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INTERVIEW: JAIME RODRÍGUEZ, PANAMA CANAL

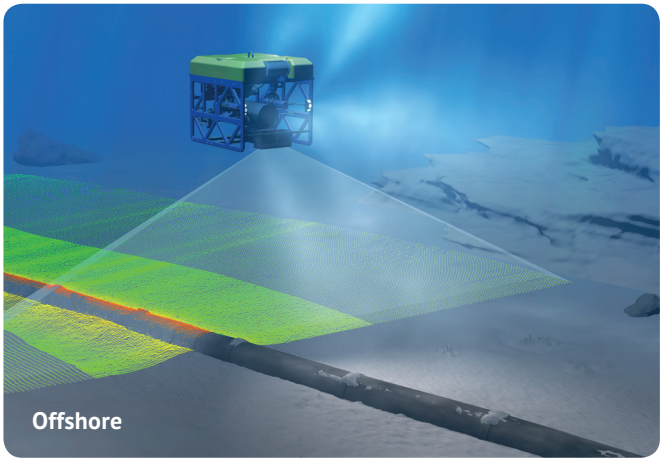
Inevitable Truths of Operating AUVs

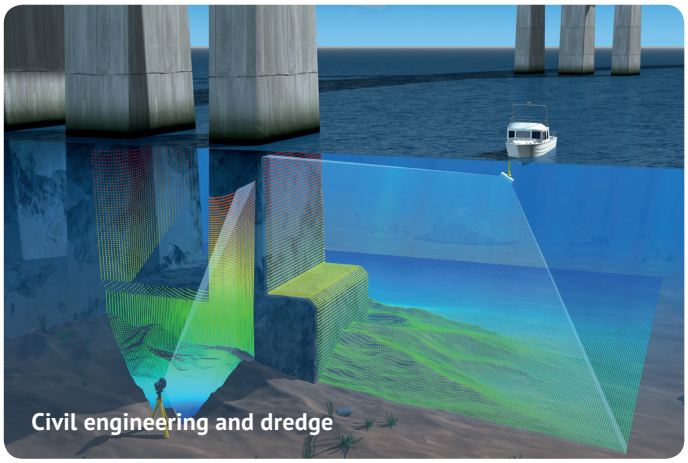
A Manufacturer's Perspective on Routine AUV Utilisation

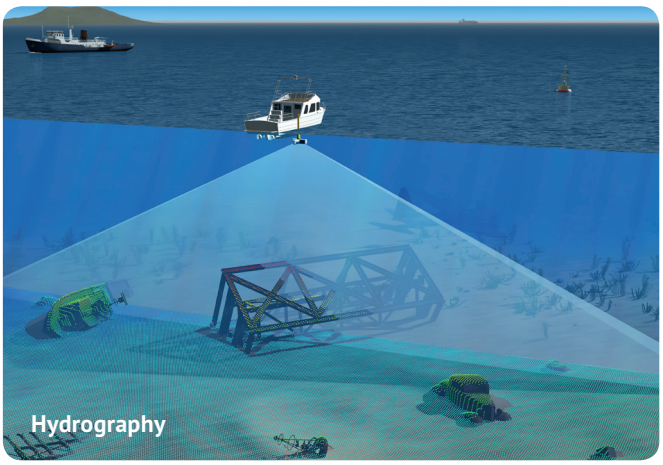
Crowdsourcing Enhances Navigation Awareness

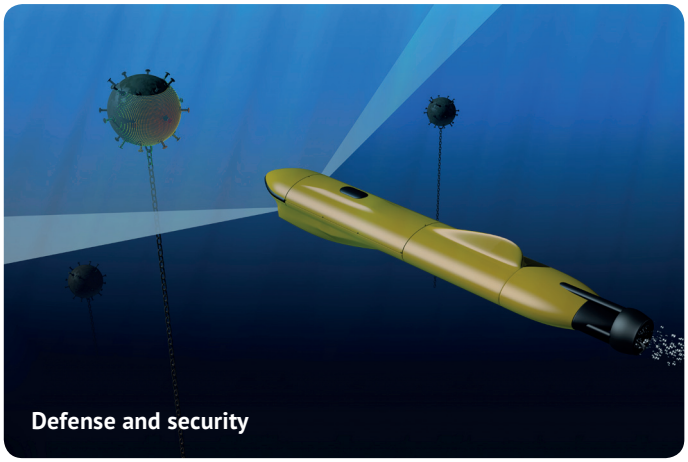
Teledyne Marine

All the sonars you need, in one place









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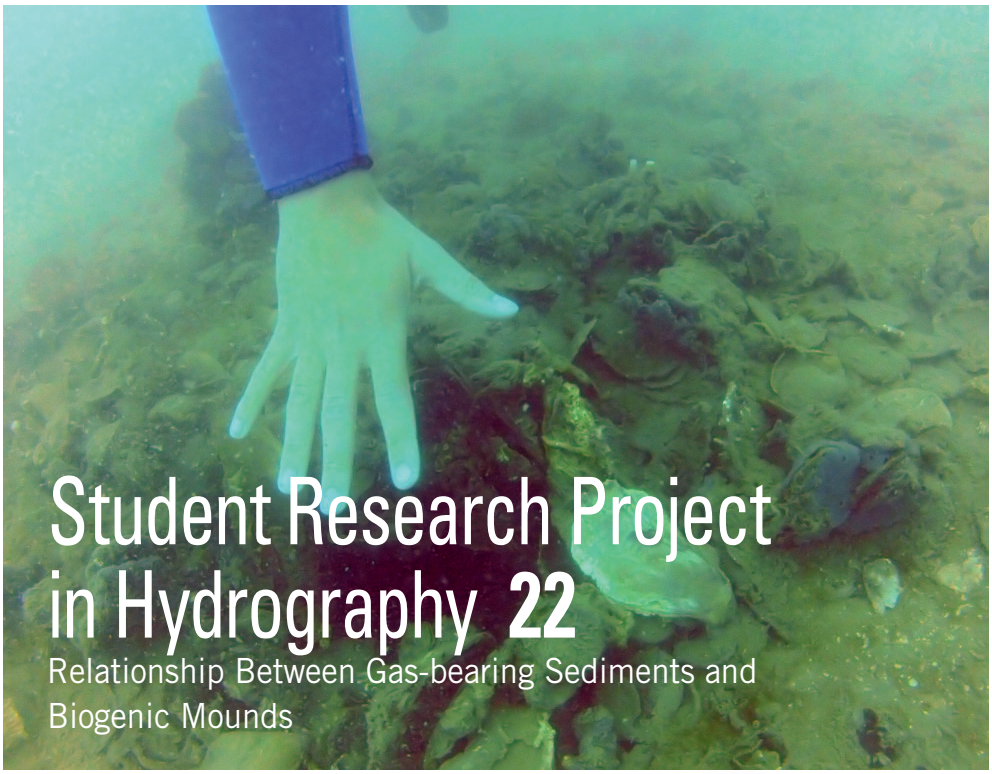

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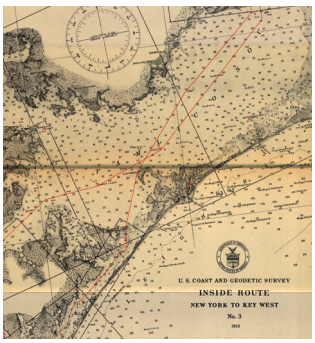

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The newly built German research vessel Sonne *on a sea trial. She was commissioned on 17 November 2014. Image courtesy: Meyer Werft, Papenburg.*

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Buyers Guide
Hydrography is booming – survey companies, data specialists, hydrographers, cartographers, oceanographers… they are all working hard to get the job done. And they need to invest for an improved handling of their clients requests. Time is scarce… that's why Hydro international is preparing a Buyer's Guide to facilitate communication between you and your clients.
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PHOTOGRAPHY: ARIE BRUINSMA (WWW.ARIEBRUINSMA.NL)

Big **Data**

The amount of data that humankind has gathered and stored over the past few decades is mindboggling. So too is the amount that is added every day, every minute even – and the speed and volumes are only increasing. And hydrography is certainly not one of the smallest contributors. Big, big chunks of data come from survey ships and airborne and satellite imagery every day for all kinds of purposes. And while many of those datasets are perfectly fit for the job they were acquired for, after they have been processed and analysed, basically put to use for the job, they end up on the shelf, lying there disconnected from neighbouring datasets on the same or another shelf. Imagine what would happen if we could connect and reuse all that data together for the betterment of the world? That idea is at the core of the data revolution that UN secretary general Ban-Ki Moon called for in 2013. He sees that the availability of qualitative and accessible data could support sustainable development, and therefore believes that a data revolution should dictate the UN's post-2015 agenda, replacing the Millennium Development Goals as a tool for reducing poverty and increasing sustainable welfare all over the world. Just a few months ago, a group of experts convened at the UN in New York for the first time to discuss how to put the plan for a data revolution into action.

The data revolution represents a massive opportunity for hydrography – after all, geoinformation is very much at the heart of every dataset – it is said that 80% of all data has a geo-component to it. It's true, we have to take into account that bathymetry is only a part of all data gathered. But if entrepreneurs, academia, hydrographic surveyors and surveying companies were to direct their resources at turning the data revolution into reality, hydrographic data could be linked to all kinds of other marine data, but also terrestrial data. Linking satellite imagery of the hinterland to bathymetric data of the coastal zone to decide where a new port needs to be developed, for instance, makes for a better decision, or linking two old datasets of biological data and bathymetric data to identify the best place to develop a fish farm or offshore wind farm lowers initial costs of a project (and delivers renewed revenue for the old dataset). Combinations of different products will take us from unimaginably huge chunks of stand-alone data to understandable, supporting grids upon which governments can base their policies.

At the highest level within the United Nations, there is consensus that the data revolution will be a major tool in the next decade. That has already trickled down to the United National Global Geospatial Information Management (UN-GGIM) initiative, which is discussing the data revolution. The International Hydrographic Organization is of course part of this discussion and succeeds in making hydrography always part of the deliberations. Ideally, members of the industry should now step up to the challenge and join the UN-GGIM in discussing and consulting; advocate a data revolution in their own countries, in their companies and institutes; and work on creating links between data for the betterment of the marine environment and the coastal zone and the enforcement of hydrography.

Durk Haarsma durk.haarsma@geomares.nl

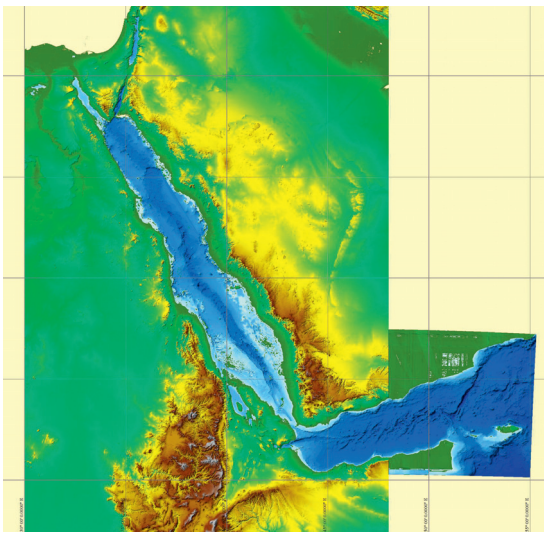
▼ *The author, aged 23, on PDR watch aboard the R/V* Chain.

GEBCO Red Sea Grid Underway

Some 50 years ago, the International Indian Ocean Expedition (IIOE) marked the first concerted international effort to study an entire ocean using forty-six vessels under fourteen flags. To help GEBCO commemorate that effort, the author is compiling a new 100m grid of this northwestern extension of the Indian Ocean.

In June 1962, I began my career as a marine geophysicist at Woods Hole Oceanographic Institution (WHOI). While I worked mostly off Bermuda and in the Caribbean, WHOI's *Chain* and *Atlantis II* participated in the IIOE. Later, after moving to Lamont and doing my PhD from a drifting ice station in the Arctic, I married an Israeli and immigrated to Israel in 1970. Since then, I have accumulated track soundings, survey results (some made with the earliest multibeams), and digitised hundreds of thousands of spot soundings from published navigational charts for the nearby Red Sea and its northern gulfs.

At the end of the October 2013 GEBCO meeting at the Istituto di Scienze Marine in Venice, it was noted that 2012-15 will officially mark the 50th anniversary of the IIOE. I seized upon this as an opportunity to finally update the 1970 Bathymetric Chart of the Red Sea at 1:2 million scale published by GEBCO's past Chairman Sir Anthony Laughton. To that end, new technologies were enlisted to produce the best available working grid of this geologically young sea, with perhaps as much as 20% having shallows less than 50m, bordered mostly by hydrographically challenged desert states.
Hydro International's recent April article by Tetteh, Peeri and Marks (website 1) showed how the latest (post March 2014) and freely available LANDSAT 8 satellite imagery may be used with inshore soundings to produce detailed grids down to 30m. The methodology for this Satellite Derived Bathymetry (SDB) is described in Chapter 11 of GEBCO's online *Cook Book* available at (website 2). In addition, on 17 October 2011, NASA and Japan's METI released their Version 2 of the 30m ASTER global land DEM (website 3), which is excellent for the desert regions involved here.



▲ *Full topography of the Red Sea.*

Although I have been producing bathymetric charts, maps and grids for years, I admit to being a GIS amateur. Therefore, after easily downloading 44 recent cloud-free LANDSAT 8 scenes covering the Red Sea and Aden Gulf, I enlisted the help of Shahar Levenson, a GIS professional and aspiring Masters student, who then developed Python scripts which rapidly produced grids using the SDB methodology. It is likely that these scripts will be appended to the *Cook Book* SDB chapter to further simplify the process for other users and areas.

Lacking the recommended shallow hydrographic control, we will initially set the Red Sea SDB depth range from 20cm to 25m, and then use the deeper soundings to define the grids of the deeper waters. A new GEBCO *Cook Book* chapter presents our DTM editing software that will merge these shallow grids with the kriged grids of all the existing soundings including land. It is a great pleasure to see that we have now arrived at a situation where the LANDSAT and ASTER2 data are coincident.

The final grid will be available from GEBCO, and hopefully will attract additional input as new or legacy multibeam surveys become available. The above-mentioned SDB scripts will allow the shallow grids to be recalculated as detailed measurements in the shallows become available for proper calibration. ◀

More information
1: http://member.hydro-international.com/articles/item/51b933836ab94d3db08a4367b8fc83e8
2: http://www.star.nesdis.noaa.gov/sod/lsa/GEBCO_Cookbook/
3: https://earthdata.nasa.gov/library/meti-and-nasa-release-version-2-aster-global-dem

Stand-alone RTK GNSS Receiver

Seabed BV, the Netherlands, has released a new global navigation satellite system (GNSS) receiver, the SGR6. This system has a Novatel technical base. The SGR6 is a stand-alone metre-level to RTK centimetre-level positioning system, and provides numerous interfaces including RS232/RS422 serial ports, Ethernet access, with web interfacing. The SGR can also be adapted with a second antenna to provide heading and attitude.

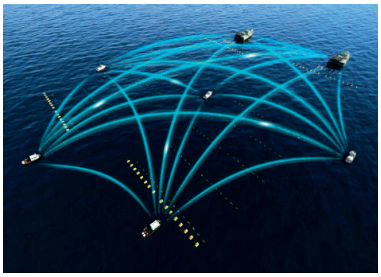
▸ ***http://bit.ly/1vE87yU***

The SGR6 GNSS receiver by Seabed.

Connecting Seismic Vessels

A communication solution developed by Kongsberg Seatex for the marine seismic sector was highlighted at SEG Denver 2014 (the Society of Exploration Geophysicists Annual Meeting), which was held from 26 to 31 October. The Kongsberg MBR system enables high-speed, high-capacity and robust data, voice and video transfer between multiple vessels and other assets.

▸ ***http://bit.ly/1vE8LfO***



An impression of the lines of communication.

Most Shared

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

New Long-term Observatory for Arctic Ocean Observations - http://bit.ly/1vE73uX
Researchers Find Ancient Sediments on Arctic Seafloor - http://bit.ly/1vE77L6
Fugro Expands High-resolution Subsea Laser Scanning - http://bit.ly/1vE79ma
QPS Unveils Qimera Bathymetry Processing Platform - http://bit.ly/1vE7fu0
Company Offering Autonomous Surface Vessels - http://bit.ly/1vE7ipR

Draft Polar Code Approved

A key milestone on the way to a mandatory Polar Code for ships operating in Arctic and Antarctic waters has been reached. The Marine Environment Protection Committee (MEPC) of the International Maritime Organization (IMO) has approved the environmental provisions in the draft International Code for Ships Operating in Polar Waters (the Polar Code), together with associated draft amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) to make the Code mandatory.

▸ *http://bit.ly/1vE9iOT*

Ocean Observatories for Seabed Research

CAGE (Centre for Arctic Gas Hydrate, Environment and Climate) has selected Kongsberg Maritime to develop and deliver two ocean observatories. The observatories will be deployed off the coast of Svalbard (Norwegian islands in the Arctic Ocean) during 2015, to monitor methane leaks from the seabed. The contract for this project was signed on 6 October 2014.

▸ *http://bit.ly/1vE9Mo3*

USBL Tracking System for Mini ROV

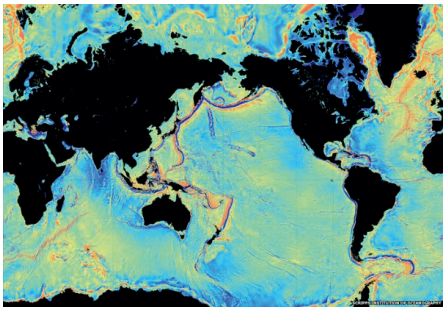
The popular Deep Trekker Mini ROV is now available with integrated TriTech MicroNav positioning system. UK-based Planet Ocean has integrated the system. Users may have experienced an added complexity when they could see where the ROV was underwater. With this new integration, operators can map the path that the Deep Trekker ROV takes while completing underwater inspections.

▸ *http://bit.ly/1vE8YQf*

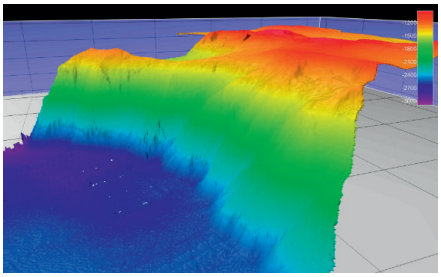
Map of Undersea Mountains Created by Satellite

The ice mission of the European Space Agency (ESA) has been used to create a new gravity map, exposing thousands of previously unchartered 'seamounts', ridges and deep ocean structures. This new picture of the least-explored part of the ocean offers fresh clues about how continents form and break up. Scientists from Scripps Institute of Oceanography at University California San Diego in the US and colleagues tapped into two new streams of satellite data to create a new gravity map mirroring features of the ocean floor. This is twice as accurate as the previous version produced nearly 20 years ago.

▸ ***http://bit.ly/1vE7k0N***



The gravity map created by Satellite.



Data on the slope of Lomonosov Ridge displayed three-dimensionally. Image courtesy: Laura Jensen, Alfred Wegener Institute.

Researchers Find Ancient Sediments on Arctic Seafloor

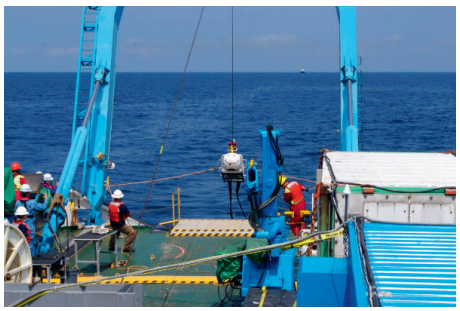
An international group of scientists headed by the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI, Germany) opened a new window into the Arctic Ocean's past during this summer's expedition on the research vessel *Polarstern*. Along steep slide scars on Lomonosov Ridge, the scientists discovered considerably hardened sediments that are presumably ten or perhaps even 30 to 40 million years old. These will provide the researchers with new insights into the history of the Arctic Ocean's climate. Upon the vessel's return to its homeport, the valuable soil samples will be unloaded and then comprehensively examined in the home laboratories in the coming months and years.

▸ ***http://bit.ly/1vE77L6***

Japanese CSEM Gas Hydrate Survey Completed

Ocean Floor Geophysics (OFG, Canada), in cooperation with Fukada Salvage and Marine Works (Fukada), has completed a high-resolution controlled source electromagnetic (CSEM) survey of near-surface gas hydrates using the Scripps Institution of Oceanography Vulcan system for the National Institute of Advanced Industrial Science and Technology (AIST) in Japanese waters. The survey comprises over 500 line kilometres of high-resolution data collected using the Fukada vessel *Shin Nichi Maru*.

▸ ***http://bit.ly/1vE93TP***



Recovery of survey equipment during the survey.

Fugro Expands High-resolution Subsea Laser Scanning

Use of underwater laser scanning has been expanded.

Fugro has expanded its services for the offshore oil & gas sector with the addition of high-resolution subsea laser scanning. This specialist technology can be applied to a wide range of subsea services including metrology, field mapping, structure mapping, change detection and integrity management.

▸ ***http://bit.ly/1vE9bTk***

Teledyne Acquires Oceanscience

A subsidiary of Teledyne Technologies Incorporated has acquired the business and substantially all of the assets of The Oceanscience Group. Based in Carlsbad, California, USA, Oceanscience designs and manufactures marine sensor platforms and Unmanned Surface Vehicles. Terms of the transaction were not disclosed.

▸ ***http://bit.ly/1vE8j13***

Geo-Matching.com Top 5

Most viewed AUVs	
OceanScan LAUV	http://bit.ly/1z1R1hS
Kongsberg Seaglider	http://bit.ly/1z1R39w
Exocetus Coastal Glider	http://bit.ly/1z1RcKk
ECA Robotics Alister 9	http://bit.ly/1z1RhO4
Teledyne Atlas Hydrographic SeaCat	http://bit.ly/1z1RmkF

3D PDF Export Feature for SonarWiz

Chesapeake Technology, USA, has added a capability for SonarWiz allowing users to easily share 3D views of their datasets with clients and the public. Using the 3D PDF exporting feature, the capabilities of the PDF standard contribute to help visualise the extents of the datasets. No longer will simple screenshots suffice when a client can zoom in, out and navigate through an interesting sonar feature simply by interacting with a PDF – and without needing a software key.

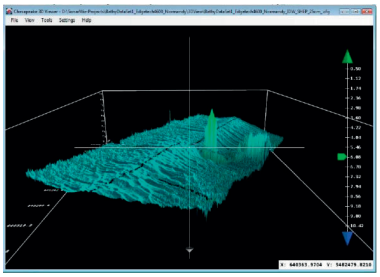


Image: screenshot of an interactive 3D PDF of the Empire Broadsword.

▸ ***http://bit.ly/1vE7Lsd***

Dutch Hydrographer Receives Alexander Dalrymple Award

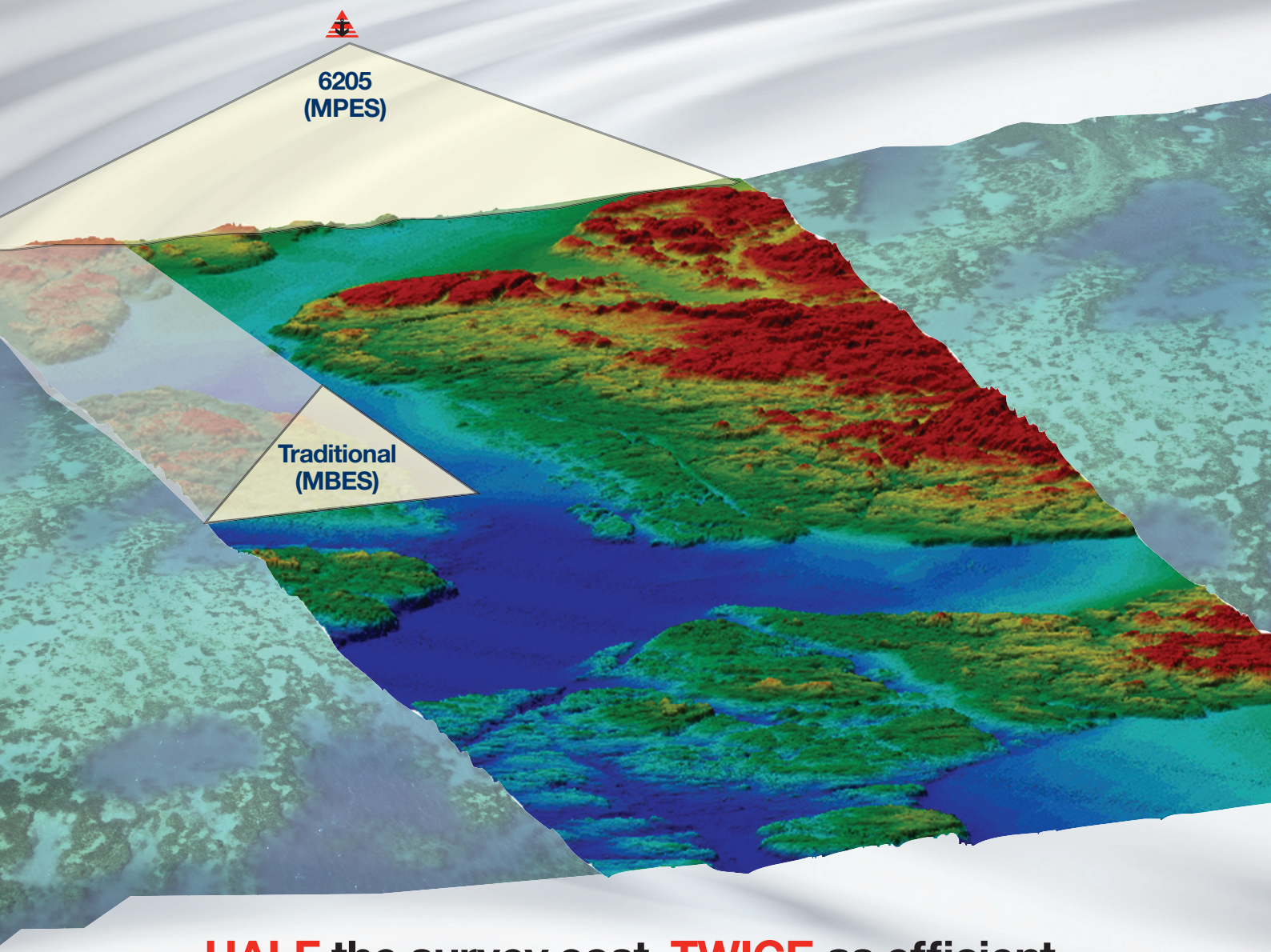
Captain Peter Kortenoeven accepting his award.

Captain Peter Kortenoeven, Hydrographer of the Royal Netherlands Navy, was presented with the United Kingdom Hydrographic Office's (UKHO's) prestigious Alexander Dalrymple Award at a ceremony in London. According to UKHO chief executive Ian Moncrieff, Peter was nominated for his role leading the Netherlands Hydrographic Office through a period of significant change and challenge and for his highly regarded contribution to the international hydrographic community.

▸ ***http://bit.ly/1vE8BFk***

EdgeTech 6205

MultiPhase Echo Sounder (MPES)



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No. 3576

AutoNaut Proves Herself in Atlantic Storm

Impression of the hostile environment that the AutoNaut *had to face.*

A British wave-propelled boat, *AutoNaut*, has arrived back in the Isles of Scilly after a 13-day autonomous mission in which she weathered a 70mph Atlantic storm, while gathering scientific data. David Maclean, director of MOST (Autonomous Vessels) Ltd, which produces the *AutoNaut*, considered this mission to be a major test for *AutoNaut*. To have delivered on time, on budget and to a very tight schedule; and for the Unmanned Surface Vehicle (USV) to have gone straight out into the Atlantic and carried out her programme through a gale and a storm is, according to him, a really solid achievement.

▸ ***http://bit.ly/1vE9ptD***

Qimera Bathymetry Processing Platform

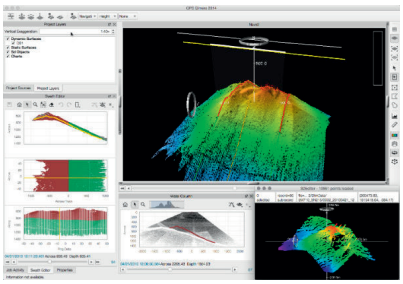
During Hydro14, which was held from 28 to 30 October 2014 in Aberdeen, UK, QPS announced a new processing product called Qimera to be released in 2015. The announcement was made at a packed QPS workshop, and being the first public unveiling of the product it brought an audible gasp as the features were presented.

▸ ***http://bit.ly/1vE7fu0***

Geo-matching.com Adds Hydrographic Processing Software and USBL

Geo-matching.com has recently added two new categories: Hydrographic Processing Software and USBL to its product categories. The website guides users through the maze of specifications and gives them the opportunity to compare products from different suppliers and read other professionals' reviews in order to reach a balanced judgement before buying.

▸ ***http://bit.ly/1uussfs***



A Qimera example screen capture.

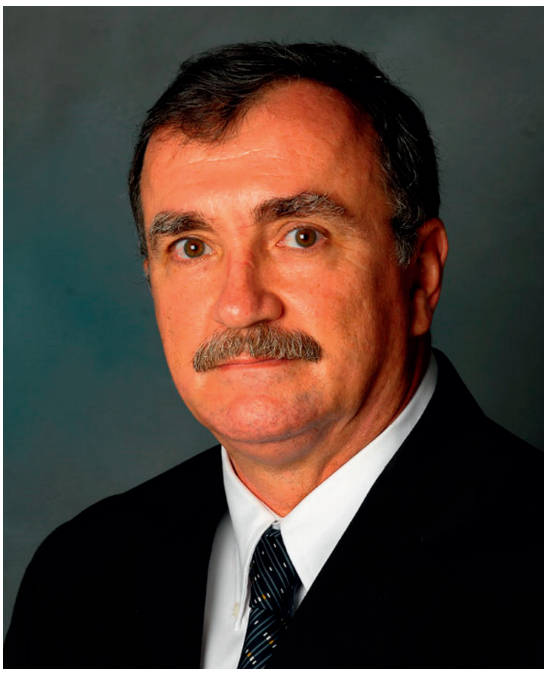
Hydro International Interviews Eng. Jaime Rogríguez

Digging Towards the **Future**

Work is ongoing in Central America to increase the capacity of the Panama Canal to accommodate more and larger vessels transiting from the Atlantic Ocean via the Caribbean Sea to the Pacific Ocean. This important construction work involves civil engineering, dredging and of course, hydrographic survey and charting as the Panama Maritime Authority takes care of its own charting, which is now being developed in accordance with the digital standards. *Hydro International* interviewed Jaime Rodríguez, manager Surveys Branch Engineering Division of Canal de Panamá.

How are the hydrographic responsibilities divided in Panama?

The Panama Maritime Authority (AMP) is responsible for conducting hydrographic surveys in waters surrounding the Republic of Panama. The Panama Canal Authority (ACP) is responsible for hydrographic surveying in the Panama Canal Operating Waters, including: the Atlantic and Pacific entrances to the Canal, Gatun Lake, Miraflores Lake, Alhajuela Lake, all the anchorage areas of the Canal and any other area that the Panama Maritime Authority authorises the Panama Canal to survey.



▲ *Jamie Rodríguez*

What role does hydrography play in the management of the Panama Canal?

Hydrography is very important in the Panama Canal. At Surveys Branch we have four units, one of them is the Hydrographic Unit. We work in very close cooperation with the ACP Dredging Division. The Dredging Division has four dredges (two dipper dredges and two cutter suction dredges). We do all before, during and after hydrographic surveys. The Dredging Division also has two drilling and blasting barges. In addition, the Hydrographic Unit does all the surveying for the contract dredging to compare with the soundings produced by the contractor. We also work in very close cooperation with the ACP Marine Traffic Control.

How will this role change during the construction and the operational phase of the new Canal?

During the construction phase we are more dedicated to the areas where we have all the dredging activities. Additionally, we have scheduled to survey most of the canal waters once a year, depending on the water depths and the sedimentation rate. There are areas that have enough water (22 metres or more water depth) that we survey every three years. In the operational phase of the new canal, we will monitor (survey) the new access channels more frequently to detect any earth slides or abnormality in the bottom of the channel.

How does the hydrographic service work with the dredging partners or do the dredging contractors take care of their own surveys?

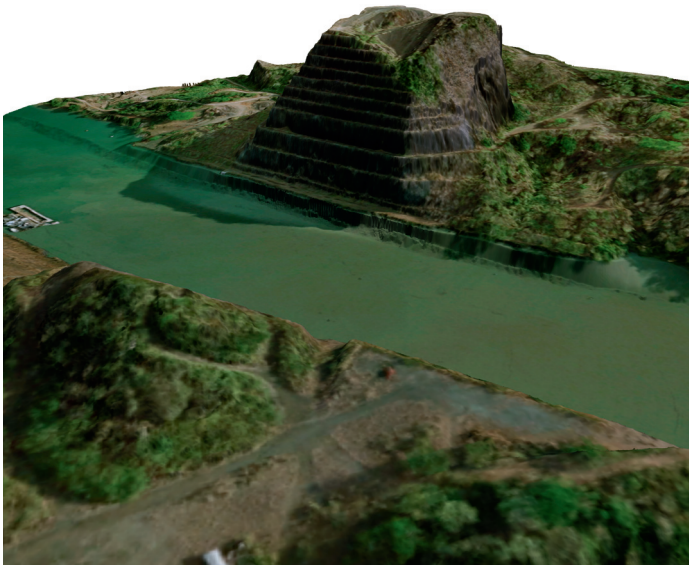
We provide all hydrographic services for in-house dredging, including volume computations, chart production and certifying that the project depth was achieved in the different areas. The Dredging Contractors take care of their own hydrographic surveys. But when they survey at the end of the month for the monthly payment, we at the Surveys Branch conduct a hydrographic survey covering the same area that was dredged at the same time by the contractor. We compare de volume dredged by both surveys and the difference has to be less than 3% for the bill to be accepted.

How accurate do your hydrographic surveys have to be, and how often do they have to be repeated?

We do class 1 hydrographic surveys to scale 1:1,000 (Contract Payment Surveys), IHO S-44 Special Order. In the areas where the Dredging Division has their dredges we survey once a week to report the volume excavated for each of the four dredges, including cross sections comparing actual dredging with original surface and we send PDF files of the surveyed areas. In the areas of Gaillard Cut, with no area dredging activities, we survey twice a year. We survey the other canal navigable waters at least once a year, including the anchorage areas. We have 10 surveying launches, four of which are equipped with a multibeam system.

What products does the Canal Authority produce to inform mariners?

The pilots of the Canal currently use a system



▲ *The Gaillard Cut.*

▲ *The Panama Canal trajectory.*

called CTAN, but this system does not provide depth information. They are actually testing new Pilot Portable Units (PPU) to replace the CTAN very soon. The new PPU will need ENCs of the Canal waters. For testing of the new PPU they are using ENCs produced by the Surveys Branch. We currently inform the Dredging Division and Marine Traffic Control using Hydrographic Charts in 1:1,000 scale.

New developments like airborne bathymetric Lidar are very important

The Panama Canal Authority has adopted a workflow and data management system to store the bathymetric information and to produce charts. How did this affect the chart and ENC production?

At the Surveys Branch we are starting to establish a Hydrographic Production Database (HPD) from CARIS to manage the production of the regular hydrographic charts 1:1,000, 1:3,000, 1:5,000, the Nautical Paper Charts, the ENCs and the Pilots Charts. We are also establishing a CARIS Bathy Database to incorporate all sources of data from historical field sheets, including the latest high-density multibeam surveys that we produce. The process is slow now, but we expect to increase the transfer of data as soon as our personnel feel more confident with the new software.

How are these products distributed?

As I mentioned earlier, we actually deliver all paper charts in scale 1:1,000 to Marine Traffic Control and we also send PDF images of the different areas of interest we survey. In the future, we plan to use the capabilities of a RENC like IC-ENC and the UKHO to distribute our ENCs, but this is an upper level management decision.

Which developments in our field are most important to you?

I consider the new developments in the area of airborne bathymetric Lidar to be very important, not only for the Canal, because you can cover an extensive area in a very short time. Still, there is more room for developing new equipment that can achieve higher depths (more than 3.5 secchi disc reading) and more precision. I also see new developments on multibeam systems making them more portable, more precise and less expensive.

How do you attract sufficiently qualified staff?

In Panama it is very hard to find qualified staff, especially in the hydrographic area. This is because at present there are no universities with Hydrography programmes. We have hired personnel that had been trained as hydrographer or oceanographer by other companies. Entry salaries are not very attractive but we are talking to management to increase the grade of the entrance level to make it more attractive.

Are there technical developments resulting in a different resurvey policy for the new compared to the 'old' Panama canal?

In some areas, like the Gaillard Cut in the old Panama Canal, we used to survey once a year and now with the multibeam system we survey every six months. We now survey other areas in the canal more frequently than used to be.

Are you expecting to make any archaeological discoveries during hydrographic surveys?

There is always a possibility of making archaeological discoveries (you never know), especially with new tools like the 'water column' from HIPS and SIPS. Without this tool you can fail to notice an object, thinking that it is a cavitation. In Gatun Lake we found 'Train Wagons' from the old Panama Rail Road Company, that were left at the bottom when the lake was created in 1913. ◀

Jaime Rodriguez

Jaime Rodriguez graduated as Civil Engineer from Panama University in 1977 and he studied Hydrographic surveying at the US Navoceano Fort Clayton in 1987. He also has a Master of Economic Engineering from Universidad Santa María. He has been manager of Surveys Branch at Panama Canal Authority since 1998. He introduced new equipment, software and systems to hydrography and cartography in the Canal as of 2005.

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No. 3559

Leveraging Technology and Social Media for Intracoastal Waterway Reconnaissance

Crowdsourcing Enhances Navigation Awareness

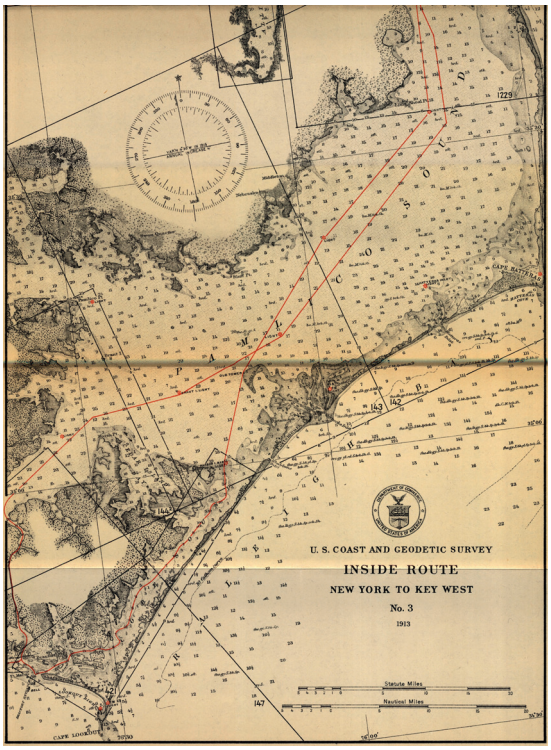
In this internet age, crowdsourcing is fast providing practical contributions to our understanding of the world around us. Whether it be software developed in an open-source environment, inputs from 'those in the know' to create and maintain wiki pages, or the provision of weather and traffic data through the mobile devices we use every day, society as a whole benefits from what we each 'know' and the ability to communicate that information with today's technology.

Autonomous crowdsourced bathymetry (CSB) is one of the newest tools in the hydrographer's toolbox, leveraging the application of 21st century technology and social media, both now an integral part of our everyday lives. While high-end surveying equipment is still unmatched in precision and accuracy in the hands of a professional hydrographer, very capable surveying technology is now low cost, readily available and already distributed worldwide in the form of standard-equipment vessel electronic charting systems, or chartplotters. Combined with the wireless and cellular networks that we are all constantly connected to, we have the ready means to aggregate and share this distributed coastal intelligence; and with the application of scientific principles rooted in hydrography and big data, we also have the ready means to compute solutions (along with uncertainty estimates) of this data to meet a variety of needs. And thus, the science of autonomous CSB is emerging as a next-generation tool that mirrors the connected mindset of the next generation of hydrographers.

One such purpose for which autonomous CSB is being successfully implemented is as a reconnaissance tool for boaters on the Intracoastal Waterway (ICW) (see Figure 1). Some sections of the waterway consist of natural inlets, saltwater rivers, bays and sounds, while others are artificial canals. It provides a navigable route along its length without many of the hazards of travel on the open sea. The regional maritime community is taking advantage of CSB as a self-enabling technology through a creative collaboration with industry. Leveraging the public's availability of modern technology and their natural desire to be well informed as well as to benefit society, mariners are providing data that bestow unprecedented insight into conditions and resources along the ICW. The Salty Southeast Cruisers' Net (SSECN) is an online social media forum focused on the Atlantic ICW, and a treasure trove of useful reports and articles provided and consumed by the ICW community. The SSECN website informs others via familiar chart displays provided by EarthNC, enhanced with access to information such as fuel prices, marina accommodations and navigation hazards like misplaced buoys and shoaling. These reports are also enhanced by the millions of water depth measurements made by cruisers during their routine ICW transits, autonomously delivered and processed through the ARGUS™ CSB innovations of SURVICE Engineering and CARIS USA. This virtual, distributed surveying 'vessel' acts as a member of the SSECN cruising community, greatly enhancing condition reports provided through the SSECN website with a continuous flow of physical measurements as portrayed in Figure 2. This model provides the ultimate opportunity to engage the public as it both leverages and supports the public's recreational and commercial interests in the ICW. What was previously a fleeting number on a chartplotter screen has become useful knowledge thanks to this pioneering partnership.

ARGUS Crowdsourced Bathymetry

Autonomous crowdsourcing for maritime applications has been pioneered by SURVICE Engineering and CARIS USA through the innovations of ARGUS. ARGUS is a patented (US Patent 8,417,451) autonomous CSB system that provides continuous, automated acquisition and processing of CSB data. It



▲ *Figure 1: The Intracoastal Waterway (ICW) is a 3,000-mile (4,800km) waterway along the Atlantic and Gulf coasts of the United States. (Image courtesy: NOAA).*

▲ *Figure 2: The information cycle begins and ends with the maritime and coastal community.*

universally interfaces with vessels' existing GPS and depth-finding systems, automatically processes the GPS and depth signals, and leverages wireless technology and social media for both data aggregation and web dissemination of process outputs. Originally demonstrated as part of a National Oceanic and Atmospheric Administration (NOAA) Small Business Innovation Research (SBIR) grant, ARGUS has processed over 100 million depth soundings from a distributed, international fleet of opportune vessels ranging from 18-foot recreational bass boats to 1,000-foot commercial cruise liners (see Figure 3). In the image, vessel traffic is clearly highest in the same coastal zones in which up-to-date reconnaissance is most needed. Studies suggest that ARGUS solutions can meet IHO S-44 Order 2 standards. ARGUS has demonstrated a powerful and practical approach that inexpensively leverages an unlimited, distributed workforce.

Fundamentally, ARGUS processes every GPS position and corresponding water depth measurement that is output from the chartplotter. The system operates autonomously with no operator interaction required other than turning on the chartplotter. Backend processing includes the application of vessel offsets, tide and other environmental corrections, various stages of quality control, and CSB-specific data aggregation methods. Output from the process can be managed through CARIS' Bathy DataBASE (BDB), which is used to compile survey data with appropriate metadata that can be used for searching. CARIS' Spatial Fusion Enterprise (SFE) then can be used to serve out the data via the web. CARIS BDB and SFE provide powerful post-processing and visualisation platforms for the web-served ARGUS solution sets, robust and scalable storage and analysis for the ever-expanding volumes of data, high-resolution graphics, industry standard bathymetric processing modules, and simple yet powerful end-user interfaces.

CSB Application on the ICW

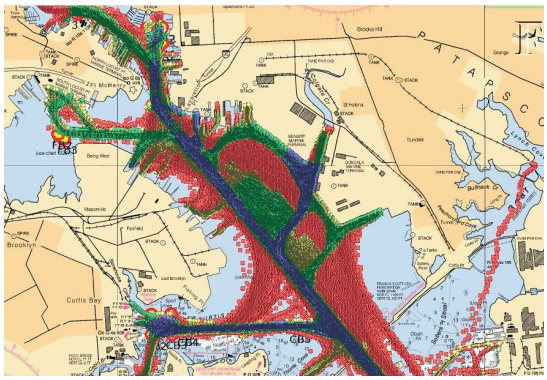
ARGUS has been in operation since 2010, acquiring over 100 million soundings from a distributed fleet of vessels navigating US and international waters. Over 20 million of those soundings have been processed over the 1,000+ miles from Norfolk to Key West, thanks to long-time contributors like Sea Tow, M/V *Altair*, M/V *Chez Nous*, Trawler Beach House, and Reality Check Sailing, and the data solution set is continually being refreshed. Figures 4 and 5 show two of the classic ICW trouble spots highlighted for SSECN readers: Georgia's Jekyll Creek and Little Mud River, respectively. These are typical examples of ARGUS data providing a real 'visual' of the conditions and of the best route of travel through these trouble spots.

Clearly evident in the case of the ICW, an especially hard-to-reach area for official survey assets, the swath of CSB data provides the partnership with a great opportunity to update the magenta line, or preferred route of travel, as currently represented on official charts. The magenta line was last comprehensively surveyed in the 1930s and desperately needs updating. Figure 6 shows one of many examples where the swath alone indicates the preferred route of travel, yet without consideration for which is the deepest part of the swath. Endorsed by the Atlantic Intracoastal Waterway Association, this project will add a continuously updated magenta line as a layer in the SSECN chart windows.

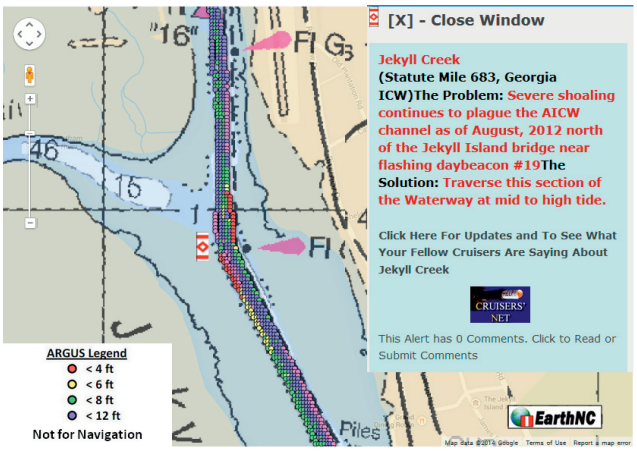
Since the CARIS-led introduction of autonomous CSB to the international hydrographic community in 2010, CSB's potential value has been noticed and is rapidly moving to leverage its benefits. Among others, the development of CSB has since been endorsed and encouraged by the United Kingdom Hydrographic Office, the International Hydrographic Organization and the Hydrographic Services Review Panel in the United States. The application of inevitable hardware improvements along with scientific expertise promise to only make CSB solutions better — in fact magnitudes better than the pre-1940s 'soundings' that are the basis for the majority of modern charts.

Who Benefits?

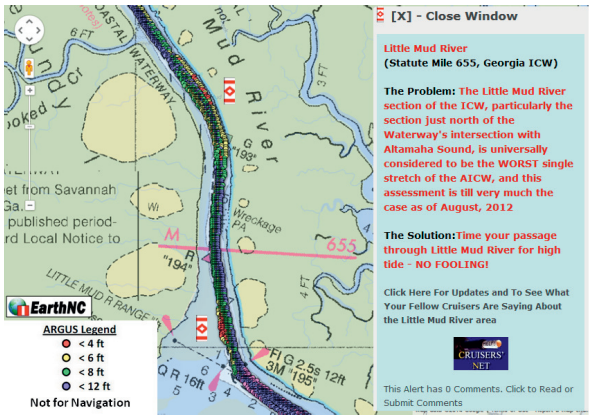
Crowdsourcing provides an opportunity to apply innovative technologies while engaging partners from academia, the public and commercial entities. It also attracts populations that are currently underrepresented in the hydrographic science workforce. The continuous flow of coastal environmental information promotes stewardship and informs decision making by stakeholders, educators, students, and the public who are interested in science. Crowdsourcing is an effective engagement of key stakeholders and the public that can enhance literacy of our coastal environments.



▲ *Figure 3: The results of ARGUS data processing in the Baltimore Harbor.*

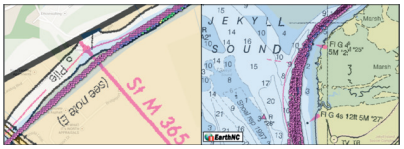


▲ *Figure 4: Cruisers navigating through Georgia identify ICW's trek through Jekyll Creek as a 'problem stretch' between Little Mud River and the Georgia/Florida state line. The shallowest spot is found abeam of marker #19 (Image courtesy: SSECN).*

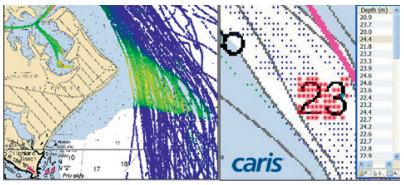


▲ *Figure 5: The Little Mud River section just north of the ICW's intersection with Altamaha Sound is a challenge for cruising vessels, made easier by the clear indications as to which side of the channel should be favoured. (Image courtesy: SSECN).*

Through this pilot application, SSECN readers are getting the benefit of a reconnaissance tool that keeps them best informed about the journey that lies ahead. The chart windows and layers allow planning for tomorrow's journey while in a slip or on the anchor with a look-ahead view of current attractions, alerts and trouble spots. Information is bolstered by local knowledge of the SSECN community as the readers monitor local solution updates,



▲ *Figure 6: ARGUS data indicate the preferred route of travel and the deepest depths along the route. A misplaced magenta line that may pose a danger to vessel traffic is clearly evident.*



▲ *Figure 7: A 'painted' shoal matches the chart contour lines (left). Processed ARGUS soundings in the vicinity of a charted depth provide confidence that the charted depth is still valid.*

make local chart comparisons and identify areas of interest (e.g., shoaling), which are then reaffirmed by and for the community. Reader testimonials indicate wide approval of these SSECN reports.

The general public benefits from a reduced need to tax current observing systems, which are already 100 years behind schedule and with growing requirements. Steadily decreasing resources have reduced the number of hydrographic survey platforms worldwide to about 65% of what it was 15 years ago. This is in the face of commercial maritime trade that has increased three-fold since the 1970s. Especially in hard-to-reach areas such as the ICW, crowdsourcing can be used as a supplement to mission planning for official surveys requiring controlled measurements as shown in Figure 7.

Resource-challenged hydrographic offices realise that they must rely not only on their own capabilities, but that they must also engage stakeholders and the public at multiple levels in order to build capacity and accomplish their missions. As demonstrated in other application areas such as the Chesapeake Bay, Antarctica, coastal New York and New Jersey, and the ports of Baltimore, New York, and Pittsburgh, one can see additional CSB networks being established to support local interests while complementing the work of hydrographic services and surveyors. Combined with the availability of the internet and wireless connectivity, remote sensing far beyond the capacity of all the world's hydrographers combined is being realised. With the challenge of reduced resources, the use of CSB and other nontraditional methods for collecting data will grow to support the ever-increasing needs and uses for hydrographic data. The newest members of the hydrographic workforce—the commercial and recreational vessel captains that value the waterways—are bringing the fruit of their efforts to the benefit of the entire ICW community. ◀

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The Salty Southeast Cruisers' Net (SSECN) Website, http://cruisersnet.net/.

The Atlantic Intracoastal Waterway Association (AIWA) website, http://www.atlanticintracoastal.org/.

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John Hersey is the Research and Technology Team leader for SURVICE's Applied Technology Operation, focused on the development of innovative solutions to meet the requirements of federal and commercial customers. He is the lead engineer and project manager for ARGUS, coordinating all of the contributing vessels and processing methodologies employed in the various application areas, such as the ICW.

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Paul Cooper is the vice president of CARIS USA and the current president of the Hydrographic Society of America. He is also vice president of the US National Section of the Pan American Institute of Geography and History and a board member of the Mid-Atlantic Regional Association Coastal Ocean Observing System (MARACOOS).

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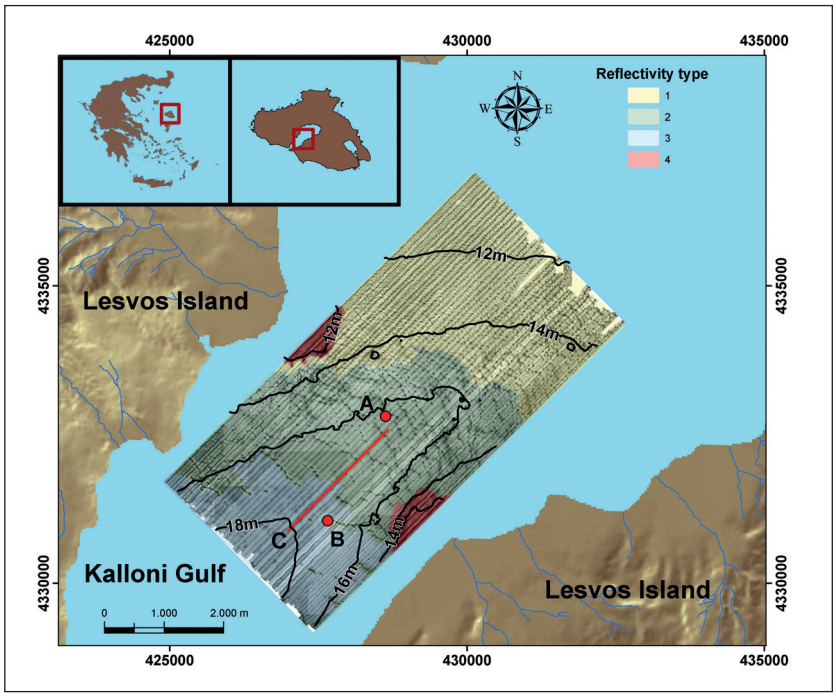
Relationship between Gas-bearing Sediments and Biogenic Mounds

Student Research Project in Hydrography

Here we present the winning project of an industry-supported student research campaign, initiated in 2013 by Innomar Technologie GmbH, Germany. More than 25 European scientific institutions participated with research proposals from Master and PhD students in order to perform a hydrographic and geophysical survey with a combined parametric sub-bottom profiler and side-scan sonar system. Complete survey equipment and on-site training was granted to the University of Wien, Austria, the University of Oxford, UK and the University of the Aegean, Greece.

The Kalloni Gulf is a large (20km long) and shallow (<20m deep) semi-enclosed embayment, on the western side of Lesvos island in the NE Aegean Sea that communicates with the open sea through a narrow strait (Figure 1). Previous sparse single-beam bathymetric studies have shown the presence of randomly distributed mounds, up to 4.0m in height relative to the surrounding seabed. An old analogue seismic section from a 3.5kHz Pinger (Figure 2) indicated gas-charged sediments along the gulf. Seabed sampling has revealed that the mounds consist mainly of molluscs of various sizes and they correlate well with some of the most productive scallop fishing locations in the gulf. The purpose of this study is to detect the surficial distribution of the mounds at the central part of Kalloni Gulf, to investigate their morphology and shallow sub-bottom structure and to determine parameters that may have affected their formation. Another scientific question is the occurrence of any preferential orientation or distribution of the mounds in relation to tectonic lines, which would indicate a tectonic influence on their formation.

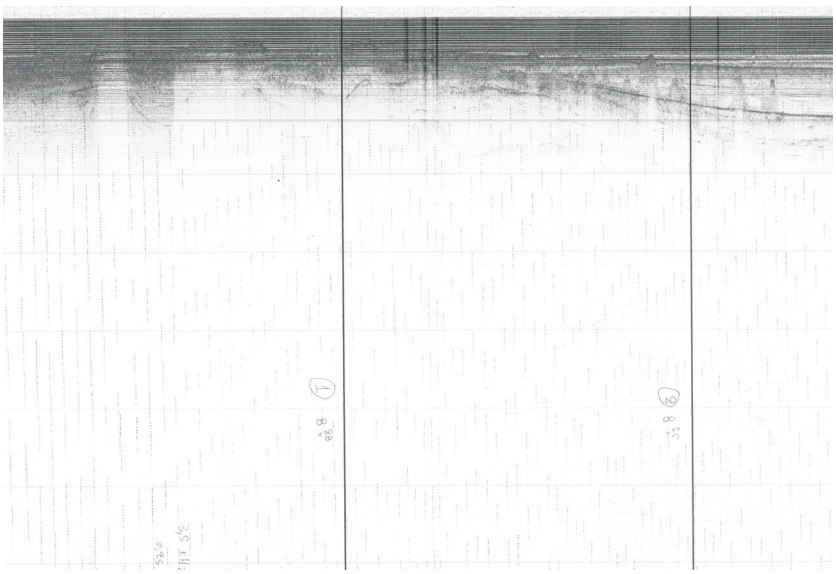


▲ *Figure 1: Side-scan sonar mosaic with overlay of depth contours, interpreted reflectivity types, diving locations (A, B) and interpreted survey line location of Figure 3 (C).*

The study detected the mounded morphology of benthic assemblages

Methods

A combined 2D seismic reflection-bathymetric survey and side-scan sonar mapping with Innomar's parametric sub-bottom profiler system SES-2000 light plus was performed in May 2013. The sonar system was mounted over the side onto the R/V *Amfitriti* together with a dual antenna DGPS system for positioning and true heading and a motion sensor for heave/roll/pitch data. The simultaneous acquisition of bathymetry, sub-bottom and side-scan data with a single pole mounted device eliminates the need for any offset or layback corrections of the individual sensor positions and has operational advantages compared to any tow fish deployment, particularly in shallow waters



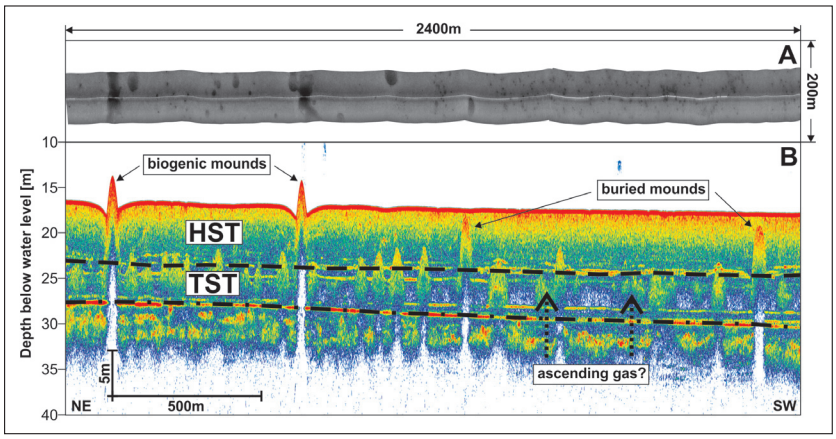
▲ *Figure 2: Pinger data (3.5kHz) from central area of Kalloni Gulf (paper record from 1987) with low resolution and significant signal ringing after transmission.*

with the presence of elevated surface features, several metres high. The narrow beam (<4 degrees) parametric system provides a high-frequency (100kHz) channel for bathymetric data and a low frequency channel with a similar beam width for sub-bottom data. A low frequency of 6kHz was used throughout the survey. The parametric system does not show any signal ringing during transmission and can therefore be operated in very shallow waters and provided a high layer to layer resolution of ca 15cm for the frequency used. The system integrated side-scan sonar was operated at 400kHz and 250kHz simultaneously. Survey lines were acquired along the gulf axis with 80m line spacing at a survey speed of about 4 knots. Some cross lines were also recorded. Ground-truthing of the geophysical data was performed with (i) scuba diving over mounded structures at two sites and (ii) few still video camera and grab drops for benthic analysis at selected locations (Figure 1). The survey covered about 33 square kilometres and a geo-referenced mosaic was produced from the side-scan sonar data during post-processing. The ArcGIS software package was used to merge the digitised bathymetry, the side-scan sonar mosaic and individual seabed and sub-seabed features for interpretation.

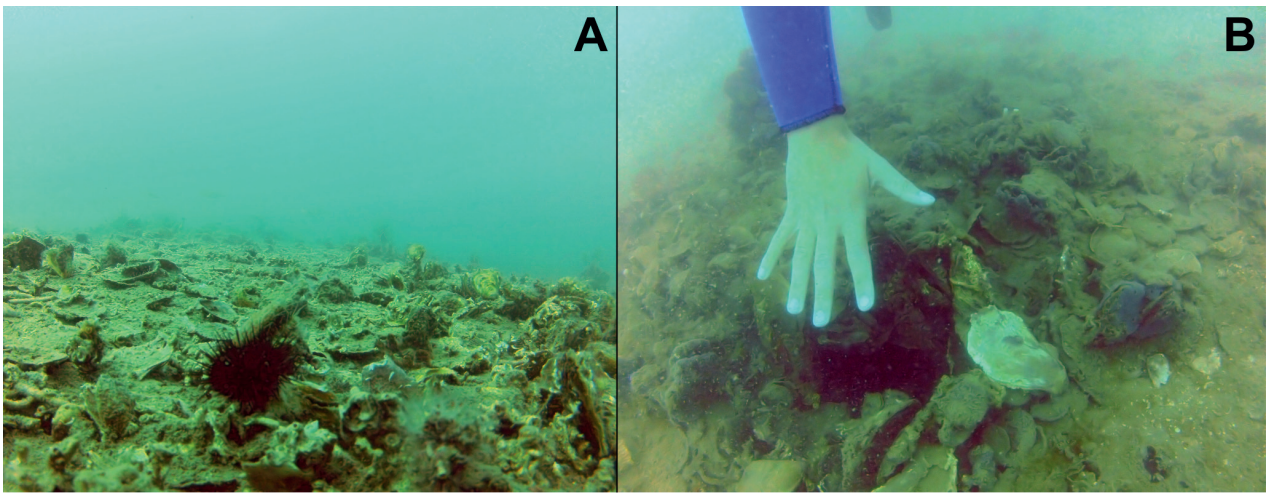
Acoustic Results and Interpretation

From the bathymetric and side-scan data four different types of acoustic backscatter (reflectivity) were identified (Figure 1). Type 1 occupies the northeastern and shallowest part (<14m depth) and corresponds to an area populated by low relief hummocks (average height of 1m). The hummocks consist of biogenic assemblages and appear to be individual or locally coalescing. They become progressively smaller and almost vanish shallower than the 10m isobath. Type 2 is found at the central zone of the study site, at depths between 14m and 17m and contains mainly short and long curved streaks of high backscatter. These features correspond to small mounded structures, up to 6m high (average height of 3 – 4m), sloping 4-17 degrees, occurring individual or coalescing with a length of up to 1.3km. Small depressions are often seen around the mounds. The orientation of these structures is almost perpendicular to the gulf axis. Type 3 occupies the southwestern part of the study zone at water depths deeper than 17m. The seabed here is typically flat with a low backscatter acoustic signature due to the presence of fine grained (muddy) sediments. Few randomly distributed mounds are also observed. Type 4 corresponds to two high backscatter bands at each side of the study area, probably consisting of coarser material from neighbouring fan deltas, built by small torrents discharging into the gulf. From the sub-bottom data two main seismic sequences are distinguished (Figure 3). The upper sequence is acoustically semi-transparent and it is divided into two sub-units from both sides of few internal faint reflectors. The lower sequence consists of few semi-prolonged reflectors. The boundary reflector between the two sequences is of high amplitude and most likely represents the basal unconformity due to a drop in the sea level during the Wurm glaciation. The thickness of the surficial seismic sequence changes from ca 7m in the shallow part to ca 12m in the deeper part of the study area. The two sub-units in the upper sequence probably correspond to the Holocene high-stand (HST) and transgressive system tract (TST), respectively. Acoustic anomalies in the upper seismic sequence and enhanced reflectors along the basal unconformity indicate the presence of gas in the sediment pores. The gas probably originates from bacterial degradation of organic matter, but a hydrothermal source is also possible due to the volcanic nature of Lesvos Island. The most interesting features observed in the upper seismic sequence are buried mounds, similar in size, shape, distribution and orientation with the modern mounds occupying the gulf seafloor.

Visual data was obtained by divers and camera drops



▲ *Figure 3: Interpreted survey line with simultaneously acquired side-scan (A) and sub-bottom (B) data.*



▲ *Figure 4: Underwater images showing benthic life over a biogenic mound (A) and the presence of a hole near the crest of the mound (B).*

Seabed Inspection

Visual data obtained by divers and camera drops verified the existence of abundant bivalves and other benthic life, covering the mound structures (Figure 4). The flat areas are mainly covered by muddy sediments with few and small biogenic fragments. A remarkable feature that was detected by the divers was the presence of one hole at the crest of each of the two highest mounds, with a diameter of ca 30cm (Figure 4). However, no depth could be obtained.

Four different types of acoustic backscatter were identified

Conclusions

This study detected the mounded morphology of benthic assemblages, their spatial distribution over the seabed and their peculiar morphology at the central part of the Kalloni Gulf. The side-scan sonar mosaic indicates that biogenic mounds may also be present towards the SW and closer to both gulf sides. The parametric sub-bottom profiler data demonstrates special morphological aspects (height, local composite morphology, neighbouring depressions) but most importantly distinguishes similar buried structures that were initially interpreted to be gas-charged sediments in older poor quality Pinger records. Consequently, the use of modern equipment with high resolution has provided a deeper insight into the morphological and stratigraphic history of the gulf and caused a refinement of the existing interpretation. Most of the buried mounds are located along the TST-HST boundary, suggesting a start of growth during the Late Holocene (~5500 BP) when a small and steady rate of sea level rise occurred. An explanation for the mound structures could be fluctuations of the physical environmental conditions, the initial formation of shallow craters due to fluid escape, the preferentially successive colonisation of benthic life within these craters and finally the build-up of the mounds possibly with a central vent where fluid seepage occasionally occurs. Future work with detailed multibeam morphology, morphometric measurements, core sampling, sediment dating, benthic surveys and fluid measurements is required in order to determine the mode of the mound formation and their possible correlation with tectonic lines with more details.

Acknowledgements

We would like to thank Innomar Technologie GmbH for granting equipment and technical support, the captain of R/V *Amfitriti* N. Hatzilias and the diving team M. Sini, L. Herold and A. Pori. ◀

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A Manufacturer's Perspective on Routine AUV Utilisation

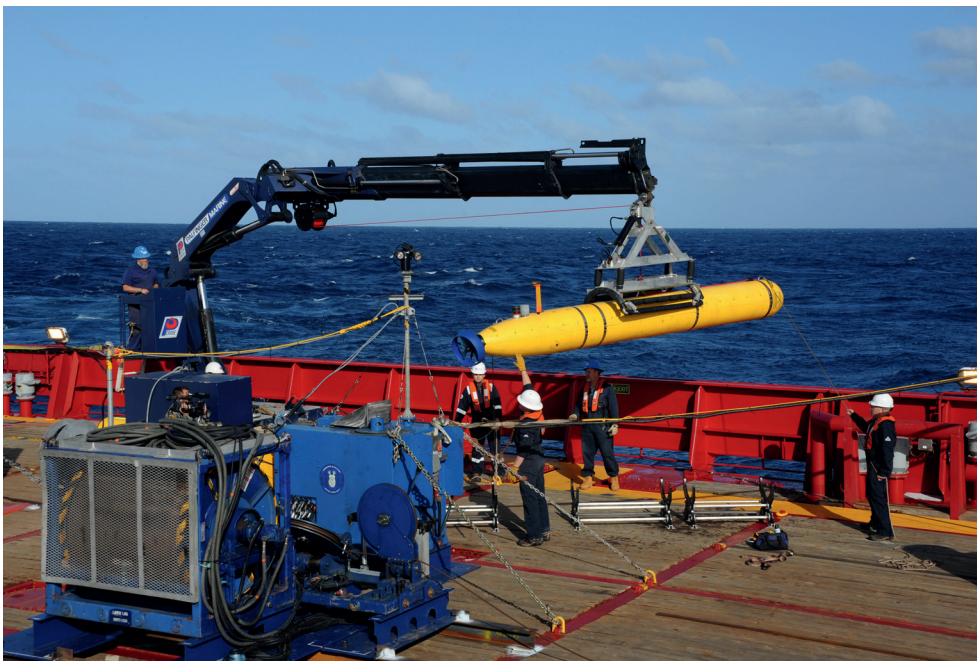
Inevitable **Truths** of **Operating AUVs**

Earlier this year, the US Navy deployed a Bluefin-21 Autonomous Underwater Vehicle (AUV) to search for the missing Malaysia Airlines Flight 370. The tragic disappearance was thought to have occurred over 1,600 kilometres offshore Perth in a remote and very deep region of the Indian Ocean. The AUV was launched 25 times in order to collect over 850 square kilometres of seafloor imagery (Figure 1). As a result, authorities successfully discounted the area as the final resting place of those on board. On-going media coverage offered a glimpse into what AUV operations are really like day-to-day, dive-to-dive. But deploying an AUV starts long before it hits the water.

Having spent nearly two decades demonstrating the capabilities, limitations and tremendous potential of AUVs, Bluefin Robotics have developed an approach to adopting AUVs for successful, real-world implementations. We will outline the realities and challenges of standing up an AUV operation, but more importantly provide key factors worthy of early consideration with the main take away being: success below the surface is a function of preparation done on land.

The Business Case

The first step is to develop a convincing business case that describes the technology, explains how it meets a demand, and outlines monetary potential to stakeholders.



▲ *Figure 1: Launch and recovery crane and docking head on the* Ocean Shield*, the ship deployed to search for the missing Malaysia Airlines Flight 370 in April 2014 (shipboard L&R, footprint, crew, etc.). Image courtesy: U.S. Navy.*

A comprehensive evaluation of routine operations is critical, as variables such as crew composition, ship selection and deployment methods can materially impact returns. It is also advisable to highlight how services will be charged - whether it be per trackline, a flat day rate or on delivery of a data product – as these all have different trade-offs. Initial conversations held with manufacturers can help with this step and is critical to establishing expectations and ultimately a specification for the system.

The Selection Process

In order to select the best AUV to meet your business goals, your team should build effective job performance metrics rather than rely on data sheet specifications. Manufacturers can provide practical guidance on how AUVs can meet your objectives. Discussions should focus on your concept of operations including number of vehicles to deploy, op-tempo, typical operational area and depth, required shipping footprint, level of spares, maintenance expectations and plans for upgrades. A factory site visit is very advantageous to learn about AUV potential, develop relationships with technical experts and witness a demonstration.

The Stumbling Blocks

Planning does not end with an AUV purchase.

▲ *Figure 2: The Bluefin AUV was mobilised on the* Ocean Shield *within days of notification.*

Stumbling blocks can quickly emerge if key areas are not addressed early in the process. At the very least, your team will need to outfit a basecamp facility, source and train personnel, work out shipboard details, plan for infield maintenance and establish a data-processing chain (Figure 3).

Data is everything when it comes to AUVs

Basecamp Facility

A well-designed maintenance facility is just as important for the operator as it is for the manufacturer. As the operator, you should consult the manufacturer to learn what space, instruments and resources are required when the AUV is not mobilised. Does it need test tanks, tools, or packing equipment (Figure 3)? Should the space be flexible for evolving needs or staged for clients demonstrations? Regardless, it should include a healthy IT infrastructure for data handling and vehicle diagnostics, and dedicated areas for battery management, maintenance and logistics.

Education and Training

Investing in a group of capable people should be top priority. Any AUV is only as effective as the team that operates it. Questions include how many people are necessary, what is the ideal skill mix for your organisation, and where will you source these people. Count on your team to develop a vital relationship with the manufacturer during initial years of ownership. Not only will personnel complete system training, but they will also receive on-going education and support to optimise system performance. It is not unusual for personnel to consult the manufacturer's operations team for advice regarding new operating environments or to strategise anticipated challenges.

Shipboard Concerns

Careful consideration of the type of host ship you plan to operate from will reduce uncertainties during the actual deployment in the field. Planning for various possibilities and building in flexibility will inevitably save you time and money. First, look for any hard requirements such as the available space. How much space will you need? Will you be staged in an ISO container or will you have access to a workspace? Can you recreate a variation of your basecamp facility? What are your options for IT networks, printers and whiteboards, and connectivity to land?

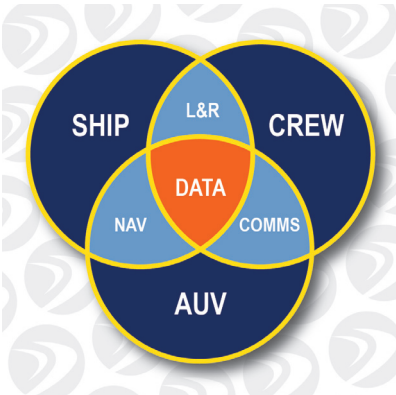
Second, determine what kind of communications and navigation equipment is required and when it can be installed and tested. Some AUVs require simple portable systems, while others have a more integrated approach. If the ship has pre-existing equipment, confirm compatibility and verify it with testing prior to mobilisation. Your manufacturer should be able to assist with this phase.

A launch and recovery plan should be a part of your initial conversations and considerations. Options depend on the AUV, the prospective ship, and the owner's requirements. If operating from a dedicated ship, a fully-integrated launch and recovery system may be appropriate. If operating from ships-of-opportunity, build in flexibility with an air-shippable docking head. As always, don't forget to test the equipment in port. An early site visit to the ship can uncover potential roadblocks or inspire modifications to the AUV or auxiliary equipment that can reduce future costs. Sharing photos and schematics can help both your team and the manufacturer.

Interacting with the ship's crew and other personnel can be challenging if those on board have never worked with or around an AUV. Educating people will be an on-going activity as an AUV operator. Before setting sail, learn whether the captain has worked with an AUV in the past and what their attitude is about the equipment. Understanding who your allies are and then spending time to gain new ones will benefit the job all around and becomes especially important if the ship has multiple objectives.

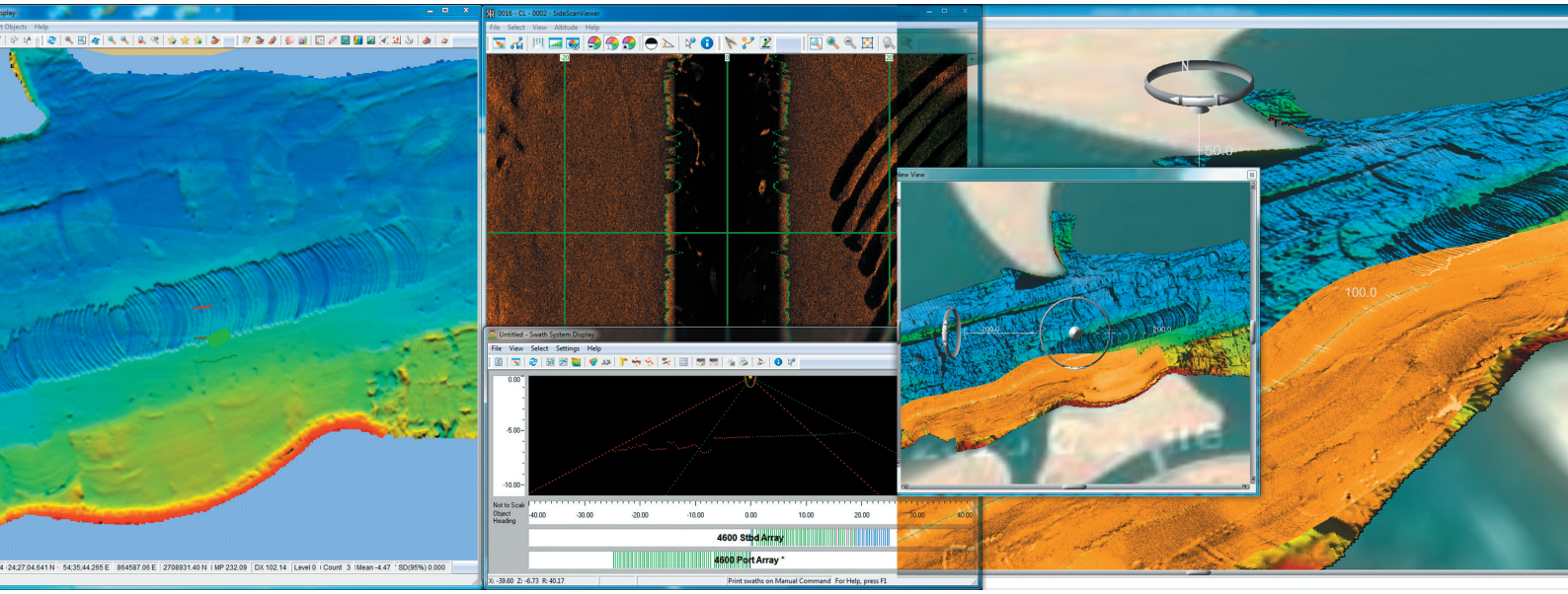
Infield Maintenance

The type of maintenance paradigm exercised at sea directly impacts short-term and long-term AUV reliability. If technicians are given no choice but to diagnose and repair electronics in the field, equipment can be exposed to the environment injecting risk to the system. It also makes finding a root cause to a failure and implementing fixes back at the factory difficult. As a manufacturer, we promote an approach



▲ *Figure 3: Successful operations in the field depend on more than just the AUV, but also on a mix of the right people, equipment and preparation.*

GEOSPATIAL TOOLBOX



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▲ *Figure 4: Low-logistics doesn't have to mean less capable. Larger, more capable AUVs including their equipment and spares can be broken down into sections for rapid transportation.*

that enables the greatest reliability for remote jobs in harsh environments. A spares package allows for in field swapping of components and subsystems. The appropriate training and necessary resources can help shift mind-sets towards applying repairs and maintenance at the subsystem level and ultimately increase reliability (Figure 5).

Data-processing Chain

Data is everything when it comes to AUVs. Handling and processing data should be at the forefront of the operation. The type of data required dictates the payload configuration. Future needs should be communicated so that an expansion plan can be designed into the AUV. Questions to ask your team include what file formats you require, what data quality is desired, what is the final data product and what will it look like.

The Dive

It is finally time to put the system in the water and all of the preparation will start paying off. Dive planning can be completed ashore or in the field as needed, but you should adhere to a stringent process to ensure that the system is configured and ready to collect the data. Once on site, pre-dive checks and procedures will confirm that the AUV is ready for work. After the vehicle is launched, the mission starts and the vehicle slips below the waves. Once the mission is complete, your team will recover the AUV, download data and swap batteries. The sequence is repeated.

▲ *Figure 5: In-field maintenance and repair should be done at a subsystem level and should focus on swapping out field-replaceable units.*

Conclusion

After you have overcome all the known challenges, you will be freed up to address new issues that arise during the deployment. Possible complications include shipping delays, unanticipated changes to the ship or equipment, personnel changes, inclement weather and adjustments to the search area or job profile. The thing to remember is that challenges inevitably emerge on every job but careful preparation will help in mitigating them and ultimately lead to successful and profitable AUV operations.

Acknowledgements

Many thanks to the good people at Phoenix International who worked with us on their AUV operations. ◀

Multi Media Sources

YouTube (animation of typical AUV operations): http://youtu.be/Wpj10Qw1RWk

This article was originally written for and published in the AUV Special of *Hydro International*, September 2014.

William O'Halloran

William O'Halloran is the director of User Experience at Bluefin Robotics, where he oversees all trials, testing and delivery of Bluefin vehicles as well as provides on-site support to customers worldwide. Since joining in 2003, he has deployed over 40 unmanned subsea systems and participated in over 50 operations.

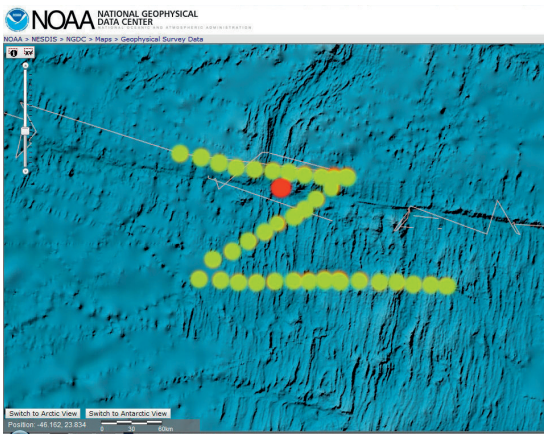
Deanna Talbot has contributed as marketing manager at Bluefin Robotics and responsible for all marketing, advertising and promotional activities with the primary objective being to measure, enhance and enrich the position and image of the company.

Confused by Fracture Zones

Seeking a **Rift**

In 1953, Hans Pettersson published *Westward Ho with the Albatross*, a popular account of his around-the-world scientific cruise on the Swedish sailing ship *Albatross*. In it he stated, "… geological evidence found in the last thirty years indicates that the Ridge is probably built up by extensive submarine volcanic action, i.e. by molten magma from deeper layers in the crust being extruded through an enormously long fissure in the bed of the Atlantic." Although Pettersson and earlier authors certainly came close to describing the concept of a rift, it was not until the late 1950s that a rift and rift valley were widely accepted by the geologic community. This was largely based on the 1956 pronouncement of a worldwide rift by Maurice Ewing followed by the 1957 publication of the Bruce Heezen and Marie Tharp *Physiographic Diagram of the North Atlantic Ocean* and the publication of *Geological Society of America Special Paper 65, The Floors of the Ocean: Text to Accompany the Physiographic Diagram of the North Atlantic* in 1959 by Heezen, Tharp, and Ewing.

Because of the iconic nature of the physiographic diagram and its role in acceptance of the reality of a rift zone, a critical look will be taken at this map and the associated publications. The map was included in the January 1957 edition of *The Bell System Technical Journal*. This volume included the article 'Oceanographic Information for Engineering Submarine Cable Systems' by C. H. Elmendorf, a cable engineer, and Heezen that discussed the physical and geological oceanography of the North Atlantic and its relation to cable engineering. The accompanying physiographic diagram was quite large, extending from 50N to 17N Latitude and between 0 and 82W Longitude. The rift valley shows as a somewhat sinuous line bisecting the centre of the diagram with no indication of fracture zones. However, south of 24N the rift is not shown as the legend has been placed over the rift zone. As Heezen and Tharp had data to 15N and a number of ridge crossings between 24N and 15N, the question arises as to why the physiographic diagram ended at 17N and hid the region between 24N and 17N.



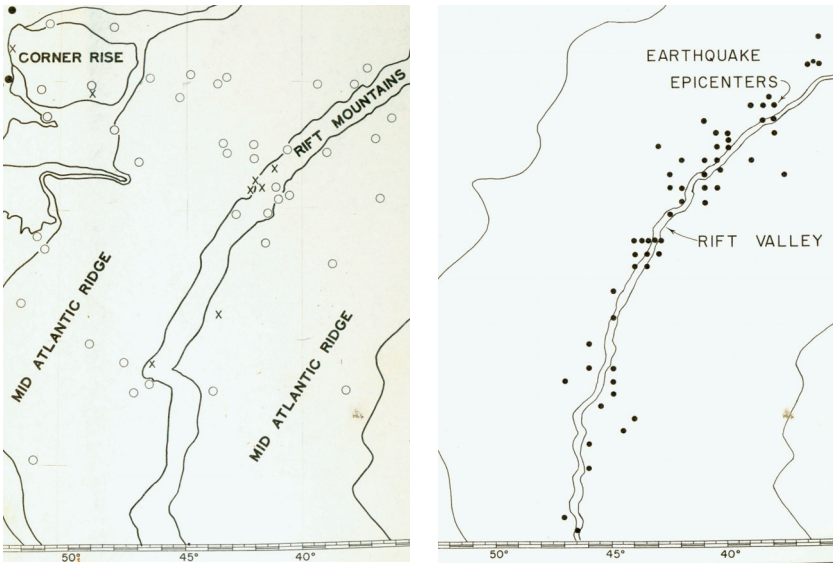
▲ *Figure 1: Heezen finally surrounds Dietrich's most impressive depression (red circle). Yellow – R/V* Vema *track from 1950s. Pink – 1968 Heezen-directed maiden trackline of USNS* Kane.

All these lines pre-dated the claim of Marie Tharp's 'discovery' of the rift valley

To understand the map and how it evolved requires study of Heezen's 1957 and 1959 publications and their accompanying graphics. These works included three basic types of associated graphics: 1) trackline maps; 2) profiles of the seafloor that displayed its nature including depictions of the rift; and 3) earthquake epicentre maps that were meant to demonstrate the correlation of earthquakes with the median rift valley. The 1959 publication also included a map showing 'Distribution of Deep Sea Sands in Relation to Physiographic Provinces', a map labelling physiographic provinces, and a 'Control Chart' that showed all trackline used in the construction of the large-scale physiographic diagram. The 1957 publication included a separate map that showed physiographic provinces including the rift valley extending from 60N to 30N and a map showing trackline extending to approximately 12N.

After reviewing these publications, Gunter Dietrich's influence on Heezen's work as related to the Mid-Atlantic Ridge becomes apparent. Recalling Heezen's discovery of a 'skimpy' paper related to *Meteor* work in the late 1930s, Dietrich's paper that described six 'striking depressions' along the MAR was found in the bibliography of the 1959 publication. Heezen referred to this article once in *The Floors of the Oceans* and only in the context of a source of soundings and not as a source of concepts. There were only two discrete soundings with associated position information in this article and four profiles. The two soundings noted the depth and location of what Dietrich called Great Meteor Seamount and the depth and location of the 'most impressive' of Dietrich's 'striking depressions'.

The trackline graphics from 1957 and 1959 show Dietrich's influence between 30N and 15N. The 'Control Chart' published in 1959 shows the tracklines used in producing the physiographic diagram down to 17N. Figure 4 of Heezen's 1957 publications shows track extending to 12N. Barely noticeable on the



▲ *Figure 2: Inconsistency in location of rift mountains and rift valley as determined by earthquake epicentres. Top bend in rift mountains is near Kane Fracture Zone.*

1959 control chart are a small number of tracks identified as coming from *Meteor* expeditions. Centred near 25 N 45 W are the three segments of line run by Gunter Dietrich on the *Meteor* in 1938 that cut the ridge and accounted for three of Dietrich's six 'striking depressions'. Between 30N and 15N all but one Heezen line cut the ridge in close proximity to Dietrich crossings. With the exception of a line run by the Lamont ship *Vema* after 1952 that brackets Dietrich's 'most impressive' depression, all of these lines pre-dated the claim of Marie Tharp's 'discovery' of the rift valley. It is difficult to avoid the conclusion that Heezen was looking for Dietrich's 'striking depressions'.

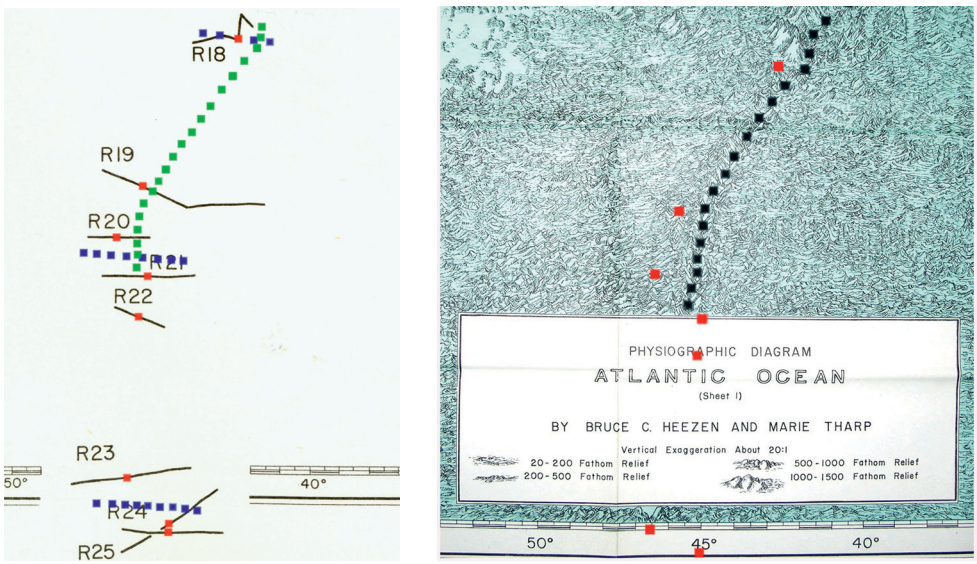
There were numerous sets of profiles produced for publication in the *Floors of the Oceans*. From the standpoint of defining the MAR and the rift valley there were two significant sets. The first is the famous set of six profiles Marie Tharp produced and from which she claimed priority of discovery of the rift valley of the MAR. As noted in the last issue of *Hydro International*, there are a number of variations of this story. Regardless of which or any version being true, the first three profiles were touted as the ones on which the rift valley was most prominent. Out of these three, two never actually crossed the ridge at the location of the notch as they showed profiles of fracture zones: Profile I crosses the Oceanographer Fracture Zone and Profile III crosses the Atlantis Fracture Zone.

A second set of twenty-six profiles, and the most convincing concerning the rift valley, is found in Figure 45 (p. 93) of *The Floors of the Oceans*. The majority of these crossings have a significant central depression. Profiles R1 through R25 extend from 48N to 15N although the Physiographic Diagram cuts off at 17N. Surprisingly, Heezen and Tharp scaled off depths from the prominent profile Dietrich had published in 1939 and used it as Profile R23. The associated track segments for profiles R1 through R25 are found on Plate 23 (plates are included as foldouts at end). When plotting the rift valley location on the trackline segments of Plate 23, a much different view of the median valley emerges from that shown on the Physiographic Diagram. There are offsets with the correct orientation at what are now known as the Oceanographer (35N), Atlantis (30N), Kane (24N), and 15 20 (15N) Fracture Zones. The location of the rift valley when superimposed on the trackline of Plate 23 compares favourably to modern bathymetric maps of the ridge and rift. Because the physiographic map was drawn to show the ridge and rift with no offsets, there are errors approaching 100 nautical miles in the location of the ridge and rift as shown on this famous map. Heezen and Tharp apparently chose to hide their confusion concerning fracture zones by a variety of tactics. The two most apparent being: 1) the placement of the legend just below 24 N which hid the Kane Fracture Zone; and 2) terminating the map at 17N instead of continuing it to 15N thereby cutting off the 15 20 Fracture Zone.

Heezen and Tharp reinforced their claim to having discovered the rift valley by correlating earthquake epicentres with the rift valley.

Heezen and Tharp hid their confusion by placing the legend in this area

Prior to the development of the World-Wide Standardized Seismological Network (WWSSN) in the early 1960s, the best that the location of epicentres could be determined in the vicinity of the MAR was approximately 100 kilometres.



▲ *Figure 3: Rift valley incorrectly mapped on 'physiographic diagram.' Red – Heezen-Tharp rift valley crossings. Green/black – map location of rift valley. Blue – fracture zones.*

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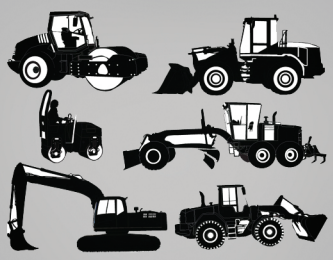

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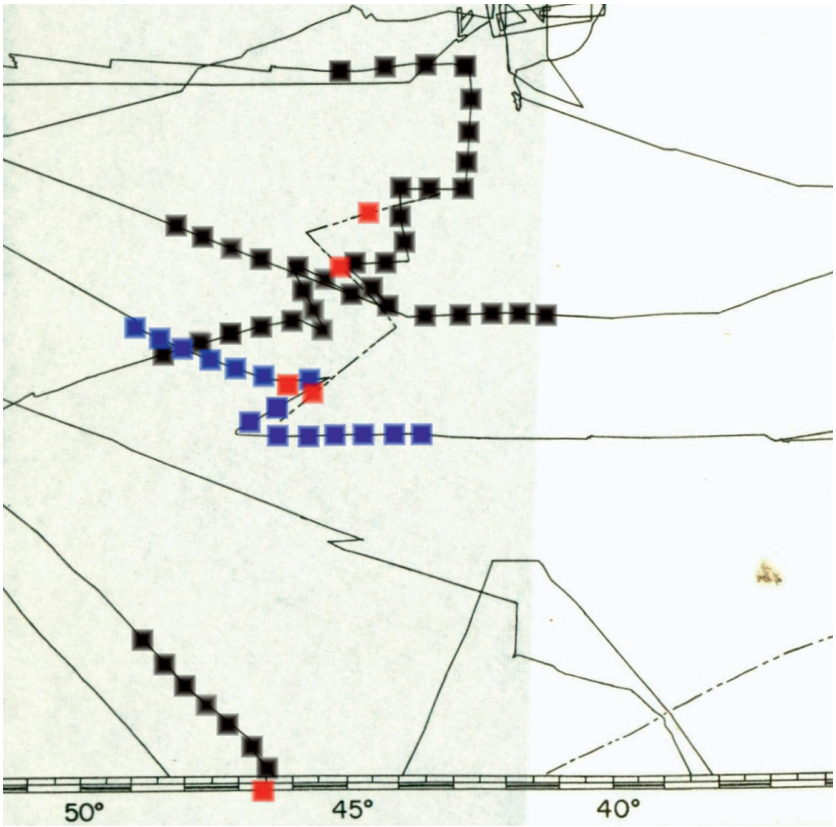

▲ *Figure 4: Coincidence of Heezen trackline with Dietrich depressions. Black – pre-1953 trackline. Blue – mid-1950s* Vema *trackline. Red – locations of Dietrich's 'striking depressions'. Dot-dash lines - Dietrich 1938 zig-zag trackline as plotted by Heezen-Tharp.*

It is noted that a number of investigators had discovered the correlation of a broad zone centred on the ridge with numerous earthquake epicentres prior to declaration of the rift. Given that the width of the median valley is of the order of 20 kilometres, it would seem impossible to find the valley based on pre-WWSSN earthquake epicentre locations.

By the early 1960s, Heezen and Tharp began to understand the nature of fracture zones and reported on Atlantic fracture zones at a conference in 1961 and then published a paper on the equatorial Chain and Romanche Fracture Zones in 1964. In 1968, Heezen was made chief scientist of the brand new USNS *Kane* and was told he could take it anywhere in the Atlantic he wished on its maiden voyage. He went straight to the feature he called 'Scarp D', which happened to be the location of Dietrich's 'most impressive striking depression' at 24N. Curiously, the track Heezen ran during this cruise, when combined with an earlier 1950s *Vema* trackline, circumscribed a polygon around Dietrich's depression. This depression is at the western ridge-transform fault intersection of what Heezen subsequently named the Kane Fracture Zone. Perhaps Heezen's apparent sailing in Dietrich's wake ended with this cruise. By this time many more crossings of the ridge had been made, most of the major fracture zones in the Altantic had been mapped, and the rift valley was a well-established fact.

To be logically consistent, the rift valley should roughly follow the centre of the rift mountains

Furthermore, many of the earthquakes associated with the ridge occur on ridge-ridge transform faults. The confusion that this caused is best shown on two 1959 Heezen-Tharp graphics – Plate 28 which shows a distinct and correct bend to the east in the 'Rift Mountains' at 24N and Plate 29 which shows the rift valley as a relatively straight feature bending to the west at 22N (Figure 2). To be logically consistent, the rift valley should roughly follow the centre of the rift mountains. Heezen and Tharp hid their confusion by placing the legend in this area.

In looking back it becomes apparent that Gunter Dietrich was the first to discover the median valley in the Mid-Atlantic Ridge and influenced Bruce Heezen, Marie Tharp, and probably Maurice Ewing in much of their work on the MAR. It seems an inescapable conclusion that Heezen was following Dietrich's lead from as early as 1948 in attempting to define the median valley and that he, Maurice Ewing, and Marie Tharp were cognisant of Dietrich's work and never gave him credit for his contribution. However, to Heezen, Tharp, and Ewing's credit, they were the first to describe the physiography of an entire oceanic region and the Heezen-Tharp follow-on maps of the oceanic basins painted by Heinrich Berann served to educate a generation as to the nature of our planet. Perhaps the moral of the story of discovery on the MAR is that the mapping of the seafloor and discovery of its true nature is not the work of one person or even one group of people. The discovery and comprehension of the nature of the Mid-Atlantic Ridge began over a century and a half ago with the work of Lieutenant Matthew Fontaine Maury and Lieutenant Otway Berryman and is still continuing today. ◀

▲ *Figure 5: Gunter Dietrich – first to note continuity of depressions marking MAR rift valley. Future head of Institut fur Meereskunde, forerunner of today's GEOMAR.*

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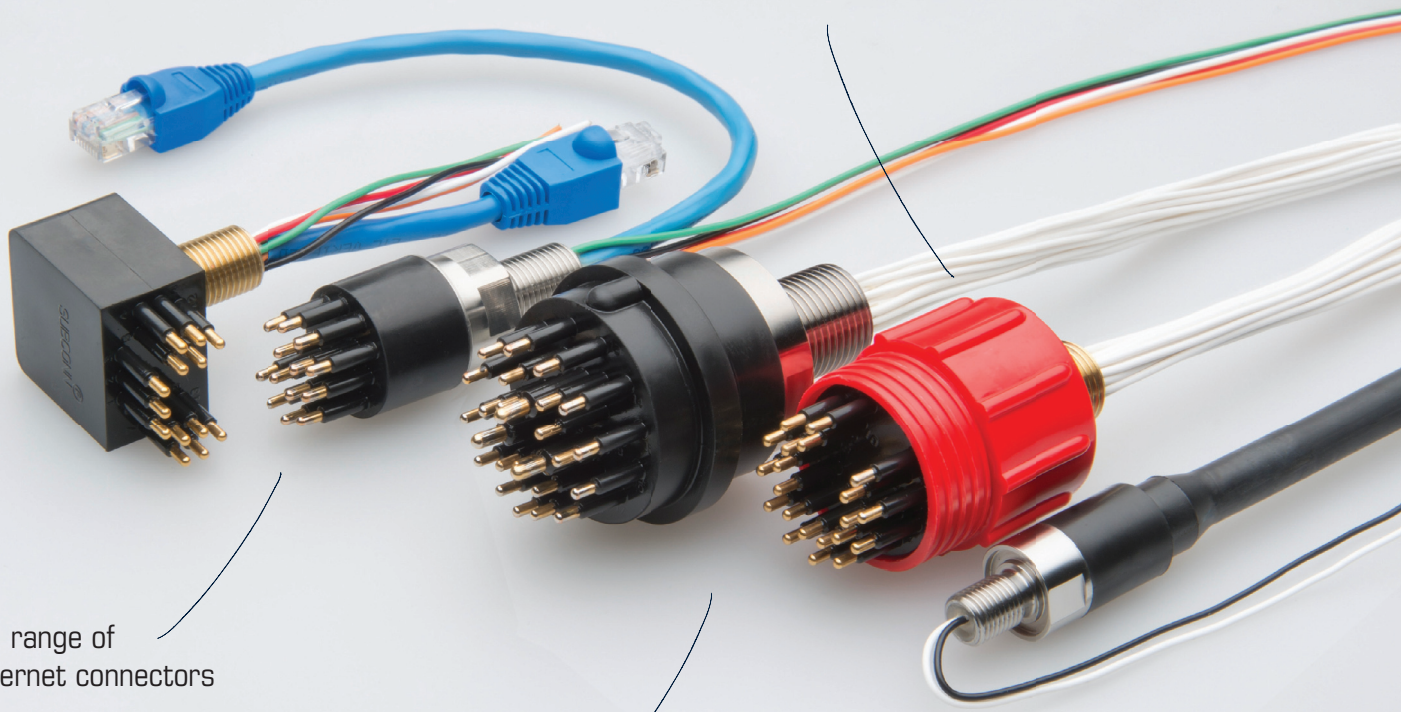

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Hydro14

Organised and hosted by the Hydrographic Society UK, Hydro14 was the latest in a series of international hydrographic symposia which date back to 1976. The three-day conference and exhibition took place at the Aberdeen Exhibition & Convention Centre (AECC) in the Bridge of Don area from 28 to 30 October 2014. Hydro14 was the 22nd event in the Hydro sequence, the 19th to take place in Europe, and the 11th in the UK. It marked the conference's return to Aberdeen, twenty years after it was first held in the Granite City, the energy capital of Europe, if not the world. The previous Hydro was held in Rotterdam in November 2012. The symposium Digital Hydrography on the Maritime Web in Southampton was in lieu of a Hydro proper in 2013.

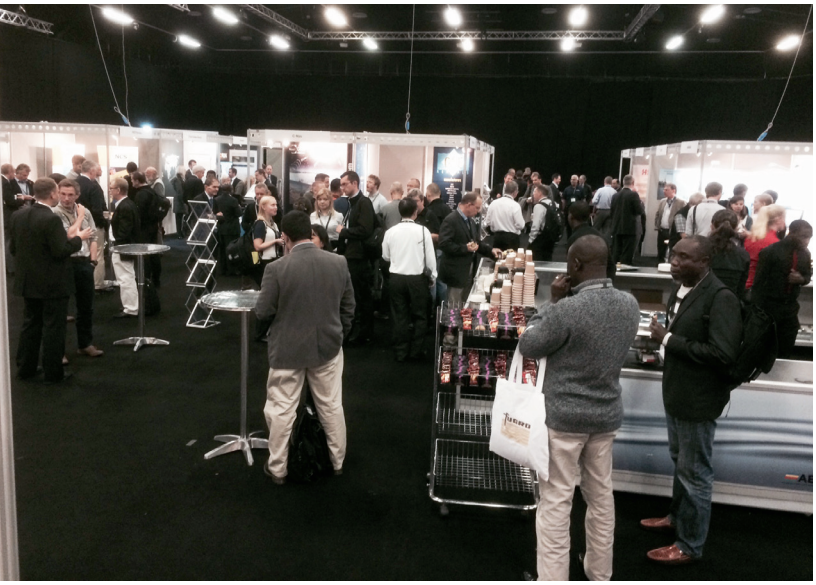
The conference programme consisted of 9 sessions with 2 keynote addresses and 25 papers. Keynote presentations were held by Monty Mountford, who put forward a philosophical insight into knowledge integration, and Don Ventura of Fugro Pelagos Inc addressing evolutionary steps in hydrographic learning and development. Session 6 on the Wednesday afternoon consisted of a well-balanced combination of workshops, demonstrations and visits. For many of us it was difficult to choose from the variety on offer. Two other sessions stood out, one was 'Our Future' in which only students appeared, and a special forum session 'The IHO & Us'. The IFHS prize for the best graduation thesis was organised for the first time. All IFHS member societies were invited to put forward their best regional MSc or BSc graduate students. This first ever award – comparable to a world championship – was presented (by the IFHS board members) to Oliver Kümpel from Germany. The other presentations in the student session were to be judged by the audience. Unfortunately, due to visa problems, the number of lectures was limited to only two. Lilian Lieber won the vote with her research on using imaging multibeam sonar to track basking sharks. I had the honour of presenting the prizes to Oliver and Lilian during the conference dinner. I hope the initiative helps to generate work of ever higher quality by students.

The AECC was a suitable location for the event, providing ample space for the exhibition with representatives of 56 hydrographic companies and organisations, and the conference for which 286 delegates had pre-booked, representing 20 countries, of which one is even land-locked (Austria).

The event showed a wonderful buzz of people networking, meeting old friends, interested in the scientific content, visiting that particular stand they hadn't been to yet, nervously preparing their presentation, or grasping their share of the very well organised catering.

The social programme was excellent (golf contest, ice breaker, Maritime Museum and conference dinner at Elphinstone Hall). Everything was meticulously prepared and well documented. The credits for this all go to Helen Atkinson. The event was sponsored by Atlas Professionals, BP, Caris, C-Nav, Esri, MMT and QPS.

With another successful Hydro behind us, we're now looking forward to the next event, Hydro15, to be held in Capetown, South Africa from 23 to 25 November 2015. ◂



▲ *Figure 1: An impression of the trade show floor during Hydro14.*

▲ *Figure 2: Preparing for the conference dinner.*

5th Extraordinary International **Hydrographic Conference**

The fifth Extraordinary International Hydrographic Conference (V EIHC) of the International Hydrographic Organization (IHO) was held in the Auditorium Rainier III, Monaco from 6 to 10 October 2014.

It was the first international conference organised by the IHB Directing Committee (Captain of the Australian Navy, Robert Ward, president, Rear Admiral Mustafa Iptes of the Turkish Navy, director and engineer , General Gilles Bessero, director of the French Navy), elected at the XVIII International Hydrographic Conference of 2012.

Dr Mathias Jonas (head of the Hydrographic Service of Germany) was elected president of the conference.

It was well attended with more than 400 persons, including the representatives of 65 IHO Member States (MS), 12 Coastal States (who may become Members), 20 international and national organisations and 28 industry exhibitors. Particularly important was the presence of the Secretary-Generals of IMO and IALA and the executive director of the Nippon Foundation.
After having thanked the Sovereign Prince of Monaco and the delegates for their presence in his opening address, president Robert Ward explained the aims of the conference. He also pointed out the need for Hydrographic Governmental Offices to become the national reference for bathymetric datasets that should lie at the heart of a Marine Spatial Data Infrastructure rather than merely producing charts.
The conference was then opened by Albert II, the Sovereign Prince of Monaco. He emphasised the need to continue the efforts for building the hydrographic capacities in the Coastal States that have to develop their Hydrographic Services. The Prince mentioned the traditional support to the IHO initiated by his great-great-grandfather Albert I who hosted the IHB in Monaco in 1921 and incited the IHO to continue its task: we have better maps of the Moon and Mars, he said, than of seabeds.
Dr Jonas convened that now is the time for us (IHO) to carefully consider our role in a digital geospatial data world and our role in Spatial Data Infrastructures, which are intended to ensure that geospatial data be the great enabler of the 21st century.
Dr Koji Sekimizu (IMO Secretary General) reiterated the cooperation between IMO and IHO, especially in the field of the electronic navigation and he emphasised the need to have navigational charts in the Arctic Ocean which can be navigated in the summer.
Finally, the executive director of the Nippon Foundation (NF) explained the support given to the project of producing a General Bathymetric Chart of the Oceans (GEBCO) initiated by the Prince Albert I of Monaco and the support given to the IHO Capacity Building effort by offering training courses within the programme called NF-IHO CHART.

The V EIHC ran smoothly on all days thanks to the presidency of Dr Jonas. Worth mentioning: Request by the Spanish speakers that the IHB continue providing documents in Spanish. It was noted that this is already made possible by cooperation among some countries.
The recruitment of an IHB employee to undertake the duties of S-100 Registry Manager should be given priority as soon as an opportunity occurs.
A proposal by France to make the work of committees and working groups consistent with the work programmes of the IHO was approved. The IHB will publish a summary

▲ *Figure 1: Opening speech by IHB president Robert Ward.*

▲ *Figure 2: HSH Prince Albert II addressing the audience of the V EIHC before declaring the Conference opened.*

▲ *Figure 3: The president of the Conference Dr Mathias Jonas in his addressing speech.*

▲ *Figure 4: The IMO Secretary-General Dr Koji Sekimizu addressing the audience of the V EIHC.*

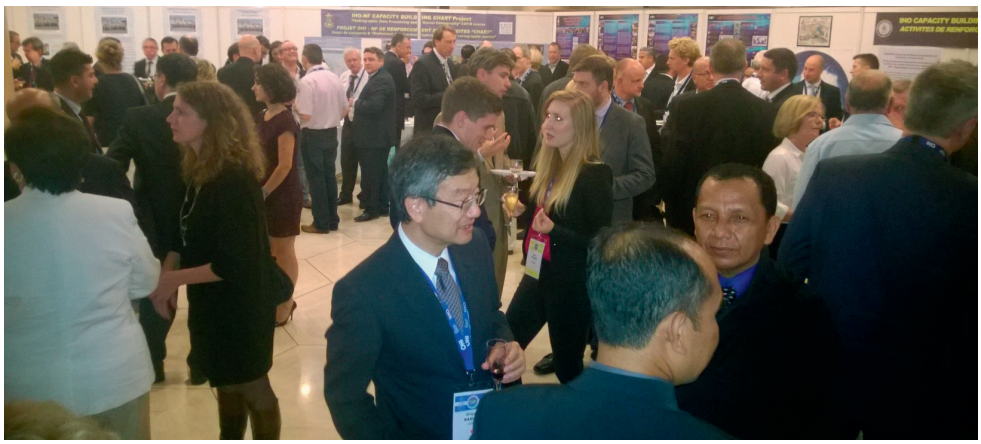
of the results twice a year in a circular letter, which will produce adjustments in the programmes' implementation.
The conference approved a proposal by the government of Monaco to award the Prince Albert I medal to individuals whose actions have contributed significantly to achieving the aims and objectives of the IHO. Those who serve or have served on the IHB will be excluded.
The increasing and very important contribution being made by industry was acknowledged.
A joint proposal by France and the USA to make use of crowdsourced bathymetry generated ample discussion and it was agreed to create a working group to prepare a new IHO publication on policy for trusted crowdsourced bathymetry with the support of the IOC (GEBCO).
Capacity Building was discussed in detail and the related strategy prepared by the Capacity Building Committee was adopted.
The implementation of the Worldwide Electronic Navigational Chart Database (WEND) Principles was also dealt with. When implemented, mariners can obtain fully updated ENCs for all shipping routes and ports across the world. Unfortunately, WEND has not yet been fully implemented thus generating a non-alignment with the decision of the IMO (in force for years) to make the use of the ENCs ECDIS compulsory. Following a proposal by France to remedy this situation, it was decided to task the Inter-Regional Coordinating Committee to assess the long-term consequences of not achieving full implementation of the WEND.

All presentations to which industry had been invited to participate can be downloaded from the IHO website. The Industry's view on e-navigation was presented by Michael Bergmann (Jeppesen), president of CIRM. He pointed out, amongst others, that HO official electronic products mainly support the SOLAS market. Other markets are starting to look for new products based on high-quality HO data such as fishing fleets, non-SOLAS commercial fleets and recreational boaters. Mr. Bergmann complained about the still persisting restrictions on obtaining official data and pointed out that industry can only build solutions if data is accessible. Fair conditions for data access are accepted (i.e. Level Playing Field). He hoped that access conditions be conceptually harmonised. Data access restrictions, he stated, or exclusive use of non-classified data is counter productive.

Before closing the conference, the Montenegro delegation, the 82nd IHO Member State, handed over the flag of the nation to the president of the IHB.

Considerations that Dr Jonas made when closing the conference were:

The IHO appears in good health with the number of Member States having grown from 58 in 1992 to 82 now, with four pending. The IHB (its Secretariat) also appears to be working well with a Directing Committee that operates in good harmony. Opening the V EIHC to private industry was shown to increase the quality of the presentations that dealt with the development of the IHO Working programmes. The rational way in which work programmes are now planned and implemented should be admired. The Capacity Building (CB), in particular, has shown great progress. The posters showing CB programme initiatives received keen interest from the Prince of Monaco and other attendees.
The cooperation with IMO, IALA and IOC appears to have become stronger over the past years thus confirming the important role of the IHO within these organisations.
In conclusion, it was a well planned and valuable conference. The receptions hosted by industry, the Government of Monaco and the IHB gave the opportunity to meet informally. ◀



▲ *Figure 5: The IHO Directing Committee reception was hosted in the exhibition area.*

emma technologies GmbH

One-stop **Solution Provider**

emma technologies GmbH, established in Kiel (Germany), is a manufacturer and supplier of marine technologies, providing customers with tailor-made marine technology. emma delivers systems on time, including training, documentation and support. emma sources specialist knowledge and components from experts who share a passion for thinking outside the box, delivering solutions that work.

In 2008, Martin Volz founded emma technologies in Kiel. With 20 years of ocean engineering experience and a large network of experts who worked with him from the start, his enterprise focuses on designing individual solutions.

The initial driver - to free customers from dealing with a wealth of companies to assemble their system - has proven to be a much-desired service many companies and government organisations relied on from the start. The ambition to provide service to small, medium and large customers alike made the transition from a start-up to a name in the business possible.

Simply ask emma – we'll see to the rest - is our mission statement for all customers looking for a one-stop provider. With ten qualified engineers we design and manufacture multi-purpose survey boats, unmanned surface and underwater vehicles, hydrographic and oceanographic electrical winches, communication systems and various inspection tools. Along with our own products and third-party components we offer fully integrated turn-key systems.

From construction and design to electrical, electronic and mechanical tasks, our staff service the systems provided and offer training and maintenance support. In 2013, the annual turnover was approx. EUR5 million.

emma's main markets are in southeast Europe and Russia. Other key areas are China and India. Many customers are research institutes and harbour authorities, but also private companies and navies. New markets for emma lie in northern Africa and South America.

Development in Deep Sea

Predicting market behaviour has never been easy but needs to be addressed. emma carefully listens to customer demands and evaluates feedback to understand individual perspectives and needs. Assessing queries systematically allows us to identify new potential targets for which to develop suitable approaches. The company sees important economic development in deep-sea research, instrumentation and communication. Technology for intercommunication systems will become more essential. A complete survey, communication, and data transfer

Figure 1: Founder and general manager Martin Volz.

Figure 2: emma seismic winch.

Figure 3: emma Winch container, example of a turn-key solution.

chain with autonomous underwater, surface and aerial vehicles and underwater monitoring stations will become a standard equipment demand in the next decades.

emma technologies concentrates on data transfer demands for sending big data via cable or wire-less over long distances. New algorithms will be applied to optimise utilisation of data. Industry-science collaborations will gain ground and new products will be developed by 'joint labs'. emma is already involved in such projects.

We still enjoy taking on new challenges and mastering them

Direct Lines of Communication

emma technologies increasingly involves experienced scientists in finding answers to current product requests. The company focuses on providing a suitable solution for the customer's budget, existing instrument environment and operator experience, with a favourable life cycle cost balance. Its lean structure enables emma to react quickly. Communication is directly with the CEO, engineers and software developers. Decisions on how to realise the customer's project can be made quickly, manufacturers are contacted, time lines for assembling components and adapting them to requirements are set, the whole solution is presented to the customer in time.

CEO Martin Volz explains the philosophy: "We experienced a steep learning curve over the past years. We have come to know many customers very well, they trusted us all the way and our mutual respect has grown from project to project. We still learn from our customers, many new ones have come on board, we still enjoy taking on new challenges and mastering them."

emma also co-finances customer projects to help overcome financing barriers or formal tender obligations. The company considers the ability to do so as a core strength.

The company is ISO certified; ISO and MIL standards are applied, as are STANAG guidelines so as to guarantee quality standards throughout the supply chain.

The company aims to acquire greater market significance as a system integrator for big turn-key solutions and innovations in the next five years.

E: volz@emma-technologies.com

More information
www.emma-technologies.com

Figure 4: emma Biosphere for observing and surveying jobs.

Canadian Hydrographic Society

Remembering Richard Michael 'Mike' Eaton

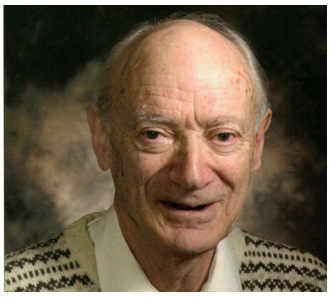
Mike Eaton passed away at his home in Cole Harbour, Nova Scotia, Canada on Thursday 9 October 2014. Richard Michael Eaton was born in England in 1928. He joined the British Royal Navy in 1945. Up to 1957, he contributed to surveys for nautical charts in home waters and around Zanzibar and Borneo.

After leaving the Navy, he joined the Canadian Hydrographic Service. He spent two years surveying in Hudson Bay followed by five years in the Arctic Ocean and Archipelago where he developed new charting methods. This led him to be elected a fellow of the Arctic Institute of North America.

He married Rosemary Gilliat, and moved to a home overlooking Cole Harbour. Rosemary passed away in 2004. Mike planted much of the property with trees but maintained a view of the harbour.

Mike joined the Bedford Institute of Oceanography (BIO) and earned a Physics degree from Dalhousie University, graduating in 1970. He started a Navigation Group at BIO and contributed to the development of the Loran-C Navaid. He was awarded the Medal of Merit from the International Loran Association in 1983 and the Canada Marine Safety Award from the Canadian Marine Advisory Council in 1988.

In the 1980s, Mike saw the Electronic Chart (EC) as a breakthrough in navigation and he supported developing, promoting and advising on the installation of these systems. One of his accomplishments was the creation of an Electronic Chart Test bed on a launch in Bedford Basin working together with CARIS and a steering group of Halifax area mariners. Doing so laid the foundation for the IHO's 'Specifications for ECDIS' (S-52), serving as the basis for the IMO's 'ECDIS Performance Standards'. From 1989 until he retired in 2004 Mike was the chairman and chief developer for the International Hydrographic Organization's working group on the design of ECDIS display.



Mike Eaton. (Archive image).

More information

Read the interview with Mike Eaton published in *Hydro International*, June 2005:
http://bit.ly/1zCU7cl

Hydrographic Society Benelux

Dredging Workshop

The Hydrographic Society Benelux, together with the dredgers organisation CEDA, assembled on 30 September at the headquarters of Van Oord in Rotterdam, the Netherlands. After a buffet dinner, the participants were able to see the simulators.

The main part of the evening consisted of presentations. Harm Wind, senior software engineer and Peter Paul Hoffman, team manager Graphic Design E&E at Van Oord started with Survey visualisation by VOSS.net software; Modelling, processes and visualisation of survey data and a seamless interface between survey and engineering. This presentation was followed by a presentation by Eric Peeters, senior surveyor and previous head of Survey at the Maasvlakte-2 project and Huibert-Jan Lekkerkerk of piLot Survey Services on Construction and Measurement Accuracies – a survey contribution to the development of the new SBRCUR handbook *Construction and Survey Accuracies. Best Practices from the Maasvlakte-2 Project*.

Figure 1: Harm Wind and Peter Paul Hoffman explaining the dynamics of survey data and visualisation techniques.

A social get-together concluded this gathering, forging links between the hydrographic and dredging professionals.

Next Events

The next HSB meeting will be held on 12 December 2014 together with NIN and GeoInfo, with the theme Satellite Navigation GPS, Glonass, BeiDou and Galileo: New Developments. Programme and registration are available on the website: www.hydrographicsocietybenelux.eu.

Looking further ahead, a joint workshop with the German DHyG is to take place on 18 and 19 February 2014 on the island of Terschelling. Additional information will be made available on the HSB website.

Figure 2: Eric Peeters and Huibert-Jan Lekkerkerk presented the contributions to a new construction and survey handbook.

DECEMBER

2nd Convention Mexican Hydrography
Manzanillo, Colima
→ 08-10 December
For more information:
E: digaohm.hidrografia@semar.gob.mx
W: http://digaohm.semar.gob. mx/ConvencionHidrografia2014/MX/codes/ConvHidro2014.htm

Ocean Tech South China Sea (SCS) Expo & Forum 2014
Guangzhou, China
→ 10-12 December
For more information:
E: daniel.shi@informa.com
W: www.maritimeshows.com/oceantech

JANUARY 2015

HYPACK 2015
San Antonio, TX, USA
→ 05-08 January
For more information:
E: sales@hypack.com
W: www.hypack.com

FEBRUARY

Euromaritime 2015
Paris, France
→ 03-05 February
For more information:
E: sabrina.jonas@euromaritime.fr
W: www.euromaritime-expos.com

The Unmanned Systems Expo (TUSExpo)
The Hague, The Netherlands
→ 04-06 February
For more information:
W: http://tusexpo.com

UI2015 - Underwater Intervention
New Orleans, LA, USA
→ 10-12 February
For more information:
W: www.underwaterintervention.com

Subsea Expo
Aberdeen, UK
→ 11-13 February
For more information:
W: www.subseaexpo.com

INC 2015 - International Navigation Conference
Manchester, UK
→ 24-26 February
For more information:
E: conference@rin.org.uk
W: www.international navigationconference.org.uk/

MARCH

IEEE/OES Eleventh
Current, Waves and Turbulence Measurement Workshop (CWTM)
St. Petersburg, FL, USA
→ 02-06 March
For more information:
W: http://cwtmc2015.org/index.cfm

US Hydro 2015
National Harbor, USA
→ 16-19 March
For more information:
W: www.thsoa.org

APRIL

Ocean Business
Southampton, UK
→ 14-16 April
For more information:
W: www.oceanbusiness.com

MAY

RIEGL Lidar 2015
Guangzhou and Hong Kong, China
→ 05-08 May
For more information:
E: riegllidar2015@riegl.com
W: www.riegllidar.com

OCEANS'15 MTS/IEEE Genova
Genoa, Italy
→ 18-21 May
For more information:
W: oceans15mtsieeegenova.org

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