imca-int.com

CARIS 2017
Ottawa, CA
→ 19-22 June
caris.com/caris2017

MTS/IEEE OCEANS 2017 Aberdeen
Aberdeen, UK
→ 19-22 June
www.oceans17mtsieeeaberdeen.org

JULY

International Cartographic Conference (ICC)
Washington, DC, USA
→ 2-7 July
icc2017.org

Marine Measurement Forum
Sunbury-on-Thames, GB
→ 7 July
www.ths.org.uk/event_details.asp?v0=606

RIO Acoustics
Rio de Janeiro, BR
→ 25-28 July
rioacoustics.org

SEPTEMBER

MTS/IEEE OCEANS 2017 Anchorage
Anchorage, US
→ 18-21 September
www.oceans17mtsieeeanchorage.org

OCTOBER

Offshore Energy
Amsterdam, NL
→ 9-11 October
offshore-energy.biz

9th Advisory Board on the Law of the Sea (ABLOS) Conference
Monaco
→ 10-11 October
www.ablosconference.com

Teledyne Marine Technology Workshop
Dan Diego, US
→ 15-18 October
www.teledynemarine.com/events/teledyne-marine-technology-workshop-2017

BIT's 6th Annual World Congress of Ocean-2017
Shenzhen, CN
→ 30 October-1 November
www.bitcongress.com/WCo2017/default.asp

NOVEMBER

Oceanology International China
Qingdao, CN
→ 1-3 November
www.oichina.com.cn

PLOCAN Glider School
Telde, Spain
→ 6-11 November
gliderschool.eu

CEDA Dredging Days
Rotterdam, NL
→ 9-10 November
www.cedaconferences.org/dredgingdays2017

Calendar Notices
For more events and additional information on the shows mentioned on this page, see www.hydro-international.com. Please send notices at least 3 months before the event date to: Trea Fledderus, marketing assistant, email: trea.fledderus@geomares.nl.

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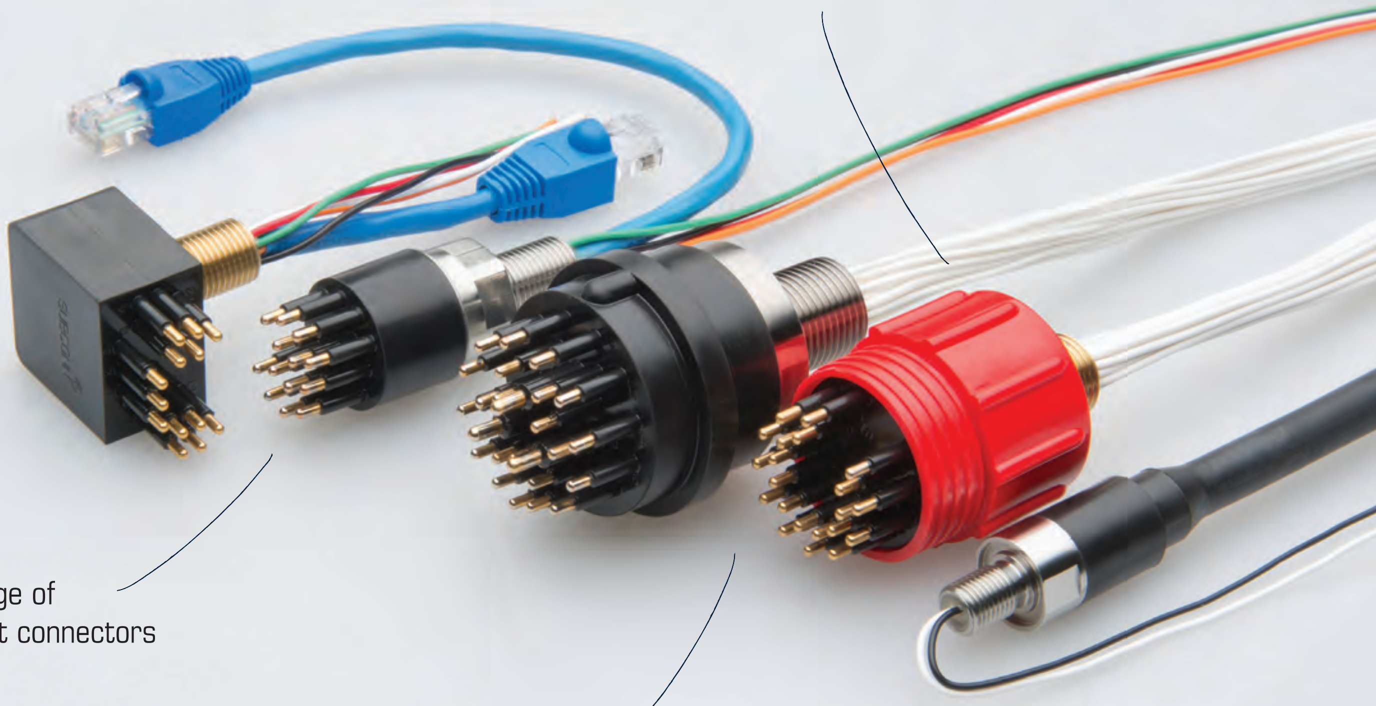

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