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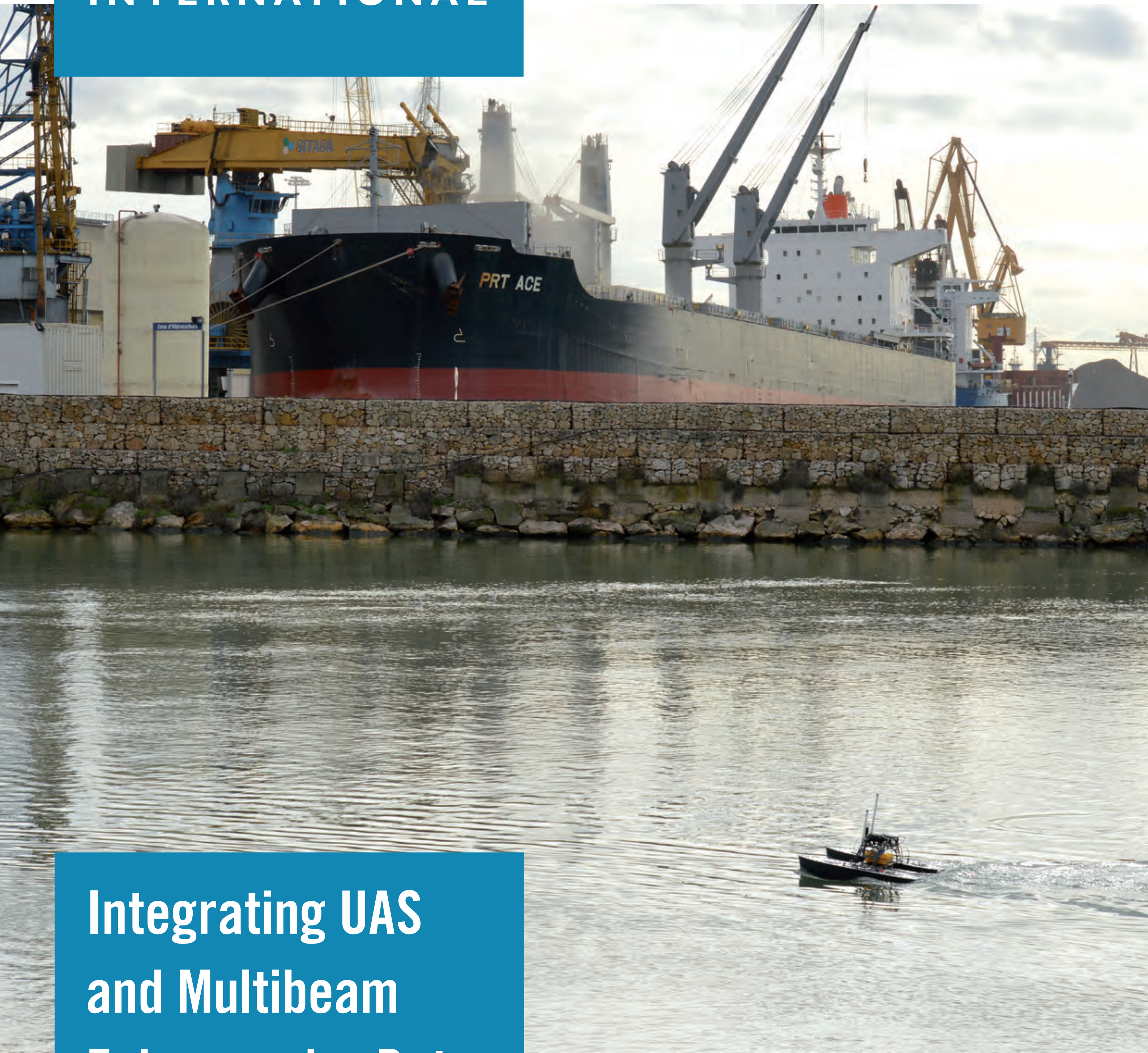
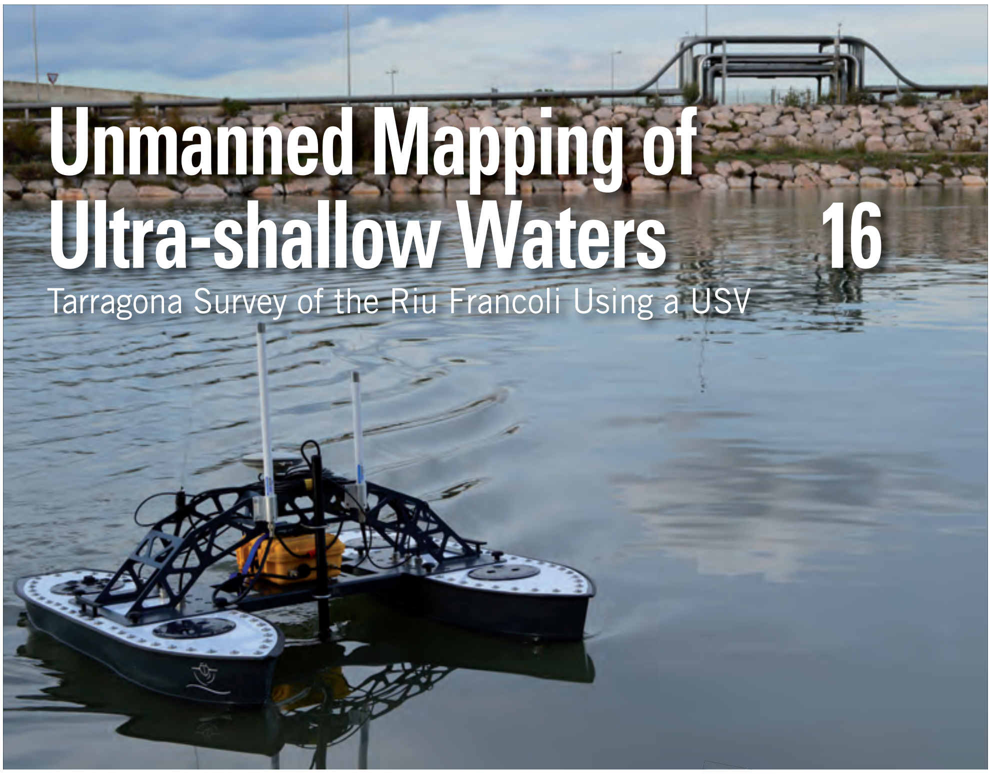
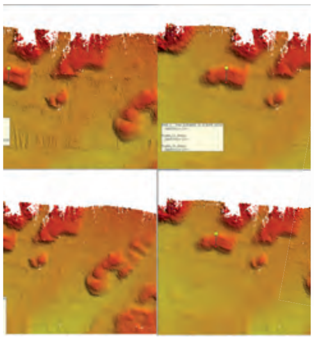


Integrating UAS and Multibeam Echosounder Data

TECHNOLOGY IN FOCUS:
GNSS RECEIVERS

Unmanned Mapping of Ultra-shallow Waters





September – October 2017
Volume 21 #5

Inland water mapping is seeing the advantages of unmanned surface vehicles (USVs) to map the often (very) shallow waters. The article by Mark Gray shows how very shallow waters near Tarragona, Spain, were surveyed. *See from page 16.*

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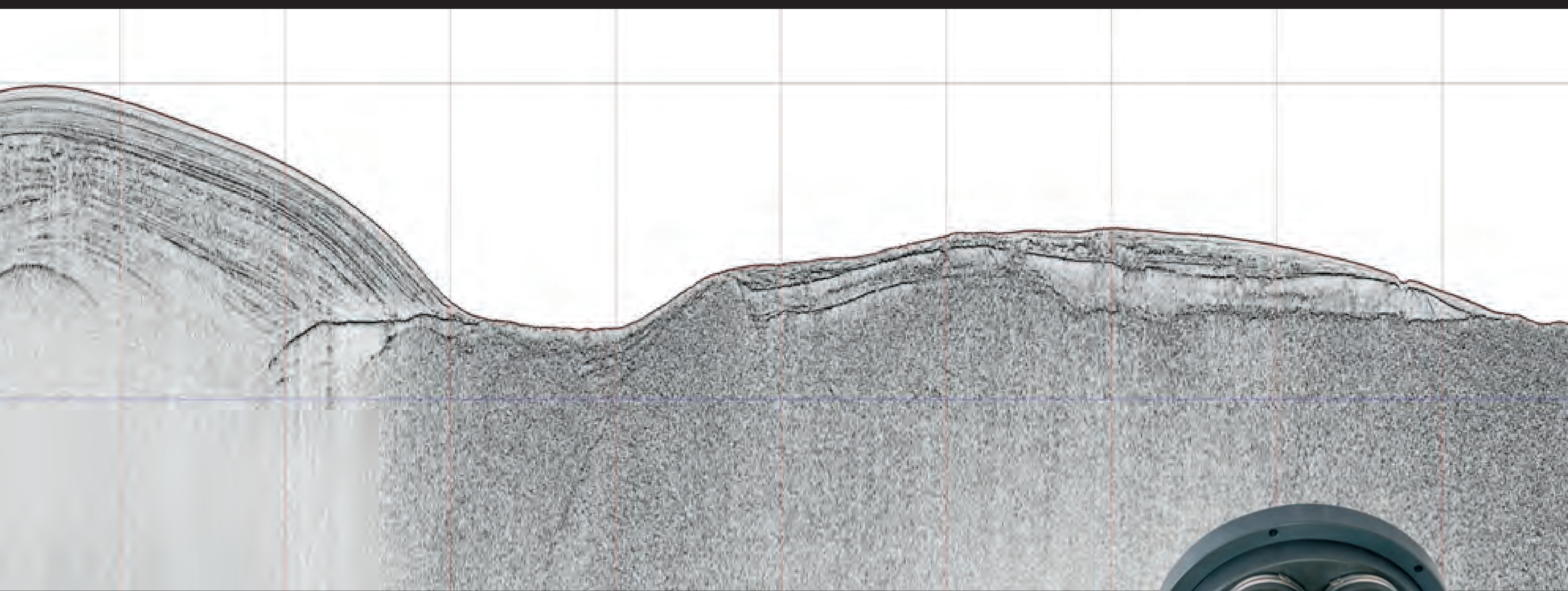
Quality results demand quality instruments.



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- Easy setup
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Hydro INTERNATIONAL

Hydro International is an independent international magazine published 6 times a year by Geomares Publishing. The magazine and related e-newsletter inform worldwide professional, industrial and governmental readers of the latest news and developments in the hydrographic, surveying, marine cartographic and geomatics world. Hydro International encompasses all aspects, activities and equipment related to the acquisition, processing, presentation, control and management of hydrographic and surveying-related activities.

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PHOTOGRAPHY: ARIE BRUINSMA (WWW.ARIEBRUINSMA.NL)

Thanks, Farewell and Welcome

The biggest change in hydrography in recent years occurred last week at the International Hydrographic Bureau in Monaco. Boxes were probably packed, they were brought in and out, briefings were held for the staff, introductions prepared and interviews held. All because the keys to the highest office in hydrography were handed over to the next Secretary-General Mathias Jonas by Captain Robert Ward. The new Secretary-General was elected earlier this year and officially took office on 1 September 2017. He replaced Robert Ward who had held the position of President and Secretary-General for the last five years. Robert Ward looks back on the ten years he served the International Hydrographic Organisation at the harbour of Monaco – and on the many, many places he visited all over the world - in the Insiders View feature on page 6 of this *Hydro International*.
It's from this place that I want to salute Captain Ward and thank him on behalf of the hydrographic community, and therefore many of our readers, for all the good work that he has done for the industry. Robert Ward has been instrumental in creating the positive and thriving atmosphere that surrounds the outlook on hydrography these days. Robert Ward saw the big picture of hydrography and was able to put a dot on the horizon, trying at the same time to steer the tanker of the IHO toward the right course while never losing sight of all the dangers and opportunities around the ship called hydrography. He combined that with an ability to go to the right places at the right time and talk to the right influencers. That resulted in awareness among a group much bigger than our own little global community about how hydrography is way more than making charts for safe seafaring. One of his last achievements was the establishment, together with NOAA and members of the US delegation, of the Working Group on Marine Geospatial Information during the last session of the United Nations Committee of Experts on Global Geospatial Information (UN-GGIM) in New York, this August. This new Working Group is the exponent of a repeated hammering on the importance of the oceans in the whole of the geospatial frame and, therefore, the importance of hydrography.
Is there nothing left to do? Oh sure, there's more awareness to create, there's more effort to be put in outreach and there's room for even more influence. But rest assured, with Mathias Jonas we have a new Secretary-General who has a very clear, down-to-earth view on the practice of hydrography and a very amicable way of interacting at all levels, reaching his goals through his knowledge and personality. We will carry an interview with the new Secretary-General soon in *Hydro International* to inform you of everything that he has already planned. But for now, suffice to say thank you once more to Robert Ward for his enduring efforts for hydrography. I really hope that the community will be able to benefit – in whatever capacity- from his knowledge and vision for many years to come! A warm welcome to Mathias Jonas and I wish him all the best with his endeavours for the coming years!

Durk Haarsma durk.haarsma@geomares.nl

A Decade of Outreach, Influence and Awareness at the IHO

By the time you read this, my longstanding friend and colleague Dr Mathias Jonas will be the new Secretary-General of the IHO. Having served in the IHO Secretariat for a decade, what do I think has been achieved in my time - particularly in my last five years as the President and latterly as the first Secretary-General?

Outreach, influence and awareness would summarise what I think are the major improvements that have taken place since I took office, together with tighter governance and clearer documentation.

The recent IHO Assembly was the embodiment of all that has changed. In addition to meeting as an Assembly under the terms of a revised Convention on the IHO, we had more Member States, more Observer Organisations and more Industry Exhibitors than ever before. We had the Secretaries-General of three of our most relevant sister Intergovernmental Organisations - all speaking enthusiastically about the role that the IHO plays in their activities and vice versa.

We also had the IHO Member States considering the part that they should play in national Spatial Data Infrastructures as the providers and the servers of the authoritative national hydrographic dataset, rather than simply as the providers of official nautical charts. They also considered their role in the UN 2030 Sustainable Development Agenda – particularly its Goal 14 about the oceans. They considered ways to improve our currently less than satisfactory hydrographic knowledge of the seas and oceans from the deepest submarine trenches to the high water line. They considered how to better harness crowdsourcing and the use of satellite-derived bathymetry. They considered the ever-expanding take-up of the IHO standard S-100 as the baseline standard for exchanging maritime data and information - especially under the eNavigation framework. They considered how to continue to build upon the ever-expanding IHO capacity building programme that aims to assist developing hydrographic countries to become more self-sufficient in meeting their hydrographic requirements and obligations.

And much of this is, in my opinion, a direct result of our focus on reaching out to other organisations and stakeholders beyond ships' navigators, to those other organisations and individuals that share a common interest and increasing dependence on knowing the depth and shape of the seafloor and identifying the hazards that may exist there.

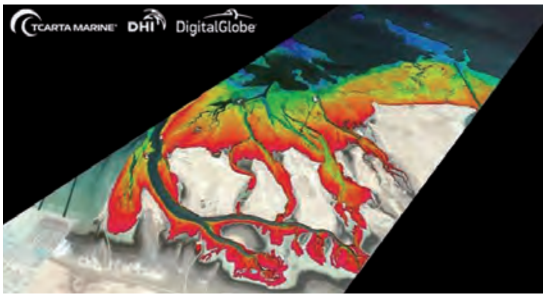
But, none of this would have happened without the dedication and the hard work of my colleagues in the Secretariat - and in particular Director Gilles Bessero, who, like me, has just handed over his responsibilities to a successor. I know already, but many of you have yet to realise, the immense and lasting contribution that he has made in the last five years, in improving the effectiveness and the reputation of the IHO as an organisation.

And what about my future? Well a holiday will be a good start! But I hope that I can find opportunities to continue to raise awareness of the fundamental part that hydrography plays in everything that happens in, on or under the sea – and the important role that all of us play in making the best use of the sea and its resources. I still want to try and make a difference.

Fast Access to High Quality Water Depth Data

The Bathymetrics Data Portal allows users to search, purchase and automatically download the best available water depth information directly from the online store to their computer. It is a combined offering by DHI, experts in water environments; TCarta, a global provider of marine geospatial products; and powered by DigitalGlobe, the provider of high-resolution satellite imagery.

▸ ***bit.ly/2xb0mMX***



▲ *2m bathymetry available in the Bathymetrics Data Portal. Image courtesy: DHI, TCarta, DigitalGlobe.*

Most Shared

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

1. Norwegian ENC Data in OpenCPN - bit.ly/2xaL4Yq
2. Centralised Data for Hamburg Port Authority - bit.ly/2uM36j9
3. A Decade of Outreach, Influence and Awareness at the IHO - bit.ly/2xacE8e
4. When Bathymetry Determines Who Might Live and Who Might Die - bit.ly/2xaypVF
5. Technology in Focus: Underwater Electromagnetic Propagation - bit.ly/2fjyYjs

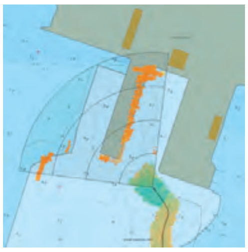
NOAA Teams up for Deep Ocean Observations

▲ *Scientists deploy a Deep Argo float off New Zealand. Image courtesy: LEARNZ.*

In a public-private partnership, Microsoft co-founder and philanthropist Paul G. Allen and NOAA's Pacific Marine Environmental Laboratory will deploy a large array of Deep Argo ocean floats to expand ocean observations in a key area of the western South Atlantic Ocean. These instruments will collect data down to nearly four miles deep, and promise to lead scientists to a better understanding of how the bottom half of the ocean may influence long-term weather, climate and sea level rise.

▸ ***bit.ly/2xabyt8***

FarSounder Overlays S-57 & S-63 Charts



▲ *Farsounder can create sonar overlay on a chart.*

FarSounder's SonaSoft software's latest release has been upgraded to be compatible with S-57 and S-63 Charts. Anyone using these chart formats is now able to overlay real-time data on their charts using FarSounder's software benefiting from its Forward Looking Sonar (FLS).

▸ ***bit.ly/2xbitlX***

Hydrography Centre of Excellence for Houston

Fugro has announced plans to establish a Hydrography Centre of Excellence for the Americas, supporting its strategic focus on growth in this market sector. Utilising specialist resources that include autonomous vessels and aircraft, integrated data acquisition techniques, remote processing and large data transfer, the focus is on reducing risk, increasing accuracy and streamlining project timelines for clients.

▸ ***bit.ly/2xaJF46***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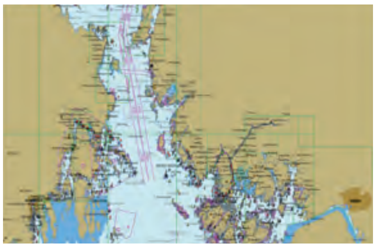
Norwegian ENC Data in OpenCPN



▲ Section of a chart viewed in OpenCPN, containing Norwegian ENC data. Image courtesy: OpenCPN.

Updated Norwegian electronic navigational chart (ENC) data can now be downloaded and used in the open-source chart plotter and navigation software, OpenCPN. The Norwegian Mapping Authority Hydrographic Service's electronic navigational chart data is available in OpenCPN's chart catalogue, O-charts.

▸ ***bit.ly/2xaL4Yq***

Oceanscan Adds Valeport Sensors

Oceanscan, a provider of sales and rentals of subsea, survey, NDT, inspection and ROV equipment, will extend its service offering with an investment in a range of Valeport products. They will also replace legacy systems to be able to offer the latest technology. Three Oceanscan technicians will receive bespoke training from Valeport to help clients get the best performance from the new equipment.

▸ ***bit.ly/2xaSWJx***

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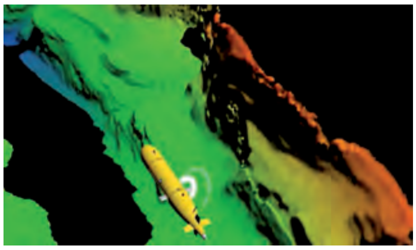
CHC N72 GNSS Sensor	bit.ly/2xdP3n4
Seabed SGR6-D	bit.ly/2xdPJc6
Satlab Multi-purpose SLC	bit.ly/2xe2i7u
Terusus GNSS PPK (Post-processing Kinematic) Board	bit.ly/2xerJpz

High-resolution Mapping of Deep-sea Vertical Walls Using AUVs and ROVs



▲ AUV mapping vertical canyon walls. Image courtesy: NOC.

A study published by the National Oceanography Centre (NOC) combines autonomous underwater vehicle (AUV) and remotely operated vehicle (ROV) mapping and imaging methodologies to reveal the complex 3D terrain of deep-sea vertical cliffs and the diversity of species associated with them. AUVs and ROVs can get much closer to the seafloor and generate higher resolution maps than would be possible with ship-mounted multibeam echo sounders.

▸ ***bit.ly/2xbpUtm***

Allocation of Secretary-General and Director Responsibilities at IHO

The new Secretary-General of the IHO, Dr Mathias Jonas, and IHO Directors Abri Kampfer and Mustafa Iptes assumed office on 1 September 2017. The Secretary-General, in consultation with the directors, has allocated primary responsibilities for the various aspects of the IHO Work Programme so as to generally conform with its three parts.

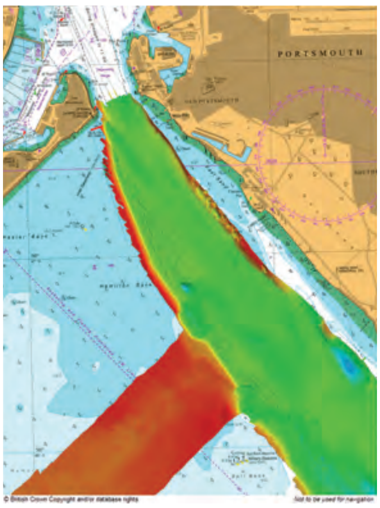
▸ ***http://bit.ly/2xeNmpm***

Boskalis Acquires Gardline

Royal Boskalis Westminster N.V. has acquired all shares of the Gardline Group (Gardline) as of today. The UK-based company's main activities include marine geophysical surveys, offshore geotechnical services and environmental surveys. With the acquisition Boskalis fulfils its strategic ambition to build a position in the offshore survey market and becomes a specialist provider of subsea geotechnical surveys with an exposure to the renewables market and the early cyclical oil and gas market. Gardline operates 15 survey-related vessels in addition to 25 smaller vessels including crew transfer vessels and survey catamarans.

▸ ***http://bit.ly/2xfisgE***

UKHO Ensures Safe Arrival of Aircraft Carrier into Portsmouth



▲ *Approach to Portsmouth Harbour using UKHO bathymetric data. Image courtesy: British Crown Copyright and/or database rights. Not to be used for Navigation.*

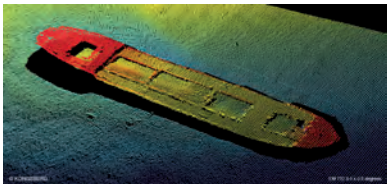
The United Kingdom Hydrographic Office (UKHO) supported the safe arrival of HMS *Queen Elizabeth* into Portsmouth on 16 August 2017 by providing specialist marine geospatial and hydrographic expertise and data capabilities. Following initial dredging operations to make Portsmouth's navigation channel and entrance deeper, hydrographic data was collected by the survey launch HMS *Gleaner* using multibeam echo sounder technology to confirm the available water depth.

▸ ***http://bit.ly/2xeLEEF***

Canadian Coast Guard Expands Northern Mapping Capability

The Canadian Coast Guard has chosen Kongsberg Maritime to provide high-resolution EM 712 multibeam echo sounders to the Canadian Coast Guard's medium icebreakers, CCGS *Pierre Radisson* and the CCGS *Des Groseilliers*.

▸ ***http://bit.ly/2xeOj0U***



▲ *Underwater image captured using a Kongsberg EM 712 multibeam echo sounder.*

International R&D Collaboration Developing Universal AUV Connection

▲ *Signing of the agreement with universal AUV connector.*

A universal interface to facilitate autonomous underwater vehicle (AUV) docking with subsea structures is being developed through international collaboration between companies and universities in Brazil, Norway, Poland, Sweden and the UK. The consortium, led by WiSub (Norway), includes leaders from industry and academia: Bergen University, DOF Subsea, easySubsea, Federal University of Rio de Janeiro, Kongsberg Maritime, Saab Dynamics, Sonardyne, Statoil, Swire Seabed and Warsaw University of Technology.

▸ ***http://bit.ly/2xfiSUB***

Bathy DataBASE Emphasises Bathymetric Lidar Surveys

Teledyne CARIS has released Bathy DataBASE (BDB) 4.4. This new version addresses the areas of feature generalisation and automation of product generation for chart compilation, as well as the increasing emphasis on bathymetric Lidar surveys.

▸ ***http://bit.ly/2xeE1hB***

Industry Brings Innovation to Inspire the **New Generation**

Looking Below the Surface and Seeing What Lies Ahead

For the fifth year in a row, the Lake Survey was held in the Netherlands. This year Teledyne CARIS collaborated with Boskalis and Fugro in a one-week all-encompassing practical survey week. Fourteen students worked with some of the most advanced equipment and technology that is currently available in the market from 26 to 30 June 2017. The organising committee had prepared a week with a varied programme. Practicals, demonstrations and presentations covered various subjects that the students are likely to encounter in their professional careers. After 5 days full of mobilisation, calibration, demonstration, information, innovation and recreation, it was time for an evaluation. Another successful edition for the third year students of Ocean Technology from the Maritime Institute Willem Barentsz (MIWB) left the students motivated for their final years and ready for their career as a surveyor.

▸ *http://bit.ly/2vVxZON*

▲ *Students and crew of the Lake Survey.*

MARCK SMIT, CONTRIBUTING EDITOR, HYDRO INTERNATIONAL

International Seabed Authority Met in Jamaica

Overlooking the large and choppy natural port of Kingston, Jamaica, and surrounded by waving palm trees, the International Seabed Authority (ISA) headquarters hosted the 23rd ISA Annual Session from 8-18 August 2017. Highlights of this session were allowing for Poland to explore an area near the Mid-Atlantic Ridge for polymetallic sulphides mining and the extension of India's contract for polymetallic nodules exploration. Furthermore, the first draft of the Exploitation Regulations was published online.

The Assembly was presided by Eugénio João Muianga (Mozambique). He emphasised during the opening the responsibility and active role of the Assembly in addressing challenges and opportunities relevant to the sustainable use of the oceans, as well as its mandate and role in cooperating with other processes and all stakeholders for better ocean governance.

The Council is presided by Ariel Fernández (Argentina). He presented a report on the status of contracts for exploration and related matters (ISBA/23/C/7), highlighting three new contracts signed since the 22nd session, and an additional one expected to be signed before the end of 2017; four agreements signed for a five-year extension of exploration contracts, with two more expected to be signed by the end of the present session; and the status of consultations regarding the establishment of an annual overhead charge of USD47,000 to cover the costs incurred by the Authority in administering and supervising contracts.

▸ *http://bit.ly/2vV99yw*

▲ *Meeting of the ISA Council.*

Hydro International interviews Dr Klas Lackschewitz, GEOMAR; Chairman ERVO Group

"Running Costs of Research Vessels Differ between Countries"

Operating research vessels is an important aspect of many hydrographic and oceanographic organisations. The European Research Vessel Operators (ERVO) Group coordinates small to medium-sized research vessels in Europe. This platform provides an opportunity to exchange experiences on issues or problems related to research vessel operators and new developments (and new build vessels) and to share best practices. *Hydro International* interviews Dr Klas Lackschewitz of GEOMAR, Germany, and chairman of the ERVO Group for 2017-2019 about the organisation and its efforts.

▲ Dr. Klas Lackschewitz. Image courtesy: Andres Villwock, GEOMAR.

ERVO Group is optimising the use of capacity of small and middle-sized research vessels. What do you consider as minimum and maximum sizes?

The European Marine Research Fleet has approximately 35 small and middle-sized research vessels that are considered to be ocean class (55-65m) to regional class vessels (30-55m).

Could you say something about the available survey capacity of European research vessels?

The European research fleets meet high standards in capabilities and equipment, e.g. multibeam echo sounding. However, maintenance and improvement of these standards require continual adaption. There seems to be no overcapacity but renewal remains necessary for the future. Installing new instruments on a vessel often requires technical adaptations of the vessel including steel works and cabling. This means that the installation of such equipment is not always an easy task and can lead to down times when using the vessel for expeditions.

How big is the discrepancy in capacity that the ERVO members are looking at?

There are a very large number of instruments for marine research with different capabilities and of different use in Europe. However, only a limited number of countries own most of the large and mobile devices. The potential for an enhanced use of such equipment, e.g. deepwater ROVs, 3D equipment, large piston corers, portable

▲ *Research vessels* Poseidon *(left) and* Alkor *(right). Image courtesy: Maike Nicolai, GEOMAR.*

winches, specialised lab containers, is considerable. However, in order to achieve an enhanced use of this pool, there are many practical issues that need to be considered, e.g. interoperability and technical support.

Can you give an example of research cruises that ERVO has facilitated and how the organisation has contributed?
ERVO is not directly involved in facilitating cruises such as the Ocean Facilities Exchange Group (OFEG) or the Eurofleets project. But ERVO is a networking group and contacts made and plans developed can lead to some sort of cruise activities.

In your profession, you manage the GEOMAR research vessels. Do you experience benefits of ERVO?
The ERVO group is very important for me because the members provide an opportunity as research vessel managers to exchange information on our national fleets, highlighting trends in the requirements for sea-going vessels and new technological developments for research vessel operations.

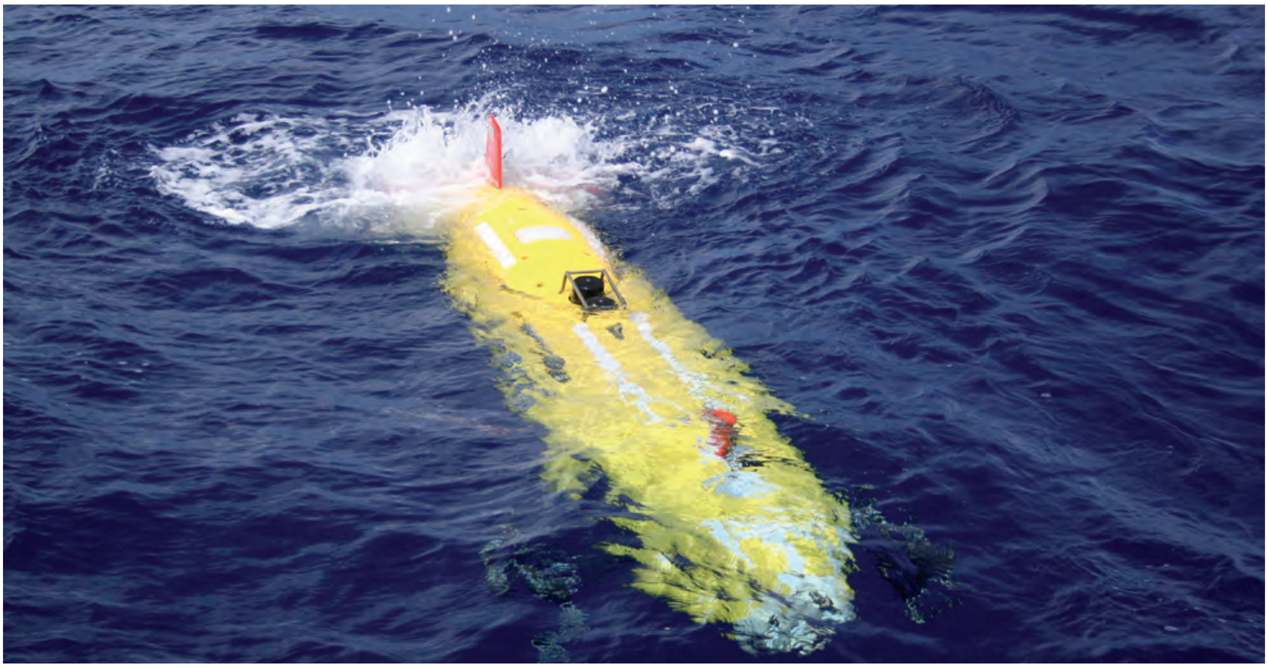
Members of the ERVO Group meet once a year during a seminar. What kind of subjects are discussed?
ERVO meetings address common technical, operational, safety, environmental and legal issues/problems that affect research vessel operators so as to identify solutions for improving services to the scientific community and developing best practice in the operation of research vessels. For example, we share experiences on all aspects of the International Polar Code with ERVO members. The Code will require ships intending to operate in the defined waters of the Antarctic and Arctic to apply for a Polar Ship Certificate. The Polar Code covers the full range of design, construction, equipment, operations, training, search and rescue and environmental protection matters relevant to ships operating in the waters surrounding the two poles. Other topics addressed during the meetings are: new research vessels being built, international safety management, vessel and equipment insurance, and crew training and health and safety issues.

Members provide an opportunity as research vessel managers to exchange information

What is the main improvement that should be achieved in managing research vessels?
Another way of using the existing fleet more efficiently is to increase the number of their potential users. Joint cruises are an excellent integrating instrument. They could cover the integration of two or more national cruise proposals to work on the same geographical site on a single large platform, each partner covering part of the cost. Joint cruises could give access to large, well-equipped vessels to scientists from countries where such infrastructures are not available.

Do different countries have different challenges when it comes to managing research vessels?
European countries that own research vessels available to the scientific community have different ways of funding the running costs of research vessels. In the case of large countries with a large research fleet, running costs of the research fleet are fully or partly covered by their government. There are, however, other countries with smaller research fleets or with only one research vessel, whose running costs are not fully guaranteed by public national funds. These vessels are often underfunded or the funds have to come from other sources, e.g. commercial charter work.

Unmanned survey capacity is increasing. Does this get the attention of the ERVO members? What could be the significance of unmanned survey vehicles for the members and the organisation?
The trend is clearly towards more capable, autonomous vehicles able to collect huge



▲ *AUV* Abyss*. Image courtesy: GEOMAR.*

amounts of data or map the seabed in real-time and high-resolution. This equipment will become heavier and must be deployed precisely at a specific location. All these factors will also require new technical adaptions on the European research vessels.

How does GEOMAR look at unmanned survey capacity?
GEOMAR is home to the autonomous underwater vehicle AUV *Abyss*, which is a modular AUV designed to survey the ocean combining geophysical studies of the seafloor with oceanographic investigations of the overlying water column. The basic mission of *Abyss* is deep-sea exploration. With a maximum mission depth of 6,000 metres, the AUV uses several technologies to map the seafloor accurately and determine its geological structure with applications from geology to biology to mineral exploration.

Could you provide more information on unmanned survey capacity?
In recent years, autonomous underwater vehicles (AUVs) have become an important tool for marine scientists to learn more about our world's oceans and large water bodies. Today's AUVs are able to gather data in orders of magnitude greater than the traditional approach, operating at a low portion of the overall costs. The enhanced AUV architecture enables the deployment of a variety of new sensors, allows onboard data processing and decision making, and supports coordinated swarming behaviour through underwater and surface communication. Swarming patterns include search and tracking behaviours. A search behaviour involves AUVs that dive over a particular physical search area in a synchronised fashion. Communication is used to exchange and adjust AUV positions during the search. Tracking behaviours are useful to observe and follow dynamically developing oceanographic phenomena. In addition to single remotely-controlled and autonomous underwater vehicles, ongoing research deals with construction of coordinated missions to be performed by groups of such vehicles. Cooperation of multiple AUVs in a single mission can provide enormous advantages in terms of navigation and communication.

The trend is clearly towards more capable, autonomous vehicles

What do you think of initiatives such as the Shell Xprize?
Initiatives such as the Shell Xprize encourage scientists from all over the world to explore the oceans with new solutions. Such initiatives will accelerate innovation for the unmanned exploration of the unknown parts of the deep sea. Therefore, I consider such initiatives to be extremely important to improve our knowledge of marine autonomous technologies.

You will be ERVO Group chairman for two years. What will be your biggest achievement once you handover to your successor?
In cooperation with the European Marine Board (EMB), ERVO will publish a newly edited version of the catalogue *European Ocean Research Fleets* in the next two years. This catalogue will register all research vessels and large-scale facilities used in Europe. I hope that our contribution will make the ERVO group more visible in the European community. ◂

Dr. Klas Lackschewitz is a graduate geologist with a focus on marine geosciences and has carried out numerous cruises (>30) on national and international research vessels as part of his scientific work. Dr. Klas Lackschewitz has been a research vessel coordinator at the GEOMAR Helmholtz Institute for Ocean Research in Kiel since 2010 and a member of the ERVO Group, which he then took over in June 2017. He has lead the advisory group on the scientific and technical equipment of the new research vessel, which succeeds the German RVs *Meteor* and *Poseidon*, since October 2016.
✉ klackschewitz@geomar.de

Tarragona Survey of the Riu Francoli Using a USV

Unmanned Mapping of Ultra-shallow Waters

Hydrographic surveying in ultra-shallow, inland and enclosed waters can prove extremely challenging and often presents increased risks and obstacles to both personnel and equipment. These considerations include health and safety issues, potential damage to equipment, lack of suitable launch sites and regions where submerged debris and physical seabed characteristics can make an area particularly hazardous to survey. In these locations, traditional manned survey vessels are often unsuited, inefficient, or incapable of completing a successful survey. In November of last year, Unmanned Survey Solutions, with support from Swathe Services, were tasked with completing a hydrographic survey of such an area.

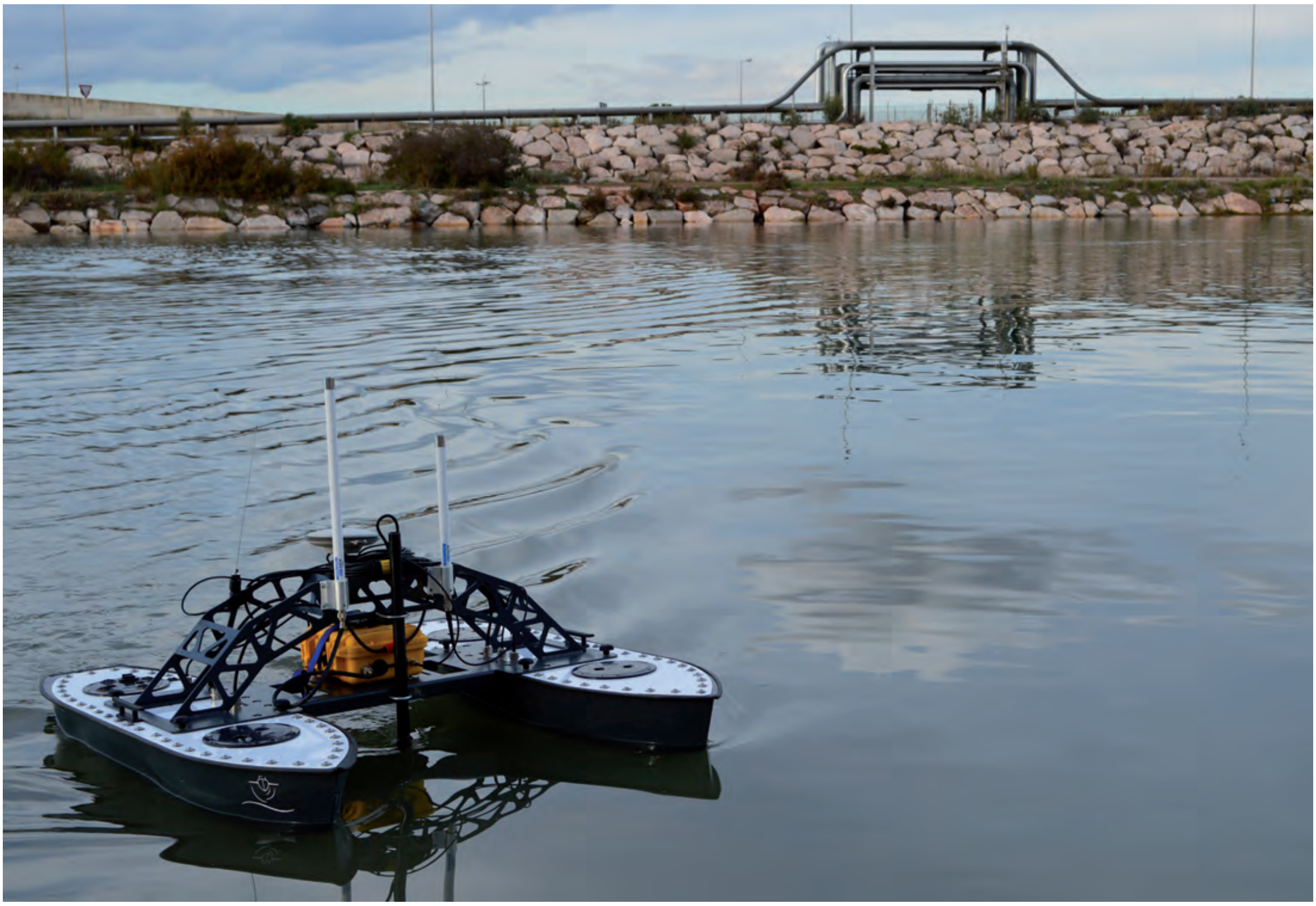


Figure 1: The USS Inception Class USV with CEE HydroSystems CEE-SCOPE USV survey system onsite in Tarragona.

Located in North-Eastern Spain, the Port of Tarragona is one of the leading port operators in Catalonia and sets a benchmark for the maritime and port community across Spain and the Mediterranean. In 2015, almost 33,000,000 tons of goods and 2,721 vessels passed through the port. The port authority required a bathymetric survey of a previously uncharted section of the Riu Francoli, which flows into the busy port. The port authority wished to assess the site for potential future development and required an initial bathymetric survey and appraisal of the site. The port authorities required sub-decimetre horizontal positioning accuracy and decimetre depth accuracy. The area was previously uncharted due to extremely shallow sections with submerged rocks, extensive sections of weeds and other hazards. This made much of the proposed survey area inaccessible to manned vessels and, as such, rendered the use of traditional survey methodology near impossible. Instead the recently developed Inception Class USV Mark I was used.

The USS Inception class USV has been developed specifically to address the large area ultra-shallow water sector. This unmanned hydrographic survey vessel is composed of tough aluminium hulls, weed cutting propellers and offers optional payloads. It has a lightweight modular design, which allows for easy transport, mobilisation, deployment and recovery and was a requirement for this project as the only suitable site for launching the USV was from a small pontoon, normally used for launching racing class sculling boats. The payload incorporated a CEE Hydrosystems CEE-SCOPE USV, which is a combined Single Beam Echo Sounder (SBES), Real Time Kinematic (RTK) capable Global Navigation Satellite System (GNSS) and Telemetry system. Data was transmitted real-time back to shore where it was recorded in the HYPACK survey software. RTK corrections were transmitted from a shore base station setup over an existing nearby benchmark.

Method

USS surveyors checked and loaded the Inception USV and payload into the company vehicle in the UK and then embarked upon a 2,500-mile round trip. Upon arrival at site, quite a crowd had gathered, not in anticipation of the USV, but due to the presence of a 'never seen before' storm surge coursing its way upriver, right through the survey site. An ominous start to the week's operations! Following an initial safety and deployment assessment, and once the surge had subsided, the Inception and RTK base station were mobilised and deployed. With

▲ *Figure 2: The area of survey at the Port of Tarragona, Spain.*

▲ *Figure 3: The Inception USV with a bulk carrier vessel in the background.*

Figure 4: Operation of the Inception from a rocky embankment.

the site surrounded by rock embankments, health and safety dictated a two-person survey operation.

Once deployed, the USV was remotely piloted from shore with the aid of the HYPACK navigation display. At a survey speed of ~2.5 knots, the total linage required to provide sufficient coverage of the 150,000m^2 area was completed within 3 days using a 10 to 20-metre line spacing to achieve sufficient bed coverage. Dependent on tide, the upper section of the river was particularly shallow with depths of less than 50cm in some areas. The Inception with a CEE-SCOPE USV payload, has a draft of only 20cm, which allowed access to even the shallowest of areas.

The Inception and payload required a battery change or re-charge approximately every 4 hours. The batteries were swapped in the middle of the day and took 45 minutes for recovery, exchange and redeployment. Contours and TIN models were created near real-time, allowing for initial charts and onsite Quality Control.

Conclusion

The Inception and its payload proved to be a successful and effective survey solution and was well suited to meet the Port of Tarragona's requirements. The weed cutting propellers sliced through the encountered reeds and vegetation efficiently and therefore prevented the Inception from getting stranded on numerous occasions. The rugged design and tough aluminium hulls fared well against the numerous submerged rocks and debris present in the survey area and returned safely to the UK with only minor scratches. The twin hull design combined with the minimal transducer draft afforded the transducer a level of protection and it emerged on completion of the survey completely unscathed. The deliverables provided the port authority with a perspective and insight into that section of the Riu Francoli river.

Figure 5: The shore-based telemetry link unit.

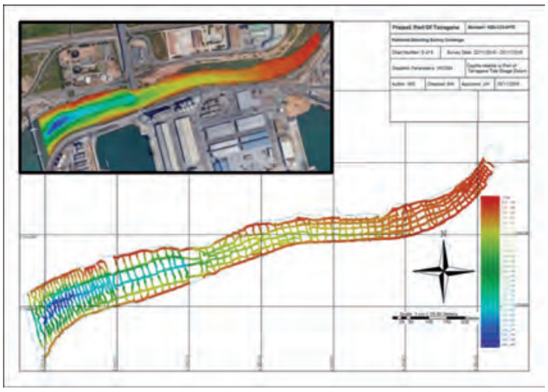


Figure 6: Final chart.

Mark Gray is a hydrographic surveyor at Swathe Services, which offers equipment rental, sales support and personnel to the marine hydrographic survey industry in the UK and Ireland. Graduating from the University of Plymouth last year with a distinction in MSc Hydrography, Mark has since been gaining skills and experience across the various hydrographic disciplines with Swathe Services.

Inland Survey

iXblue's Sub-bottom Profiler Solution

The need for lake and river surveys constantly increases as human activity expands in these areas. While navigation remains a main focus, nowadays other applications such as hydraulic construction inspection, biomass and resource control, pollution tracking or historical sedimentology represent a significant market share.

This article has been brought to you by iXblue.

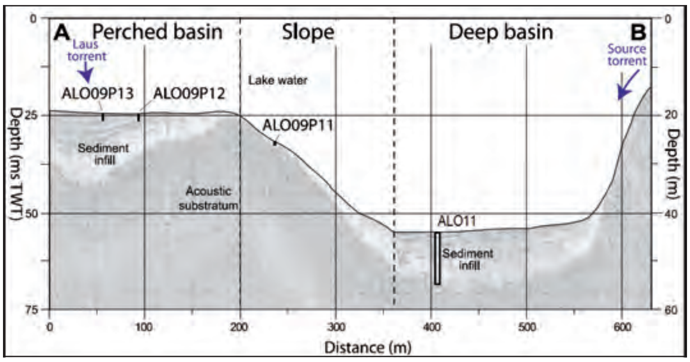
Operational and technical challenges in this new type of inland survey often relate to difficulty of access to survey sites, significant constraints on equipment size and weight, energy, as well as the need for acquiring very high-resolution data with a limited crew. As iXblue strives to develop complete solutions for demanding environments, tightly integrated sensors and software are proving to be a successful solution to cater for these inland water survey requirements. The Inertial Navigation System delivers precise positioning data even when GPS is masked by bridges or mountains, while the compact sub-bottom profilers deliver precious high-resolution data depicting near-surface geology and sediments. This equipment can be pole-mounted on small crafts, allowing for quick response times and access to difficult areas with perfect geo-referencing. The multi-sensor software processes the collected surface and sub-bottom data both in real-time and offline, adding see-and-act capability during survey and 2D/3D tools for interpreting the complete dataset.

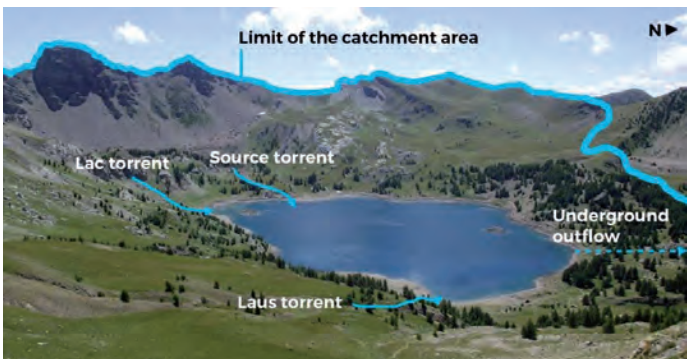
The two following case studies describe instances of how users benefitting from these technologies are succeeding in surveying such challenging environments.

Climate History and Altitude Lake Sediments

A consortium of French universities, including the LIENSs Laboratory of La Rochelle University, the EDYTEM Laboratory of Chambery University and the GEOAZUR laboratory at Nice University, studying the high altitude lakes of the southern French Alps, has succeeded in conducting

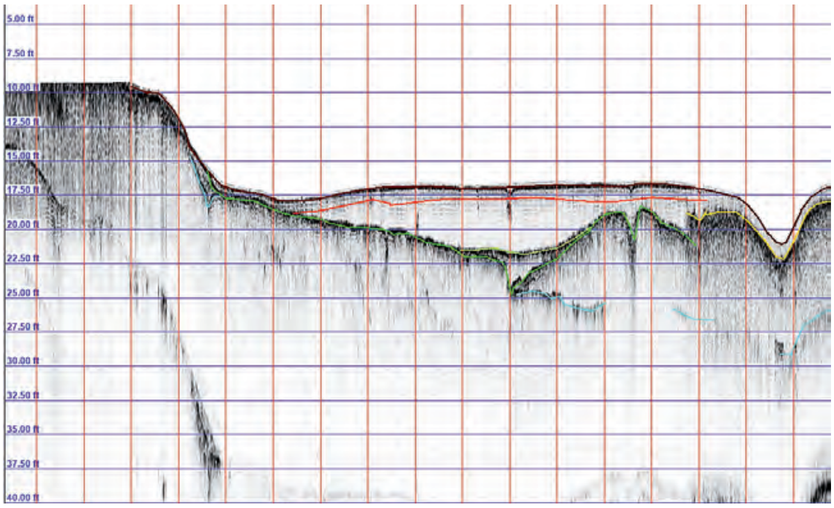
▲ *Eric Chaumillon and Pascal Tiphaneau (both La Rochelle University)*





▲ *Photograph of Lake Allos and its catchment area.*

seismic surveys, under the direction of Eric Chaumillon (La Rochelle University), using a balloon-mounted iXblue Echoes 5000 sub-bottom profiler. Since all devices were airlifted by helicopter, the seismic surveys were conducted from a small inflatable boat. Coring sites were chosen in real-time from dense pseudo-3D seismic grids.
In the Allos Lake study, the explored sediments revealed ~160 graded layers of flood deposits, stretching over the last 1,400 years. Comparisons with records of historic floods support the interpretation of flood deposits and suggest that most recorded flood events are the result of intense meso-scale precipitation events (Wilhelm et al., 2012). There is no evidence for any major changes in erosion processes in the catchment since the Medieval Warm Period. Records at Allos Lake, combining SBP profiles and coring, bear witness to repeated intense precipitation events over the last millennium, with a low flood frequency during the MWP and more frequent and more intense events during the Little Ice Age.
Subsea compact and stable assembling perfectly fit the purpose of such surveys and most requested scientific accuracy layer discrimination.



▲ *Seismic profile of Van Etten Lake (Michigan, USA).*

LAKE POLLUTION SURVEY

AFFILIATED RESEARCHERS utilised an iXblue Echoes 10,000 to conduct sub-bottom profiling surveys beneath an inland lake in order to map sub-terrain conveyance of contaminated groundwater.

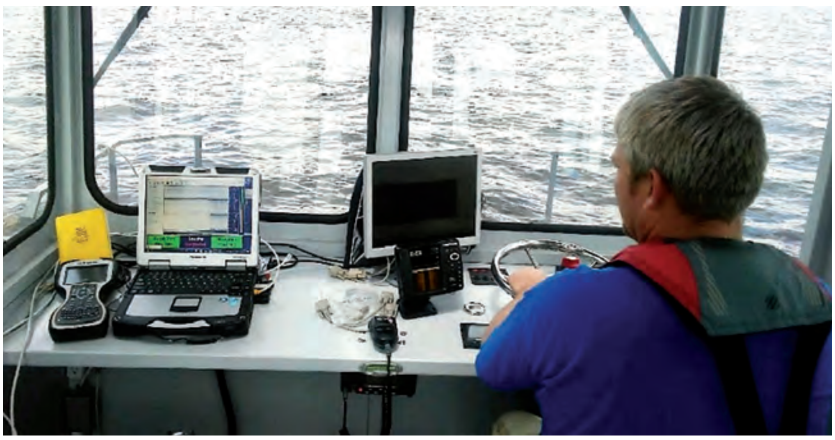
As part of ongoing groundwater investigations at a former military installation, AFFILIATED RESEARCHERS conducted a sub-bottom profiling survey of the stratigraphy beneath an adjacent inland lake. AFFILIATED RESEARCHERS successfully utilised an iXblue Echoes 10,000, high-resolution sub-bottom profiler (SBP) to survey the clay, sand, and gravel substrates beneath the lake for purposes of mapping the potential conveyance of contaminated groundwater.
For this project, AFFILIATED RESEARCHERS used the high-quality iXblue Echoes 10,000 SBP system, capable of 5-15kHz variable chirp frequencies and 3" resolution.
The project Hydrogeologist was very impressed and pleased with the performance of the Echoes 10,000 SBP system, as it was able to penetrate to a depth of more than 25' into the clay, gravel, sand substrates, and provide detailed image-data of the lake bed stratigraphy. The SBP data were compiled to develop digital terrain models of the stratigraphy of the lake, and to enable the mapping of potential channels of groundwater conveyance.
AFFILIATED RESEARCHERS' experience with shallow-water SBP spans a decade of real-world applications with several different types of SBP systems, on numerous projects, under various site conditions throughout the United States. The Echoes 10,000 SBP system was selected for this project because of:

- its excellent penetration and resolution capability in shallow-water environments;
- the ease of its deployment from a relatively small, shallow-water vessel; and,
- the powerful and versatile Delph software used for data collection and processing.

The Echoes 10,000 SBP system performed beyond expectations, providing a wealth of geophysical data on the sub-bottom stratigraphy, that will prove invaluable to the project scientists, engineers and managers in their work to further environmental restoration efforts in this area.

Conclusion: whether inland or at sea, a fully integrated SBP solution transforming transducer signals into real-time or post-process geophysical & georeferenced image display demands top-level acoustic systems expertise.

Acknowledgements
Many thanks to Eric Chaumillon and Rollin C. Reineck, Jr. for their contribution to this article. ◀



More information:
www.ixblue.com

Creating a 3D Landscape Model of a Gravel Quarry in Germany

Integrating **UAS and Multi-beam** Echosounder Data

Knowing the volume of material present in a gravel quarry can make the difference between profit and loss. A gravel quarry in Hartheim am Rhein, southwest Germany, is partially covered by artificial lakes. To determine the volumes of both the above-water gravel dumping grounds and the water in the lakes, high-precision data captured by a UAS was combined with multibeam echosounder data obtained by boat. The author describes acquisition of the two types of data, how they were integrated and the benefits for the mining company.

Figure 1: Simultaneous hydrographic and air survey.

A gravel quarry is associated with diggers, rough terrain, artificial lakes and heavy vehicle traffic. Surveying should not hinder the digging work as this would waste time and thus affect revenues. Therefore, to avoid interruptions or delays, the quarry site was captured by an unmanned aircraft system (UAS) while the lakes were mapped from a survey boat equipped with a multibeam echosounder (Figure 1). Both surveys were conducted simultaneously. Not only does the use of a UAS avoid interruptions to the digging work but it also prevents surveyors having to venture onto hillsides or slippery slopes on foot to install a levelling rod, a GNSS pole or a total station prism. It is thus a very safe surveying technology and also eliminates a considerable amount of on-site work.

Quarry Site

The Hartheim am Rhein site, run by Knobel-Bau GmbH, is the biggest quarry site in southwest Germany. Located alongside the A5 motorway and covering 55 hectares, the quarry includes two artificial lakes both resulting from the removal of gravel (Figure 2). The lakes are flanked by trees, rocks and agricultural fields on one side and by the motorway on the other. A municipal road divides the quarry into two separate areas. On both lakes, floating dredgers excavate gravel on five to six days per week. The banks are largely inaccessible and the mined gravel is stored on two dumping grounds. There is a single access road leading to the two lakes, which are not connected. A trailer is required to

▲ *Figure 2: The Aibot X6 in operation at the quarry site (image courtesy: Bernd Schmidt).*

move the survey boat from one lake to the other. This is a time-consuming endeavour which involves a team of three engineers in its planning and execution.

Equipment

The Aibot X6, a hexacopter with a diameter of 105cm and a height of 45cm, has an unladen weight of 3.4kg and can carry a maximum payload of 2kg. Equipped with the Nikon Coolpix A, a standard camera with a CMOS sensor and rolling shutter, the take-off weight of 4.75kg guarantees a maximum stay in the air of 15 minutes under optimal conditions. The maximum speed of 40km/h makes it possible to fly over the furthest corners of the quarry within the 15 minutes of available flight time. The UAS works with a standard GNSS resulting in a precision of 2cm, which is more than enough for the present application. The flights can be conducted with or without automatic take-off and landing, position hold, point-of-interest hovering or other support functions. The navigation sensors, including GNSS, gyroscope, accelerometer, barometer, magnetometers and ultrasonic sensors, allow the Aibotix AiProFlight flight planning software to execute nearly fully autonomous flights. The gimbal supports the

Official permission is needed to fly over motorways and most cities

▲ *Figure 3: Survey boat.*

switching of the sensor within minutes. The survey boat, built in 2011 by Lorsby in Winsen/Aller, Germany, is equipped with a multibeam echosounder and a Leica GNSS receiver (Figure 3). The echosounder measures single depth points in grid cells of 20cm x 20cm. A total station on the ground, the Leica Nova MS60 MultiStation, captures additional measurements of terrain features.

Legislation

In Germany, official permission is needed to fly over motorways and most cities. Legal regulations prescribe that flights have to be executed in line of sight and the pilot must be able to control the UAS manually at all times (Figure 4). To guarantee safe operation, two pilots executed the survey: one operated the UAS and the other assisted in sighting the UAS. Commercial operation of a UAS requires permission from the local aviation safety organisation and the police must also be informed. While it was easy to obtain the relevant permission, it was a challenge to plan the survey without flying over the motorway since it passes some parts of the quarry at a distance of just 10 metres.

Survey

Using Aibotix AiProFlight, it is possible to plan the flights both in the office and on site. The pilot can define all waypoints and the camera exposure positions using a PC or a tablet and upload the survey details wirelessly. For experienced pilots, the planning procedure only takes a few minutes. The weather during the survey in November 2015 was sunny but windy. The image capture was planned to be carried during five individual flights while flying at a height of 90m above ground, but due to the wind the decision was made to increase the number of individual flights to seven. To ensure safe flights the wind speed should not exceed 6m/s and the planned flying time should allow for a margin of 30% of the total flight time as back-up. For GNSS positioning, 10 satellites could be tracked during the flights. For georeferencing purposes, 12 ground control points were distributed over the area so as to ensure visibility from the air.

Eight Days Only

To create the deliverables, the data captured from the ground, water and air had to be combined. Back in the office, a digital surface model (DSM) with a grid spacing of 4cm and an orthomosaic were created from the UAS imagery using Agisoft PhotoScanPro. The georeferenced depth values acquired by the hydrographic survey were processed using Autodesk AutoCAD to generate a DSM of the lake bottoms. Next, both DSMs were

▲ *Figure 4: The author monitoring an autonomous UAS flight (image courtesy: Benjamin Federmann).*

▲ *Figure 5: Orthoimage superimposed with contour lines.*

combined in AutoCAD to compute volumes of the terrain features and the lakes and to generate contour lines. The contour lines were superimposed on the orthoimages (Figure 5). The entire project took eight working days, from planning, execution of the flights and the hydrographic survey to the final volume calculation, orthoimage generation and the creation of the 3D landscape model (see Figure 6).

The project took eight working days, from planning and execution of the flights to the creation of the 3D landscape model

The orthomosaic with contour lines and the 3D landscape model provide the mining company's management team with all the information necessary for monitoring and managing the exploitation of the quarry. A DSM automatically generated from imagery may contain artefacts. Although not 100% realistic, the virtual representation of the quarry in the form of 3D landscape models has been an eye-opener for the managers as it gives them at-a-glance insights into what is on the ground and hence enables them to improve their plans and save costs. The products have also been used to update all site plans, and bimonthly or quarterly updates are envisaged for the future.

Concluding Remarks

The biggest challenges in this project were posed by the flight restrictions around the quarry, with the two lakes and the wind adding to these challenges. The combination of aerial, hydrographic and ground-based total station data made it possible to considerably reduce the costs for monitoring the quarry site. ◂

▲ *Figure 6: 3D landscape model of the quarry.*

This article has originally been written for, and published in, *GIM International*.

More Information

- www.it-geo.de
- Video: bit.ly/uasandmultibeam

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To Process Data from a Survey with CARIS HIPS

General Description of XML File CUBE Parameters

Interferometric sonar acquire millions of soundings in a hydrographic survey. The processing of these data by a hydrographer without a reliable statistical algorithm like CUBE (Combined Uncertainty and Bathymetry Estimator), to obtain a bathymetric map, would be practically impossible. CARIS HIPS software allows the use of the CUBE algorithm, invented by Dr Brian Calder, with an editable XML file to process the millions of soundings acquired in a survey. A good adjustment in the values of these parameters improves the outcome of the CUBE model, obtaining a seafloor as close to reality as possible. The values of these parameters mainly depend on the working depth, the roughness of the seafloor and the equipment used.

CUBE is a very complex statistical algorithm that uses all the information from acquired soundings to assign the most probable depth of the proposals with their respective uncertainty value, in accordance with the established resolution, to each position. CUBE generates hypotheses (depth values) and selects the best solution in each position, according to the values of the XML file parameters.

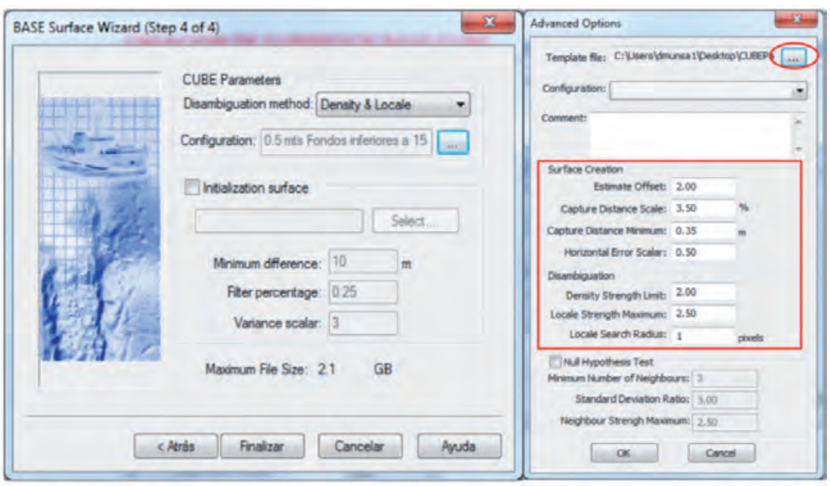
CUBE model is a mathematical representation of reality. Therefore, if data from the survey are of a good quality (good sea state, high overlap between adjacent lines, high updating of sound velocity in the water column, adequate speed of the boat/vessel, etc.) and CUBE parameters of the XML file have a good adjustment, the bathymetric model will give efficient results, resembling the seafloor. Otherwise, the bathymetric model will be less similar to the real seafloor, and the hydrographer will spend more time processing acquired data.

Generation of Hypotheses in CUBE

Generally speaking, it is possible to wonder which soundings have greater weight than others in a node, and how CUBE generates hypotheses. The weight assumptions are:

- Soundings with a low vertical uncertainty have greater weight than those with higher vertical uncertainty.
- Soundings with a low horizontal uncertainty have greater weight than those with higher horizontal uncertainty.
- The closest soundings to the centre of the node have greater weight than those that are far away.

It is important to highlight that from these assumptions the importance of knowing all uncertainties of the equipment used in the system are deduced because the CUBE algorithm depends on them.

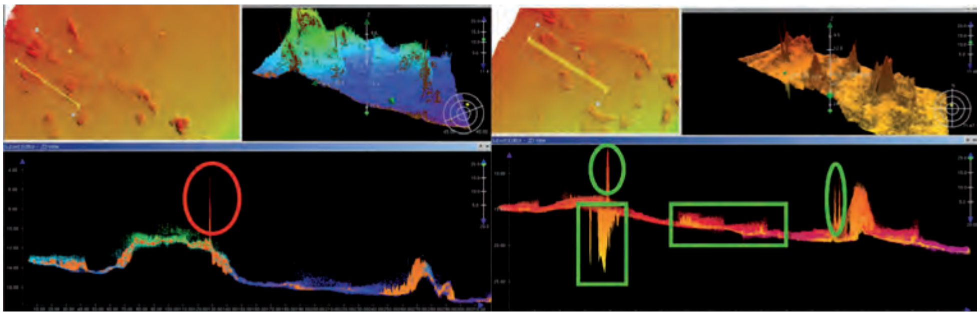


▲ *Figure 1: CUBE parameters of the editable XML file.*

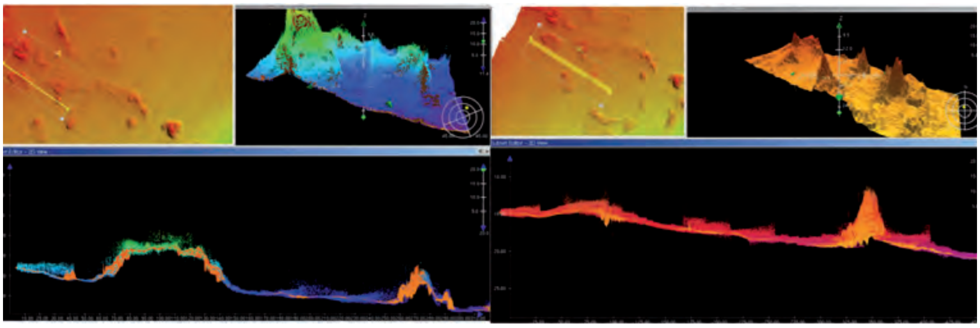
Hypotheses are generated at each node. There may be more than one hypothesis per node. If the value of a sounding does not vary from the previous soundings significantly, the value of the hypothesis is maintained. However, if the value of the sounding varies with respect to the previous soundings, a new hypothesis will be generated. All this is related to the survey quality. If the data are of poor quality there will be a greater dispersion of data and more hypotheses will be generated.

Disambiguation Methods to Determine the best Hypothesis

Starting from the premise that acquired data are of high quality, it is only necessary to analyse



▲ *Figure 2: When using the default XML file, the resultant CUBE model is coarse, which does not represent the real seafloor.*



▲ *Figure 3: When adjusting parameters of XML file efficiently, the final CUBE model represents a more realistic seafloor.*

which values are the best to use in the XML file. For this, it is necessary to know, in general terms, how the CUBE algorithm works.

CUBE parameters are set in accordance with two methods of disambiguation, namely density and local.

- The 'density' method selects the hypothesis that presents the largest number of soundings at the same depth in the node (in accordance with the established resolution).
- The 'local' method selects the hypothesis that is more consistent with the neighbouring nodes, in compliance with a set of constraints. This method, which is more difficult to understand, works as follows:

A bathymetric map that resembles the real ocean floor

A radius of influence is established around the node of interest, controlled by the parameter 'locale radius'. Only the nodes within this radius are used to determine the robust average depth, according to the values of parameters 'density strength cut-off' and 'locale strength max' (minimum and maximum thresholds of this method respectively), which have the same scale as the hypothesis strength.
For each node, in its radius of influence, is determined if the hypothesis strength (which is 5 x [1 - (number of consistent soundings / number of soundings per node)]. The lower the hypothesis strength value, the better) is acceptable. If so, the best hypothesis (i.e. the lowest hypothesis) is used in each node of the radius of influence. Otherwise, that node is omitted in the calculation.

With the best hypothesis of the nodes that influence the radius of influence of the node of interest, an arithmetic mean of soundings is computed, discarding the extreme soundings of the nodes in the radius of influence, i.e. the average value of depth of adjacent nodes that influence the radius of influence of the node of interest without considering the depth of the adjacent nodes with the highest and lowest value. Finally, the algorithm in the node of interest selects the hypothesis with the closest depth to this robust average value.

Therefore, it is recommended to use a combination of both methods. At first, each node selects the hypothesis containing the largest number of soundings at the same depth (density method), and if the value of the hypothesis strength of a node is greater than the cut-off value of the parameter 'Density strength

CUBE parameters/Type of seafloor at 1 metre resolution	Flat seafloor	Varied rocky seafloor	High gradient seafloor
Estimate Offset Value	8	7	6
Capture Distance Scale Value	7	5	5
Capture Distance Minimum Value	0.6	0.5	0.5
Horizontal Error Scalar Value	2.0	1.5	1.5
Density Strength Cut-off Value	1.5	1.5	2.0
Locale Strength Maximum Value	3.0	3.0	2.5
Locale Radius Value	8	2	2
CUBE parameters/Type of seafloor at 2 metre resolution	Flat seafloor	Varied rocky seafloor	High gradient seafloor
Estimate Offset Value	9	5	5
Capture Distance Scale Value	6	6	6
Capture Distance Minimum Value	1.2	1.2	1.2
Horizontal Error Scalar Value	2.0	2.0	1.5
Density Strength Cut-off Value	1.5	1.5	2.0
Locale Strength Maximum Value	3.0	3.0	2.5
Locale Radius Value	5	2	2

▲ *Table 1: Possible values to use in CUBE parameters XML file with an interferometric sonar, at resolution 1 and 2 metres, depending on type of seafloor.*

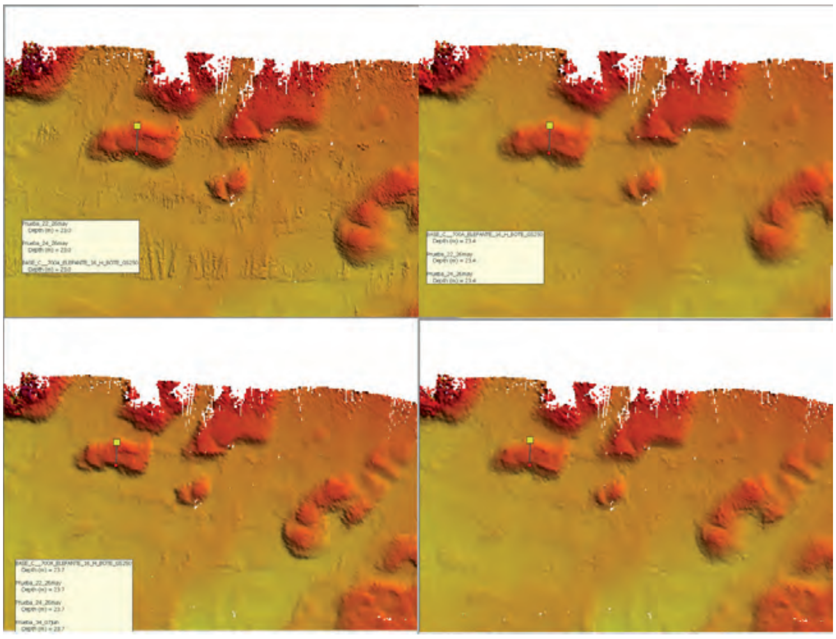
Hydro17

The Hydro17 Conference in Rotterdam is approaching rapidly. The event on board the ss Rotterdam will take place between November 14th and 16th in Rotterdam, The Netherlands. The theme of this year's conference is "Connecting 4D Future". An attractive programme and a selection of special keynote speakers offer inspiration and food for thought. A broad range of companies present their products and services in more than 40 stands located on two decks of this unique venue. Throughout the event workshops, commercial presentations and on water survey demonstrations may be visited. Connecting for the future will kick-off at the Icebreaker Party on November 13th on board the ss Rotterdam.

Our keynote speakers are:
Peter Westbroek, Mathias Jonas, Rob Luijnenburg, Alok Jha, Martijn Manders.

The themes of the presentations are:
Airborne/Lidar, Autonomous Survey, Backscatter, Bathymetry, Construction Support, Cross-border Challenges, Data Processing, Education, Morphology.

The ss Rotterdam offers comfortable accommodations which allows delegates to further meet and connect after closures of the official daily programme. For more information please visit our website: hydro17.com



▲ *Figure 4: The following mosaic of images illustrates how comparisons have been made in specific working areas, depending on the type of seafloor, with varying CUBE parameters at different resolutions.*

cut-off' and lower than the value of the parameter 'local strength max', the local method is used to select the closest hypothesis to the robust average depth (see Figure 1).

CUBE Parameters of the XML file

After modifying CUBE parameters one by one, and generating more than 40 XML files to analyse the results in different types of seabed, the final conclusions are:

Estimate Offset Value: It is the threshold to generate more or fewer hypotheses. It is advisable to increase its value to generate fewer hypotheses, when acquiring quality data.

Capture Distance Scale Value: It is a value (in percentage) for an estimated depth, using a radius of influence (for the soundings) to determine the data at each node. If, for example, the value 3.5 (3.5 x depth) in an area where the mean depth is 20m, the radius of influence would be 0.7m.

CUBE model is a mathematical representation of reality

Capture Minimum Distance Value: This value (in metres) is used along with the previous parameter (Capture Distance Scale) to limit the minimum search radius and determine the data. The recommended value to use depends on the used resolution (it could be a value close to the value of the hypotenuse of the right-angled triangle formed by the sides that each one measures half resolution).

Horizontal Error Scalar Value: The value used to exaggerate or reduce the horizontal uncertainty scale of each sounding. The recommended value would be 2. However, it may be also reduced.

Density Strength Cut-off Value: It is the value of the hypothesis strength used to change the disambiguation method, from 'density' to 'local'. The default value to use is 2. However, it may be reduced to 1.5.

Locale Strength Maximum Value: It is the maximum value of hypothesis strength allowed in the local method so that weaker hypotheses do not influence the calculation. The default value is 2.5. However, it may be increased up to 3.0, giving good results.

Locale Radius Value: It is the search radius for the calculation of the average value of neighbouring nodes. The value is in nodes and its default value is 1. However, it is recommended to increase this value.

Conclusions and Recommendations

On the condition that all data are of good quality, the use of CUBE algorithm in CARIS HIPS with an effective adjustment of its parameters in the XML file allows the hydrographer to reduce processing time to obtain a bathymetric map that resembles the real ocean floor (Figures 2 and 3).

The study and analysis conducted on the statistical model CUBE and the wide variety of tests performed in different survey areas, at different resolutions, has given rise to convincing conclusions in different types of ocean floor, with data from an interferometric sonar (Figure 4).

Therefore, it is advisable to generate CUBE parameters for each system, depending on type of seafloor, the depth and the desired resolution. ◀

More information

CUBE User's manual v. 1.13 (2007), Brian Calder, David Wells, University of New Hampshire.

Lieutenant Commander **Gustavo Adolfo Gómez-Pimpollo Crespo** is Hydrographic Engineer, and has been the Commanding Officer of R/V *Malaspina* since July 2017. He started his studies in Hydrography in 2005 and he has worked on board various hydrographic vessels (R/V *Tofiño*, R/V *Rigel* and R/V *Antares*) and in the Hydrography Section of IHM as data validation and processing chief since then.

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Evolution Towards Higher Accuracies

Technology in Focus: GNSS Receivers

GNSS has now been operational in the surveying industry, and especially in hydrography, for more than 25 years. Where the first receivers such as the Sercel NR103 (once the workhorse of the industry) boasted 10 parallel GPS L1 channels, current receiver technology has evolved to multi GNSS, multi-channel and multi-frequency solutions. In this article, we will look at the current state of affairs and try to identify the areas where development can be expected in the years to come.

In hydrography, we can distinguish between 'land use' and 'marine use' of our GNSS receivers. Especially in the dredging, nearshore and inshore domains both land survey as well as maritime receivers are employed. They do not differ in their basic capabilities such as positioning accuracy or number of channels (and GNSS) they can receive. The main differences lie in the form factor of the receiver (portable for land survey, rack mounted for marine survey) and the method of operation. Whereas a land survey receiver is almost always combined with a separate controller running extensive data acquisition software, the marine receiver is more and more of the black box type with at most a minimal display (and sometimes none). Setting of the pure marine receiver is done using a network interface with the computer browser whereas the positioning data is transported over the network (or if required RS232) connections to the data acquisition software.

GNSS Signal Reception

If we look at the major developments over the last few years, then it is the continuous addition of systems to the satellite constellation such as Beidou and Galileo as well as the longer existing GPS and Galileo. But even within the existing systems developments are ongoing, with new frequencies such as L1C, L2C and L5 being added to the spectrum of available signals. Most receivers are ahead of actual GNSS operations and will supply their receivers prepared to receive all GNSS and the maximum number of satellites and signals available. As a result, a modern receiver may boast over 400 channels with an average of around 200 channels in a receiver. A single channel will receive a single frequency from a single satellite for a single GNSS. Thus, current high-end receivers can track over 125 satellites at the same time! Be aware however that not all systems are currently at full operational capability (FOC). GPS and Glonass are at FOC whereas both Beidou and Galileo have limited coverage. Those working in the far East will benefit from Chinese Beidou, the Japanese QZSS and the Indian IRNSS as the local coverage is very stable. However, elsewhere in the world Beidou coverage is still marginal and QZSS and IRNSS coverage non-existent due to their regional character.

This is more evolutionary than revolutionary

	L5 / L5OC / E5a / B2a	L2 / L2C / L2OC	E6 / LEX	L1 / L1OC / E1 / B1
GPS	30	30		30
GLONASS	24	24		24
Galileo	30		30	30
BeiDou	35		35	35
QZSS	3	3	3	3
IRNSS	7			
	129	← ARNS* Bands	→	122

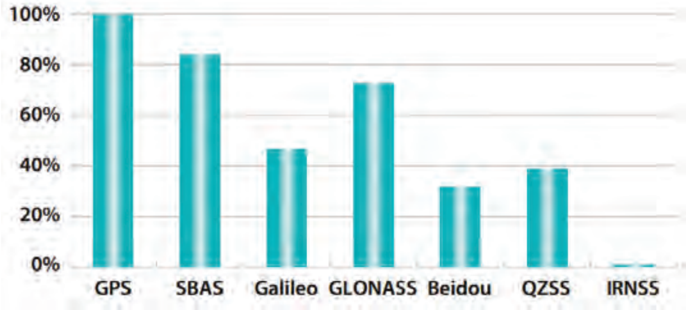
Frequency band used by the system, with N = number of satellites

Frequency band not used by the system

▲ *Figure 1: GNSS constellations, their associated frequencies and the number of satellites ultimately transmitting these signals [source: gsa.europa.eu]*

Signal Processing

The processing of GNSS signals is still being improved although this is more evolutionary than revolutionary. The availability of ever greater processing power allows the GNSS receiver to allow, for example, for a better multi-path rejection. Also, receiving weak signals and being able to detect the direct signal from a confused set of GNSS signals is currently possible. Better tracking and multi-path rejection is not only the result of higher processing power but also of developments in antenna design. Thus, it becomes easier to move the GNSS in difficult situations whilst still keeping relatively stable and accurate positioning. The increased computing power also makes it easier to implement algorithms that have an increased accuracy when processing multiple GNSS signals at the same time. The increased processing power also makes it easier to integrate Precise Point Positioning (PPP) and heading solutions on a single receiver board making the units effectively smaller.



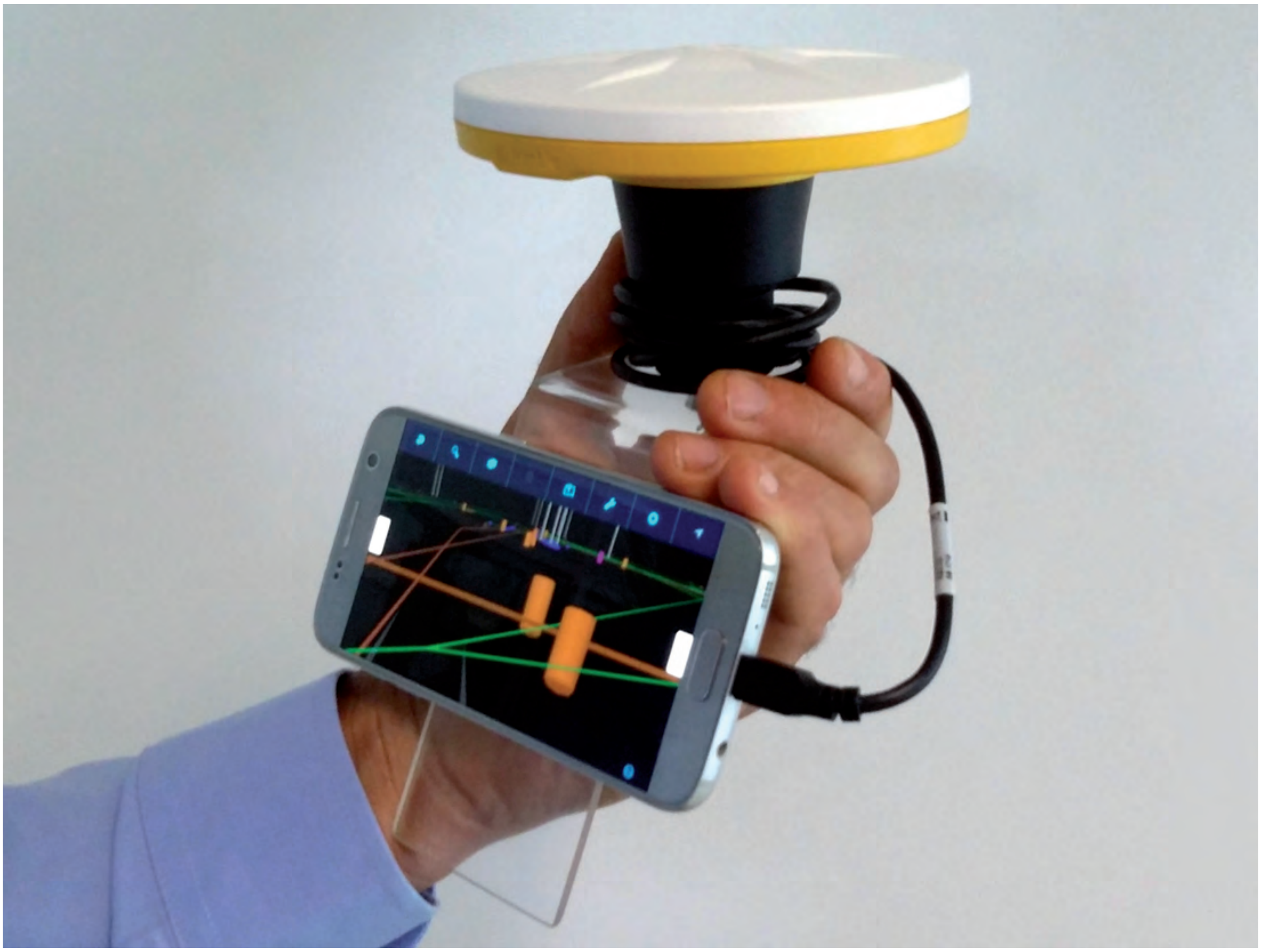
▲ *Figure 2: Percentage of GNSS receivers able to receive a certain constellation in 2016. Image courtesy: gsa.europa.eu*

In general, the use of PPP seems to be increasing with major suppliers of correction signals now supplying PPP corrections for all four global GNSS. Most professional receivers are now dual frequency receivers, but these are expected to be replaced by triple frequency systems as the Galileo commercial service becomes available and GPS will have introduced L5 in more satellites. Triple frequency processing promises even more accurate RTK and PPP solutions with faster initialisation times.

A modern GNSS receiver will start within a minute even in situations where it has not been started for a while if connected to the internet such as in most land survey receivers. Without assisted-GNSS start-up times can be longer for a cold start. Re-acquisition times are now well below 15 seconds with the more high-end receivers boasting re-acquisition times of just a few seconds in most situations.

Software Defined Receiver

One of the latest developments is the low-cost software defined receiver. Where a traditional receiver has all the processing power in a



▲ *Figure 3: Trimble Catalyst software defined receiver with an Android device connected capable of RTK solutions. Image courtesy: Trimble.*

Figure 4: Dynamic Positioning requires a high update rate without significant degradation of positioning accuracy.

standalone device, the software defined receiver uses the computing power of an existing device. This means that the actual receiver is reduced to an antenna and analogue-digital converter to allow the GNSS signals to be processed by the positioning device, for example, a tablet. The lack of dedicated hardware means that the software defined receiver is relatively cheap and lightweight and can be integrated into existing applications that have direct access to the positioning system rather than to just the output.

Triple frequency processing promises even more accurate RTK and PPP solutions

Data Output

As stated earlier, most modern receivers employ internet connection to transmit their data to the survey computer. Serial connection (RS232) is still available with modern receivers although the number of ports are being reduced in favour of the network connection. The frequency of data output is becoming higher with less latency for the signals with a higher update rate. While in the past the interpolation of 'intermediate' positions between the 1s formal output was very visible, modern GNSS receivers can output at relatively high frequencies without a significant degradation of positioning accuracy. However, most manufacturers still advise using the 1 second output if the utmost accuracy is required in favour of update rates of 20 – 100Hz. The main advantage of the higher update rates is that for applications where this high update rate is required such as in dynamic positioning it is available with a limited degradation of positioning accuracy, especially when operating in PPP.

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The Banana Belt – Southern Alaska

As opposed to the Alaskan Arctic, portions of south Alaska are relatively balmy with average annual temperatures approximately 28 degrees Celsius higher than Alaska's north coast, thus giving rise to the humorous name 'Banana Belt'. The weather here is modified by the warm Alaska Current, a remnant of the Kuroshio Current. Besides having relatively warm weather, Southern Alaska is a region of mountains interspersed with labyrinthine waterways, glaciers and rain forests.

Weather conditions range from glorious on some summer days, to seemingly continuous fog, torrential rains and winter blizzards. Areas with over 150 inches of precipitation are not uncommon in SE Alaska. Even today, much of this area is sparsely settled and is a veritable wilderness. Bears, wolves, and other wildlife are quite common on land while whales, seals, and sea lions frequent the waterways. Wild surf accompanying North Pacific storms pummels the outer coast while strong currents, tidal ranges between 10 and 30 feet, and numerous pinnacle rocks rising nearly to the surface added to the danger of navigating the channels. Numerous submerged rocks and pinnacles in Alaskan waters bear the name of the unlucky vessel that struck it and was lost. Potentially hostile natives, landslides, volcanic eruptions, and the occasional great earthquake and tsunami rounded out the pantheon of difficulties facing the surveyors. The United States Coast Survey began operations in this challenging environment in 1867 when coast surveyor George Davidson headed a party of scientists that studied the geography and resources of Alaska prior to completing its purchase from imperial Russia. Davidson's influential report was a factor in the completion of the purchase.

A few years later the Coast Survey vessel *Yukon*, commanded by William Healy Dall, was in Lituya Bay checking the accuracy of the old charts and determining the positions and heights of the surrounding mountain peaks that rose to over 16,000 feet. As noted in the Coast Survey report for 1874, "Vertical angles were measured to determine the heights of mountains in that region that serve as landmarks at sea. Observations for time, azimuth and latitude were made at Lituya Entrance, and the position given on most charts found to be erroneous. The chart of the inner bay, by La Perouse, was tested, and proved to be generally accurate. Here the party on the *Yukon* had much difficulty in preventing the persistent attempts of the natives to board the vessel, but fortunately they were kept off without bloodshed. It is added in the report that these natives distill their own rum, and are well supplied with the best kinds of firearms."

As the commercial riches of Alaska became apparent, demands were placed on the then Coast Survey (Coast and Geodetic Survey after

▲ *Figure 1: Survey launch* Wildcat *in Alaska.*

▲ *Figure 2: Launch, skiff and survey vessel* Cosmos.

▲ *Figure 3: Caught on a rock with the tide headed out. One of the hazards of having to find the rocks.*

▲ *Figure 4: Automatic tide gauge at Port Protection. Installation by Wire Drag Party No. 4.*

1878) to accelerate the surveying of its waterways. Ships were sent north to accomplish this Herculean task encompassing over 30,000 miles of tidal shoreline. This effort continues today. The methodology followed by the surveyors was basically the same up to the end of World War II. Captain Thomas Maher described the field season of 1911:

"I was placed in camp … to make astronomical observations for the determination of latitude, longitude, azimuth and magnetic variation, a plane table survey of the shore line, and in spare time a preliminary survey of the channel over the bar. Of course it was never thought that these Great Expectations would be realized, as it rained about fifty percent of the time and blew gales the balance. The ship party dumped our camp equipment and instruments on the beach and then departed immediately. That was part of the psychology underlying large scale surveying operations. Get away before the shore party finds out what they have been handed. I was a victim on numerous occasions, but the knowledge thus absorbed was very useful when I became Chief of Party."

"During the following year work was resumed in this general area. Storm followed storm and the indications by the barometer were unreliable. On these trips to the northward and westward, part of the crew and many of the officers would not see port nor civilization from the beginning to the end of the season, as they were often left in camp, to carry on survey work while the ship went to the nearest port for supplies. Survey work, mountain climbing, surf landings, soundings in tide rips, create a necessary cooperation and closer association than is customary aboard ship. Of course there was the natural gripe about food for which there was a foundation. For three months, while doing launch hydrography, the lunch consisted of beans, pork, coffee and bread." (Concerning launch lunch, the editor can attest from personal experience that the tradition of poor fare continued well into the 1970s.)

The practice of leaving parties ashore while the ship departed continued for at least another forty years in all Alaskan waters. Until the advent of radio communications, these parties were left to work on their own until the return of the vessel.

Storms were one problem for the surveyor, fog another. An example follows from the 1500-foot ridge leading north from Cape Muzon, near the southeastern tip of Alaska: "Our observing was over long distances, that to the Canadian side being forty or more miles in length. Frequent banks of fog swept in from the Pacific, obscuring distant stations, and twenty-eight ascents were made before the work was completed."

Not all was striving against unrelenting nature. H. Arnold Karo, a future director of the Coast and Geodetic Survey, was commanding officer of a small survey vessel working in Glacier Bay when the following incident occurred while a shore crew was conducting a plane table topographic survey:

"On this particular day the party was working in the bight south of Berg Bay - a particularly choice location for the elusive strawberry. Seeing the rodman waving frantically and hearing him shouting to hurry up with the rod readings, the rest of the party were at a loss to understand this sudden burst of activity on his part. After each rod reading he would literally run up the beach to the next point, and would again wave frantically and beseech the topographer to hurry and read the rod. He was rodding toward the plane table setup and as he rounded the point and approached closer, the reason for all this agitation was soon apparent; for rounding the point about a hundred yards astern of him, was a black bear of no mean proportions! Each time the rodman stopped to give a reading, Mr. Bear stopped still and stood upright, almost in imitation. When the rodman started up the beach, after him came Mr. Bear on all fours."

"This strange game of tag or "hare and hounds" was most amusing to the party gathered around the plane table. Closer and closer came the rodman and after him the bear. It soon became apparent that Mr. Bear was bent on a thorough job of investigating these strange creatures who had apparently interrupted his feast of strawberries. Having no firearms, the party armed themselves with the axe and stood their ground, although ready to take to the boat if necessary. The rodman reached the party and on came Mr. Bear. Brandishing the axe and clubs and letting forth blood curdling yells, the whole party gave a good imitation of a headhunter's dance. In spite of this unholy din, it looked as if a Kit

▲ *Figure 5: Tidal range at Anchorage. Low tide reading approximately 7.5 feet on the tide staff.*

Carson act was called for or else that discretion should be the better part of valor and the entire party would have to retreat to the boat. Just as the party was about to abandon its position, the bear turned around and lumbered off, having approached to within thirty yards of the party."

Sometimes working in the vicinity of glaciers could be dangerous. The following two incidents, as described by Lieutenant George Morris, occurred during a plane-table survey of Taku Inlet, an area rivalling Glacier Bay in scenic grandeur:

"At one time, the rodman had gone ahead to select a point for a plane table set-up. Stopping before the overhanging face, he called back, 'The glacier's dead along here, so this will be a safe spot and you can see well from here. Anyway, if it starts to fall, you can see it in time to run.' He marked the spot and returned to the table to help carry the equipment to the new set-up. A sharp crack made the group look up from collecting the equipment in time to see a huge block of ice break from the top of the glacier and fall with a thundering crash, completely obliterating his recently-pronounced "safe" set-up point."

"On another occasion, the topographer was working farther away from the shore, leaving the launch engineer to take care of the dinghy. In odd moments, the engineer took moving pictures of small pieces of ice falling from the face of the glacier. While so engaged, he failed to see a much larger piece than the one he was photographing fall into the water, but the loud crash made him look in time to see a small tidal wave racing towards the boat."

"… The engineer was out of the boat and making for the beach like greased lightning as soon as he saw the tidal wave. As it struck the dinghy both wave and dinghy came racing up the beach, but he was two jumps ahead -- he broke the sprint record for men dressed in oilskins and sea boots. The dinghy was deposited without damage nearly one hundred feet from the water line."

One thing was and is common to many of the surveyors who worked in 'Alaska's Banana Belt' – love for the wild country. Captain Maher captured that feeling in the following passage:

"I was greatly impressed by the magnificent scenery of the Inside Passage to Alaska, which afforded a panorama of grandeur, the memory of which has never been effaced, creating a longing to see, once again, one of nature's great masterpieces. The high mountains, the narrow deep channels, the currents and swirls in Active Pass and Seymour Narrows, the whirlpools and tide rips at Ripple Rock (a feature of the past), the currents in Peril Straits and Sergius Narrows, beautiful Wrangell Narrows, Mendenhall Glacier, majestic Mt. Edgecomb, seen when approaching Sitka - here we have nature's handiwork at its best."

(Editor's note: This article is based on information excerpted from http://www.history.noaa.gov/alaska_tales.html) ◀

▲ *Figure 6: This marine fauna was not in the textbooks: Alaska Brown bear (Ursus Arctos). Tide pooler's nightmare.*

The Dutch Marine Energy Centre

Marine energy refers to the renewable energy that can be generated from oceans, seas and rivers. The marine energy resources are contained in waves, tides, differences in salinity gradients and water temperatures. The Dutch Marine Energy Centre (DMEC) builds strategic collaborations to accelerate innovations in this emerging sector.

Marine energy is a relatively new form of renewable energy which is now reaching viability as potential commercial energy source. Compared to other renewable energy sources such as solar and wind power, marine energy is a reliable source of energy because of its high predictability. In addition, marine energy technologies can be integrated in existing delta and offshore infrastructures, making profitable multiple-use business cases possible. Another positive aspect is that the technologies have limited or even no visual impact. Moreover, and most importantly, the global potential of this sustainable energy source is significant; by 2050, an estimated 300GW of electricity can be generated globally. In Europe, it is expected that marine energy will generate 100GW of energy (10% of Europe's electricity demand), and create more than 200,000 new jobs throughout the entire supply chain.

Netherlands Solid in Marine Energy

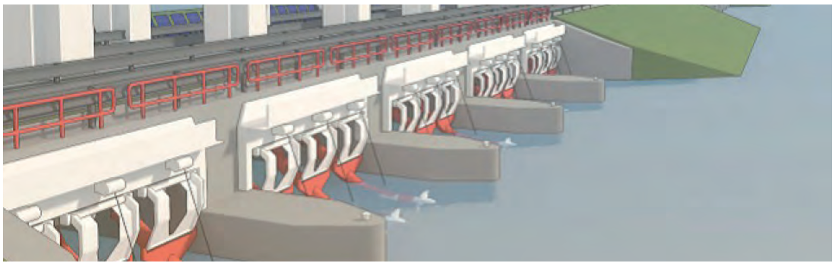
Current activities within the emerging marine energy sector are geared towards technology and project development, including the realisation of suitable test locations and demonstration sites. The Netherlands has a solid position in the global marine energy sector, with high-potential technology developers, renowned academic institutes and offshore industry, and a variety of test facilities where new technologies can be demonstrated, including two test sites operated by DMEC; an inshore test site at the Afsluitdijk (Figure 1) and an offshore test site at Marsdiep. For both sites, DMEC designs and executes technical, support packages for marine energy device testing including technology certification services. Further south, in Zeeland, a new test facility (TTC-GD) is planned for low head tidal range testing. Together with the Dutch offshore, maritime, and delta-tech sectors, unique and

▲ *Inshore test site at the Afsluitdijk.*

commercially viable concepts are being developed. One example is an Energising Delta (Figure 2) combining water safety with the generation of clean energy.

While moving towards commercialisation, it is important that the emerging sector integrates expertise and lessons learned from existing maritime and offshore companies. Additionally, there is also a hydrographical challenge in determining the potential of marine energy. Previous studies have shown different predictions for the amount of energy that could be generated. On a more local basis, hydrographical knowledge is imperative to determine which locations are best suited to marine energy generation and to provide confidence to investors for certification. Although hydrodynamic tools are being developed to map out optimal sites for deployment, knowledge is still lacking in how to practically use existing hydrographic tools and experience.

In short, there is a significant potential for the adoption of marine energy in the renewable energy mix. To realise this potential, the synergies between the marine energy sector and the maritime, offshore and hydrography sectors should be exploited. DMEC aims to achieve this by initiating new activities, joint projects and business cases across sectors, regions and industries. In this way, DMEC accelerates technology and business development, shortens the time to market for marine energy devices, and boosts their export to global markets. Please get in touch with us if your organisation would like to discuss the possibilities. ◂



▲ *Energising Delta*

More information
www.dutchmarineenergy.com

Iris Hoefnagels has been working as a project manager at the Dutch Marine Energy Centre (DMEC) since 2016, where she is responsible for the ongoing projects in the Netherlands. She has a background in innovation science, with a focus on renewable energy. She obtained her Bachelor's degree with a dissertation on collaboration in the marine energy industry. In addition to working for DMEC, Iris is currently also studying for her MSc in Physics on renewable energy at the University of Amsterdam.
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Depth Data: Measure Once - Use Many Times

Over the last decade the focus of the IHO has widened from the production and distribution of nautical charts and services to the provision of hydrographic data for other activities in the seas and oceans. This follows a similar trend in national land mapping agencies, where the focus has moved from specialised national mapping to the provision of geodata in the national interest.

IHO Resolution

At the first session of the IHO Assembly in April this year, the IHO Member States approved a Resolution setting out principles for ensuring the widest possible availability of bathymetric data to support the sustainable development, management and governance of the marine environment. The Resolution emphasises that more data is required and goes on to encourage data collection methods that are not specifically targeted to chart improvement programmes, including crowdsourcing, satellite-derived bathymetry and the re-processing of or access to scientific and other data previously collected for purposes other than charting.

Crowdsourced Bathymetry

Taking into account the lack of depth data for most of the world's seas, oceans and coastal waters, the IHO established a Crowdsourced Bathymetry Working Group in 2015 to provide guidelines on how crowdsourced bathymetry might be collected, its quality maximised, and then made available for use as appropriate. The working group has completed a draft guidance document which is now available for public comment. It is expected to be finalised and approved by the IHO in 2018.

IHO DCDB

The IHO's Data Centre for Digital Bathymetry (DCDB) was established in 1990 to steward the worldwide collection of bathymetric data, and is funded and supported by the USA as part of the world database system. It is currently undergoing progressive upgrades to its web-based portal to provide better data discovery, and upload and download capabilities. It is also preparing to be the principal portal for IHO's crowdsourced bathymetry project.

MSDIWG

Aware of the growing development of spatial data infrastructure for land-based geodata, the IHO established a working group to consider Marine Spatial Data Infrastructures in 2007. In particular, the MSDIWG was instructed to provide guidance to Hydrographic Offices on how to contribute their valuable base data in support of such things as national infrastructure development, marine spatial planning and natural disaster mitigation. A second edition of its guidance document (IHO publication C-17) is expected to be approved later this year.

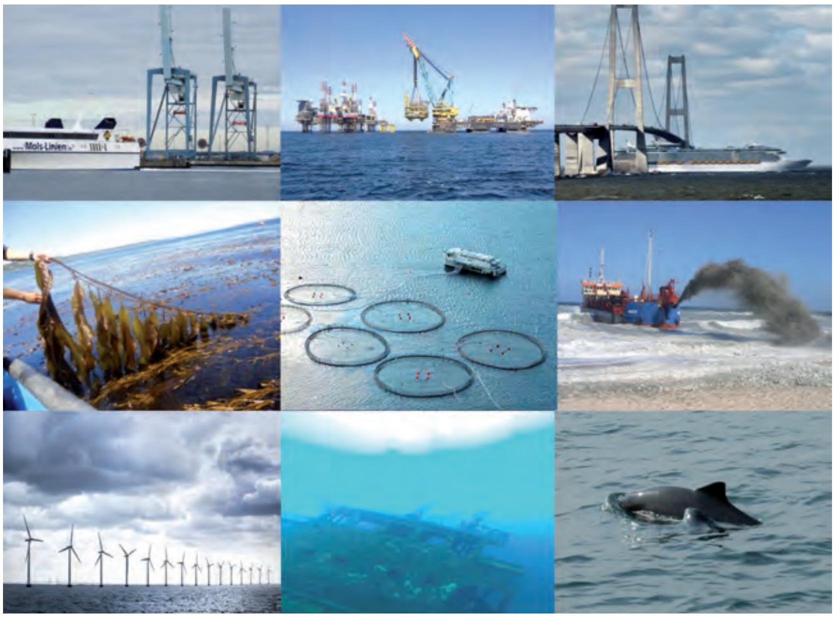
GEBCO

Meanwhile, the GEBCO (General Bathymetric Chart of the Ocean) project, co-sponsored by the IHO and the Intergovernmental Oceanographic Commission (IOC) of UNESCO, undertook a review of its progress in providing the world's open source, authoritative bathymetric mapping dataset. It concluded, at its Forum for Future Ocean Floor Mapping, in June 2016, that considerably more efforts were required. As a result, its aim is to map every significant undersea feature by 2030. This aim will be assisted by further generous support announced recently by the Nippon Foundation as Project Seabed 2030.

UN-GGIM

A further signal of the growing acknowledgement of the importance of marine geospatial information for purposes other than charting, is the very recent establishment by the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM) of a Working Group on Marine Geospatial Information. The IHO has been specifically invited as a permanent observer organisation in the working group, which aims, through the UN-GGIM, to provide truly global policy guidance on geospatial information - for the first time, joining land and marine geospatial information policy together from an inter-governmental and UN perspective.

All IHO documents and draft documents are available free of charge for download from the IHO website: www.iho.int.



▲ *Hydrographic information supports more than just nautical charts.*

Australasian Hydrographic Society

2017 Alexander Dalrymple Award for Adam Greenland

The Alexander Dalrymple Award is given by the United Kingdom Hydrographic Office (UKHO) in recognition of an outstanding contribution to world hydrography. First presented in 2006, it is named in honour of the first Hydrographer of the Royal Navy in 1795.
The Award was presented at a reception in London by Rear Admiral Tim Lowe, UK National Hydrographer and Deputy Chief Executive of the UKHO. Admiral Lowe commented: "Adam has made a significant contribution to capacity building and improving maritime safety in the Southwest Pacific region. As National Hydrographer, he has a wide ranging and busy portfolio from managing a very efficient national and regional production/delivery unit through to representing New Zealand at a variety of strategic fora within the International Hydrographic Organization (IHO).
"He is also a member of the New Zealand Geographic Board (NZGB) and a hugely active Capacity Building Coordinator for the South West Pacific Hydrographic Commission (SWPHC). In the latter, he has delivered significant training and mentoring initiatives in areas such as maritime safety information, hydrographic surveying training and nautical cartography training. These aspects have significantly benefitted developing Member States across the breadth of an enormous sea area."
Adam Greenland is the twelfth recipient of the Alexander Dalrymple Award. Educated at the University of East London and the University of Greenwich, and a former Merchant Mariner, Adam Greenland is a Chartered Surveyor who has been with Land Information New Zealand (LINZ) since 2005.
The award presentation took place at a reception held at Lancaster House in London to mark the UK Government's celebration of World Hydrography Day 2017, a United Nations-endorsed recognition of the vital role of hydrography in supporting safe navigation and sustainable use of the world's seas, oceans and waterways.

Presentation of the Dalrymple Award.

Hydrographic Society Benelux

Hydro17 Presents Preliminary Programme

The Hydro17 Organising Committee is pleased to present the preliminary programme for the Hydro17 Conference to be held in Rotterdam from 14 to 16 November 2017. With almost 50 papers being presented, it promises to be an interesting conference. In addition, there will also be 45 exhibitors showing you the latest equipment and software. Survey techniques and equipment will be demonstrated on the water.

Meet the keynote speakers:
Peter Westbroek is Emeritus Professor in Geology. He actively participated in the creation of the new science, Earth System Science, and is author of the book *The discovery of the planet Earth*. After Erasmus, Peter Westbroek is the first Dutch Professor to be appointed to the 'College de France' in Paris and is the first to be honoured with the Vladimir Vernadski medal by the European Geophysical Society.
Rob Luijnenburg's passion for hydrographic survey and offshore constructions originates from an education in offshore engineering at Delft University of Technology and military service at the Hydrographic Department of the Royal Netherlands Navy. In the course of his career of more than 40 years, offshore surveying was always close to Rob's day to day activities.
Alok Jha is the science correspondent at ITN, working on news and current affairs for ITV. Prior to this, he worked at the Guardian for more than a decade, where he wrote news, features and reviews, and presented the award-winning Science Weekly podcast. He has also reported live from Antarctica and written and presented several TV and radio programmes for the BBC.
Please visit the event website for more information or join Hydro17's LinkedIn group.

More Information:
- hydro17.com
- www.linkedin.com/groups/13515244


Peter Westbroek


Rob Luijnenburg


Alok Jha

OCTOBER

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

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

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

Underwater Vehicles Conference
Aberdeen, GB
→ 24 October
subseauk.com/8328/underwater-vehicles-conference

Global Science, Technology and Innovation Conference (G-STIC)
Brussels, BE
→ 23-25 October
gstic.org

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

NOVEMBER

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

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

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

Marine Autonomy and Technology Showcase
Southampton, GB
→ 13-17 November
conference.noc.ac.uk/matshowcase

Hydro17
Rotterdam, NL
→ 14-16 November
hydro17.com

GEBCO Symposium: Map the Gaps
Busan, KR
→ 15 November
mapthegaps.org

Asia-Pacific Deep Sea Mining Summit
Singapore, SG
→ 21-22 November
asia.deepsea-mining-summit.com

Sustainable Ocean Summit
Halifax, CA
→ 29 November – 1 December
sustainableoceansummit.org

DECEMBER

AGU Fall Meeting
New Orleans, US
→ 11-15 December
fallmeeting.agu.org/2017

JANUARY 2018

HYPACK 2018
Savannah, US
→ 16-19 January
hypack2018.com

FEBRUARY

Ocean Sciences Meeting
Portland, US
→ 11-16 February
bit.ly/osm2018

MARCH

Oceanology International 2018
London, UK
→ 13-15 March
oceanologyinternational.com

Calendar Notices

For more events and additional information on the shows mentioned on this page, see www.hydro-international.com/events. Please submit your event online using https://www.hydro-international.com/events/submit. We can help you to increase awareness for your event. For more information, please contact Myrthe van der Schuit, myrthe.van.der.schuit@geomares.nl.

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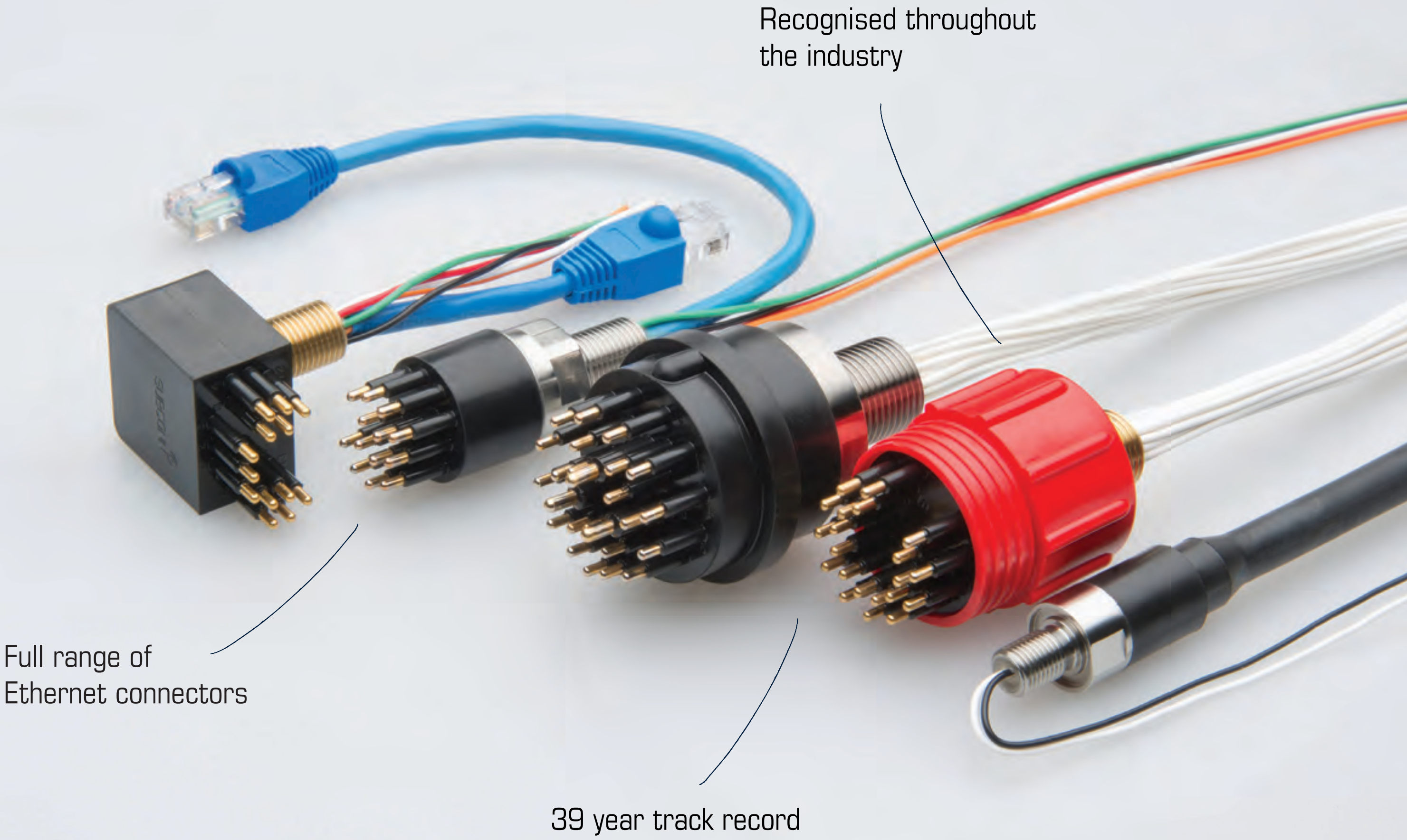

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- flexible SiNAPS positioning software
- reliable data transmissions
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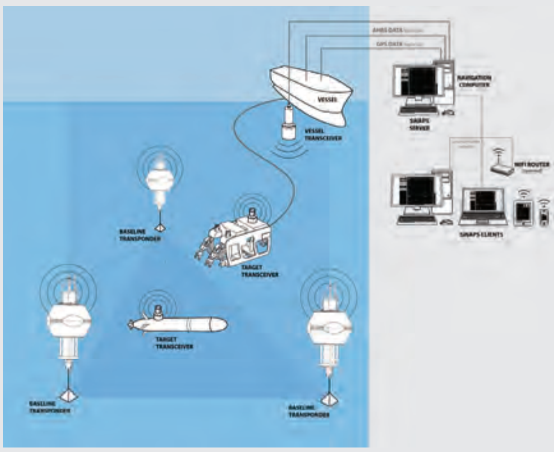
- accuracy: better than 0.01m

UNDERWATER ACOUSTIC MODEMS

reliable data transmissions even in adverse conditions, customizable R-series modems, light and compact M-series "mini" modems, **new S2CM-HS high-speed modem**, special editions for developers, S2C communication and positioning emulator - remote access or standalone device

- range: up to 8000 m
- depth: up to 6000 m
- data rate: up to 62.5 kbps



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