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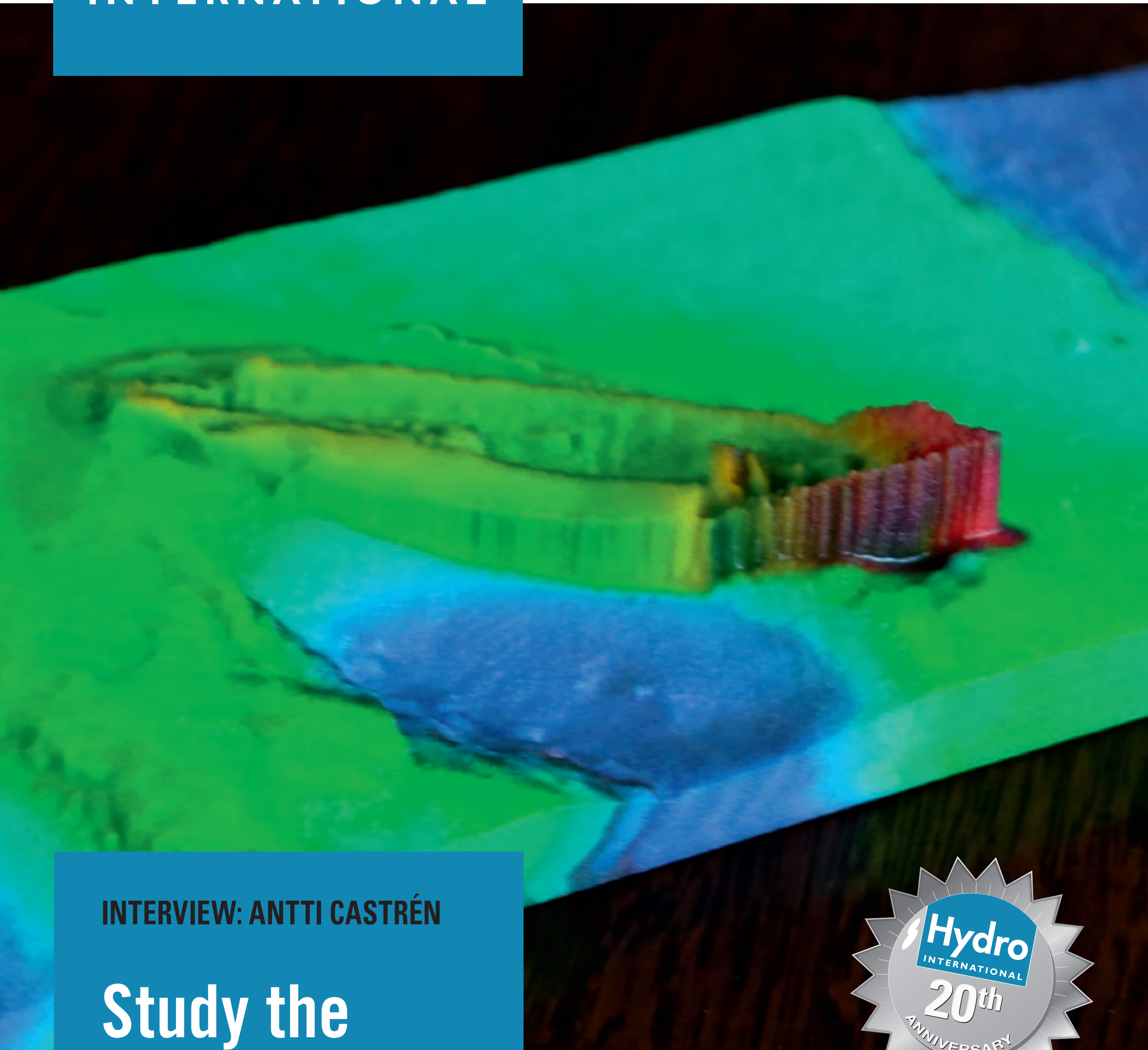


INTERVIEW: ANTTI CASTRÉN

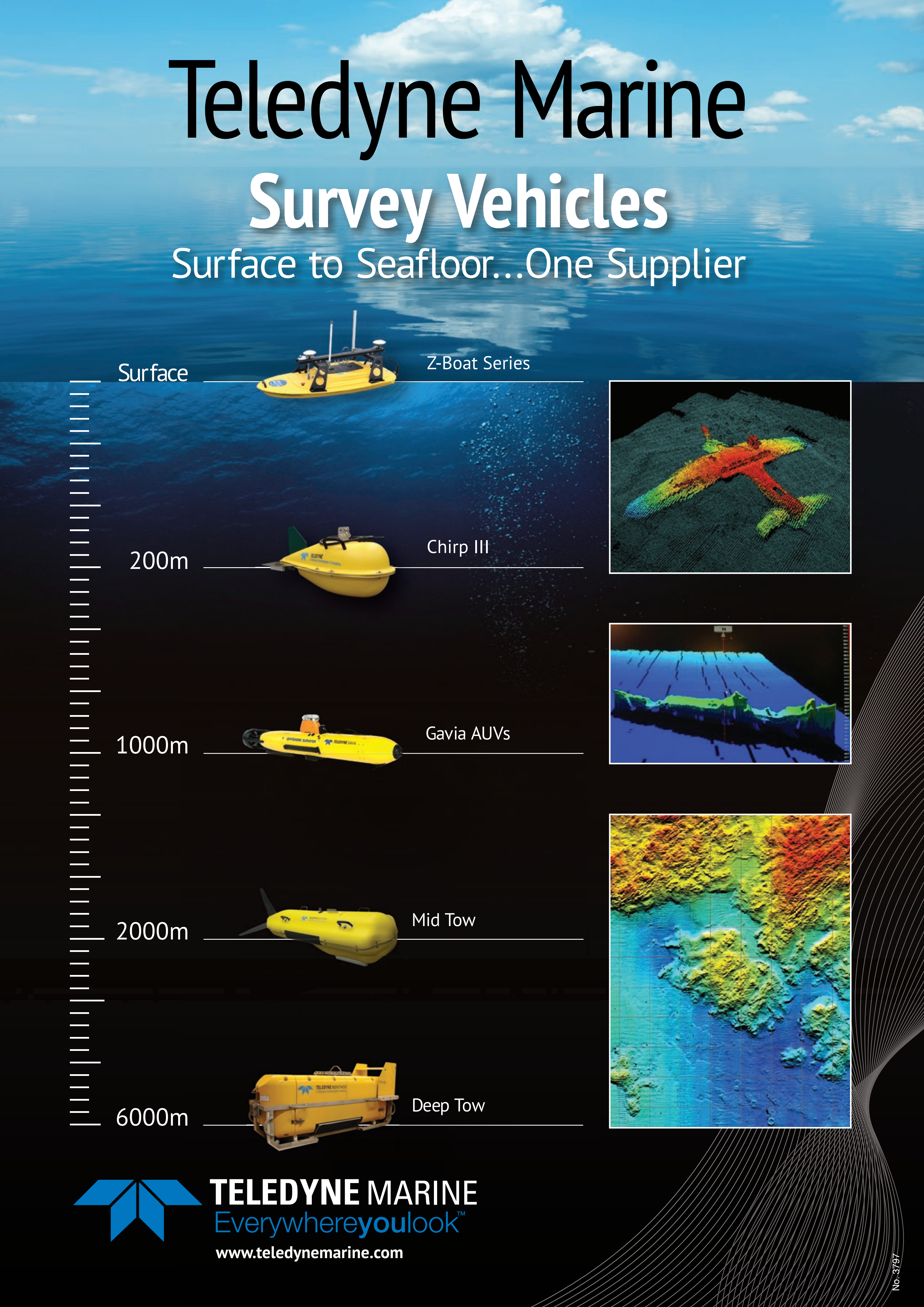
Study the Basics and Ask for Support

INSIDES OF SIDE-SCAN SONAR

Hydro INTERNATIONAL 20th ANNIVERSARY

The Art of Bathymetry

USING 3D PRINTER TECHNOLOGY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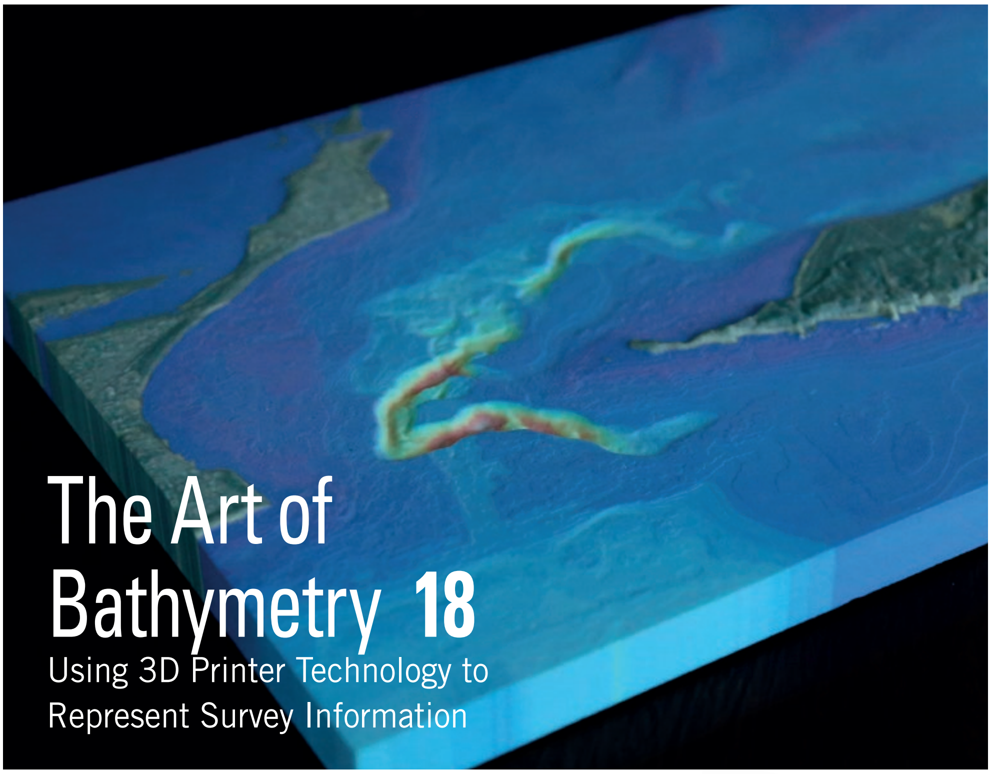
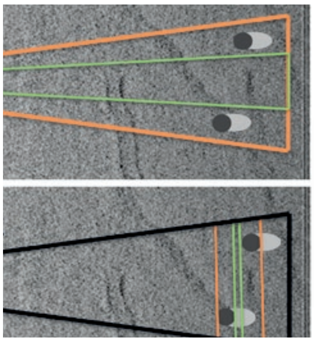


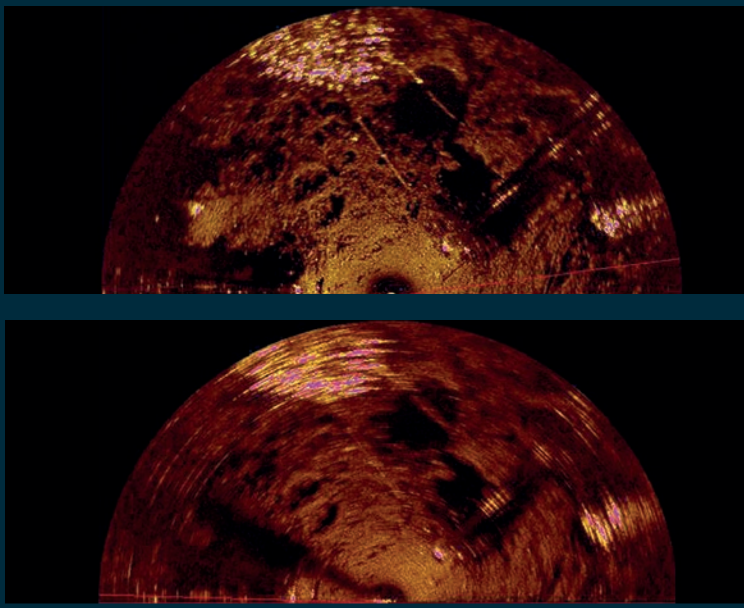


May/June 2016 Volume 20 #4

3D printing is 'hot' and the technology is gradually being introduced in the hydrographic profession. It can be used to represent data as Andrew Ternes describes on page 18.

CLARISCAN SONAR

KONGSBERG MESOTECH'S LATEST INNOVATION IN ACOUSTIC LENS TECHNOLOGY



Data comparison with the top image showing the Clariscan sonar result.

- Improved performance in deep water operations
- Significant improvement in resolution and usable operating range
- Significant reduction in side-lobes and beam width
- Variable-frequency, wide-band, composite transducer

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Buyers Guide
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PHOTOGRAPHY: ARIE BRUINSMA (WWW.ARIEBRUINSMA.NL)

Cooperation

Our world today is one of more globalisation thanks to the internet, extensive travel, international trade and disappearing borders: the global village where everybody knows everything about everybody, and vice versa if possible. There are more possibilities and opportunities for the generations of today than for those of preceding centuries. In hydrography we have been living in an international world for much longer than the last decades: the sea – working area for hydrographers in the field – always holds a promise for a world behind the horizon. In addition, the most important product that hydrographers come up with, namely nautical charts, are often cross border products. In this issue of *Hydro International* we carry an interview with Antti Castrén of the Finnish Hydrographic Office (see page 15). Mr Castrén is also chairman of the IHO Data Quality Working Group. He is an advocate of cooperation on an international level. According to Castrén, navigation has always been truly international in nature. Therefore, cooperation in the field of hydrography has to be international. The development of international standards on nautical charts and hydrographic surveys started decades ago and its importance is only increasing. Imagine if there wasn't enough cooperation at international level: the risks for shipping companies in addition to extra costs would be tremendous.

An international group of experts from academia and industry will be meeting in Monaco for the Forum for Future Ocean Floor Mapping from 15 to 17 June 2016. The group has been brought together by GEBCO and the aim of this event is to provide a ten-year vision for the organisation. The General Bathymetric Chart of the Oceans (GEBCO) is an independent, non-profit project under the joint auspices of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO that aims to map the world's seafloor from the coast to the deepest trench and make it publicly available in the most authoritative and comprehensive format. GEBCO still faces a huge task as large parts of the ocean remain just as unfamiliar and unknown to us as they were 110 years ago when GEBCO started. Despite the daunting task that still lies ahead, much has been achieved, surveyed and mapped and resulted in beautiful products that are making the life of many at sea more safe. The GEBCO initiative – back then and now in Monaco – also shows the real added value of international cooperation.

There is a trend nowadays to shy away from international cooperation, to withdraw from international bodies, to return to national grounds and even to close borders again because of fear of the unknown. I think that hydrography can serve as an example of how international cooperation can help to make a safer and better world – more specifically , safer and better seas. That is a message that should be carried out and one we should be proud of!

Durk Haarsma durk.haarsma@geomares.nl

Social Media and its Influence on Naming a Polar Research Vessel

What's in A **Name**?

Research vessels are a huge investment. They are developed to meet current standards and even move the bar as they are also a national showcase of science and technology. The United Kingdom has been developing an Arctic icebreaker research vessel that will be operating in the North and South Poles exploring depths that are often hidden by a layer of ice, even though this layer is becoming thinner. The investment by the National Environment Research Council (NERC) amounts to GBP200 million. And of course, she needs a name.

This is where things get interesting as, instead of establishing a name, the NERC has decided that the community should have a say. They created an online tool for suggestions, and subsequently allowed people to vote for their favourite name: #NameOurShip. The name was to be inspirational, highlighting the purpose of the vessel's mission as a state of the art science showcase for a country with its long-standing tradition of maritime research.

The voting lines were opened and plenty of suggestions were submitted and of course there were some original and funny ones. Iain Sayer suggested RRS *What Iceberg?*. RSS *Notthetitanic* was put forward by Pieter Pretorius. Then, suddenly, the site crashed. One name attracted attention and received a flood of votes: RSS *Boaty McBoatface* by James Hand. It ended up receiving the most votes: a total of 124,109 – way ahead of the runner-up RSS *Poppy-Mai* (Nicola Maher) that received 39,886 likes.

One would think that it's clear, there is no doubt as to which name the international public wants this state of the art flagship to have! However, the judges probably had meetings expressing their concerns on the turn the poll took. Would the popular name fit the ambition to be inspirational and match the scientific tradition? How would it look moored in a port? Would this name express the nation's pride in exploring the polar seas and oceans?

The concept of the online quest for a name was a great success. There has never before been so much enthusiasm for an ocean-going research vessel. One goal was certainly met, namely, making the public aware of NERC, oceanography and marine science in general. The wise men and women – including members of the House of Commons – questioned the outcome of the online poll and with frowned eyebrows wondered how they could acknowledge this overwhelming interest and still christen the vessel with a name that would reflect the investment made? Finally choosing the name RRS *Sir David Attenborough* is in line with tradition and the principles of the procedure. It captures the vessel's scientific mission and celebrates the contribution to natural science of the well-known broadcaster who celebrated his 90th birthday a couple of days after the naming was announced. The popular suggestion *Boaty McBoatface* will, however, still be used. It will be the name of the ROV operating from RRS *Sir David Attenborough*, which will collect data and samples from the deepest waters of the Arctic and the Antarctic.

I truly hope this experience will not discourage other organisations from opening up and asking the public for their opinions. The exposure for new developments in science and ocean science was huge, in a way different to how David Attenborough did this. It may not have been the predictable or preferred way, but it made it clear internationally what marine science developments are in progress and I'm sure this triggers interest in exploring the oceans.

RRS Sir David Attenborough, *artist impression.*

GBP15m Investment into UK Marine Autonomous Systems

The Natural Environment Research Council (NERC) has announced an investment of GBP15m in Marine Autonomous Systems (MAS) and sensors over a five-year development programme. The investment will be made through the National Oceanography Centre (NOC) to ensure the UK remains at the forefront of global marine science and technology innovation.

▸ ***http://bit.ly/1T6U1op***

Phantom FlyImager Side-scan Sonar Drone

Deep Ocean Engineering has introduced an underwater vehicle, the Deep Ocean Phantom FlyImager. This is a hybrid system, co-developed with EdgeTech, allowing the user to utilise a side-scan sonar system, the EdgeTech 4125, combined with the functionality of the powerful, versatile and rugged Phantom T5 ROV.

▸ ***http://bit.ly/1T6UqqH***

The Deep Ocean Engineering Phantom FlyIMager.

Key DP Documents Revised and Published

Two International Marine Contractors Association (IMCA) documents, often written into contracts by clients, have been fully revised and published. *Guidelines for the Design and Operation of Dynamically Positioned Vessels* (IMCA M103 Rev 2), and *Guidance on Failure Modes & Effects Analyses (FMEA)* (IMCA M166 Rev 1) are both now freely available on the IMCA website.

▸ ***http://bit.ly/1T6Von1***

Teledyne to Acquire CARIS

CARIS and its international affiliates have agreed to be acquired by a wholly owned subsidiary of Teledyne, Teledyne Digital Imaging. Terms of the transaction have not been disclosed. The closing of the transaction, which is subject to customary conditions, is anticipated to occur in the second quarter of 2016. CARIS, headquartered in Fredericton, Canada, is a developer of geospatial software designed for the hydrographic and marine community.

▸ ***http://bit.ly/1T6W3oo***

Most Shared

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

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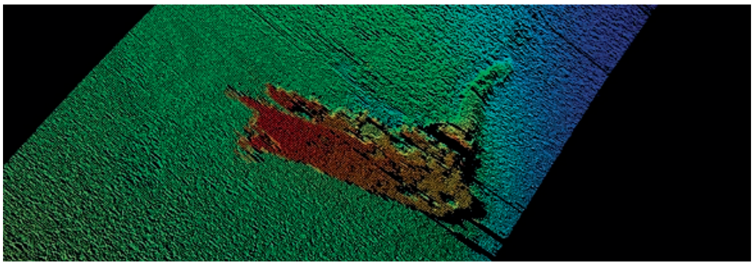
Stop Using DGPS! - http://bit.ly/1XiG4Xh
A Flooded Landscape Revealed - http://bit.ly/1XiGcWU
Surveying Japanese Inland and Coastal Waters - http://bit.ly/1XiGfSq
MH370 Search to Recover Towfish - http://bit.ly/1XiGjBM

Creature From the Deep: 'Monster' Discovery of 'Nessie'

Kongsberg Maritime Ltd, UK, uncovered the elusive Nessie in mid-April 2016. That is, the long lost model of Nessie that was used during filming of 1970's 'The Private Life of Sherlock Holmes'. The discovery was made during a survey of Loch Ness, led by Kongsberg Maritime Ltd and supported by The Loch Ness Project and VisitScotland. Operation Groundtruth is the first survey of its kind in Scotland, making use of Kongsberg Maritime Ltd's MUNIN AUV (Autonomous Underwater Vehicle). The underwater vehicle is able to map vast areas up to a depth of 1,500m at high resolution.

▸ ***http://bit.ly/1T6VJ98***



Monster of Loch Ness Recovered.

Unmanned Systems and Solutions for Argentina and Uruguay

Liquid Robotics has entered into a new channel partnership with Ingenieros Electrónicos Asociados (IEA), one of Argentina's trusted suppliers of oceanographic electronics and naval communications. This channel agreement enables IEA to sell, support, and service Liquid Robotics' Wave Gliders throughout Argentina and Uruguay.

▸ ***http://bit.ly/1T6UG9d***

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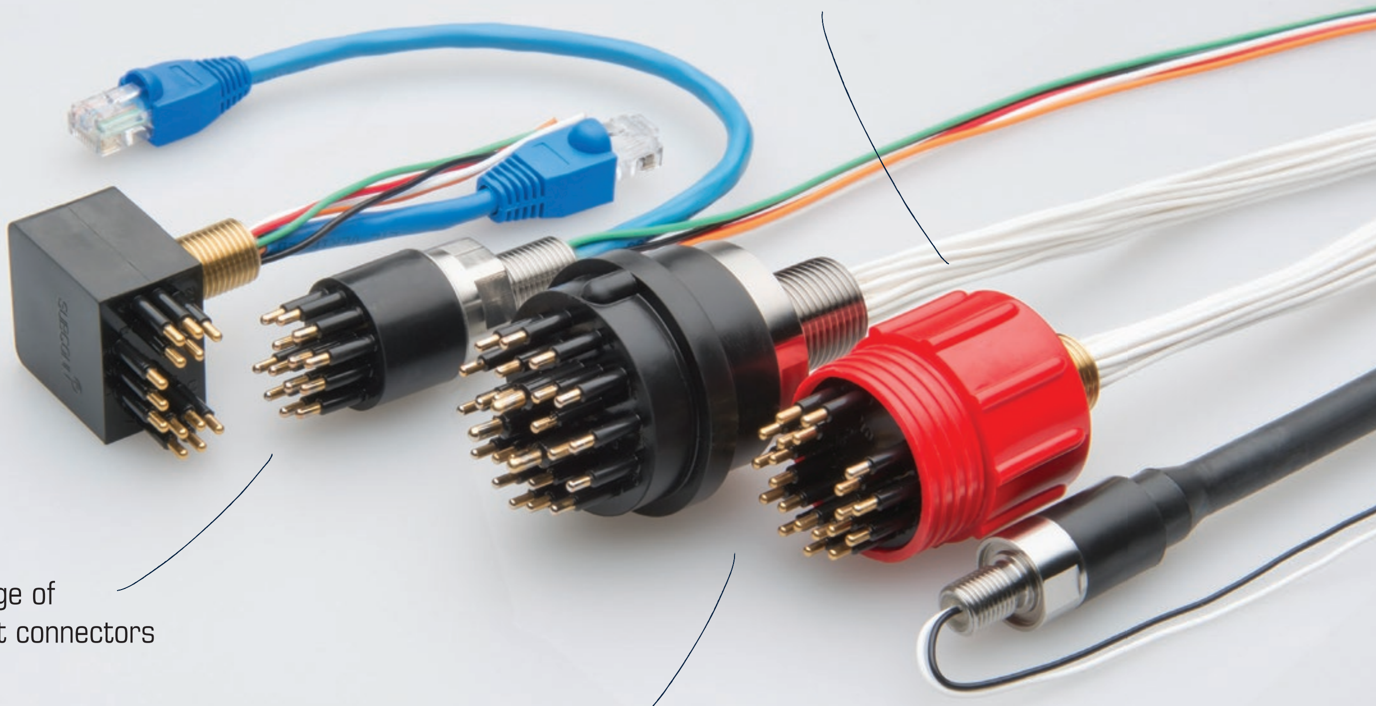

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N-Sea Awarded Renewables UXO Contract

Subsea IMR provider, N-Sea, has been awarded a contract with Galloper Offshore Wind Farm Ltd (GWFL). The contract for pre-construction unexploded ordnance (UXO) clearance works commenced in April 2016 and includes UXO risk management, target investigations and clearance on the Galloper Wind Farm, off the coast of Suffolk. Expected to run for between 3-6 months, the project sees the *Siem N-Sea* multi-support vessel utilise a WROV to investigate potential UXO targets within the array areas and export cable corridor. N-Sea's dive support vessel, *Neptunus*, will also undertake similar tasks in shallow water areas.

▸ ***http://bit.ly/1T6US8r***

White House Science Fair ROV vehicle demo.

RANGER Class Winners at White House Science Fair

The MATE ROV team AMNO & CO of Seattle, USA, was one of about 40 student groups invited to participate in the annual White House Science Fair, which was held on 13 April 2016 and attended by President Obama. During the fair, the White House became a hands-on showcase of student innovation featuring robots, prototypes and inventions that were researched, built and designed by the next generation of America's scientists and engineers. These included AMNO & CO team members Alex Miller, Nicholas Orndorff and Clara Orndorff, who set up an ROV demonstration exhibit on the White House lawn.

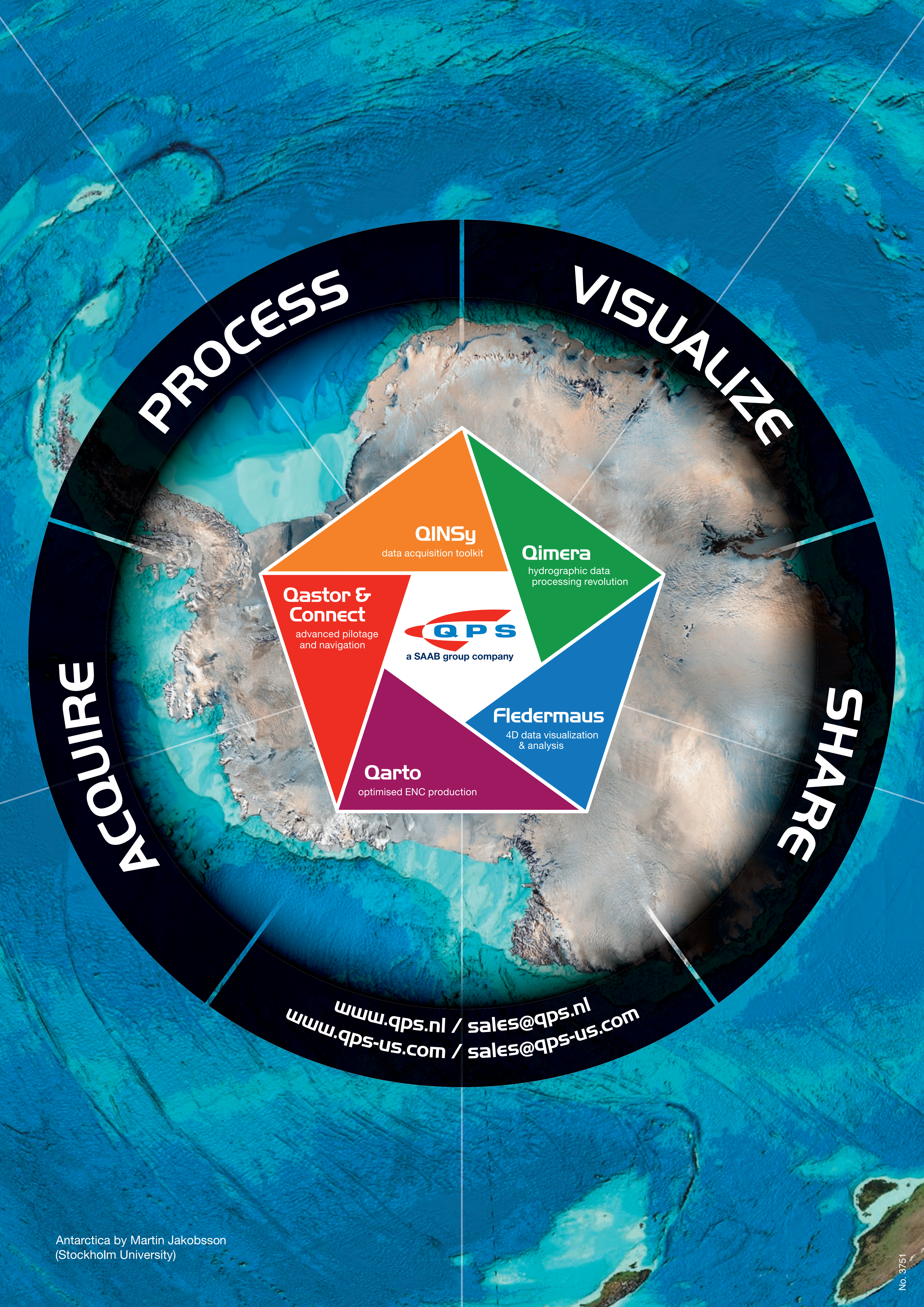
▸ ***http://bit.ly/1T6V3Rc***

Bibby Tethra *on shore for maintenance and upgrade.*

Payload Upgrade for *Bibby Tethra*

In addition to performing planned 5-year vessel maintenance, Bibby HydroMap have also upgraded a number of key systems on the 27.5m DP1 catamaran, *Bibby Tethra*. The most notable is the installation of a dual-head Kongsberg EM2040 multibeam echo sounder, providing superior sounding density along track at a reasonable vessel speed. The single transmitted, dual receiver system allows surveying of up to 10 times water depth, matching the capability of the dual head Teledyne Reson 7125 on *Bibby Athena*.

▸ ***http://bit.ly/1T6U5V4***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Antarctica by Martin Jakobsson
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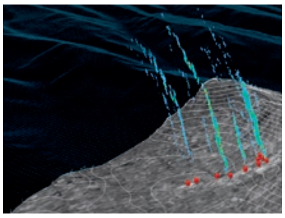
No. 3751

Characterising Offshore Sinkholes and Gas Seeps



Gas seeps. Image courtesy: Terrasond.

TerraSond has been awarded a contract to map offshore sinkholes and identify potential gas seeps. The data collected in conjunction with near-surface seismic provides information for the impact assessment of sinkholes on the water supply of South Florida, USA. An AUV will support the seafloor mapping and seep detection.

▸ ***http://bit.ly/1T6VzhX***

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Nortek: Signature55	http://bit.ly/Signature55
Aanderaa Data Instruments: In-line DCS	http://bit.ly/In-line
SonTek: Argonaut-XR	http://bit.ly/Argonaut-XR

Investment in Antarctic Icebreaker to Boost Australian Science

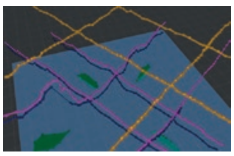
Geoscience Australia welcomes the Government's investment in a new Antarctic icebreaker for Australia. Equipped with world-class technology, the new icebreaker will enhance Australia's seafloor mapping capability — enabling Geoscience Australia and its partners to develop a greater understanding of Antarctic geoscience.

▸ ***http://bit.ly/1T6UoPB***

3D Interpretation for Survey Engine

Coda Octopus has announced the release of its Geophysical Survey Post-processing software Survey Engine Version 5.2. This latest release adds significant new features to their Seismic+ software, including the ability to view Seismic data interpretation in a 3D fence diagram, the ability to export processed data in XTF format from any of the Survey Engine modules (Mosaic+, Sidescan+, Seismic+ and Pipeline+) and general fixes.

▸ ***http://bit.ly/1T6Uy9M***

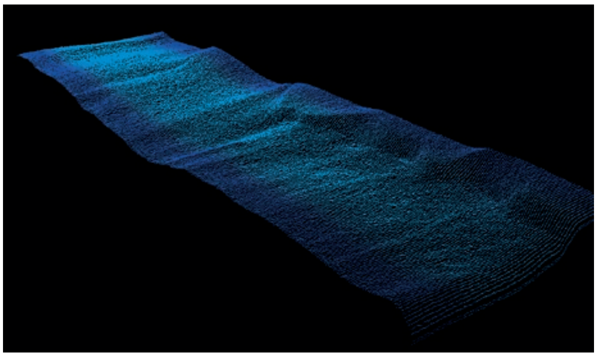


Coda Octopus Survey Engine data example.

Underwater Laser Scanners for Sediment Transport and Scour Analysis

Genex Systems, USA, has trialled and purchased a 2G Robotics' ULS-100 underwater laser scanner. The objective of the trials was to test the capabilities of the ULS-100 for bridge scour experiments and sediment transport analysis. The trials were conducted at the TFHRC J. Sterling Jones Hydraulics Research Laboratory. 2G Robotics' ULS line of underwater laser systems produce true-scale high-resolution 3D models of underwater structures and environments in real-time. These 3D models function as dimensional records and serve as reliable references from which to obtain accurate measurements and information.

▸ ***http://bit.ly/1T6VfQs***



ULS-100 underwater laser scan point cloud.

Sediment Sensor LISST-200X

Geometius, the Netherlands, has introduced the LISST-200X of Sequoia Scientific as the successor to the LISST-100X. The device is a small-size submersible particle size analyser with integrated depth and fast response temperature sensors to improve profiling data. This model measures particle sizes from 1 to 500 microns at up to 600 metres water depth.

▸ ***http://bit.ly/1T6W9MU***

The Sequoya Scientific LISST-100X.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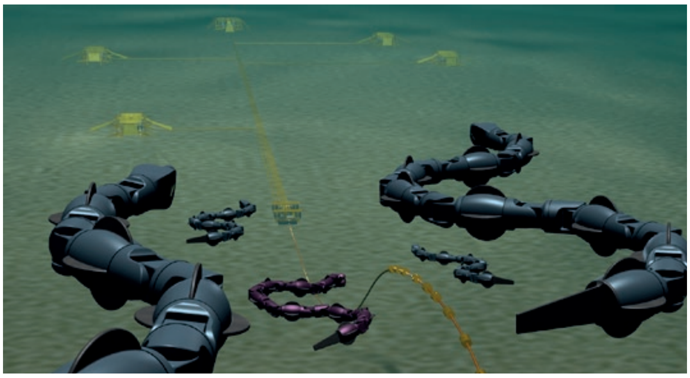

Eelume snake-like underwater robots swimming down to subsea templates.

Snake-like Swimming Robots

Kongsberg Maritime and Statoil have signed an agreement with Eelume, a Norwegian University of Science and Technology (NTNU) spin-off company, to accelerate new technology that will significantly reduce costs related to subsea inspection, maintenance and repair operations. NTNU and Sintef have been conducting research on snake robotics for more than 10 years. Eelume is now developing a disruptive solution for underwater inspection and maintenance in the form of a swimming robot.

▸ ***http://bit.ly/1T6VvPu***

Barents Sea Metocean and Ice Network Project

Fugro has begun a three-year period of metocean and ice data acquisition as part of the Barents Sea Metocean and Ice Network Project. The data will help operators to better understand relevant operational uncertainties and risk factors in the region known as 'The Far North'.

▸ ***http://bit.ly/1T4G7UT***

Fugro Wavescan buoys.

Hydro International Interviews Antti Castrén

Study the **Basics** and **Ask** for Support

Hydrographic mapping is all about collecting and processing data that leads to products such as nautical charts and other products contributing to safe navigation, a better environment and secure constructions offshore. The quality of the data is important and this is where the IHO steps in and facilitates standards for acquisition and presentation. *Hydro International* interviews Antti Castrén, project manager at the Finnish Transport Agency and chairman of the IHO Data Quality Working Group (DQWG). He touches international aspects of data quality in general, opportunities available for many Hydrographic Offices as well as hydrographic challenges in the Baltic.

Why did you join the specialized IHO Data Quality Working Group (DQWG)?

The concept of data quality has been one of my interests for a long time. I wrote my Master's thesis on spatial data analysis and during the research it became clear how important it is to have good data or at least to know how good (or bad) the data in question is. That knowledge also has to be transferred to the end user of the information in an understandable and logical way.

Back in 2010, Mr Juha Korhonen, an active IHO committee member from Finland, suggested that DQWG could be a good place to learn more and share knowledge. I was immediately hooked to international standardisation work after the first meeting that I attended.

Could you briefly tell our readers what the most important issues are regarding hydrographic data quality?

The single most important part of information on a nautical chart is bathymetry, because it shows the invisible form of nature's features to the mariner. Therefore, the quality of bathymetric data has to be the highlighted topic in hydrographic data quality.

It can be divided into three aspects, namely positional uncertainties, completeness and temporal variation. All of these have an impact on how the mariner should use the bathymetric data in various situations on different kinds of vessels with varying cargo. Mathematically speaking the decision making is always about risk calculation, and in navigation the mariner should weigh the above-mentioned three aspects on a case-to-case basis. In order to do that he must have the quality information readily available to him.

Many other types of hydrographic data features can have their own quality indicators as well. Tide predictions at given locations, ranges of radio transmissions and sectors of lights, to mention a few.

The crucial point in all forms of data quality is the communication to the end user. The portrayal of quality is not an easy task; it is even harder than portrayal of features themselves. For example, in current ECDIS systems the symbology for the most common quality indicator, the category of zone confidence (CATZOC), is somewhat misunderstood or not used at all in some cases.

The Finnish Transport Agency (FTA) focuses on R&D and innovations. Can you name examples that apply to hydrography and nautical charting?

Currently digitalisation is a big thing in Finland. FTA has been very active in enabling new services with its data. Hydrography plays a key role in the Intelligent Fairways project portfolio in which high-resolution bathymetry, observed and expected water level information, virtual aids to navigation and many other types of information are combined as services to provide the best available knowledge in digital form to commercial shipping. The goal is to promote safety and to make the most economical and most environmentally friendly cargo logistics possible.

Another example is our participation in research projects in which mathematical models of shoals and rocks in the Northern Baltic were studied and developed. Those models can be used to design better hull structures for oil tankers, for instance. A link to the published article on the study can be found at the end of this text.

FTA is very open-minded when it comes to pilot projects of developed technology. Recently FTA contracted Lidar surveys in waters where the performance of Lidar has previously been questionable. The results from the analysis are still pending, but soon we will know if the technology is mature enough to give us reliable data from difficult to survey shallow waters.

What aspects of hydrographic surveying are specific to Finland or more broadly, the Baltic?

The Baltic is generally a rather shallow body of water with long stretches of indented coastlines and scattered archipelagos of tens of thousands of islets, rocks and shoals. It means that coastal surveys are especially challenging projects.

In these hazardous, and in some places crowded waters, oil tankers and passenger ferries crisscross each other. Luckily there is very good international cooperation between coastal states around the Baltic. This is not limited to just HOs, there is also an intergovernmental Baltic Marine Environment Protection Commission (HELCOM), which has also given resurvey tasks and resources to ensure safe navigation in the Baltic. An example of cooperation is the Baltic Sea Bathymetry Database (link below).

In Finland, a unique aspect is our inland waters. There are dozens of lakes, large and small, with commercial shipping. The lakes are mostly very shallow with narrow sounds and countless rocks. Most of the hydrographic surveys have to be done with small or shallow draught vessels. Civilian authorities in Finland have outsourced all hydrographic surveys since 2010, which has had quite an effect on our work at the Finnish HO.

The quality of bathymetric data has to be the highlighted topic in hydrographic data quality

What is the importance of international cooperation regarding hydrographic data?

Navigation as a trade has always been truly international in nature. Therefore, cooperation in the field of hydrography has to be international. The development of international standards on nautical charts and hydrographic surveys started decades ago, and its importance has grown tremendously along ENCs.

One could argue that international cooperation in nautical charting is essential to world trade. If the charts or data from each coastal state lacks enough standardisation and harmonisation there would be tremendous extra costs and risks for shipping companies.

I think this is the best place to express my gratitude to all of my international colleagues at DQWG, the IHO and its Member States and in industry. The achievements are the results of work around the world for a common cause.

How can organisations improve their data quality? Are there quick wins?

The first step is to start collecting and managing metadata in addition to the data itself. The next step is to define the quality standards for the data in a structured way. The quick win is already there once the organisation knows more about its own key data, and it is therefore capable of giving the data user much more value.

The rest is just taking quality into account in all data-related processes from data gathering to information sharing. Eventually a quality management system helps the organisation to understand its level and to continuously improve it.

How will mariners, in particular, benefit from the efforts of the DQWG?

Our end user, the mariner, benefits from our work through hydrographic products. A good use case is passage planning with nautical

chart products. Through our work and the work of various hydrographic offices the mariner has the information available to make decisions: Which one is better for my passage, deeper water with more depth uncertainty or shallower water with less uncertainty?
An expert data user could even have tools to show him where to deviate from the planned course in a sudden emergency. The information could, for example, be just a traffic light coloured layer on a chart display showing the calculated risk of grounding.

How does the DQWG help HOs?
The DQWG and the IHO can, in general, provide standards, guidelines and other forms of guidance and support for HOs. Any Member State can raise a topic for us to study and to give our recommendations on. We do actively look around and try to determine what new opportunities and challenges evolving technology brings. Hopefully we will be able to share our knowledge and best practices with HOs on topics like crowdsourced bathymetry or satellite derived bathymetry.
We are currently finishing our work on bathymetric data quality within the S-101 standard. There are still some other data quality issues within S-101, but we also look ahead to a few other evolving S-10x standards.

What advice would you give to organisations looking to start implementing a data quality policy?
The best way to start is to learn from others. Study the basics and ask for support. As mentioned earlier, a quality management system is not a bad idea, but I guess it's good to start with just defining and formalising data processes. That helps the organisation to locate the risks within the system.
Almost all organisations have legacy data and they also need quality information, otherwise its huge potential is partially lost. This aspect is not always realised early enough.

Is crowdsourced bathymetry a potentially good addition to collect more data? What would be needed to improve the data quality?
Crowdsourcing will be part of mainstream bathymetric data collection in the near future. There are schemes already in progress to gather and centrally manage the data. The impact of crowdsourcing to nautical charting and hydrographic offices is hard to foretell. The data could at least be used in planning of professional surveys, if not applied to charts. There are obvious challenges regarding quality assessment of individual data sources, but geostatistical analysis can potentially help determine the quality attributes of big data. The more metadata recorded about the data collection, the easier it is to evaluate in terms of quality.

Crowdsourcing will be part of mainstream bathymetric data collection in the near future

How do you feel environmental data and habitat mapping should be included in hydrographic charting?
The intended use of a nautical chart is navigation, and the information on the chart should serve that purpose. When environmental data and habitat mapping information gives added value to navigation and at the same time does not clutter the chart product, I could personally see that type of information being included on the chart. Added value has to be understood broadly including safety and sustainability aspects.

Should hydrographic data acquired by commercial companies be made available for public use?
Personally I think that if there is public funding involved the data should be available for public benefit. How that is achieved is another matter. It could mean completely free, open access survey file database or depth models or just contours.
If the survey is completely funded by private companies, they probably should have the possibility to decide how much and when they want to share the data. But if they find previously uncharted shoals or other hazards to navigation they should have an obligation to inform the local authority to share the knowledge with mariners. Of course, national legislation and international treaties could require a certain level of data sharing in the future. ◂

More information
Baltic Sea Bathymetry Database: http://data.bshc.pro/
Sormunen et al. Estimating sea bottom shapes for grounding damage calculations. *Marine Structures*, 45 (January 2016), pp 86-109 http://www.sciencedirect.com/science/article/pii/S0951833915000775

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Using 3D Printer Technology to Represent Survey Information

The **Art** of **Bathymetry**

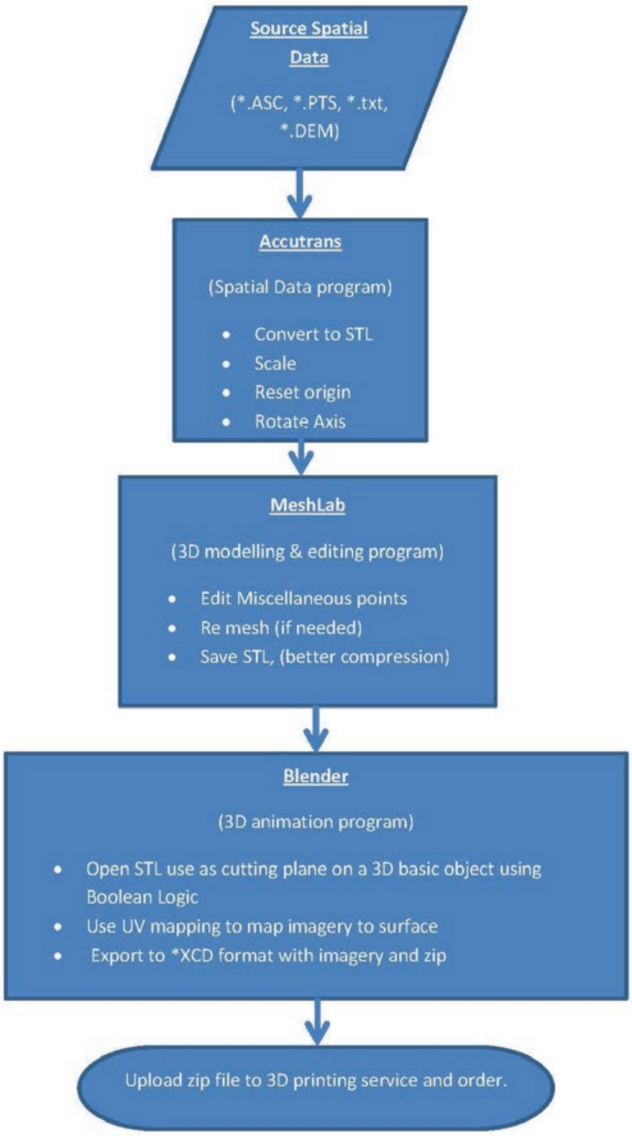
Great advancements have been made in three dimensional printing over the last few years and have made an impressionable impact across a variety of industries. 3D printings' versatility can be incorporated into any industry that has some form of three dimensional design. An exciting application is to model point clouds from survey techniques to create three dimensional scaled models for visualisation and communication. In this article we will explore a new medium using 3D printed technology.

Over the last few years great advancements have been made to all forms of surveying in three dimensional data capture, whether it be multibeam echo sounders in hydrography, laser scanning in terrestrial and bathymetric surveying or photogrammetry through aerial surveying. Three dimensional data capture techniques produce vast amounts of information in the form of a point cloud from which useful information can be extracted. The information is usually translated to a two dimensional format in the form of a computer aided drawing (CAD), a Chart, a two and half dimensional digital format for visualisation or analysis to derive secondary products such as terrain metrics.

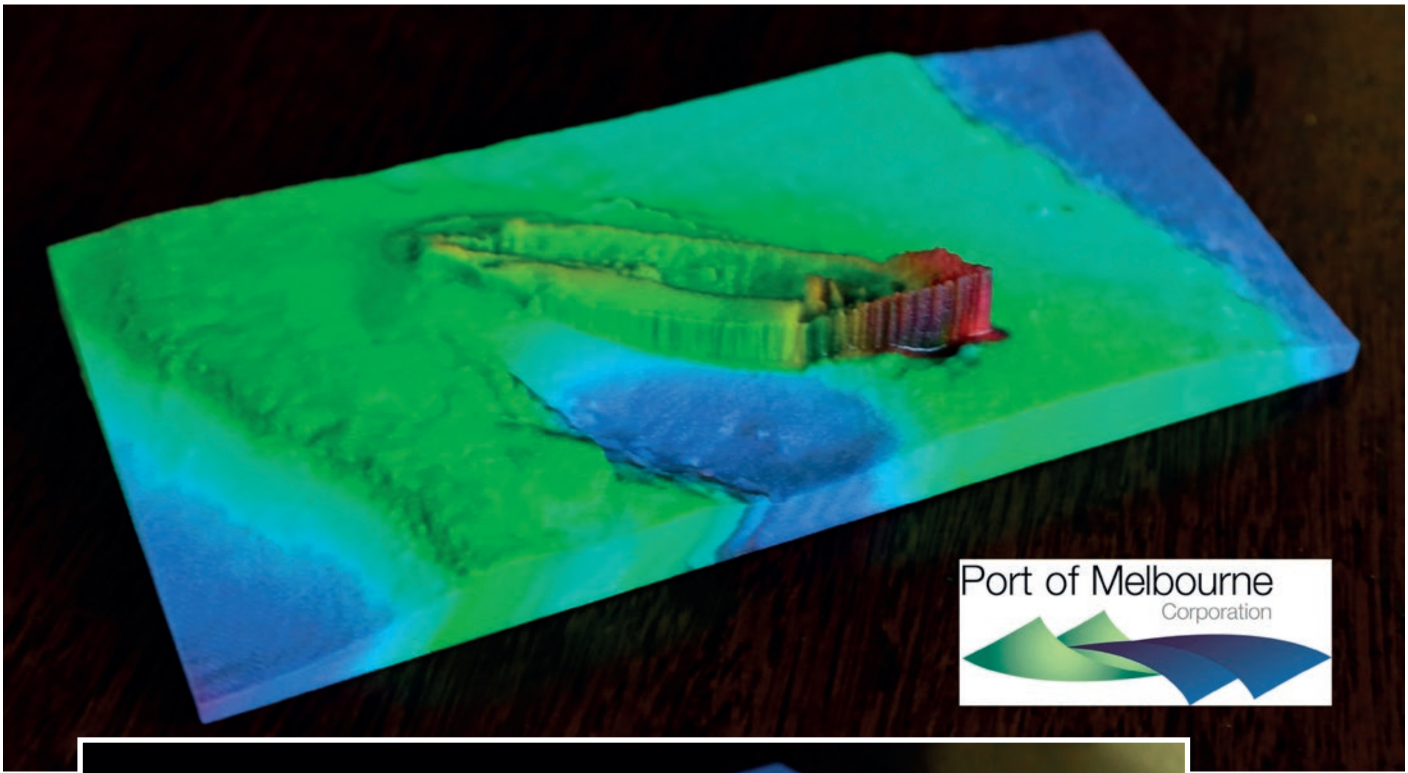
To convey three dimensional form cartographer's employ varying techniques including colour gradients, contours, relief or sun shading to show variations in depth and the use of oblique angles instead of the typical orthogonal view. These techniques are not usually misinterpreted by spatial

Varied elevations being represented by different colours

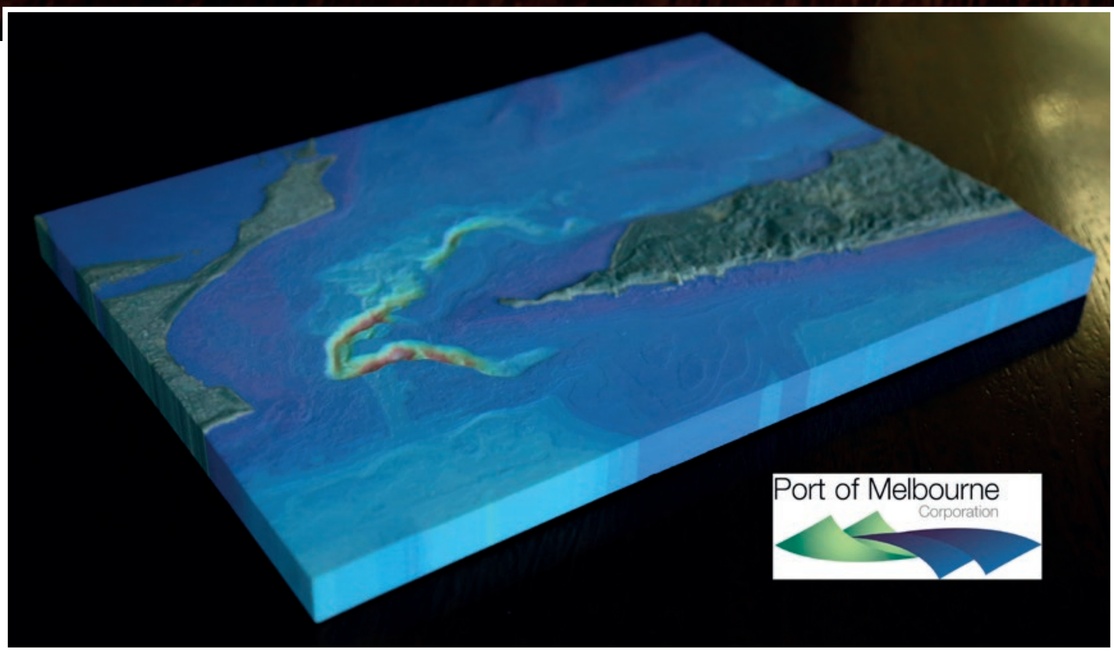
professionals but can be difficult for non-spatial individuals to comprehend. Colour gradients have varied elevations being represented by different colours, which can be difficult to interpret, particularly if a



▲ *Figure 1: Data to 3D model work flow.*



▲ *Figure 2: Eliza Ramsden shipwreck from Multibeam.*



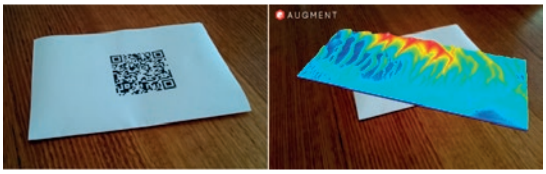
◀ *Figure 3: Port Phillip Entrance, multibeam, Lidar and aerial photos.*

legend has not been provided. Shaded relief or shadowing can provide extra information to the viewer but has been known to cause optical illusions where depressions can appear as rises and vice versa. The use of oblique angles from a set perspective can show form, but may hide points of interest depending on the complexity of the information. The oblique angles are usually static images or displayed as a digital model that can be navigated on a computer, with a screen that is still two dimensional.

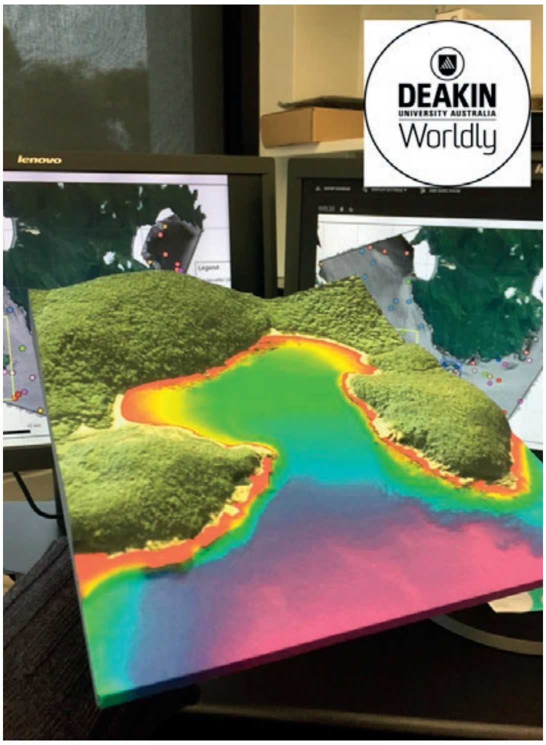
Utilising multiple open source software that was designed for GIS, point cloud manipulation and 3D modelling & animation; datasets captured by the Port of Melbourne Corporation and Deakin University were designed into 3D models and then sent to a 3D printing service provider.

An initial learning phase was required to learn the various software programs required to manipulate the point cloud data into a 3D model suitable for print. The point cloud is either turned into a surface as a Digital Terrain Model (DTM) or a Triangular Irregular Network (TIN). A surface cannot be printed alone, as it is too thin to be considered printable by a 3D printer, so a 3D polygon or a cube is used to enclose the surface. The surface is then used as an intersecting plane using Boolean logic, anything above the surface is deleted while everything below is kept, resulting in an impression of the surface on the top of the 3D polygon, while leaving a flat base for ease of display.

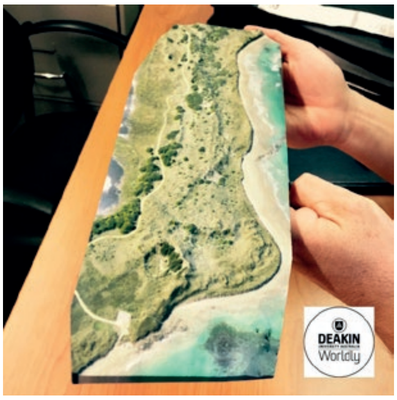
Orthometric photos or images of the



▲ *Figure 4: A simple QR code, and the same code viewed with the Augment app showing a bathymetric sandwave field.*



▲ *Figure 6: Refuge Cove, Wilsons Promontory, Multibeam, Lidar, Satellite elevation and imagery*



▲ *Figure 5: Killarney Beach between Warrnambool and Port Fairy.*

modelled area can be used to apply textures to the model by wrapping around it and providing contextual information (Figure 1).

Important points to consider in creating a dataset to be 3D printed

Choose the right 3D printer for your intended purpose and associated material, which can vary from plastics to colour coded layered sand with epoxy. The models you see in this article have all been printed using the Shapeways 3D print service utilising 'Full colour sandstone'. The material was chosen for its durability and its ability to display multiple colours. When creating a model to be 3D printed, the printer's capabilities needs to be taken into consideration. For instance, the maximum printer dimensions for the models shown here were 250 by 380 by 200 millimetres with a resolution of 0.4 of a millimetre, but can vary by printer type and material used. This influences the scaling of the model to the printer dimensions and the level of detail you will be able to see in the final print. Resampling the dataset to a coarser resolution may be necessary if trying to model a large area. The model of Eliza Ramsden was at a resolution of 0.25m with an area of 5,577m^2 (Figure 2) whilst the Port Phillip heads were modelled at 20m with an area of 93km^2 (Figure 3). In our case, models had to conform to printer provider accepted file formats and restricted to file sizes of 64MB or 1 Million polygons. The 1 million polygon restriction can be problematic when trying to balance terrain size and detail. For coloured prints we found the best formats to use to be VRML and X3D, whilst for non-colour prints STL, OBJ and Collada were appropriate but likely to vary according to format requirements by print services.

Another apparent problem had to do with applying the colour. The colour was captured using an orthogonal geotiff of the survey areas with some of the models having the land terrain masked with aerial photography instead of a bathymetric colour scale. Using an open source 3D animation program the geotiffs were draped over the elevation models using a process called UV wrapping. There was not a single program that can handle all the processes to create a 3D print and was therefore a combination of several programs, all with different intended purposes. Hopefully in the future survey software can adopt some of the formats and functionality to future versions of their software for standard 3D print formats.

The methodology has been applied to multibeam bathymetry, UAV captured Photogrammetry and DSM models, terrestrial and bathymetric Lidar data and satellite derived elevation data either as a single dataset or combination of multiple datasets to form a comprehensive model. The final models are not limited to being 3D printed and have been used in other 3D virtual viewing mediums and show promise as communication tools for the rapidly developing field of augmented reality. The Augment website and mobile phone application allow the models to be uploaded and shared. A tracker can be a customised information sheet that can include the company logo or a simple Quick Response (QR) code. When the application is run on your device it reads the QR code or the unique layout and overlays the 3D model over the camera view, allowing the user to explore the model (Figure 4).

Dr Ierodiaconou from Deakin University, School of Life and Environmental Sciences, Warrnambool, Victoria has been exploring the value of 3D printed models as communication tools (Figures 5 and 6). He found an immediate benefit with 3D printable products for communication of environmental values. This includes the application of low cost unmanned aerial vehicles for defining endangered hooded plover habitats on nesting beaches funded by Birds Australia. The first model (Figure 5) shows storm cut of the beach face whilst providing quantitative spectral and elevation data tied to a datum using RTK GPS (Real Time Kinematic GPS). Time series analysis allows the investigation of management interventions such as the spraying of the invasive Marram grass that has been linked

He found an immediate benefit with 3D printable products for communication of environmental values

to stabilisation of mobile sand dunes and steepening of the beach face. The second model (Figure 6) shows the integration of terrestrial imagery and elevation combined with high-resolution seafloor mapping data (10cm resolution) of Refuge Cove, a popular anchorage on the east coast of the most southern tip of mainland Australia. The project was funded by Parks Victoria and multibeam sonar data was captured using a Kongsberg 2040C fitted to Deakin's 9.2m research vessel *Yolla*. "We find it an amazing way to communicate the value of marine ecosystems, showing a direct link to the terrestrial realm with continuation of headlands and drowned coast and river features from lower sea level stands".

The Port of Melbourne Corporation use the models at sponsored events and festivals, and the response from the public is invariably positive. "It's always more effective to show, rather than tell, especially when discussing something that cannot ordinarily be seen, and the 3D models are very effective engagement tools in this regard. These 3D models can provide an immediate sense of spatial relief with minimal interpretation or miscommunication through cartographic techniques especially when communicating with non-spatial professionals" Ierodiaconou said. Whilst three dimensional fly throughs will always have a place in science communication (see an example from Wilsons Promontory Marine National Park) new communication mediums provide exciting opportunities whether in hard print where you can feel the texture of the spatial domain or augmented reality for immersive experiences with unlimited field of views. ◀

More information
Wilsons Promontory Marine National Park https://www.youtube.com/watch?v=3unzhtQUufY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DORIS Software

New Tool to **Process Sound Velocity Profiles**

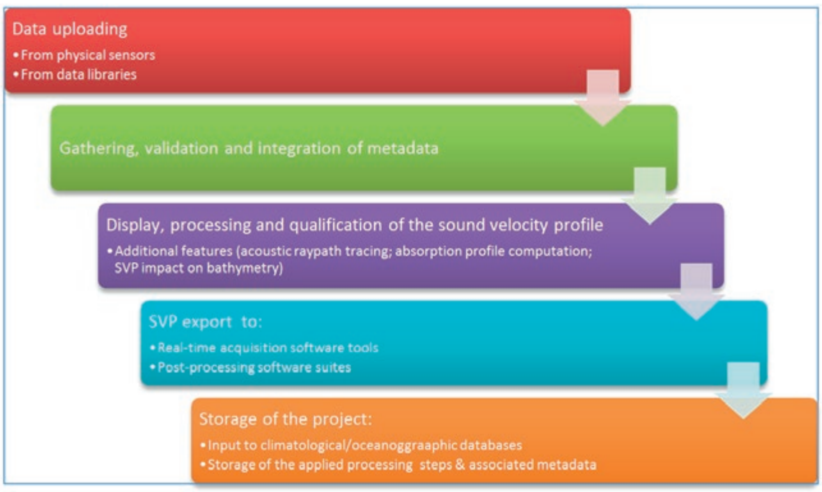
Hydrographic and geosciences surveys, using acoustic devices, need to use accurate water sound velocity profiles. Because the acoustic path depends on the sound velocity profile (SVP), the use of the most accurate SVP is one of the keys to conducting effective surveys (with multibeams, for instance). To date, the existing software available does not answer to both the needs of efficiency and simplicity (sometimes not so easy to operate, sometimes not so accurate). DORIS provides a handy freeware to post-process SVP for the hydrographic communities.

DORIS has embedded useful functionalities to provide an accurate post-process sound velocity profile, mainly, but not only, dedicated for multibeam echo sounders (MBES). Besides, some additional options are available, such as acoustic ray path simulation. This tool, designed by hydrographic operators, reads velocity files in the various formats of probe manufacturers and exports post-processed data in formats readable by commonly used acquisition and post-processing packages.

Formats readable by commonly used acquisition and post-processing packages

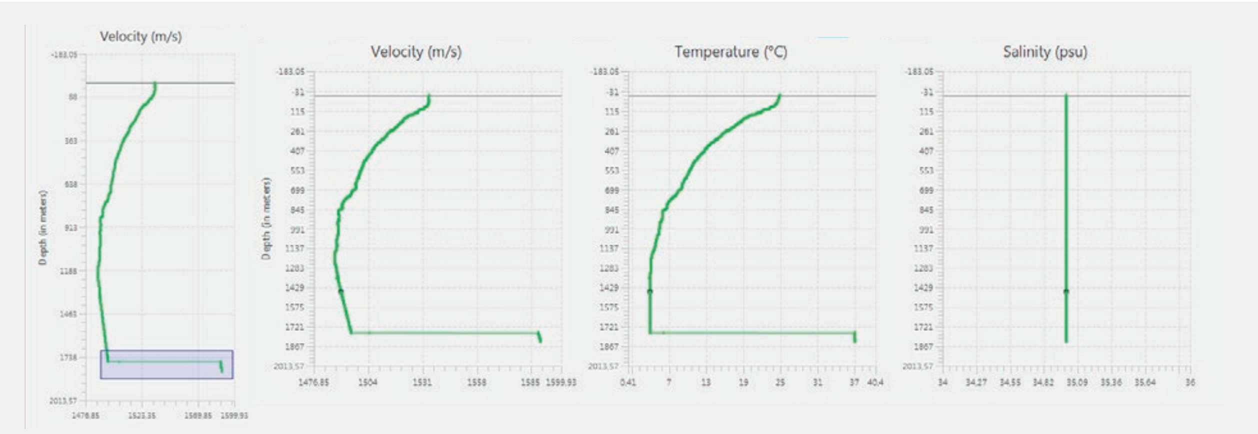
DORIS' Origin

For the last ten years, most on-board operators have used their manufacturers software or scientific programs to post-process raw profiles acquired by probes. This was the case at Ifremer, which used the CARAIBES Software suite at sea and, it was also the case at SHOM, which used Timica-Célérité, a dedicated software application. In 2014, after a benchmark of existing tools available on the market, such as the SVP Editor by UNH and tools provided by MBES manufacturers, both Ifremer and SHOM decided to collaborate on the development and implementation of a new software, in accordance with their operational and scientific needs. The goal was to deploy this tool by the end of 2015 in the joint hydrographic and oceanographic fleet, and perhaps on other vessels. The newly developed software, called 'DORIS', is based on these joint specifications, and is mainly focused on the accurate hydrographic requirements and validated formal methods for both institutes.



▲ *Figure 1: General structure of the DORIS workflow.*

DORIS provides a complete suite of functionalities to load, display, modify and export the sound velocity collected by the main existing marine velocity probes, such as Sippican, NKE, Turo or Valeport. In addition, DORIS can use statistical databases such as Levitus, for instance, to extend the SVP collected by devices to the maximum depth and can export the results to a multibeam acquisition workstation on board (SIS for Kongsberg or PDS2000 for Reson). Drivers are included in the software allowing for easy



▲ *Figure 2: Selection of raw data to be invalidated, by selection either on the graphical plot or inside the table.*

data exchange with main acquisition and post-processing software packages such as CARIS, SIS, RESON/PDS2000, HYPACK and others.

The Technical Environment

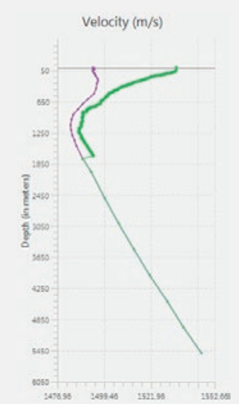
DORIS' setup is available for several common platforms such as Windows_x64 7, 8 and 10, Linux_x64 Debian, Fedora, Ubuntu and also for MacOSX.

The 'look & feel' of DORIS' application is a user-friendly design embedded application using the recent programming technologies of Java8 and JavaFx for the main interfaces.

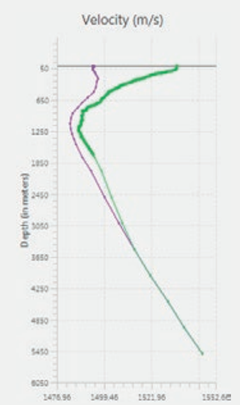
The Existing Functionalities

The main functionalities of the DORIS workflow have been written by SHOM, with feedback from their surveyors. DORIS workflow is end-user dedicated, and divided into five major steps. Firstly, the data collected by probes is imported. The following formats are supported: Sippican (.edf), Valeport (.000 or .vpd), Turo (.nc), Seabird (.txt) and NKE (.cnv). Then, the raw SVP and its metadata are displayed and checked. Metadata can be modified if necessary, i.e. location of the probe launch, identification of the vessel, weather information, etc. Additional parameters can be set up to a CORIOLIS' workflow compliancy. CORIOLIS is a project which contributes to the French operational oceanography programme for in-situ observations; it is a part of the international ARGO programme. The graphic interface allows the user to validate or invalidate values interactively on their graphs or tables; both are interconnected.

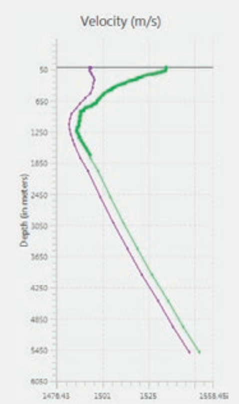
Subsequently, if the SVP does not reach the bottom, a 'climatological' profile from one of the existing databases can be loaded and the SVP can then be extended using these 'climatological' values. So far, two different databases can be read by DORIS interface: Levitus and ISAS (In Situ Analysis System). These databases provide statistical profiles that have been built previously by lab operators from Data centers reference. For instance, the ISAS database is managed by the Pole Ocean in France: this is an optimal interpolation tool developed to synthesise the global dataset of Argo profiles. Of course, the 'climatological' profile loaded is the one closest to the SVP. The interface shows the distance between the probe location and the profile loaded from the statistical database. Salinity, temperature and depth from statistical databases are used to compute the sound velocity, applying the algorithm



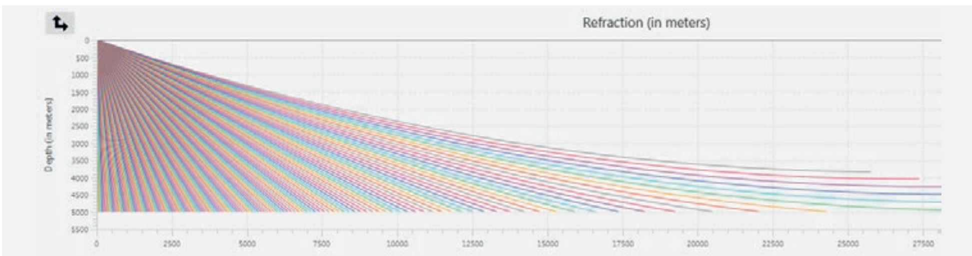
▲ *Figure 3: Direct - The lower end of the recorded SVP (green) is connected to the statistical profile (purple).*



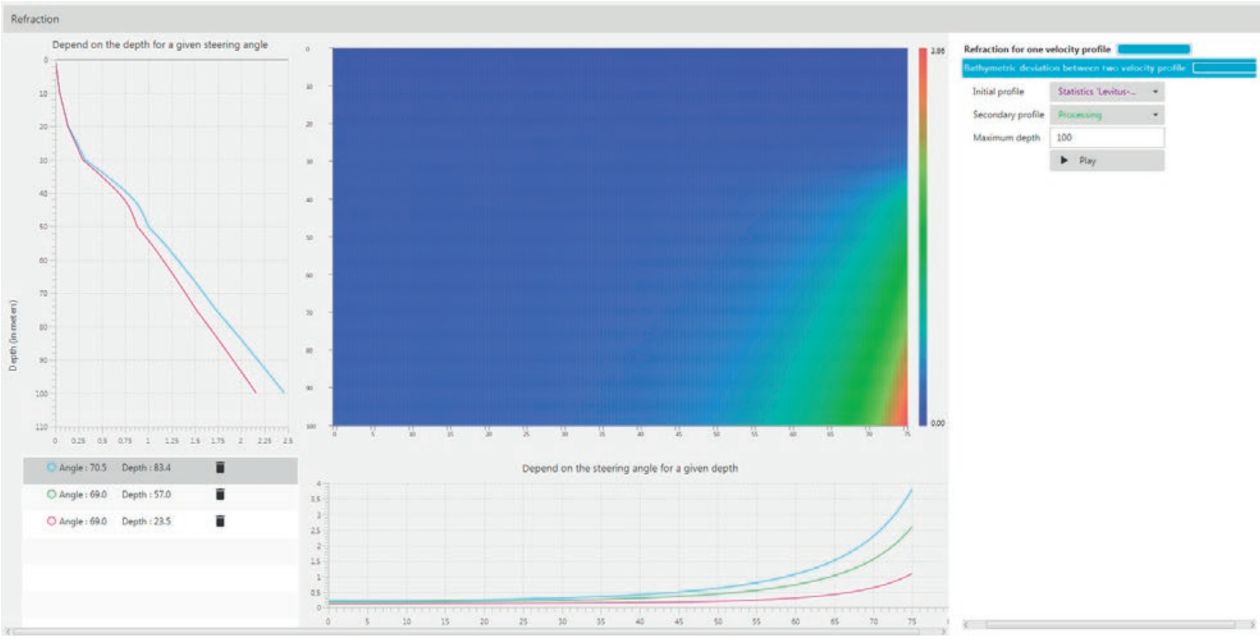
▲ *Figure 4 : Progressive - the recorded SVP (green) is progressively linked to the statistical profile (purple).*



▲ *Figure 5: Shifted - The statistical profile (purple) is shifted for continuity with the recorded SVP (green).*



▲ *Figure 6: Example of acoustic ray-path plot as a function of depth and transmit angle.*



▲ *Figure 7: Display of the impact of a SVP change upon computed bathymetry vs depth and lateral range.*

◀ *Figure 8: Display of a seawater absorption profile computed from salinity and temperature data.*

previously set in the configuration window (Chen&Millero, DelGrosso or TOES-10). To extend the SVP correctly, using the climatological profile, three methods are available (direct, progressive or shifted). As a following step, extension of a maximum depth of the existing profile takes place, by increasing the depth assuming constant temperature and salinity (using dedicated algorithm). Typically this is done to extend up to 12,000 metres for the Kongsberg configurations.

Provides a complete suite of functionalities to load, display, modify and export the sound velocity

Once the SVP has been correctly extended to the right depth, the next step, due to the limitation of some echo sounders, is to reduce the number of SVP points. For this task, the Douglas-Peucker algorithm is used. A reduction factor is available to reach the expected number of points, according to the echo sounder capabilities.

Finally, the last task consists of exporting or sending the SVP to the acoustic system under a defined datagram. Major export formats are available under the options list: CARIS (svp), Hypack (vel), SIS (asvp), … The latter functionality uses a UDP datagram format which is compliant with the Kongsberg and Reson systems.

Advanced Functionalities

Two functionalities can be used by advanced users. The first one plots the acoustic ray path

computed from a selected sound velocity profile. The user can select either a loaded raw profile or a climatological one (from Levitus, for instance).
The second function provides a graph that computed the vertical deviation between two profiles for different depth and angles. Hence, impact of a new SVP can be estimated, and could help surveyors.

Qualification and Validation Aspects

The first version of DORIS has been available since June 2015 and tests are now being conducted at sea by SHOM on board RV *Beautemps-Beaupré* and by GENAVIR (Operator of the IRD and Ifremer oceanographic fleets) on board RV *Pourquoi pas?*. These are the first sea trials being undertaken by the hydrographic community. Other French operators are interested in DORIS, including IPEV (Institut Paul Emile Victor) after the refit of their vessel RV *Marion Dufresne*.
DORIS can be downloaded from the website (doris-svp.org), including documentation and a wiki. DORIS is available under a freeware licence contract.

Conclusion

DORIS is the result of close collaboration between SHOM and Ifremer and is a win-win situation, based on the need to renew old tools, with efficient and simple software, designed by end-users. DORIS has now been finalised with all the required features. The preliminary versions of the tool have been installed on different survey vessels for operational sea tests, and the first feedback from operators and scientists for various organisations is extremely positive and full deployment on both fleets, SHOM and Ifremer (almost 10 vessels), is expected in early 2016. Other hydrographic offices or research institutes are very welcome to use and evaluate this new software. Upgrades have already been identified for the next versions.

Acknowledgements

GENAVIR team (H. Bisquay & Al.) for pictures, qualification steps and feedback; UMR LPO team (F. Gaillard & Al.) for ISAS13 support; IDM Coriolis team (J. Detoc & Al.) for interface of Coriolis workflow; SHOM Hydrology team (M. Le Menn & al.) for sound velocity computation algorithms and IFREMER NSE/AS team (X. Lurton & Al.) for qualification steps and specification of the refraction toolsets.

Carrier	LAPEROUSE {LP010}
Date	18/11/2016
Time	18:11:16
Sequence	475
Serial number	01154928
Salinity (+N/-S)	42 ,47º N
Longitude (-E/-W)	7,6492º
Depth (m)	2700.0
Athmospheric pression (Hpa)	1015.2
Surface water temperature (ºC)	16.9
Dry air temperature (ºC)	19.5
Humid air temperature (ºC)	13.8
TNMG	1330
Wind { direction (º) / strength (Knt) }	000/05
Swell { direction (º) / period (s) }	999/99
Sensor type	T-7
Sample number	--
Comment	Sea Tests

Table 1: List of the metadata available in DORIS.

More Information

Chen&Millero. Algorithms for computation of fundamental properties of seawater –1983 - Unesco technical papers in *Marine Science* 44

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Douglas-Peucker. David Douglas & Thomas Peucker, "Algorithms for the reduction of the number of points required to represent a digitized line or its caricature", *The Canadian Cartographer* 10(2), 112–122 (1973) doi:10.3138/FM57-6770-U75U-7727

Levitus: Boyer, T.P., J. I. Antonov, O. K. Baranova, C. Coleman, H. E. Garcia, A. Grodsky, D. R. Johnson, R. A. Locarnini, A. V. Mishonov, T.D. O'Brien, C.R. Paver, J.R. Reagan, D. Seidov, I. V. Smolyar, and M. M. Zweng, 2013: *World Ocean Database 2013*, NOAA Atlas NESDIS 72, S. Levitus, Ed., A. Mishonov, Technical Ed.; Silver Spring, MD, 209 pp

ISAS: Gaillard Fabienne (2012). ISAS-Tool Version 6 : Method and configuration. http://dx.doi.org/10.13155/22583

Jean-Marc Sinquin is project manager for marine onboard software manufacturer Oceanographic Research Institute and has over 20 years' experience in IT marine solutions. He holds an engineering and IT computer science degree obtained from H.E.I. (Lille, France) in 1992 and a Masters degree in Software Development from ENSTB in 1994. He is currently working on many projects (CARAIBES, GLOBE,…) such as DORIS. For the last eight years he has been closely involved in the Eurofleets1, Geoseas and EMODnet projects.
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Christophe Vrignaud is an Engineer for the French Ministry of Defence. His main interest is related to underwater acoustics. Early in his career he focused on fishery acoustics. He has been in charge of the French Hydrographic and Oceanographic Service onboard acoustic systems since 2007. For SHOM, he mainly focuses on MBES qualifications and training of surveyors. He has been conducting multiple acceptance and qualification surveys at sea.
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Grégory Mathieu has served as a hydrographer for French hydrographic service (SHOM) since 2006. In 2010, he was promoted to administrator of the computer systems on board SHOM fleet vessels. Having participated in many campaigns at sea as a hydrographer, he now brings his expertise to various projects related to the collection and processing of data. DORIS is one of these projects and is carried out in collaboration with IFREMER.
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A Fruitful Cooperation Between SHOM and OCEA Shipyard

Two **Oceanographic Research** Vessels for Indonesian Navy

In December 2013, SHOM and OCEA French shipyard decided to enter into a technical cooperation for the construction of two modern 60m aluminum hydrographic/Oceanographic research Survey Vessels (OSVs) ordered by the Indonesian Navy, after an international competition won by OCEA. This article describes the close partnership that led to the successful delivery in 2015 of the *Rigel* (11 March) and *Spica* (17 October) sister ships of the OSV190 range of OCEA (Figure 1), fitted with hydrographic launches and undersea exploration vehicles (AUV & ROV). These two OSVs are dedicated to the exploration of Indonesian waters for a better knowledge of hydrography, oceanography, halieutic resources, and a better Exclusive Economic Zone supervisory.

The technical agreement between SHOM and OCEA involved assisting the shipyard in the integration of the scientific measurement systems onboard the vessels: general design review and preliminary studies, scientific equipment integration follow-up, support to harbour and sea acceptance tests, scientific and technical crew training.

The originality of the cooperation is that the partnership continues after the delivery of the ships on site, so that both partners support the Indonesian Navy for the operation and maintenance of the ships in its waters by the means of technical assistance that includes training, maintenance and guarantee follow-up, coaching for preparation and realisation of sea hydrographic trials and missions, and support in implementing an efficient technical organisational structure for the scientific activities.

▲ *Figure 1: The ship* Rigel *(with the courtesy of OCEA).*

Close Cooperation

SHOM expertise was useful at different steps of the construction, giving adequate advice when necessary to all actors in the shipyard. This cooperation took place at different stages:

- consolidation of the predefined scientific equipment in order to validate their relevance and consistence with the vessel missions;
- validation of integration of acoustic sensors in the gondola, and the mechanical, electrical and electronic integration of all scientific equipment in the different rooms and decks of the ships.

The specific gondola (Figure 2), sheltering acoustic transducers (single and multibeam echo sounders, sub bottom profiler, vessel mounted current profiler) under the hull, has a perfect design to limit hydrodynamic turbulence due to water flow, and prevents sensor vibration and acoustical noise of the ship platform.

One capital stage in integration was the elaboration of the vessel metrology file, the purpose of which is to keep records of the different sensors bearing mounting tolerances extracted from suppliers' data sheets, and to keep records of the different sensor's offsets measured from a reference location in the vessel. This is the only way to guarantee a proper collected data geolocation when conducting hydrographic surveys.

This integration was formalised by interface documents describing equipment location and their interconnections.

Relationships between SHOM representatives, OCEA and subcontractors have been always fine and constructive, despite the usual constraints of such a project (technical, financial, deadlines).

Large Panel of Scientific Equipment

SHOM hydrographers have extensive expertise in both hydrography and oceanography. Throughout this project the representatives

▲ *Figure 2 : The gondola sheltering echo sounders.*

▲ *Figure 4 : 'Hugin' autonomous underwater vehicle / AUV (with the courtesy of OCEA).*

◀ *Figure 3 : The hydrographic launch for shallow surveys.*

have used their extensive expertise in the field of hydro-oceanographic equipment to deal with the whole spectra of onboard equipment and to manage the computer networks dedicated to data acquisition and post-processing.

Let us emphasise that *Rigel* and *Spica* vessels designed and built by OCEA are broadly equipped with the most up-to-date, accurate and high-performance sensors, to cover all required missions in coastal, deep-sea and offshore waters.
Integration files and schemes are clear, easy to use and useful for operation and maintenance phases. All plug connections are defined to improve system understanding for end users, and to facilitate later modularity and autonomy.

The ships have multi-purpose capacities, and offer a wide variety and complementary data acquisition systems:

- precise positioning (GNSS) and attitude (inertial unit),
- hydrography and seabed mapping from shallow to deep water (7000m) with echo sounders and side-scan sonar,
- oceanography with subsurface water currents, temperature and salinity and sound velocity profiles from surface to bottom,
- Sedimentology and geophysics with sub-bottom profiler, sediment sampler and gravity corer, magnetic field tow fish,
- weather station,
- underwater exploration (ROV & AUV).

Operational Missions

The principal and complete missions that can be addressed by these modern ships are:

- nearshore hydrographic operations with the hydrographic launch (Figure 3), up to 500m depth: high density and accuracy sensors, low draft, good visibility from the bridge;
- offshore and deepwater operations with the OSV vessel: high density and accuracy and complementary sensors, with sea endurance and platform stabilisation system;
  - o for hydrography: seabed mapping up to 7,000m;
  - o for oceanography: temperature and salinity profiles from surface to bottom to map water masses circulation, sea water current measurements from surface to 300m;
- ROV operation for underwater exploration and deepwater intervention (1000m): high precision acoustic positioning, seafloor mapping with OSV multibeam echo sounders, VM-ADCP current measurements on the water column;
- AUV operation: as for and in addition to ROV capacities, the 'Hugin' autonomous underwater vehicle (Figure 4) is the perfect tool for very high accuracy exploration up to 1000m depth, with its own sensors (multibeam echo sounder, ADCP & CTD);
- Geophysics operations: both OSV and launch are equipped with sub-bottom profiler and towed magnetometer to investigate the first metres of the seabed sediments and the magnetic field.

Scientific Layout

The configuration of the scientific, technical and life rooms and decks has been specifically drawn by OCEA for the efficiency and comfort of the crew: centralisation of scientific rooms (operating, processing, wet and dry laboratories) on the same deck, spacious and efficient deck for the handling of winches and hydrographic launch.
The operating room offers a wide and modular screens wall of data acquisition work stations, configurable by operators according to needs and missions (Figure 6). Networking is easy and collaborative work is efficient thanks to modern computer networks and geographical proximity between hydrographers and ship crew (navigation, boatswains…).

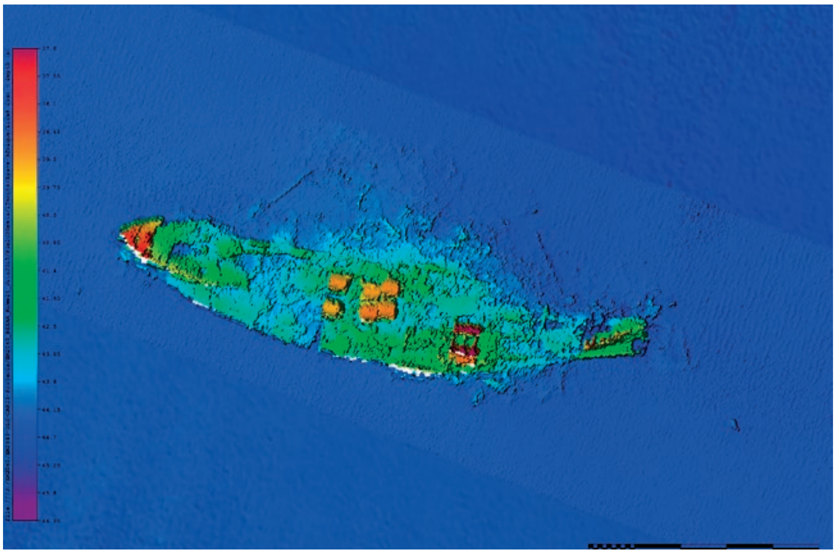

Figure 6 : Technical assistance in the operating room in Indonesia.

Figure 5 : First results: wreck mapping.

High Measurement Performances

The sea trials proved the excellent stability of the OSV platform and showed greatly reduced noise, a convenient situation for good working conditions and a chance to collect good quality data.

The SAT (sea acceptance tests) have been defined by SHOM with OCEA to comply to suppliers' specifications and to qualify the data collected by each measurement system. Nonetheless, it is the efficient overall integration and interfacing of the systems onboard the platform that has been qualified. The SAT was performed, where possible, on the SHOM reference qualification areas off the coast of Les Sables d'Olonne or Brest (France), especially suitable for the evaluation of the acoustic echo sounders data quality (Figure 5).

A remarkable behaviour of the ship and excellent quality of scientific echo sounders data, even in rough seas (state of sea 3 to 4), or at high speed (13 to 14 knots), were shown, whereas typical speed to perform hydrographic surveys is under 8 to 10 knots. Thanks to this excellent integration, Indonesian hydrographers will be able to fulfill IHO standards required for hydrographic surveys (S-44), to achieve all orders of survey (2, 1b, 1a, special).

Technical Assistance

Addressing the Indonesian Navy requirement, both OCEA and SHOM representatives bring support to the Indonesian Navy in its waters through technical assistance during the 18 months following the delivery. This assistance began in May 2015 with the arrival of the *Rigel* in Jakarta (Figure 6).

This assistance is essential as these vessels and their subsystems (launch, ROV, AUV) are very complex and accurate, and need an excellent overall and detailed understanding. The following tasks will be dealt with by the technical crew and hydrographers: refresher training, maintenance and guarantee follow-up, coaching for preparation and realisation of sea hydrographic trials and missions, support in implementing an efficient technical organisational structure for the scientific activities.

Conclusion

Understanding and managing such specialised and innovative vessels is not simple and easy because of the variety of scientific sensors, gigabytes of data transiting, the number of cables, plugs and computers to tame, and the multiplicity of configurations to master. It is a long process to become comfortable with all the sensors and the vessel's capacities.

OCEA and SHOM offer a real partnership and support, from ship design to the first operational missions at sea, and the issue is the real and complete autonomy of Indonesian hydrographers on all the sensors and vessel equipment, including planning, configuration, data acquisition, data processing, troubleshooting and maintenance. This collaboration resulted in a high added value vessel with operational capabilities allowing collection of data and samples of excellent quality at higher speed than usual scientific vessels. Accordingly, these innovative, multipurpose and efficient OCEA vessels will allow the Indonesian Navy to get to know their waters better and faster.

Acknowledgements

The experiences and skills of numerous persons contributed to the successful design and construction of the Indonesian sisterships. Many thanks to them, in particular to the SHOM engineers (Patrice Laporte, Sébastien Beuchard, Christophe Vrignaud, Julien Lagadec, Daniel Levieuge) and OCEA staff (Fabrice Weinbach, Luc Boulestreau, Franck Mayet, Jean-Marie Coudé, Gwenole Peronno and the production staff).

Eric Duporte has been the head of the Business Development Department at the SHOM institute since 2015. He has been at SHOM since 1992, where he was responsible for the organisation of oceanographic cruises for 10 years, then became involved in the technical supervision of the building of the French oceanographic ship *Pourquoi pas?*. Prior to his present position, he was director of technical services at SHOM, including scientific equipment, logistics and information systems.

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Fabrice Weinbach has been the director of the Maritime Safety and Security Business Unit at the OCEA shipyard since 2010. Prior to this, he was deputy for this activity and director for the Fishing Boats Business Unit at the OCEA shipyard. He initiated the project with the Indonesian Navy in 2011 and was in charge of building up the OCEA technical and commercial proposal that won the tender in 2012. He supported the customer throughout the contract period together with the project management team within OCEA.

Advancing Technology for a Wide Range of Purposes

Insides of Side-scan Sonar

Although today's multibeam echo sounders come with a backscatter option the more traditional Side-scan Sonar (SSS) still has many advantages when it comes to bottom imaging. Over the past years, SSS technology has gone through an evolution rather than a revolution. In this article we will zoom in on the current state of the art of this useful acoustic imaging device.

Side-scan Sonar is mainly used for the detection of objects and bottom structures. To obtain those images it digitises a sound pulse sent out from two transducers mounted on each side of the SSS fish. Images are based on the amount of reflected sound energy and presented on a time basis resulting in a continuous image of the bottom (Figure 1). As a tool it gives very highly detailed images indicating not only the existence of objects but also the type of material (strong reflector or weak reflector). SSS systems are commonly towed using a 1m to 2m long tow fish, although some manufacturers provide smaller systems of around 0.4m in length as well as pole mounted systems for shallow water where towing would be impossible or ROV / AUV mounted transducers for deepwater imaging.

SSS vs Multibeam Echo Sounders

SSS systems do not provide direct height/depth information; this has to be inferred from the image (object height as a ratio between fish altitude, shadow length and total distance between fish and end of shadow). There are manufacturers providing so-called hybrid SSS / bathymetric systems. In general, these systems provide full SSS images with interferometric multibeam bathymetry.
Conversely, a beam forming multibeam echo sounder (MBES) will provide depths from dedicated transducer arrays allowing for high-accuracy beam discrimination. Nowadays, most MBES systems can also provide backscatter information. The difference between MBES backscatter and a true SSS is that the MBES will provide one backscatter value per beam whereas the SSS will provide an (almost) continuous signal thus giving a higher resolution.
As such, a hybrid SSS is not a replacement for a multibeam echo sounder for high accuracy work and neither is a multibeam with backscatter a replacement for a SSS when it comes to the detection of small objects and/or bottom type differences. There are, however, many jobs where one is more important than the other and the additional information provided is still valuable.

Range

A SSS system is defined by a number of parameters of which the range and resolution are probably the most important. The resolution of the SSS defines the image quality and can be divided in 'along-track', 'across-track' and backscatter resolution (Figure 2). The range defines how effective the SSS will be (how much of the bottom can be surveyed in one track). Range is effectively a function of the frequency at which the SSS operates; the higher the frequency the smaller the range (500m @ 150kHz vs 35m @ 1600MHz). Modern SSS often have the option of running two or even three frequencies at the same time, allowing for both a long range (but with less detail) and a short range with high detail without having to switch the system and run multiple survey tracks.

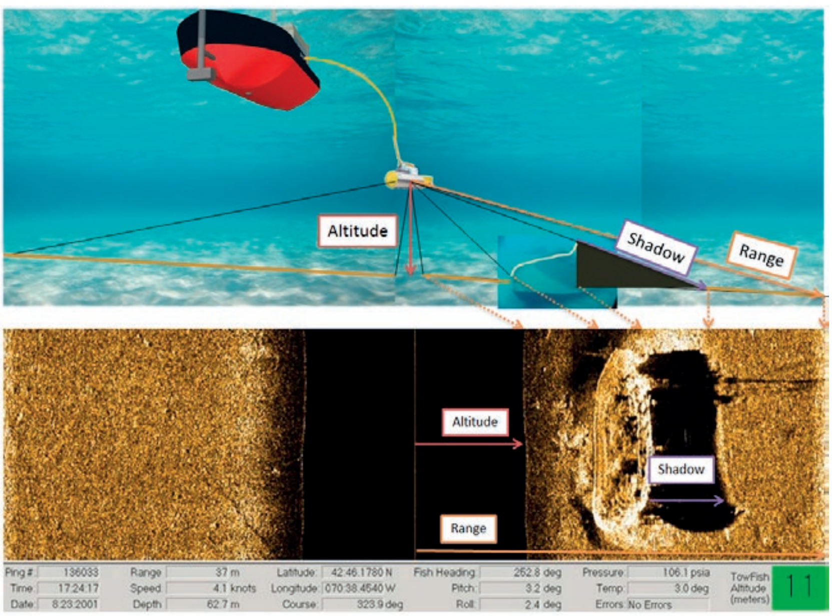
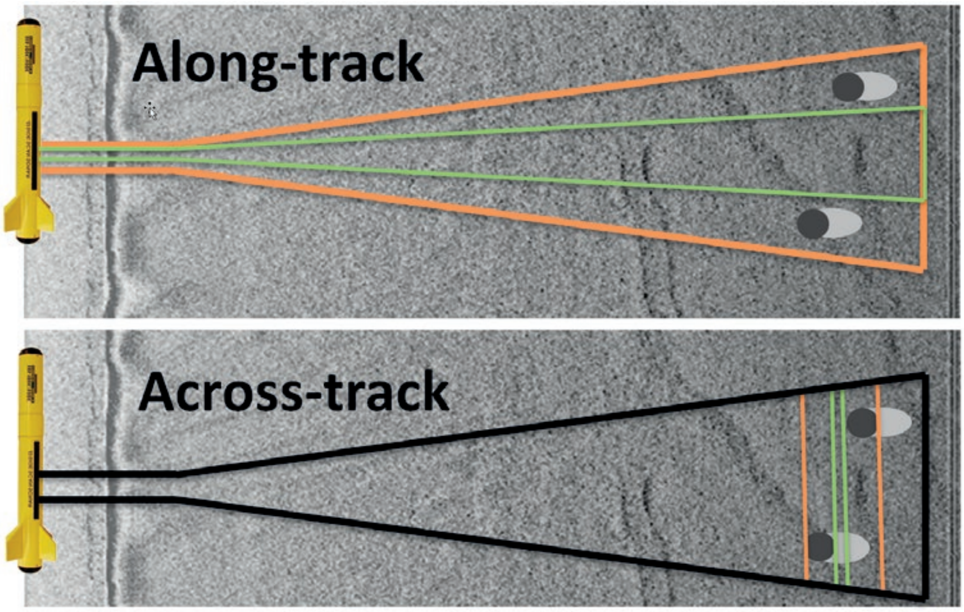


Figure 1: General principle of Side-scan Sonar imagery.

Range Resolution

The across-track or range resolution defines what the smallest distance is between two objects that are 'behind' each other in the direct path of the SSS beam. Where in the past the transmitted signal would have been of the 'continuous wave' (CW) type, a modern SSS transmits what is called an FM or CHIRP signal (CHIRP = Compressed High Intensity Radar Pulse). The main advantage of the CHIRP is a longer range with better range resolution.

For a CW type SSS the range resolution is defined by the pulse length of the signal whereas for a CHIRP type SSS the range resolution is defined by the bandwidth of the signal allowing longer pulses and therefore more power to be transmitted. For a high-frequency, short range (1600MHz, 35m) CHIRP SSS the range resolution is sub-centimetre allowing very fine detail across track to be shown in the image.



▲ *Figure 2: Definition of resolution in Side-scan Sonar for two different systems (orange, green).*

Along-track Resolution

The along-track resolution of a SSS is traditionally defined as the product of the so-called horizontal beam angle of the side-scan (typically between 0.2° and 1.5°), the effective range and the tow-speed of the SSS. A small beam angle at short range will allow the detection of small objects spaced apart along the track of the SSS. When scanning for objects 100% bottom coverage is usually required; NOAA specifications state that at least three hits should be obtained from a 1 metre cubed object. As a result there is a maximum speed at which a SSS can be towed before consecutive beams / pings at a certain distance are spaced too far apart to detect an object; for regular SSS systems this is somewhere in the 4 – 5kts region.

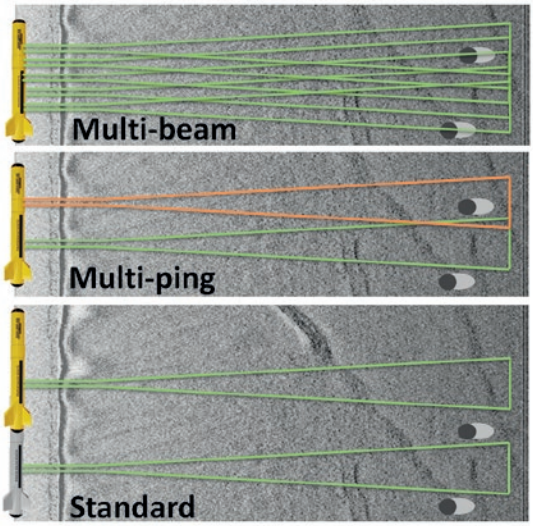
A hybrid SSS is not a replacement for a multibeam echo sounder for high accuracy work

Multibeam and Multi-ping

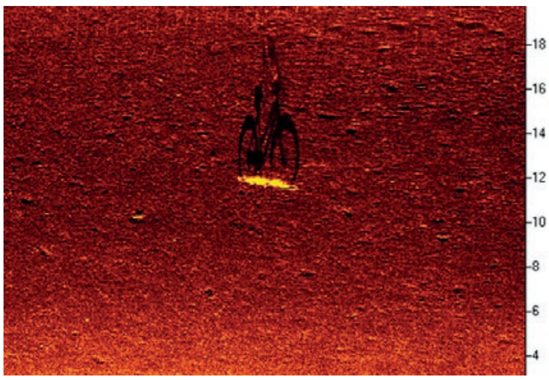
Higher tow speeds can be obtained if more hits were to be obtained from an object. Currently there are two different solutions employed by SSS manufacturers to achieve a higher tow rate (Figure 3). One is to make use of multiple beams. If, for example, 5 beams are used on a single side of the SSS then the effective along-track resolution is multiplied by 5 allowing higher tow speeds. The alternative solution is to have multiple pings in the water. With CW type SSS this is not possible but with the CHIRP type this can be done. If there are two pings in the water for a certain range then the effective tow speed can be doubled as well. Modern multibeam SSS or multi-ping SSS systems can be used at speeds of up to 12kts.

Backscatter Resolution

The last parameter to define the image quality in digital systems is the level to which the received acoustic signal is digitised into a digitally usable signal. In the past, SSS data collection was done on paper where digitisation would not be performed. However, the modern SSS uses digital data transmission over network from the fish to the sonar processor. For this an A/D convertor is used to convert the analogue (A) signal into a digital (D) signal. In digital signals the



▲ *Figure 3: Solutions to improve along-track resolution.*



▲ *Figure 4: High-resolution, high-frequency image of a bicycle on the bottom demonstrating the level of detail of a modern SSS (image courtesy: www.edgetech.com).*

number of bits used for the signal defines the level of detail that can be captured. The more bits used to do this, the more detail in terms of different types of material / backscatter can be captured. For a modern SSS the signal is captured in between 12 and 28 bits. Although these numbers seem quite low it should be realised that a 24 bit SSS can capture over 16 million different shades of grey where a 12 bit 'only' captures 4096 shades of grey. In comparison, a modern digital camera captures around 12 – 16 bits per colour channel.

A 24 bit SSS can capture over 16 million different shades of grey where a 12 bit 'only' captures 4096 shades of grey

Options

All SSS will provide a backscatter image as that is the main purpose of the SSS. The resolution and range will differ from one system to another and is where manufacturers differentiate their offerings.

Finally, it is the number of available options that may sway a buyer from one model to another. Some interesting options include a motion sensor, a compass and depth or altitude sensor integrated into the SSS fish allowing for motion correction and a fine adjustment of tow depth. In select SSS systems the motion sensor is used to dynamically stabilise the beams allowing a continuous (straight) path across the bottom. Some SSS fishes include a water temperature sensor allowing for real-time adjustment of local sound velocity.
Most SSS have an optional tow bracket to tow a magnetometer simultaneously with the SSS whereas some SSS are integrated with a Sub-bottom Profiler allowing complete geophysical surveying in a single track.
An interesting option is a so-called 'gap filler sonar', which covers the area directly under the SSS where a regular SSS cannot survey. Such a gap filler would therefore theoretically allow a full bottom image and allow a significant reduction in overlap between SSS tracks.

More information
bit.ly/sidescan-sonar

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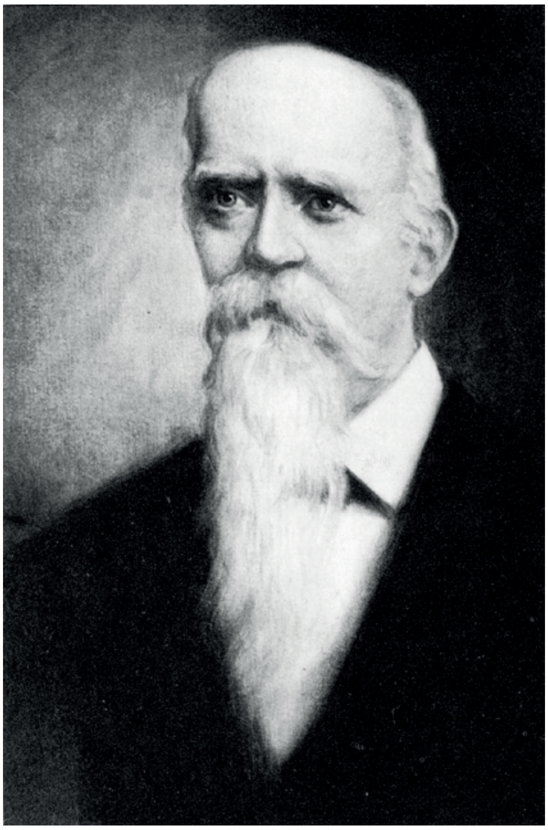
Mountains in the Sea

One can hardly discuss the configuration of the deep ocean bed without eventually using the term 'seamount'. Today, the existence of tens of thousands if not over 100,000 seamounts is taken for granted. But in the not so distant past, their existence was unknown and not even suspected.

In 1878, Alexander Agassiz, one of the greatest oceanographers of the nineteenth century, wrote: "The monotony, dreariness, and desolation of the deeper parts of the submarine scenery can scarcely be realized. The most barren terrestrial districts must seem diversified when compared with the vast expanse of ooze which covers the deeper parts of the ocean, - a monotony only relieved by the fall of dead carcasses of pelagic animals and plants, which slowly find their way from the surface to the bottom, and supply the principal food for the scanty fauna found living there."

Even as Agassiz was writing these words, there had already been whisperings of how wrong he was. In 1869, the Swedish corvette *Josephine*, with scientists Professor F. A. Smitt and Dr. Axel Vilhelm Ljungman directing operations, was engaged in an ambitious project to conduct deep-sea dredging operations between Europe and North America. On 2 July, it deployed its dredge approximately 200 nautical miles west of Cape San Vincent, Portugal, on a trip that it was assumed would travel at least 2,000 fathoms vertically and take an hour or so to reach the bottom. However, after a few minutes the dredge rope stopped paying out and slack was noticed in the line. The dredge had struck bottom at a little over 100 fathoms. It had landed on what has become known as Josephine Seamount, the first seamount discovered as a direct result of oceanic exploration. It is doubtful that either Smitt or Ljungman ever realised the significance of their discovery.



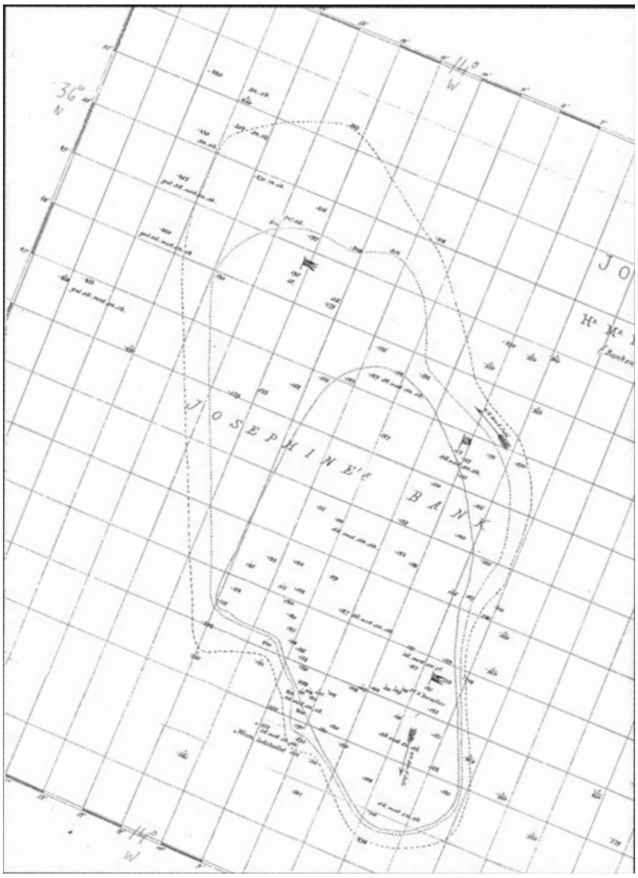
▲ *Figure 1: Frederik Adam Smitt, chief scientist of the Josephine Expedition and first to discover a seamount as result of a scientific oceanic exploration.*

Four years later, Lieutenant George Belknap on the USS *Tuscarora* began a revolution in deep-sea sounding methods by being the first to successfully use Sir William Thomson's piano-wire sounding machine while conducting a telegraph cable survey in the North Pacific Ocean. This expedition discovered the first known stand-alone seamounts in the Pacific Ocean. The first of these was a peak on the Gorda Ridge off the coast of northern California. It rose nearly 700 fathoms above the surrounding seafloor. Subsequent to that discovery, the *Tuscarora* sailed south to San Diego and thence to Honolulu. This first leg netted indications of a seamount when a 500 fathom jump occurred between soundings of 2159 fathoms at Latitude 26 22 N 137 22 W and a subsequent sounding of 2650 fathoms approximately 40 nautical miles distant. Another seven were sounded upon as the *Tuscarora* traversed the Mid-Pacific Mountains, the Marcus-Wake Seamount Group, and the Ogasawara Plateau region of the western Pacific Ocean. Amazingly, many of Belknap's soundings can be found on the most recent edition of NOAA Chart 530 of the North Pacific Ocean.

The scientific community took little note of Belknap's work. The majority of his soundings also recovered bottom samples. On virtually all seamounts that he sounded on in the western Pacific Ocean, coral fragments were recovered indicating that these peaks were once in shallow water. This was both a clue as to the age of the mountains as well as evidence supporting Darwin's theory of island subsidence versus John Murray's theory of upward accretion of coral reefs. The scientific community argued over aspects of Darwin's theory for over 75 years following the *Tuscarora* expedition until vindicating Darwin.

In 1875, Commander Henry Erben relieved George Belknap as commanding officer of the *Tuscarora*. His initial orders took him from San Francisco to Honolulu and on to Samoa. On this route he discovered and developed a great seamount, now known as Erben Seamount. For many years this was the largest known seamount in the Pacific Ocean. In discussing these discoveries, Rear Admiral Daniel Ammen, a hydrographer and Chief of the Bureau of Navigation, related that the *Tuscarora*'s soundings across the Pacific revealed "a dozen or more submerged elevations, veritable mountains 'full many a fathom deep.' In fact, these soundings furnish the first extended and undeniable development of extraordinary and abrupt inequalities in the depths of the sea far away from land."

Curiously, the contemporaneous Challenger Expedition apparently did not discover any seamounts. John Murray, the editor of the Challenger Reports, seemed to have been more concerned with 'deeps' than with submarine peaks as his maps from the expedition had many named deeps but few named bathymetric highs.



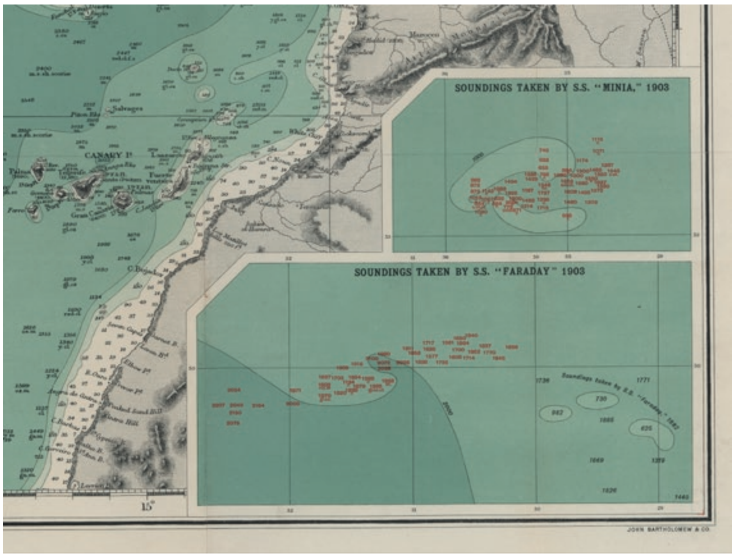


Figure 3: Piano-wire sounding developments of Minia and Faraday Seamounts. About 100 soundings in a total area of 100's of square nautical miles. Note Dacia Bank and Concepcion Bank on the small scale map.

Figure 2: Josephine Bank, the first seamount discovered as a direct result of intentional exploration.

In spite of these successes, few additional undersea peaks were added to knowledge of the seafloor over the next decade. An exception was a sounding expedition across the Atlantic in 1878 in which the USS *Gettsyburg* after passing over Josephine Seamount approaching the Straits of Gibraltar, sounded on Gorringe Ridge with its accompanying peaks of Gettysburg Seamount and Ormonde Seamount. The ridge was named for the captain of the *Gettysburg*.

British telegraph cable surveyors developed the Lucas Sounding Machine, a type of piano-wire sounding machine in the mid-1880s and discovered a few more peaks. Among them were Dacia Bank, Seine Bank, and the Coral Patch – all discovered in the same region as Josephine Bank. Seine Bank was discovered by the breaking of a cable on a line previously surveyed with a spacing of 25 miles. When laying telegraph cable between soundings of 2400, 1967, and 2332 fathoms, the cable suddenly parted. When checking the depth, it was found to be 100 fathoms. Thus, Seine Bank was discovered and named for the unfortunate cable ship. Faraday Seamount and Minia Seamount in the North Atlantic Ocean were discovered in 1882 and 1903 respectively by the cable ships *Faraday* and *Minia* . These seamounts were in the path of the preferred telegraph cable route between Ireland and Newfoundland.

As a result of such experiences, George Littlehales of the United States Navy Hydrographic Office, in 1890 wrote a paper titled 'The average form of isolated submarine peaks, and the interval which should obtain between deep-sea soundings taken to disclose the character of the bottom of the ocean'. After a somewhat convoluted mathematical analysis, Littlehales concluded that in average ocean depths, a minimum sounding interval of 10 miles was required to discover features that would approach the near surface. This in fact would find most large seamounts on a survey trackline although many smaller features would remain unknown. Given the technology of the times, this was infeasible as the time required was prohibitive. As a consequence, only about 20,000 deep-sea soundings were made prior to the advent of acoustic sounding, an average of one per 7,000 square statute miles throughout the world ocean. Few additional seamounts were discovered in this period.

In 1922, this all changed when the USS *Stewart*, equipped with a Hayes sonic depth finder, crossed the Atlantic, passed through the Mediterranean, through the Suez Canal, and on to the Far East for service from bases in the Philippines and China. Curiously, it did not encounter one stand-alone seamount on this initial transit; but in March of 1924, while transiting from Manila to Hong Kong, soundings showed a rapid decrease from 2,140 fathoms to 300 fathoms. A short development followed which revealed a relatively flat-topped peak with depths less than 200 fathoms. William Morris Davis (1850-1934), the Harvard geologist and geographer, was given access to the soundings and produced the first contour map of a seamount based on acoustic soundings and dubbed it the Stewart Bank. He foresaw the revolutionary aspect of acoustic systems and observed," Clearly a new era of oceanic exploration and discovery is opening, when so admirable a use of a most ingenious instrument may be made…."

The famous German Meteor Expedition, and follow-on German expeditions, discovered a number of south Atlantic seamounts including Spiess, Schmidt-Ott, Merz, Meteor,

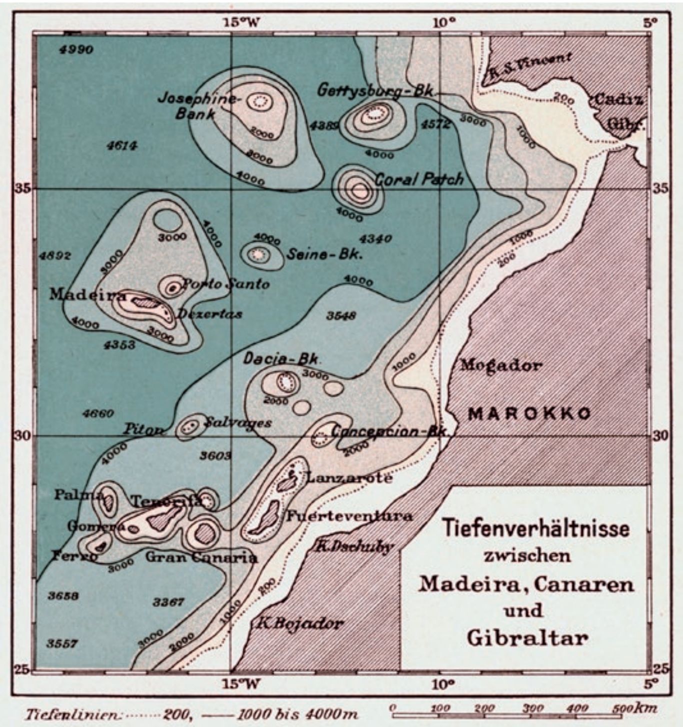
and the north Atlantic seamounts – Echo, Altair, and Great Meteor. While German scientists were exploring the Atlantic, the United States Coast and Geodetic Survey much of the material for Navy Charts 5485 and 5486 which had numerous seamounts among other features. However, few of these Pacific seamounts were named at the time of

A fleet oiler, the USS *Ramapo*, made 65 transits of the North Pacific between 1929 and 1940 and made tens of thousands of soundings

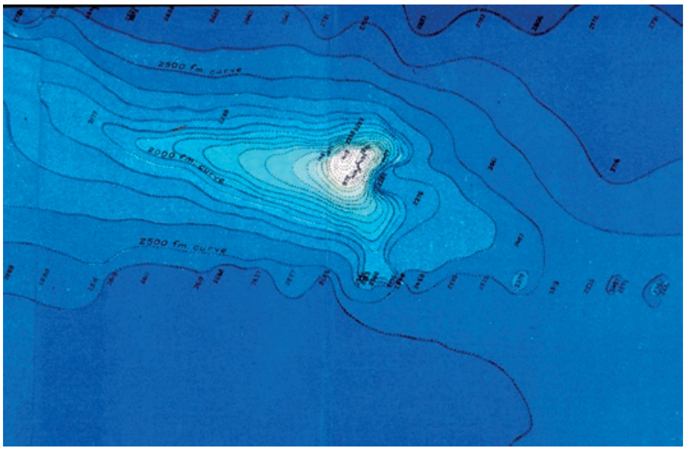
embarked on a programme to survey the United States West Coast and the Gulf of Alaska. Year after year until the beginning of World War II, C&GS ships marched down the west coast with systematic surveys and also followed a systematic series of tracklines crossing the Gulf of Alaska. These surveys netted San Juan, Rodriquez, Davidson, Guide and Pioneer Seamounts off the California coast, and a number of seamounts named after C&GS officers in the Gulf of Alaska. The United States Navy was also active during this period. In particular, a fleet oiler, the USS *Ramapo*, made 65 transits of the North Pacific between 1929 and 1940 and made tens of thousands of soundings. Soundings of the *Ramapo* and other naval vessels provided discovery. This outpouring of effort in the early years of acoustic sounding netted approximately 200 seamounts.

But in spite of its use in this article to describe mountains in the sea discovered by early surveyors, the term seamount was not widely used until 1938 when the United States Board on Geographic Names designated a large undersea mountain Davidson Seamount. This mountain was discovered by the C&GS ship *Pioneer* in 1933. Citation for the official name read: Davidson Seamount: a submarine elevation in mountain form which rises from a depth of 1900 fathoms to within 729 fathoms of the surface, near lat. 35°43'30" N., long. 122°43'10" W., about 75 miles west of Point Piedras Blancas, California, in the Pacific Ocean. Named in honour of George Davidson (1825-1911) of the US Coast and Geodetic Survey who, as chief of party and later in charge of all Coast Survey operations on the Pacific Coast, was active in charting the waters of the west coast." This note goes on to add: "The generic term 'seamount' is here used for the first time, and is applied to submarine elevations of mountain form whose character and depth are such that the existing terms bank, shoal, pinnacle, etc., are not appropriate." Since 1938, over 1100 additional seafloor features have been termed seamount while more than 150 have been designated by the related terms tablemount and guyot.

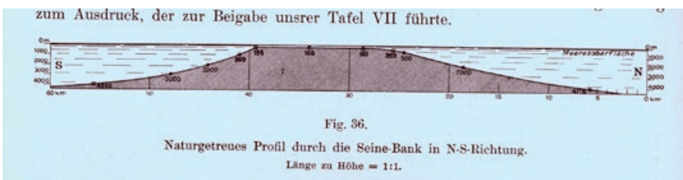
Harking back to the words of Alexander Agassiz, by the advent of World War II much had been done to show that the submarine landscape was not as monotonous, dreary, and desolate as Agassiz had envisioned. In fact, there was growing proof that the landscape was in the words of the nineteenth century oceanographer, Matthew Fontaine Maury, as "rugged, grand, and imposing" as any scenery to be found on Earth. A start had been made on exposing Maury's "very ribs of the solid earth, with the foundations of the sea." ◂



▲ *Figure 5: A 1912 map of the east-central Atlantic Ocean off NW Africa showing the seamounts discovered by scientific exploration and cable surveys. Produced by the German geographer Gerhard Schott, 1912.*



▲ *Figure 4: 1893 depiction of Erben Seamount in a surprisingly modern appearing map appearing in a report detailing a cable survey by the United States Fish Commission Steamer Albatross.*



▲ *Figure 6: Profile of Seine Bank, discovered by the breaking of a telegraph cable. Produced by Gerhard Schott in 1912.*

General Bathymetric Chart of the Oceans (GEBCO)

From the **Coast** to the **Deepest Trench**

More than a century after its creation, the General Bathymetric Chart of the Oceans (GEBCO) remains a unique project at the heart of the drive to map the world's seafloor from the coast to the deepest trench. As an independent, non-profit project under the joint auspices of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO, GEBCO is well placed to act as a central repository and forum for global ocean mapping-related information, products and expertise, led by GEBCO Guiding Committee.

Backed by the wealth of information being garnered through today's advanced surveying, mapping and interpretative techniques, GEBCO's principal aim now is to provide the most authoritative and comprehensive publicly-available bathymetry of the world's oceans yet available.

It is a vital task. Huge parts of the oceans, especially those far removed from coastal and national areas, are still inadequately mapped. Environments such as those beneath the polar ice sheets and ice-covered oceans are as unfamiliar to us even today as the deep ocean was for GEBCO's founders over 110 years ago.

To add momentum to the process, GEBCO is bringing together experts from the academic and commercial worlds for the Forum for Future Ocean Floor Mapping. The aim of this event, to be held in Monaco from 15 to 17 June 2016, is to provide a ten-year vision for the organisation.

A Rich History

The venue in Monte Carlo reflects the long-standing relationship between the Principality and GEBCO.

The organisation has its origins in a meeting chaired by Prince Albert I of Monaco in Wiesbaden, Germany in 1903, where a commission appointed by the International Geographic Congress was established to oversee the publication of *la Carte générale bathymétrique des oceans*.

That rapidly prepared chart was published in Paris in 1905 and then superseded by an improved version that emerged between 1912 and 1931, which included tints for ocean and land to better show terrestrial relief, as well as a revised nomenclature.

While the second edition was being compiled, rapid growth in data available due to the increased use of sonic and ultrasonic technology meant a new approach was required.

Following the death of Prince Albert in 1922, his small scientific team, which had largely been responsible for the chart, was disbanded. The newly created International Hydrographic Bureau (IHB), founded by a number of important maritime states, was invited to take over the project. Prince Albert had played a central role in the IHB's creation and provided it with a headquarters on the seafront in Monaco, where it remains today, as the secretariat of the IHO.

New Era

The impact of World War II and other international disputes slowed down progress in updating the chart to the extent that by the early 1970s only a limited number of sheets for further editions had been published.

However, following recommendations by the Scientific Committee on Oceanic Research (SCOR), the project was given a new lease of life. Expertise from the wider scientific community was brought in to modernise GEBCO and better meet the needs of users. The IOC was invited to co-sponsor a fifth edition with support from the Canadian government.

The GEBCO Guiding Committee was established to be in a position to offer marine geoscientists around the world the possibility of publishing their work in a prestigious, high-quality chart series. World coverage on the original scale of 1:10 million was completed and published by 1982, followed by a small-scale world sheet in 1984.

The fifth edition of the GEBCO chart series proved highly successful, attracting considerable support for the GEBCO's work. In 1994, the GEBCO Digital Atlas (GDA) on CD-ROM was published. It represented the first seamless, high-quality, digital bathymetric

▲ *Figure 1: The founding meeting of GEBCO, in 1903, led by HSH Prince Albert I of Monaco. Image courtesy: Collection Musée océanographique de Monaco.*

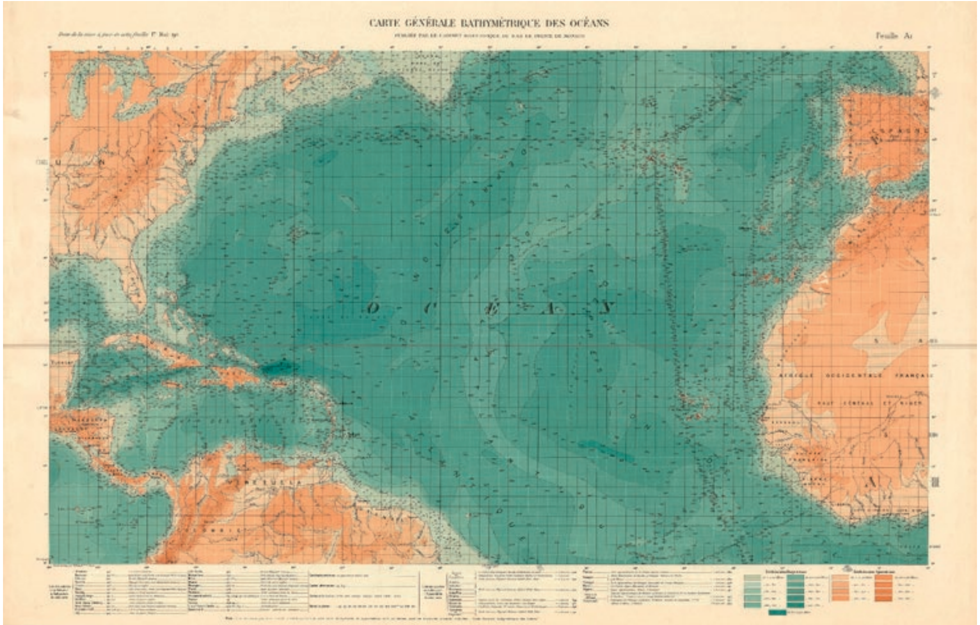
contour chart of the world's oceans. A second release was published in 1997. GDA's Centenary Edition was published in 2003, 100 years after Prince Albert initiated GEBCO.

One arc minute grid of bathymetry contained in GDA, which was based on manually drawn contour lines of the fifth edition of the GEBCO chart series, has been frozen since then. A new 30 arc second gridded bathymetry was published in 2008, which uses satellite altimeter data for guidance in interpolating data sparse areas. It was last updated in 2014 and is available on GEBCO's website.

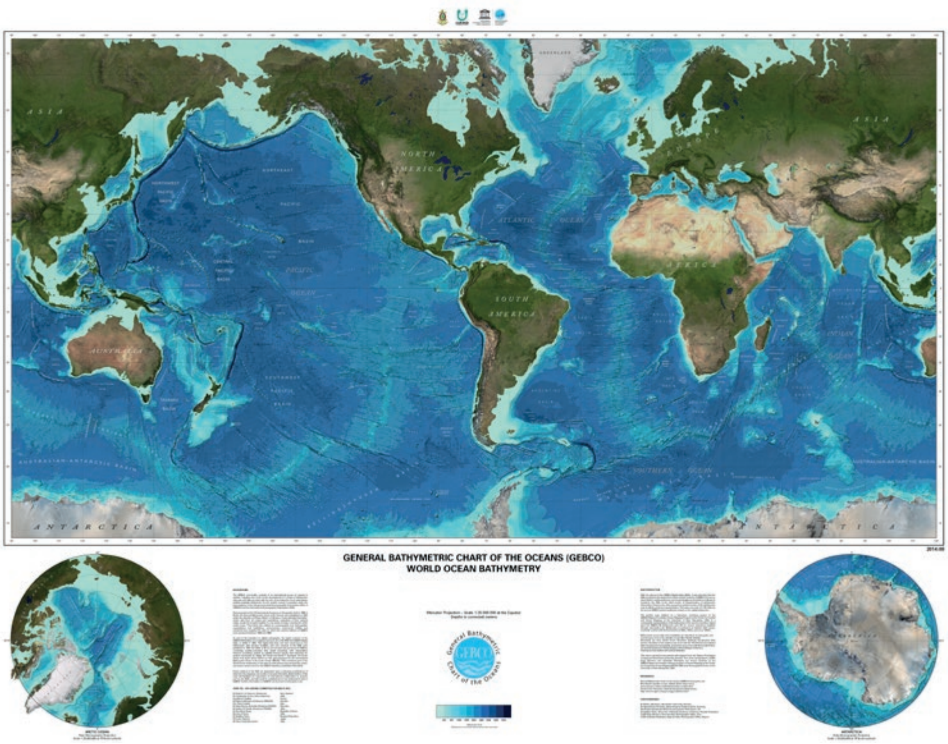
Now GDA contains a global set of digital bathymetric contours and coastlines, the latest GEBCO 30 arc-second grid, GEBCO One Minute Grid and the GEBCO gazetteer of geographic names of undersea features. It is accompanied by software for viewing and accessing the datasets.

Today, GEBCO relies on voluntary contributions from an enthusiastic international team of geoscientists and hydrographers. GEBCO's work is directed by its Guiding Committee, which is supported by technical sub-committees and working groups made up of experts in many fields and from organisations across the globe.

GEBCO has also leveraged its coordinating role to instigate programmes to encourage more young scientists and hydrographers to become involved in mapping the ocean floor. GEBCO has been funded by the Tokyo-based Nippon Foundation to train a new generation of ocean bathymetrists through the Postgraduate Certificate in Ocean Bathymetry (PCOB) at the University of New Hampshire (UNH) in the US.



▲ *Figure 2: From the 1912 second edition the paper General Bathymetric Chart of the Oceans. Image courtesy: GEBCO.*



▲ *Figure 3: Since 1903, five separate editions of paper bathymetric contour charts covering the whole world have been produced. GEBCO is now maintained in digital form as the GEBCO Digital Atlas. Image courtesy: GEBCO.*

The Next Phase

When the Forum for Future Ocean Floor Mapping opens in June, the next phase in GEBCO's story will be launched, as delegates help map out the GEBCO's path for the next decade.

Leading figures from GEBCO and senior executives of major ocean-related exploration, international regulatory, industry and academic organisations will give their views on the critical ocean issues and how mapping coordination can be improved to solve them. Experts will discuss emerging technologies for collecting and analysing ocean depth data, as well as how best to coordinate efforts to achieve the broadest possible global bathymetric coverage.

GEBCO will continue to link individuals and organisations worldwide and enhance existing global networks, driving ocean mapping and a deeper understanding of the current and ancient processes shaping the ocean floor. ◀

More information
www.gebco.net

MAY

Connecting Paleo and Modern Oceanographic Data
Boulder, USA
→ 23-25 May
usclivar.org/meetings/2016-paleo-amoc-workshop

UNB-OMG/UNH-CCOM Multibeam Course 71
Den Helder, The Netherlands
→ 23-28 May
bit.ly/MBC071

JUNE

Seanergy
Biarritz, France
→ 1-2 June
www.seanergy-convention.com

UDT 2016
Oslo, Norway
→ 1-3 June
www.udt-global.com

30. Hydrographentag
Oldenburg, Germany
→ 1-2 June
www.dhyg.de

Oceanographic Survey Vessels 2016
London, UK
→ 7-9 June
www.oceanographicsurveyvessels.com

Hydroacoustic Assessment Workshop
Seattle, USA
→ 7-9 June
www.biosonicsinc.com/contact-training-registration.asp

SeaWork 2016
Southampton, UK
→ 14-16 June
www.seawork.com

JULY

UK Marine Energy Conference
Glasgow, UK
→ 5 July
www.marineenergyconference.co.uk

International Workshop on the Advances in the Use of Historical Marine Climate Data (MARCDAT-IV)
Southampton, UK
→ 18-22 July
conference.noc.ac.uk/marcdat-iv

SEPTEMBER

International conference on Marine Data and Information Systems (IMDIS)
Gdansk, Poland
→ 11-13 September
imdis2016.seadatanet.org

MTS/IEEE Oceans '16
Monterey, USA
→ 18-23 September
www.oceans16mtsieeemonterey.org

India Cleanseas 2016
Goa, India
→ 22-24 September
www.cleanseas.in

EWEA Annual Conference/WindEnergy Hamburg
Hamburg, Germany
→ 27-30 September
www.windenergyhamburg.com

OCTOBER

SaferSeas/Sea Tech
Brest, France
→ 10-14 October
www.saferseas-brest.org/Accueil-257-0-0-0.html

Euro Naval
Paris, France
→ 17-21 October
bit.ly/10anvm1

Iranimex
Kish, Iran
→ 18-21 October
www.europort.nl/about-europort/europort-exports/iranimex

Offshore Energy
Amsterdam, The Netherlands
→ 25-26 October
www.offshoreenergy.biz

NOVEMBER

Trimble Dimensions
Las Vegas, USA
→ 7-9 November
www.trimbledimensions.com

North Sea Open Science Conference
Ostend, Belgium
→ 7-10 November
www.northseaconference.be

Hydro '16
Rostock-Warnemünde, Germany
→ 8-10 November
hydro2016.com

Oceanology International China
Shanghai, China
→ 9-11 November
www.oichina.com.cn/en/home

Asia-Pacific Dredging Summit
Singapore
→ 23-24 November
bit.ly/10aoD9n

GSDI World Conference
Taipei, Taiwan
→ 28 November-2 December
bit.ly/gsdi2015

JANUARY 2017

HYPACK 2017 Training Event
New Orleans, USA
→ 9-12 January
hypack.com

FEBRUARY

Oceanology International North America 2017
San Diego, USA
→ 14-16 February
www.oceanologyinternational-northamerica.com

APRIL

Ocean Business
Southampton, UK
→ 4-6 April
www.oceanbusiness.com

XIXth International Hydrographic Conference
Monaco
→ 24-28 April
For more information:
www.iho.int

JUNE

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

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

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