Hydro INTERNATIONAL

THE GLOBAL MAGAZINE FOR HYDROGRAPHY

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geomares PUBLISHING

OCTOBER 2016 | VOLUME 20 NUMBER 7

Hydro INTERNATIONAL 20th ANNIVERSARY

INTERVIEW BRENDAN HYLAND

Subsea Internet of Things

CONTINENTAL STREAMFLOW MODELLING

Can I Communicate with my AUV?

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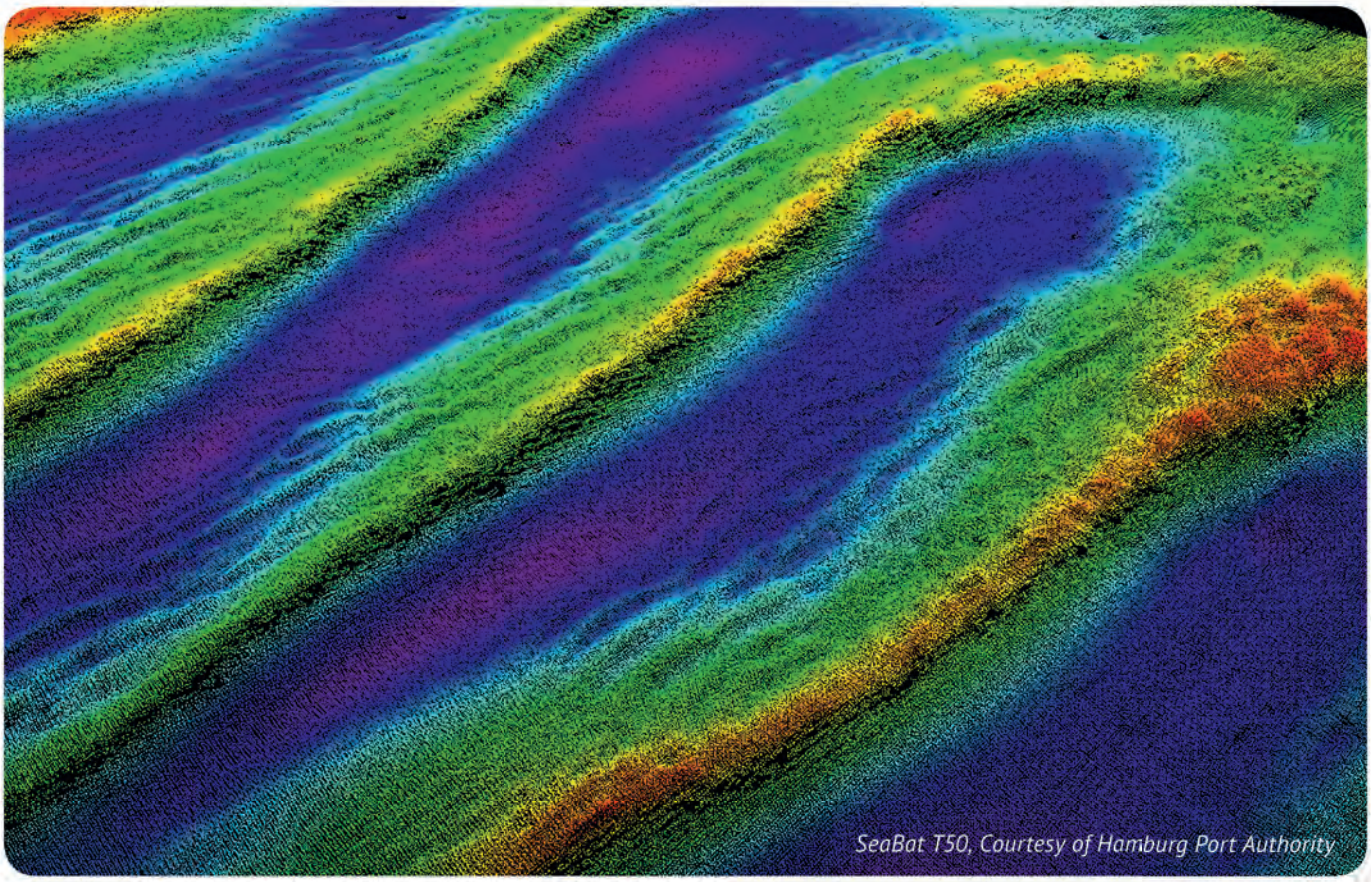

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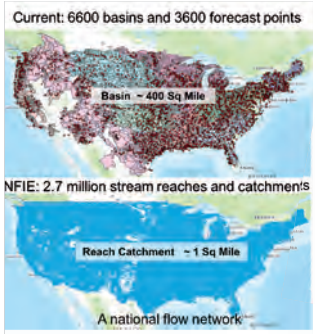

Hydrography for Continental Streamflow Modelling 23

Water Data Standards Enable New Models and Applications

October 2016 Volume 20 #7

OceanServer Technology, in partnership with YSI, has launched the new generation EcoMapper. This i3XO EcoMapper AUV is based on the Iver3-580 taking advantage of YSI's expertise in water quality solution. See also http://bit.ly/2cFD97X.

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Hydro INTERNATIONAL

Hydro International is an independent international magazine published 8 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)

Chart maker, fisherman and sailor

The role of the Hydrographic Offices needs to change. This is the message conveyed by the Secretary-General Robert Ward of the International Hydrographic Organization in Monaco in this issue of *Hydro International* (see Insider's View on page 6). It's not the first time that Captain Ward promotes a much broader role for the Hydrographic Offices of the Member States of the IHO. He bases his ideas on the ever-growing role of the Maritime Spatial Data Infrastructure (MSDIs), that part of the Spatial Data Infrastructure (SDI) concerning the coastal zones and the seas, in supporting the policy-making of governments all over the globe. A big push behind it is the initiative of the United Nations gathering in the Global Geospatial Information Management (UN-GGIM) and its derivatives on regional level. A major part of the discussions within UN-GGIM are always about the fact that geodata supports and boosts economic development and the increasing welfare of citizens, and therefore contributes to the earlier Millennium Development Goals and the new Sustainable Development Goals of the UN. Geodata have hit the heart of governments, which is a very good thing for our sector. Many of the Hydrographic Offices are embracing a bigger and broader role beyond chart making, There are also a few that don't, a concern for Captain Ward, but also a concern for those citizens living in coastal areas covered by those HOs. They deserve to also have the HOs in their regions take on the role that supports their lives, well-being and welfare!

On a completely different note: it was with great sadness that we learned of the passing away of Adam Kerr on August 8 of this year. He was the former director of the International Hydrographic Bureau in Monaco, but also a long-time contributor in many ways to *Hydro International* and not to forget *The Electronic Chart* – a book published by Geomares Publishing for which Adam served as editor and as conscience for the authors of the book in many ways. As one of the pioneers in ECDIS he kept abreast of developments until the very end, and not just in this field. We had many, many chats over the years on hydrography, chart making, sailing, restoring old and monumental fisherman's ships and numerous other things… Adam deserves our utmost respect and his family our sincerest condolences on his passing away. You will find an obituary on page 15 of this issue by our contributing editor RADM Giuseppe Angrisano, who worked very closely with Adam Kerr when they were both director at the IHB in Monaco.

The title of this editorial is 'chart maker, fisherman and sailor', which is a tribute to Adam Kerr, who really was all three of them. It is also a referral to the obituary that Angrisano wrote. It is also a befitting referral to the direction that Robert Ward sees for the Hydrographic Offices in particular, and hydrography in general: hydrography and the HOs need to serve everyone and in particular the chart maker, the fisherman, the sailor and all who use the sea and wish to be guided by the gatherers of geodata in the best possible, most respectful and wisest way.

Durk Haarsma durk.haarsma@geomares.nl

Embracing the Importance and Value of Data

With one year left as President (name soon to become Secretary-General) of the IHO, it seems like a good time to consider where I think the world's national Hydrographic Offices (HOs) need to go next. Simply said: "*it's no longer about charts and maps only - it's now all about data and data access!*".

What do I mean? Well, when I look at the world's national mapping agencies, I see a rapid move away from organisations existing to make and maintain a country's national map collection to organisations acting as providers of the national collection of primary geodata. They are re-organising to make data, rather than just maps, available to a diverse user community: government departments, commercial developers and the public. This drive is recognition that fundamental geodata is a key enabler for economic development and the sustainable use of the environment. In this context, elevation and its marine counterpart, depth, must be one of the most fundamental of those geo-datasets.

Turning some of the geodata in the national data-store into official map-like products is a specialism of these organisations, but it is no longer the reason they exist. Indeed, the creation of map products and services is often out-sourced or licensed, even when the national organisation remains responsible for the provision of these services. National mapping agencies increasingly see themselves at the heart of the national spatial data infrastructure. They mostly follow the concept of open-data, where data is openly accessible and provided at a moderate or no cost to users - the national economic rewards being derived through the secondary and subsequent use of the data.

Considering what is going on, should our national Hydrographers focus data gathering efforts primarily on supporting their national nautical chart series or should the scope of their activities be broadened, as with mapping agencies? While supporting safe navigation remains a fundamental responsibility, unless HOs also support the maritime element of Spatial Data Infrastructures, it is only a matter of time before other agencies take on the role. Indeed, this has already been done successfully in several countries - and there is no reason to think it is a bad solution.

I am concerned that a number of our HOs represented in the IHO are significantly limited in their ability to expand their mandate to embrace a Maritime Spatial Data Infrastructure (MSDI), particularly those HOs embedded in defence organisations, where nautical charts, supporting freedom of manoeuvre for warships, and the provision of operational

geospatial intelligence, remain paramount. HOs subject to a cost-recovery regime may be similarly constrained, particularly when the global trend is to make access to fundamental geodata free or at minimal cost. For some HOs, adopting a wider, important national infrastructure development and investment role by supporting the blue economy and the overall governance of the marine environment, may not be easy.

I am, nevertheless, pleased to see that an increasing number of our IHO Member States are moving in what I consider is the best direction. An increasing number are realising that data from all sources, such as crowdsourcing and remotely-sensed data, can be useful in helping to populate a national geospatial database - even if not all the information is suitable to incorporate directly into a chart or map. This is why the IHO has working groups considering these options, assisting and advising our Member States accordingly.

However, the question remains whether all our HOs are in a position to choose to make the move towards being at the heart of MSDI - or must they wait until they are either pushed out or taken over?

IHO to Change its Organisation and Structure

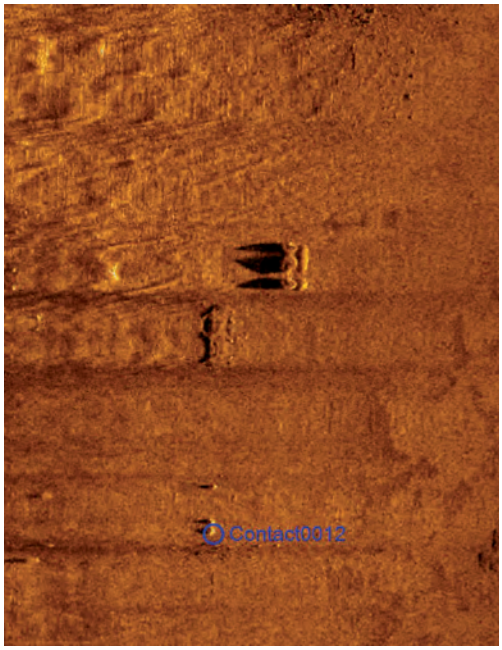
The IHO already has been working on organisational changes for a couple of years. During the EIHC in 2005 and the IHC in 2007, the constitutional documents were approved in the meeting but they needed the support of 48 Member Countries. As this now has been achieved, changes will be made, entering into force on 8 November 2016. The term International Hydrographic Bureau for the headquarters will change to IHO Secretariat, led by the IHO Secretary-General and two subordinate directors.

▸ *http://bit.ly/2cTeHmR*

Real-time SonarWiz Interface for PulSAR Side-scan Sonar

Marine professionals using Kongsberg GeoAcoustics' PulSAR side-scan sonar can use the Chesapeake SonarWiz interface for real-time seafloor mapping. This interface allows PulSAR users to acquire data from multiple sensors, process imagery in real-time, generate mosaics, create detailed contact reports and produce outputs leveraging a wide range of formats.

▸ *http://bit.ly/2cTewbm*



Kongsberg PulSAR side-scan sonar data processed with Chesapeake SonarWiz.

Most Shared

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

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On the Cusp of A New Hydrographic Era - http://bit.ly/2d50dO7
Ocean Floor to be Mapped by 2030 - http://bit.ly/2d5079j
Autonomous Underwater Vehicles - http://bit.ly/2d517dF
New Tool to Process Sound Velocity Profiles - http://bit.ly/2d50XTx

Peruvian Oceanographic Vessel with Polar Capacity

BAP Carrasco *during her trials at sea*

The Peruvian Navy, Directorate of Hydrography and Navigation, has commissioned a hydrographic and oceanographic vessel, designed and built by Freire shipyard in Vigo, Spain. Its structural design achieves the Polar Class 7 (PC7) requirements of the DNV-GL classification society, which allows the vessel to navigate in polar areas during the austral summer. It was launched to sea in 2016 and is expected to start operations in 2017. *BAP Carrasco*'s (BOP – 171) design is similar to the research vessel RRS *Discovery UK*.

▸ *http://bit.ly/2cTeBMp*

Collaborative Platform for Oil and Gas Industry

The National Oceanography Centre (NOC, UK) has launched a collaborative way of working with the oil and gas industry. NOC will provide science and technology to enable industry to work safely and efficiently, with minimum impact on the marine environment. NOC has expertise in marine autonomous and robotic systems and sensors, for operations in challenging, hazardous and deep-sea environments. NOC's fleet of autonomous underwater vehicles, remotely operated vehicles, unmanned surface vehicles and submarine gliders have all been developed to operate in extreme conditions.

▸ *http://bit.ly/2cTihxi*

Oceanstar Enhances Vessel Safety

Fugro has introduced a service to its range of satellite positioning systems. Oceanstar is an onboard decision support system that has been developed to improve navigational safety and reduce the operating costs of commercial vessels such as cruise ships, container ships, ferries, ro-ro vessels, bulk carriers and tankers.

▸ *http://bit.ly/2cTgxEB*

Stanley Harvey Appointed as US Navy Deputy Hydrographer

Stanley B. Harvey has assumed responsibilities as the deputy Hydrographer of the Navy on the Commander Naval Meteorology and Oceanography Command (CNMOC) staff. Rear Admiral Tim Gallaudet, the command's leader, is designated as Hydrographer of the Navy.

▸ ***http://bit.ly/2cTf80L***

Stanley Harvey.

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USBL and SSBL	
1. EvoLogics - S2C R 12/24 USBL	http://bit.ly/EvoLogicsS2CR1224
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4. EvoLogics - S2C R 7/17 USBL	http://bit.ly/EvoLogicsS2CR717
5. EvoLogics - S2C R 18/34 USBL	http://bit.ly/EvoLogicsS2CR1834

Ocean Airline Tracking Gap to be Filled

Liquid Robotics, USA, has entered into a business and technology partnership with Maritime Robotics, Norway. One of the first customers from this partnership is the flight-tracking service Flightradar24. Sea trials are currently underway to test ocean-based ADS-B reception with Wave Gliders. Wave Gliders have the potential to fill the current air traffic communications tracking gaps that exist over remote ocean expanses.

Wave Gliders can serve as ground stations to fill in ocean gaps for airline tracking.

▸ ***http://bit.ly/2cTg5pE***

First Practical Survey Project for CIDCO's Cat-B Students

This summer, the students who followed the first session of the CIDCO IHO-recognised category B course in hydrographic surveying completed their field project in Rimouski (QC), Canada. After an 8-month period of e-learning lectures, the students had acquired the necessary knowledge in various fields such as positioning, tide, bathymetry, acoustics, data processing and survey planning to be able to accomplish the 5-week residential survey project.

CIDCO Students working on the integration of a complete survey system on an Unmanned Surface Vehicle.

▸ ***http://bit.ly/2cTgIQg***

FLS for Australian Survey Vessels

FarSounder, Inc. has been awarded a contract to provide four complete FarSounder-1000 systems plus spare parts for the upgrade of four Paluma-class hydrographic survey motor launches operated by the Royal Australian Navy (RAN). The 360-tonne survey motor launches, HMA Ships *Paluma (IV), Mermaid, Shepparton (II)* and *Benalla (II)*, were designed for operations in the shallow waters of northern Australia. Each survey motor launch carries the latest in survey and computerised hydrographic data processing equipment and is fitted with the latest navigation aids.

▸ ***http://bit.ly/2cTiH7c***

HMAS Shepparton (II) *- Survey vessel. Image courtesy: Royal Australian Navy.*

Successful Sea Trials for TRIAXYS g3 Wave Sensor

AXYS Technologies' TRIAXYS g3 wave sensor has successfully completed a series of rigorous sea trials. The trials were conducted both in the German Bight and off the West Coast of Canada and used both AXYS' own TRIAXYS wave buoy and other industry standard buoys as references. The TRIAXYS g3 demonstrated high levels of correlation against all reference buoys, confirming that the TRIAXYS g3 sensor meets AXYS' high standards of accuracy for wave height and direction measurement.

▸ ***http://bit.ly/2cEXpqo***

TRIAXYS wave buoy.

UK Coastal Monitoring Contract Extended

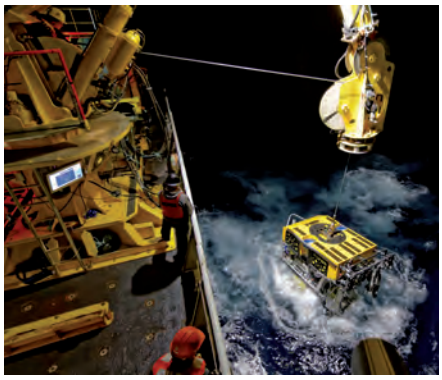
Fugro's coastal oceanographic team has been awarded a contract extension by England's Regional Coastal Monitoring Programmes (RCMP) for a further five years to manage the Southwest, Northwest and Northeast regional programmes. The network monitors 5,672 kilometres of English coastline.

▸ ***http://bit.ly/2cThvQY***

Syrinx DVL for Flagship Canadian Ocean Science ROV

Doppler Velocity Log (DVL) technology from Sonardyne (USA) has been selected to help navigate Canada's flagship undersea research vehicle, *ROPOS*. The order for a 4,000 metre depth rated, 600kHz Syrinx DVL was placed by the Canadian Scientific Submersible Facility (CSSF), the not-for-profit corporation who operate *ROPOS*, following a trial to evaluate its capabilities. This concluded that Syrinx was able to maintain, and regain bottom lock over a wide range of altitudes and seafloor terrains including soft fine sediment and rugged steep slopes close to hydrothermal vents.

▸ ***http://bit.ly/2cEXYjZ***

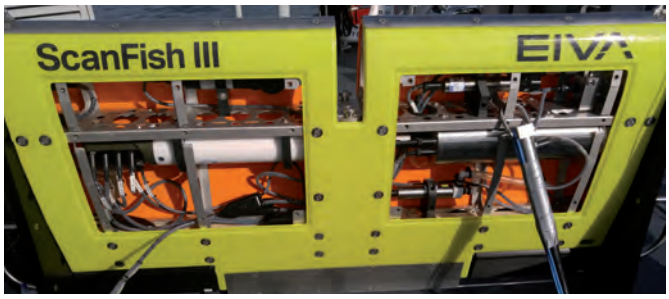


Syrinx DVL has been selected to navigate ROPOS*, Canada's flagship undersea research vehicle. Image courtesy: Ed McNichol (CSSF).*

ScanFish ROTV Increases Survey Efficiency

Using two vessels and a wide array of oceanographic sensors, the City of San Diego, California, USA, continually inspects and reports on two wastewater outfalls: Point Loma Ocean Outfall (PLOO) near the mouth of San Diego Bay and South Bay Ocean Outfall (SBOO) near the US/Mexico border. The City of San Diego looked to the ScanFish Rocio model in EIVA's ScanFish remotely operated towed vehicle (ROTV) product line as a means of increasing data coverage and quality while at the same time decreasing vessel time.

▸ ***http://bit.ly/2cEYe2n***



Open EIVA ScanFish ROTV.

Hydro International interviews Brendan Hyland WFS Technologies

'Subsea Internet of Things' to Transform Amount of Information Available

It's fascinating to see that communication techniques are evolving. On the shore there already is a clear trend towards eliminating cables and wires. So a logical consequence would be to see this also happening underwater. One of the pioneers of underwater wireless communication has been Wireless Fibre Systems Technologies, or WFS Technologies. They have succeeded in making underwater communication wireless and are even going a step further by initiating the subsea internet of things, as they do themselves indicate it. *Hydro International* interviews Brendan Hyland, founder of WFS Technologies.

What made you start WFS Technologies?

I started WFS to deliver innovative wireless services to support the ever-increasing appetite for internet-based services. I was excited by the potential of short range wireless technologies to change business models by reducing costs and increasing flexibility.

The first venture was underwater radio for short distances – was this developed as a kind of bridge for difficult to access places?

I was excited by how Bluetooth and WiFi have opened up the world for land-based communications. I set out to see how this could be replicated in the underwater world. I employed a team to carry out some research on underwater radio and they developed some groundbreaking technology.

What was the breakthrough for broadband capacity and greater distances?

The broadband capacity and distances are dictated by the laws of physics but the critical breakthrough was developing the technology that could extend the battery life of wireless systems by at least two orders of magnitude when compared with equivalent acoustic alternatives. The batteries on conventional wireless sensor systems typically have to be replaced after six months. Today, we can deploy equipment for up to 15 years using modest battery packs – in most cases the remaining life of the field.

We have also made the packages lighter and more compact to reduce the cost and complexity of installation.

We see hybrid technology as the future

▲ *Brendan Hyland.*

WFS Technologies uses the slogan 'Wireless for Subsea'. In what cases can underwater data communication replace cabled devices?

WFS has long believed that the subsea world should benefit from the same revolution in wireless communications that has transformed our world. Wireless will not replace hard-wired systems but complement them.

What is currently the biggest challenge for underwater communication?

The biggest challenge faced by suppliers of underwater communications solutions is the acceptance by the industry of automation, to increase profits, improve safety and extend asset life. The industry is inherently conservative and has been reticent to adopt the same level of automation subsea that is the norm in land-based process industries. The industry downturn, however, has focused the minds of operators on using automation to increase production output and drive down costs.

Wireless will not replace hard-wired systems but complement them

How is the acceptance of wireless underwater communication?

We have seen a sustained acceptance of wireless on the back of successful deployments. Operators have recognised the benefits, particularly the reduction in costs and the increase in flexibility.

There is a perception that wireless is used to displace cables. This is not true. Wireless can actually extend the capability of cabled systems by providing automation in applications where it is not cost effective to deploy a cabled system.

WFS Technologies emphasises the 'Subsea Internet of Things', referring to monitoring applications. Do you see a potential for moving communication from – or between - AUVs as well, for example?

'Subsea Internet of Things' architecture goes beyond remote harvesting of sensor data by ROVs and AUVs. Smart sensors process data locally to implement efficient control strategies. Efficient subsea architectures balance the trade-offs between timeliness and cost. For example, many asset integrity monitoring applications do not require real-time control – harvesting information every 6-12 months by AUV is quite acceptable. Other applications require an instantaneous response which can be achieved using extended wireless networks at the well-head.

At some stage the data needs to be linked above water. Gliders and AUVs need to reach the surface to achieve this. How will this change in the future?

Seatooth communications can transmit data through the splash zone. We can use this unique capability on offshore structures to extend wireless networks through the air-water interface, to sensors and actuators located subsea.

We can also incorporate Seatooth technology into subsea control modules to extend the reach of wireless communications, using existing cables for back-haul to the surface.

We foresee the use of AUVs to harvest data from remote sensors, uploading this information via subsea docking stations. Similarly, pigs will be used as 'AUVs in pipes' to harvest asset integrity information from remote sensors.

What possibilities do you anticipate outside your traditional markets like oil & gas and defence – like science and ocean mapping?

We see great potential deploying wide area sensor networks across littoral waters, providing real-time data communications to extend the 'Internet of Things' to the 'Subsea Internet of Things', transforming the amount of information available for research.

In cabled systems, it becomes increasingly expensive to install sensors farther away from a subsea node due to the material cost and the large vessels necessary to lay the line. This is not an issue with wireless systems. Sensors can be installed in isolated locations outside the economic range of cabled systems.

What are industry standards? What kind of developments are being made?

WFS is an active participant in open standards initiatives to facilitate wireless communication in the underwater world. We are a founding member of the Subsea WIreless Group (SWIG) that has worked hard in designing and structuring standards to feed into the American Petroleum Institute (API) 17F which deals with subsea controls. Earlier this year, Chris Curran, the chair of the 17F committee, joined WFS as its Houston - based project director.

WFS is equally supportive of work on subsea standards being driven by the US Department of Defense and sees a beneficial cross-fertilisation between the two sectors.

How is WFS Technology working together with universities? Or is the organisation conducting its own research?

WFS has undertaken its own fundamental research in the technology but continues to work with universities to develop applications further. We are particularly active with universities to support cost-effective deployment of environmental monitoring sensors.

How do you see the future of light as wireless underwater communication medium?

Light is a very exciting medium for high bandwidth, relatively short range communications. WFS is developing Seatooth Hybrid, an innovative subsea wireless communications and control system incorporating radio, acoustic and optical technologies. We see hybrid technology as the future.

What would you like to share with* Hydro International *readers?

Seatooth is a sophisticated modem technology that can be linked with a variety of sensors. In specific applications, this could enable hydrographic instruments to significantly reduce the deployment and lifetime costs. ◀

Brendan Hyland studied electrical and electronic engineering at Queen's University of Belfast. Since then he has worked in the chemicals industry, management consultancy and in the industrial instrumentation sector. After completing an MBA at the University of Durham, Brendan founded Kymata Ltd in 1998; an optoelectronics company that designs and develops planar optical devices. He raised USD160m in funding and assimilated an international shareholder base that included Kleiner Perkins, IBM, BT, JP Morgan and Royal Bank of Scotland. He established operations in Scotland, the Netherlands, the USA and Canada before selling the business to Alcatel in 2001.

Brendan founded WFS in 2003 and has steered it to become the world leader in underwater and underground radio products.

Adam Kerr

It was with great sadness that the Directing Committee of the International Hydrographic Bureau (IHB) announced the death of Adam Kerr (former director), who passed away in his home in Lamorna (United Kingdom) on 8 August 2016.

Adam Kerr a 'chart maker, fisherman and sailor'. This is how he defined himself at the end of his autobiography. To this I would add:… and a true gentleman of the sea.

I first met Adam in Genova (Italy) in my office as director of the Italian Navy Hydrographic Institute (IIM). It was 1988 and he had come to ask for the cooperation of the IIM to support the creation of a Hydrographic School in Trieste (Italy) as part of a project that had been agreed upon between IMO and Italy, to establish a Maritime Academy. The hydrographic school was established and operated for many years thereafter. Adam was, at the time, the brand new director of the International Hydrographic Bureau, the secretariat of the International Hydrographic Organization (IHO), based in Monaco.

Listening to him that day I immediately realized that I had in front of me a dedicated and enthusiastic hydrographer and sound and experienced seaman, who had the clear vision that organisations are made up of people who, when inspired and properly guided, can achieve great things. Adam was definitely the man to both inspire and to guide.

I was fortunate that only a few years later, in 1992, I was elected as a fellow director of the IHB alongside Adam, with Rear Admiral Christian Andreasen as the president of the Directing Committee in Monaco.

This was the beginning of five years of intense cooperation. It was the period in which the now well established IHO electronic chart standards were developed, the number of Member States of the IHO were increased, the technical cooperation and assistance to developing hydrographic services was expanded and ties with the relevant United Nations Specialized Agencies were strengthened. Adam worked intensely and helped me greatly.

I particularly admired his efficiency and capacity for work. His desk was always tidy, there were no files piling up waiting to be dispatched. His writing was extremely clear and direct: no doubt about the meaning and the intention. A quality that he had not only inherited from his father, a reputed writer, but also from his long seagoing experience: sailors do not need many words to develop a concept and to get to the point.

Surveying and charting inhospitable waters as he did in British (claimed) Antarctica and in the Canadian Arctic made him a very knowledgeable and experienced hydrographer and an expert seaman. Before joining the IHO he served in the Canadian Hydrographic Service for thirty years during which time many novel surveying techniques were trialed and some implemented. On his desk, at the IHB, there was a model of the famous Dolphin: a torpedo shaped craft with a snorkel and fitted with an echo sounder. Its purpose was to increase a ship's survey output by cruising in parallel to the track of its mother survey ship.

Adam had a clear vision of the advantages of fostering close cooperation between Government Hydrographic Offices, industry and academia. He narrates in his book how successful the cooperation between the Canadian Hydrographic Service, the enterprise CARIS and the University of New Brunswick was in the collection and subsequent processing of digital survey data.

Adam also tried to overcome the skepticism and sometimes hostility of Government HOs towards private industry that had been producing electronic charts since the early eighties. In his book, he says "I was of the opinion that some of the most innovative work was being done by commercial companies such as C-Map and Navionics".

When I passed on the sad news of his death to the founders of C-Map and of Navionics, they wrote:

"We remember Adam as a most brilliant civil servant, one who could see very far - without being drawn into small matters, and a master at using his superior charisma and diplomatic skills to resolve conflicts that looked like unstoppable forest fires.

We also like to celebrate Adam as a great example of how to enjoy life: the party at his home and his curriculum as a boater have always been a great inspiration for us."

In fact, Adam contributed significantly to the social life of the IHB. At IHO Conferences and meetings, we, the three directors, used to invite the delegates to our homes. I remember that the guests at Adam's receptions, coming from all over the world, deeply appreciated his kindness as well as that of his wife Judith and his sons Andrew and Timothy. A charming family indeed.

I do not want to close these few lines without mentioning that Adam was a fine watercolour painter who was capable of catching the most emotional moments of his life at sea. After he retired from the IHB he used to send watercolour Christmas cards to his many friends and colleagues.

In conclusion, those who had the pleasure to work with and alongside him had the chance to experience a remarkable person. We miss you deeply Adam, have a nice navigation in eternity's ocean!

The book: Charting Polar Seas. *Author Adam Kerr printed by Amazon in 2016. A genuine and full of adventures autobiography of a sailor, surveyor, boating and vigilant father of a charming family*

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Performance and Challenges in shallow water

Can I **Communicate** With My AUV?

The prospects for an increased future use of autonomous underwater vehicles (AUVs) in the Maritime & Offshore sector are high, mainly due to the search for cost effectiveness. AUVs reduce the need for large crews, divers and vessels in the operational area. AUVs are already operational for bathymetric and environmental mapping, pipeline tracking and mine hunting, and there is a trend towards their use for inspection and environmental monitoring.

When using non-tethered solutions, underwater communication becomes crucial for data transfer and positioning. The latter holds even more given that the long-term goal is the deployment of multiple autonomous vehicles, possibly working in a network to carry out joint operations. As of today, the best technology to set up long-range underwater communication links is acoustic communication, of which the performance is highly dependent on the environmental conditions. In the North Sea, for example, the combination of shallow water and strong winds complicates performance prediction for an underwater acoustic network. Sea trials with underwater acoustic modems have taught us that communication ranges can be much less compared to the nominal performance as advertised by the vendors, depending on environmental conditions. In this article, we make an inventory of what can affect the performance of underwater acoustic communications, with a focus on shallow-water environments typical for the North Sea. Knowing what influences underwater communications enables better planning of autonomous subsea operations.

The Performance of Underwater Acoustic Communications

Underwater acoustic communication using acoustic modems consists of transforming a digital message into sound that can be transmitted in water, and vice versa. Based on our experience, we can group the factors influencing the success of communications into three categories: sound propagation conditions, specific modem properties and background noise in the communication band (Figure 1).

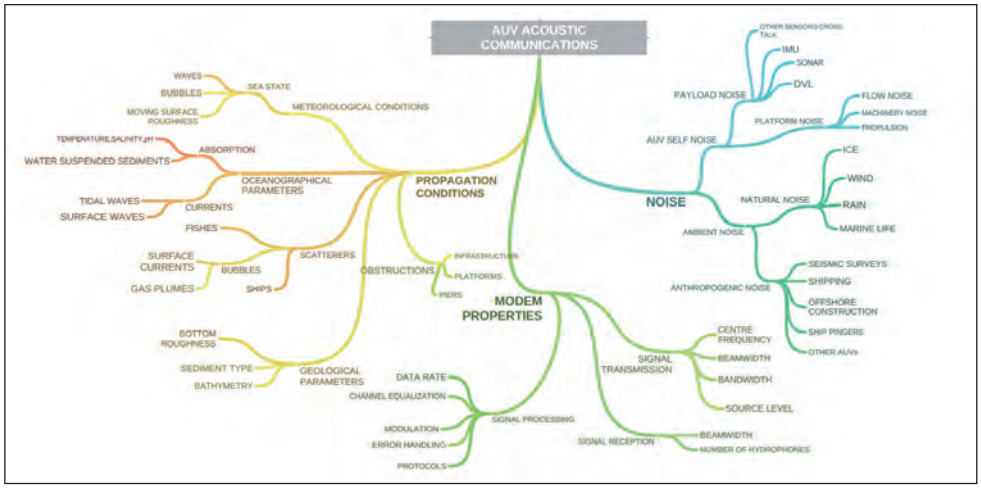
Propagation Conditions

The following physical mechanisms can deform the signal and challenge the reception and interpretation of the contained message:

- **Frequency-dependent attenuation:** for frequencies relevant to underwater communications (1-100kHz), attenuation by water strongly depends on frequency. This results in a strong dependence between the communication range and the useful acoustic bandwidth.
- **Geometrical spreading and multipath propagation:** As acoustic energy spreads over larger areas the level diminishes with range. Furthermore, reflection from the bottom and sea-surface boundaries will cause distortion of the signal, the net effect being a spreading of the received signal over time.
- **Ocean surface variability:** The movements of the surface due to wind and currents strongly affect the surface communication paths, causing Doppler spreading of the signal in frequency. For a realistic channel, the distribution of signal power over time and frequency (Doppler shift) is shown in Figure 2.
- **Variable speed of sound:** Sound bends towards regions where the sound speed is lower. In deep waters, this is the main factor affecting communication between two platforms due to the creation of 'shadow zones' where no acoustic communication is possible. In the North Sea, the sound speed profile is relatively constant over depth due to the mixing of the water by currents and waves.

Modem Properties

An underwater modem translates digital messages into waveforms that can be transmitted acoustically. Digital modulation is the technique that allows a digital signal to be transferred over an analog channel and



▲ *Figure 1: Overview of factors influencing underwater communication performance.*

Non-coherent modulation methods			
Type	Rate [kbps]	Band [kHz]	Range [km]
M-FSK	1.2	5	3
M-FSK	2.4	5	5
Coherent modulation methods			
Type	Rate [kbps]	Band [kHz]	Range [km]
M-PSK	0.5	0.3-1	90
M-PSK	0.02	20	0.9
M-PSK	6.7	2-10	2
16-QAM	40	10	0.3

▲ *Table 1: Overview of commonly used modulation methods with typical ranges and nominal bandwidths. Courtesy of Akyildiz et al.*

consists of mapping the information bits into analog waveforms that represent the data that we want to transmit. After propagation through the medium, received analog signals are sampled and demodulated to recover the original digital message.

The main characteristics of an underwater modem are its communication bandwidth, its carrier frequency and the employed modulation method. The useful bandwidth is strongly dependent on the environment and the communication range. Often, for a modem designer, the goal is to optimise effective data rates while simultaneously focusing on robustness. To reach both these goals, the modulation must be spectrally efficient, and be able to cope with the time-varying underwater conditions. Within their designated bands, most underwater modems are not limited by ambient noise, but by delay and Doppler spreading, i.e. the signal can be heard but not understood due to its distortion by the channel. At present, most commercial modems use non-phase-coherent modulation. Improvement can be attained by using phase-coherent modulation schemes, which require estimation and tracking of the phase of the transmitter. An overview of common underwater modulation methods tested in shallow waters is given in Table 1.

This article has originally been written for, and was published in, *Hydro International* Unmanned Systems Special, July/August 2016.

The main ones are based on Frequency Shift Keying (M-FSK), Phase Shift Keying (M-PSK) or Quadrature Amplitude Modulation (QAM).

Noise in the Communication Band

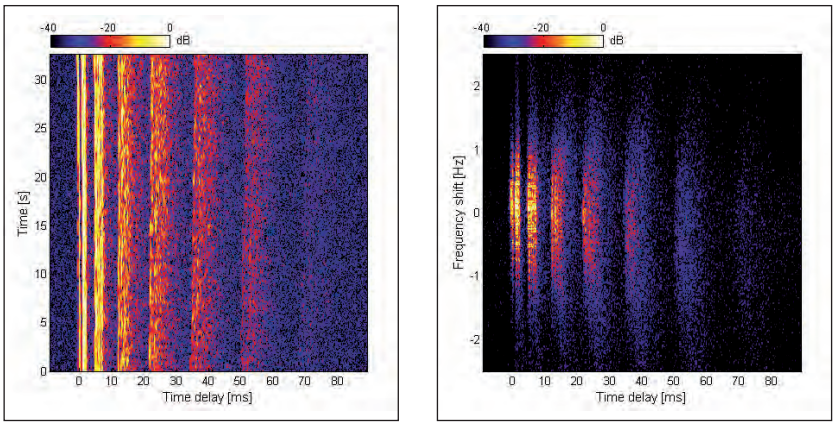
AUV Noise

Noise from an AUV can interfere with the onboard modem and with the reception of acoustic messages from a receiving hydrophone. Noise sources at the AUV include hull vibrations and mechanical noise, propeller noise, electronic noise, flow-induced noise and payload cross talk. We measured the net radiated noise by an AUV during a sea trial in the EDA-NECSAVE project. Figure 3 shows the uncalibrated sound pressure spectral density level (0 - 35kHz) measured by a receiving hydrophone while the AUV was approaching at a speed of 2m/s from a distance of 500 to 50m. Acoustic messages are transmitted and received in the 18-34kHz band (Figure 3: the sharp vertical lines are acoustic messages between the AUV and the control station). The AUV noise contributes mostly to the lower part of the frequency spectrum (<15kHz) at these distances but on approach the high frequency contribution increases, because of the diminished attenuation. At close distance AUV self-noise can therefore be a significant source of disturbance for communications. It is easy to understand how this could be even more important for an onboard acoustic sensor.

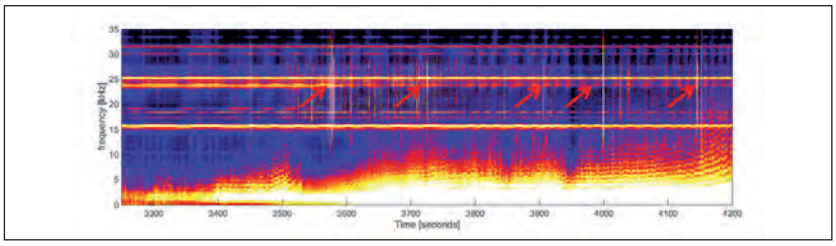
Ambient noise

Ambient noise is most prevalent in the low frequency band. However, anthropogenic noise originating from nearby sources can have a disruptive effect for communications, as can be seen in the recording shown in Figure 5 where a ship is passing nearby an AUV communicating to a control station. At time 15:00, the ship is at its closest point of approach and the noise covers the whole communication band causing potential

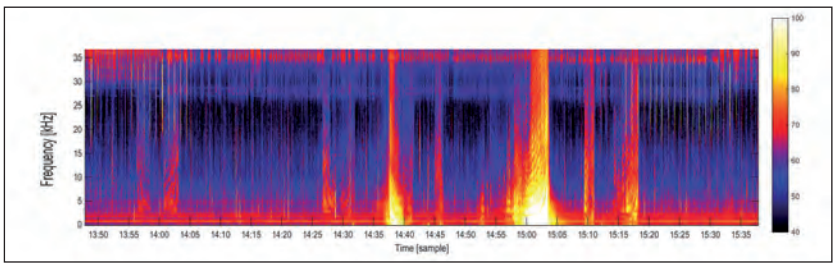
Noise from an AUV can interfere with the onboard modem and with the reception of acoustic messages



▲ *Figure 2: Impulse response evolution measured in time (left) and the delay-Doppler spreading function (right) from the TNO RACUN trial. Image courtesy: H. Dol.*



▲ *Figure 3: Uncalibrated spectral density level for a small size AUV approaching the receiving hydrophone at a speed of 2m/s up to 50m distance starting at 500m.*



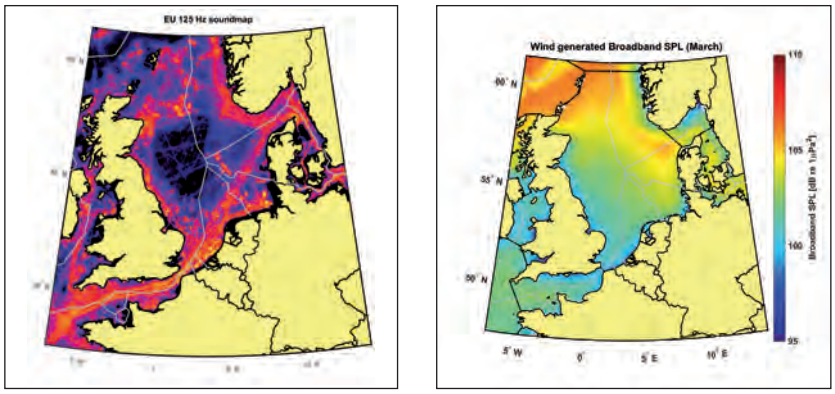
▲ *Figure 4: Calibrated recording of underwater sound from a test in a harbour with a small size AUV and multiple ships passing. The colour scale is sound pressure spectral density level in dB re 1μPa²/Hz.*

drop-out of messages. Although this effect is only significant for close passages, the intensity of shipping in the North Sea makes it an important effect to be taken into account when performing operations. As an example, a sound map due to shipping in the North Sea is shown in Figure 5 (left).
Models such as the Wentz curve do not capture the strong variability in space and time and of the noise sources. Figure 5 (right) shows a sound map for wind in the North Sea in March that has strong location and season dependence due to the variability of oceanographic parameters.

Conclusions

Many factors can affect underwater communication to and from AUVs. By having good knowledge of these factors in situ, it is possible to plan AUV operations more efficiently by adapting the bandwidth, communication protocol, network topology, and level of autonomy of the vehicle used. In particular, future networked operations in the North Sea should be complemented by planning tools that take all the parameters presented in Table 1 into account to realistically predict and improve the performance of AUV communications (giving an 'underwater communication range of the day'). ◀

Physical mechanisms can deform the signal and challenge the reception and interpretation



▲ *Figure 5: (left) The modelled yearly-averaged spatial distribution of ship-generated sound pressure level in the 125Hz one-third octave band. (right) Broad-band SPL for wind-generated sound for the average wind speed in March. Both maps are generated with the Aquarius sound mapping software developed by TNO.*

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Dr. Koen Blom received his MSc in Computer Science in 2009 and received his PhD on blind equalisation techniques for underwater communications in 2014, both from the Technical University of Twente, the Netherlands. He has been working at TNO's Acoustics & Sonar department since February 2015, where he contributes to projects on acoustic communications, both in air and underwater.

New Horizon of Underwater Explorations

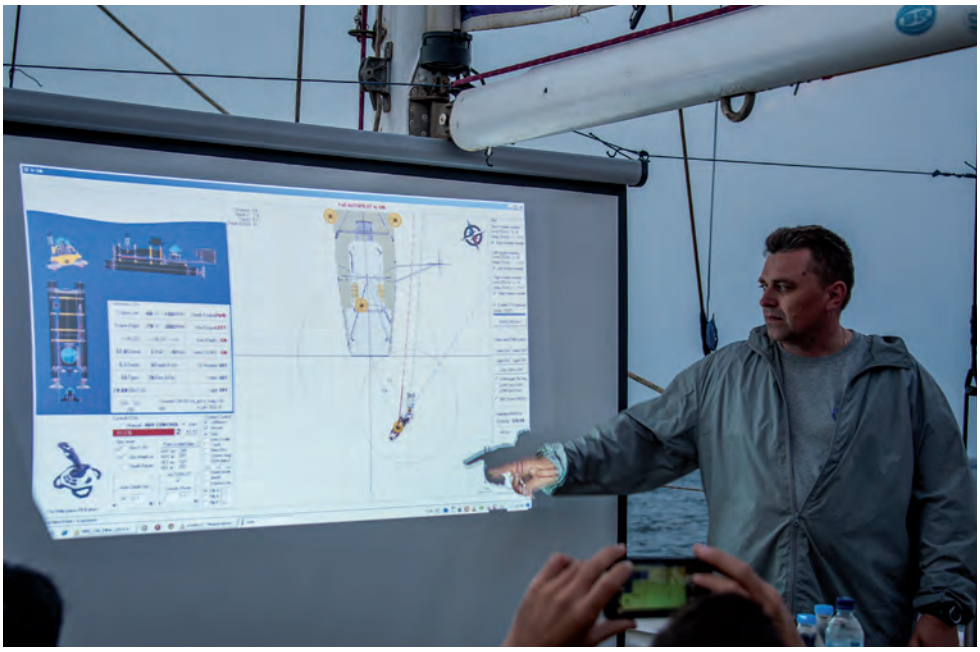
Underwater Wireless Video Communication

This article presents the development, production and testing of wireless underwater acoustic video communications, which is unique in the world today. It also discusses the implementation of this technique on Autonomous Underwater Vehicles (AUVs) to perform inspections of underwater oil and gas pipelines. The achieved characteristics, limitations and upcoming prospects are presented.

Currently, there are about 1000 Remotely Operated Vehicles (ROVs) and up to 700 AUVs in the world, according to Douglas-Westwood. In the coming 4 to 5 years it is expected that this fleet can be increased by 50-60% and may be even more than doubled.

The vast majority of AUVs currently belongs to the defence industry, where they are called Unmanned Underwater Vehicles (UUV). There is no difference in meaning between UUV and AUV, but the abbreviation UUV is used in the defence industry and in military circles, and therefore corresponds to military applications; AUV is used in civil applications. In the military applications, approximately 35% are 'heavy' vehicles, 25% are 'middle' vehicles and 40% are 'light' vehicles.

The majority of heavy ROV vehicles are used in drilling and construction support of the subsea infrastructure in the oil & gas industry. Light ROV vehicles are often used in Inspection Repair and Maintenance (IRM). Of these approximately 70-80 percent of all ROVs are 'heavy' to 'medium' and 20-30 % are 'light' vehicles.



▲ *Figure 1: Automatic routing and DP.*

There have been attempts to shift UUV applications from the defence to civil market, assuming that AUVs will take over some IRM tasks from ROVs. Much attention has been paid to deep water ROV & AUV operations in depths up to 3,000 metres of water. Although from a market point of view, such 'frontier types' of vehicles will not be decisive because about 80% of the total pipelines length are located in depths shallower than 500 metres.

The Oil & Gas industry has been under pressure over the past 2 years, which has resulted in a challenge to reduce prices and therefore also a critical review of approaches to development in the industry. For example, with regard to IRM of underwater pipelines. Currently the total length of pipelines in the world is approximately 150 thousand km, and will increase by 20% towards 2019. As a majority of these pipelines is older than 20-25 years, the approaching end of their life cycle will mean that the requirements with respect to conducting regular inspections will be tightened and the inspection frequency increased.
Ecological requirements and government regulations will press the operators to increase IRM operations with the increasing of age of

▲ *Figure 2: AUV 'X-3A'.*

▲ *Figure 3:* Maeksa *in St Julians Bay.*

pipelines, despite the decline in oil prices. Furthermore, the need to optimise the budgets in this situation requires the introduction of new advanced technologies, including the transition from ROV-based inspections to AUV-based ones.

Thus, the objective reasons and formal requirements force operators to increase the operating costs while the optimisation of budgets is more urgent on the agenda!

What does this means in terms of money? The cost of renting a vessel with an ROV is roughly estimated to be around USD100,000 per day. The 'availability factor' taking into account the weather conditions influence is about 0.3 in the equatorial regions, and less in the North Sea. In theory, vessel & ROV can inspect some 10-20km per day, but the actual average productivity per day is usually about 2-5km per day due to missed days/weeks of hard weather! This initial data will enable us to calculate that for 5km the financing of the inspection of 25% of extent would be around USD2-3 billion! This is a substantial amount. Although, if you consider that BP paid USD62 billion for the Deepwater Horizon spill in 2010, and the real damage to nature cannot really be estimated, the USD 2-3 billion seem to be fully justified. Any possible optimisations will therefore be welcomed by operators.

There are also some ROV limitations: hooks' of tethers, 'start' and 'extracting' breaks, weather limitations etc.

Automation can be used to optimise these costs. In this case we can attain greater effectiveness if we expand the limits for weather conditions and have more 'availability factor'. The first and the second lead to AUVs instead of ROVs.

"The lack of breakthroughs in wireless underwater communication and battery capacity is prolonging the wait for a fully autonomous underwater vehicle (AUV), one that will not need a USD100,000/day vessel and crew, a heavy tether for power and control or hours to complete a task that might take minutes onshore." This quote clarifies the essence of the problem: to go to the automatic inspection on the basis of AUVs it was necessary to first solve the problem of transmitting video wirelessly. The problem of power is not very critical for light AUVs; it is quite acceptable to have batteries that provide mission durations of up to 24 hours or even more. When an AUV can cruise up to a speed of 5 knots it has the possibility of carrying out inspections at a distance of 100km!

The History of Wireless Underwater Video Development

Dozens of scientific and industrial groups from almost all the leading countries of the world have been involved in developments over the past 20 years. BaltRobotics have designed a solution and successfully tested it.

However, the mere existence of the underwater wireless video transmission channel is not yet the NDT application for the inspections of oil & gas subsea pipelines.

Firstly, a specialised vessel is required for permanent marine testing, which is a key element of the cost to develop a system. The lack of testing in real marine environments can be seen as the main factor for failure. BaltRobotics redesigned the former German Fish Hunter vessel built in 1935 and combined special laboratories and scientific facilities.

An AUV X-3A was designed with all needed subsystems: DVL &NS, SBL, etc. The AUV X-3A differs from many other solutions in that it has a 'Dynamic Positioning' mode that it critical in offshore but usually absent in UUVs; and the automatic routing system was also implemented. This means that AUV X-3A can be remotely controlled wirelessly simply using a joystick. A demonstration of the vessel & AUV complex was held on 21 May 2015 in Malta (St. Julian's Bay, Sliema).

The vessel *Maeksa* is a motor sailing boat 21m in length with 66 tons of displacement. Initially it that was a former 'fish hunter' made in Germany before WWII. The vessel was equipped with an SBL (Short Base Line) reference navigation system for AUV, a wireless underwater acoustic video communication channel and a command channel for AUV. During the demonstration the audience on board was presented: 1) wireless undersea acoustic video communication – AUV transmitted the video online; for which it used the 'softly constructed' target (to be constantly

moving) – the 'white tube' with the signatures of participants to prove the video was real and valid, 2) the automatic routing of AUV was demonstrated by one of the participants who had no previous experience of controlling undersea vehicles, 3) Dynamic Positioning of AUV was demonstrated (DP) with the bottom current in the bay around 1m per second (see the photos).

Configuration and Channel Characteristics

The System has adapted its characteristics to the remote control mode – 'wireless ROV' mode. This is very important at the beginning of the inspection mission: to search the pipeline, to search sacrificial anode, etc. All this can be wirelessly controlled remotely at a distance up to 200m. Is this a lot or a little? More than 50% of the length of the undersea oil & gas pipelines in 2015 were at depths of 0-100m, and about 20% were at a depth of 100m to 500m, i.e. on the continental shelf (depths up to 500m). Thus, more than 50% of all subsea pipelines can be inspected by the systems with underwater wireless video.

Prospects

Research conducted by BaltRobotics revealed that the principal limit for wireless underwater acoustic video, namely 500m, will be difficult to overcome in the nearest future. The current plans of the company are to enlarge the working distance to 350m. ◂

More information

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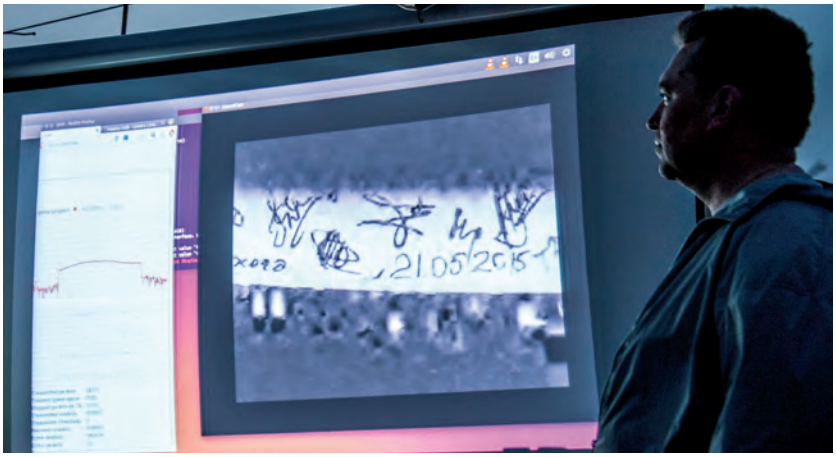

▲ *Figure 4: Wireless underwater video.*

▲ *Figure 5: Participant controls the AUV.*

Acoustic High Data Rate Modem: working distance – till 0.2km; data rate – 115.2kbod; full duplex mode; interface – Ethernet.
Antenna with Positioning & Control System: frequency - 500kHz/1000kHz; beam width - 4°.
Video Camera: HD
Video Blaster (Black Magic)
PC & 'NVideo-560' (processors – 512 cores, 0.9 GHz)
Underwater Unit Software for Video Compression of 'UltraVNP-Compression Algorithm': 0.02 bit per pixel; 30 frames per sec; buffering – 0.1 sec.

▲ *Table 1: System parameters and configuration.*

Kirill Otradnov– partner, CTO and chief designer at BaltRobotics. He is an experienced project manager in complex international projects on robotics, telecommunication and control systems and has been team leader in many international projects for such customers as PETRONAS (Malaysia), DARPA (USA), NASA (USA), Hollywood (USA), and many others. He has more than 22 years of experience.

Volodymyr Shuliak - Partner at BaltRobotics. He is a business entrepreneur and investor of innovative start-ups. Several businesses have been started by Volodymyr, including the manufacturing of activated basalt flakes as the fillers of anti-corrosion polymer coatings for a high level of protection.

Sergii Kornieiev - CEO/president of BaltRobotics. He was project manager of many large innovative international projects and has business administration experience in engineering companies, cooperating with IFS AB, Siemens, PETRONAS, and many others. His scientific interests include artificial intelligence, ERP, telecommunications & control systems and he has published more than 50 articles.
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Water Data Standards Enable New Models and Applications

Hydrography for Continental Streamflow Modelling

Land surface hydrography now supports the modelling of continental-scale streamflow at high resolution and in near-real-time. The US National Hydrography Dataset contains about 2.7 million stream segments averaging 2km in length. This database establishes a national topological network of streams and their drainage areas. This network is now being used in computational models of streamflow that can be run in just 12 minutes for the entire country. This approach is starting to be applied globally.

Imagine a continental-scale hydrographic dataset being used for local-scale operational forecasting of streamflow and flooding in near-real-time. This article outlines the surface water hydrography, datasets, standards and models that have become key parts of the National Water Model (NWM) for the United States National Weather Service (NWS), as well as global outreach to bring this capability to other countries. This starts with a discussion of the National Flood Interoperability Experiment (NFIE).

The first-ever continental-scale simulation of the national river system as a single network

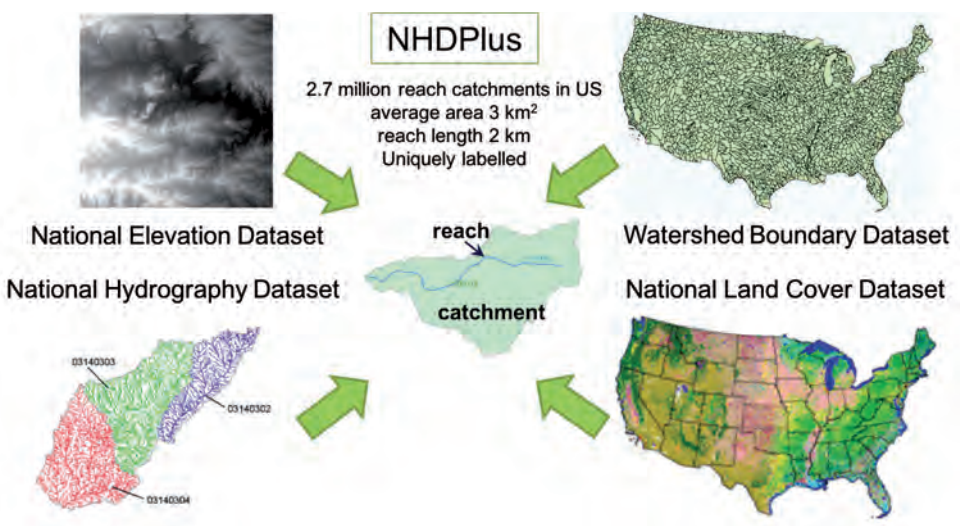
How It Started: NFIE 2015

As a contribution to the US Open Water Data Initiative, NFIE began organising a collaboration of academia, commercial software and engineering firms, and federal agencies in the fall of 2014, for improving our ability to model the nation's streamflow and flooding (Maidment 2015). NFIE brought together experts and tools in hydrographic and other representations of the nation's landscape, land-surface modelling of hydrometeorological dynamics, and streamflow routing of runoff from rainfall. These tools built on each other, leading to an operational workflow running every three hours, every day.

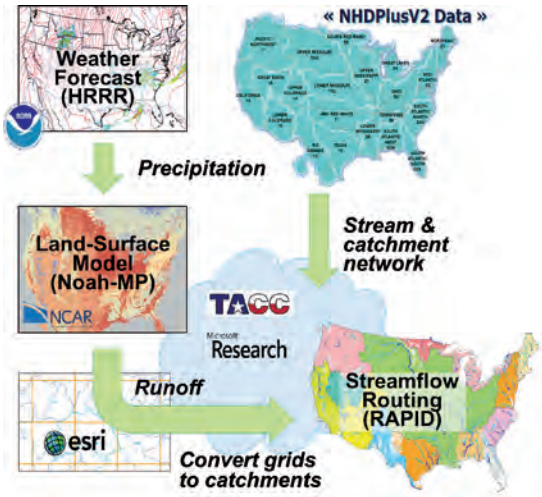
The NFIE Summer Institute 2015, conducted at the National Water Center (NWC) in Tuscaloosa Alabama, was a 7-week laboratory bringing together dozens of researchers from around the world, to start tackling flood mapping, data integrity, calibration, uncertainty, and other topics. Their work was published in a special theme issue of the *Journal of American Water Resources Association (JAWRA)*. The next NFIE Summer Institute 2016 was held in June-July at the NWC.

Hydrologic Geospatial Fabric

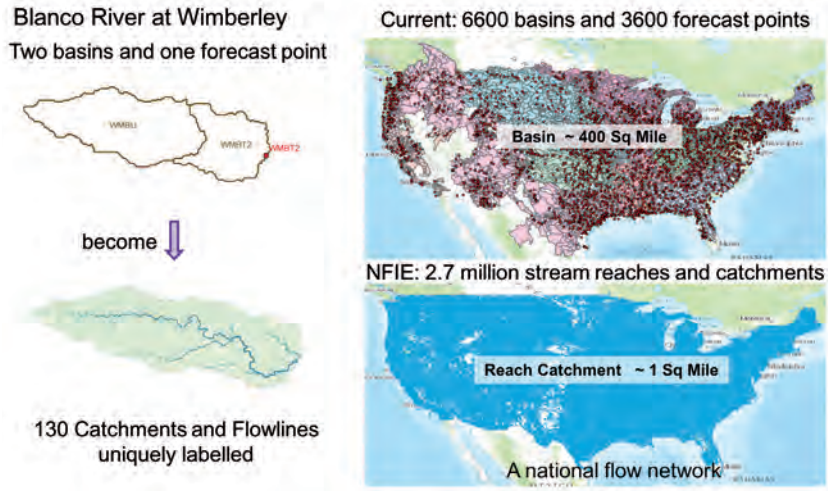
The foundation data for this process is the hydrologic geospatial fabric, or just geofabric, a term first introduced in Australia. In the US, this refers to the hydrography, land cover, and surface elevations of the landscape. The hydrography component of the geofabric in NFIE is based on the US National Hydrography Dataset (NHD) and Watershed Boundary



▲ *Figure 1: Hydrologic Geospatial Fabric Data.*



▲ *Figure 2: National Flood Interoperability Experiment (NFIE) Modelling Workflow.*



▲ *Figure 3: National Weather Service Regional Forecast Points and Basins.*

Dataset (WBD), developed by the US Geological Survey (USGS) to portray surface water features on The National Map. The NHD was first generated at a scale of 1:100,000, then later densified to 1:24,000. The NHDPlus (now in version 2) is the NHD at 1:100,000 scale, augmented to incorporate the unique drainage area (catchment) associated with each stream segment (reach). At this scale there are about 2.7 million reach-catchment pairs in the continental US, averaging 2km in length and 3 square km in area. The surface elevation started with the National Elevation Dataset (NED) which has 10-metre resolution, but this will transition to the USGS 3D Elevation Program (3DEP), which started collecting 1-metre and 3-metre resolution elevations by Lidar in 2015. The computational models can work with varying resolutions of landscape, but the high-resolution elevation is more critical for flood mapping than it is for streamflow routing; 10-metre resolution or better is needed. The geofabric's land cover is from the National Land Cover Database (NLCD). These are illustrated in Figure 1.

Streamflow is controlled by a number of factors that can be affected by dams and other flood control structures

Weather and Land-Surface Models

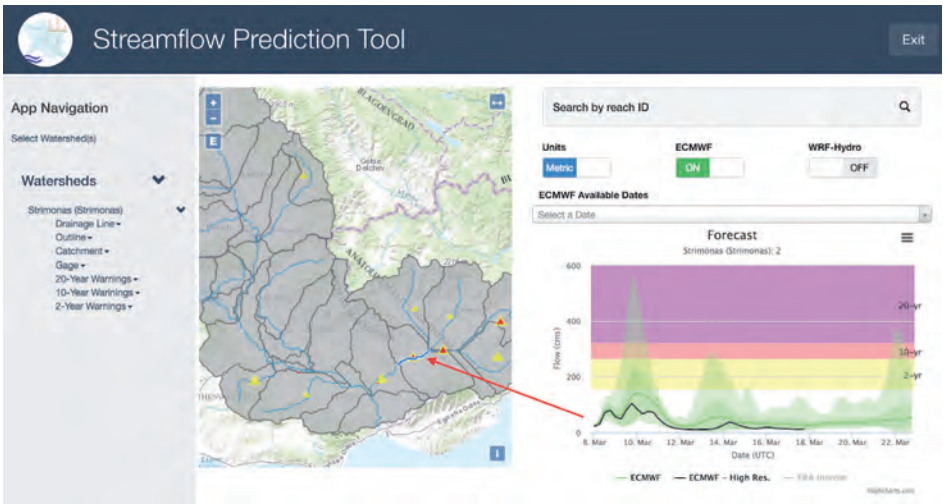
Streamflow, typically measured in cubic feet (or metres) per second, is controlled by a number of factors, mainly precipitation, runoff, elevation change, and upstream contributions, which might be affected by dams and other flood control structures. The NWS generates a range of forecasts, from near-term (0-15 hours) to long-term (up to 30 days). For the NFIE 2015, the High Resolution Rapid Refresh (HRRR) 15-hour forecast was used. This estimated rainfall and snowfall, divided over a seamless grid of 3km x 3km cells across the country, updated every 3 hours.

For NFIE 2015, this forecast was processed to estimate surface and subsurface runoff to the stream network, by a land-surface model called Noah Multi-Physics (Noah-MP). Based on land-surface descriptions from elevation and land cover, Noah-MP predicted runoff, soil moisture, and many other parameters. The runoff data and NHDPlus stream network were then fed into the streamflow routing model, RAPID (River Application for Parallel Computatlon of Discharge), which estimated the streamflow for each of the 2.7 million NHDPlus stream reaches. Noah-MP and RAPID were integrated through the WRF-Hydro (Weather Research and Forecast – Hydrological) framework, managed by the National Center for Atmospheric Research (NCAR), and run on a high-performance platform at the University of Texas Advanced Computing Center (TACC). Figure 2 shows the overall workflow.

What a Difference This Made

Before NFIE, the national weather forecasts were developed into streamflow forecasts by thirteen Regional Forecast Centers (RFC). Each RFC had its own streamflow models, which had much coarser spatial resolution than NHD. There are 3600 forecast points and 6600 basins across the country, averaging 400 square miles per basin. Many coastal areas were not included in these forecast points and basins, totaling about 100 million in population. With NFIE, this densified to 2.7 million forecast points and catchments, fully coast-to-coast, for an improvement in forecast points by a factor of 750 (see Figure 3). Moreover, the overall quality of predictions was generally good, particularly when reservoir releases could be taken into account.

The NFIE procedure took a combination of efforts and accomplishments including extensive cloud usage, high-performance computing, consultation with XSEDE experts, and a lot of attention to performance. As a result, depending on the number of processors used, the workflow from ingest of HRRR precipitation forecasts to output from the combined WRF-Hydro/RAPID system could be run in 10-12 minutes, for the 2.7 million stream reaches in the continental US, for each 15-hour forecast. This is the first-ever continental-scale



▲ *Figure 4: Tethys Streamflow Prediction Tool, showing Strimonis River basin in Bulgaria and Greece.*

simulation of the national river system as a single network.

Data Exchange Standards

Underlying the workflow are data exchanges to feed the weather forecast (rainfall gridded at 3km x 3km) and NLCD to the Noah-MP land surface model; then to feed the land surface model output (runoff gridded at 3km x 3km, converted to reach-catchment boundaries) to the RAPID streamflow routing model. The data payloads for these exchanges were encoded using the Open Geospatial Consortium (OGC) international standards, network Common Data Form (netCDF) and Climate and Forecast (CF) Convention. NetCDF defines an application programming interface (API) to multi-dimensional array-based datasets, while the CF convention defines rules for handling Earth observation data specifically within netCDF. This is a compact binary data format that is portable across computing platforms.

The project also collected daily observations at about 9000 USGS stream gages operating in real-time across the country, through the National Water Information System (NWIS). These observations were published in another OGC standard encoding WaterML 2, converted to netCDF-CF, then compared with the model forecasts to calibrate and improve the model predictions (Lin et al, 2016). WaterML 2 is preferred by the USGS for publishing water observations because of its rich metadata. NetCDF-CF, however, is much more compact, taking just kilobytes of storage vs. megabytes of WaterML, with the same timeseries data content. Both forms have important roles.

Global Outreach

Fast, accurate streamflow and flood forecasts are goals throughout the world, and the need is particularly acute in developing countries. An important programme started by the European Centre for Medium-Range Weather Forecasting (ECMWF) in Reading, UK, and the Joint Research Centre (JRC) in Ispra, Italy, is called the Global Flood Awareness System (GloFAS), which is an extension of the European Flood Awareness System (EFAS). EFAS provides real-time flood forecasting throughout Europe. GloFAS predicts floods elsewhere up to 2 weeks in advance using ECMWF's longer-term forecast. A team based at Brigham Young University (BYU) has developed an application called the Streamflow Prediction Tool that uses the same ECMWF 2-week forecasts of rainfall and runoff used in GloFAS, but applies them to the RAPID model for streamflow routing, instead of the model used in GloFAS. This was built using BYU's Tethys Platform. Figure 4 shows an example of using this tool to predict recent high streamflow in the Strimonis River basin which crosses Bulgaria and Greece. The yellow and red triangles in this figure are warning symbols, and the red arrow indicates the reach being graphed. Note the reach-catchment hydrography in Figure 4, which was necessary for using RAPID. This hydrography was developed locally, and the model workflow could be run on a desktop computer; did not require high-performance computing.

Acknowledgements

Thanks to the visionary teams led by David R. Maidment, Edward Clark, David Gochis, Peirong Lin, Fernando Salas, Jim Nelson, Peter Salamon, and Florian Pappenberger, and Emmanouel Tsiros! ◀

More information

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Small Boat Work – Dangerous Then, Dangerous Today

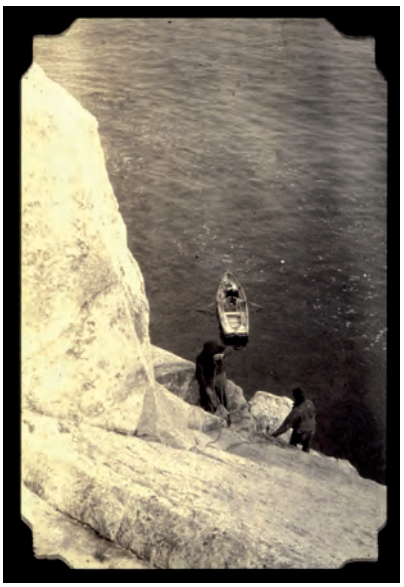
The ability to conduct inshore hydrographic surveys has always been dependent on small boats and the seamanship of those conducting the surveys. Besides the obvious use of small boats for the acquisition of soundings and their accompanying positions, it was not so long ago that many surveys of remote and open coastlines also had to transport topographic and geodetic survey crews to shore camps or daily work areas. Although the nature of both shore work and hydrographic work has changed somewhat over the years, small boat work with its attendant dangers has remained a constant.

Before the days of radio communications, mechanical propulsion systems, radar and electronic navigation systems, the surveyors were dependent only on their seamanship to make their way safely to and from their ships. For propulsion, they had only their skill with oars and sometimes sails. And sometimes, even when in sight of the ship or shore, disaster could strike. When out of sight of the ship, the surveyors were on their own.

Although hydrographers experienced many halcyon days of gentle seas and glorious weather, as little as twenty to thirty years ago hydrographers had little knowledge of what the afternoon weather or seas would be when putting the boats over from a mother ship in the early morning. Unpredictable weather and seas, unknown and hidden dangers to navigation, and sometimes hostile natives all combined to make the work of the hydrographer dangerous and sometimes deadly.

The hydrographers of all nations engaged in charting have experienced the danger of the

▲ *Figure 1: Landing under oars in rough waters – a dangerous proposition.*



▲ *Figure 2: Sometimes the work was more dangerous after departing the boat.*

▲ *Figure 3: Landings were sometimes hazardous for the crew ashore as well. Landing on a steep-to beach.*

work. Although Spanish, Portuguese and Dutch hydrographers pioneered the early sea routes, few accounts can be found of their early work, particularly as related to small boat work. Curiously, two of the earlier accounts of the dangers of small boat work occurred within a few hundred miles of each other on the coast of Alaska.

Vitus Bering, who sailed through Bering Strait but missed seeing the Alaskan coast in 1728, embarked on a northern Pacific voyage in search of the American continent in 1741 with two ships, the *St. Peter* and the *St. Paul*. The ships separated in poor weather and Bering's second in command, Alexei Chirikov on the *St. Paul*, actually made landfall one day earlier than Bering on 15 July 1741. Chirikov's landfall was on what was probably Prince of Wales Island in today's southeast Alaska, while Bering made landfall on 16 July in the vicinity of Mt. St Elias, over 400 miles to the northwest. For three days Chirikov proceeded to the north looking for a harbour. Apparently he was far offshore as there are numerous openings that he could have entered. Instead, on July 18, he finally spied what he thought would be a safe harbour and sent a boat crew with eleven men to sound it out and attempt to make contact with the natives. The boat did not return and poor weather set in for a number of days before Chirikov could send in a second boat with four men to investigate. This boat did not return either – seemingly both disappeared into thin air. Chirikov had no choice but to abandon his men to their fate as he had no other boats. This first European attempt to sound out a harbour on the coast of northwest America netted fifteen men lost. Whether they were victimised by weather, seas, or native Americans remains a mystery.

Forty-five years later, the French explorer Jean François de Galaup, comte de Lapérouse, embarked on a scientific circumnavigation of the earth, only to vanish with his ships somewhere north of Australia. Before meeting this end, he had investigated the Alaskan coastline earlier and discovered a bay that he called Port des Francais (today called Lituya Bay) in July 1786. He brought his ship through the narrow entrance on July 3 and commenced surveying the bay. He erected a small observatory on the central island of the bay for observing latitude and longitude as well. By the 13th the survey was nearly finished except a few remaining soundings to finish the work at the entrance of the bay. Three boats were sent out. Initially one boat was swamped and overturned in the breaker line. A second boat that went to the rescue was also overturned. The third boat, fearing a similar fate, watched helplessly and then returned to the ship with the sad news. In total, twenty-one men had lost their lives on the bar of Lituya Bay. The next two weeks were spent in fruitlessly searching for bodies. The remaining crew also erected a cenotaph on the central island and named the island Cenotaph Island, a name that has survived up to the present. Like the boat crews that had been swept away earlier, the memorial was swept away by the Lituya Bay mega-tsunami of 9 July 1958, a wave that swept trees off the surrounding mountains over 500 metres above the surface of the bay.

By the early 1800s, the British Admiralty's Hydrographic Office had embarked on an ambitious programme of surveying the coastlines of the world. In this they largely succeeded, however, sometimes at the cost of surveyor's lives. Half a world away from the early Alaskan disasters, Matthew Flinders embarked on his great Australian surveys on the first HMS *Investigator*. Leaving England in July 1801, the *Investigator* proceeded to Australia via the Cape of Good Hope. On 6 December, Flinders made landfall at Cape Leeuwin and then conducted a running survey along Australia's south coast. Two months later he had arrived off the western entrance to Spencer Gulf. Here he sent a cutter ashore in search of water with his good friend and shipmate since 1794, Mr. Thistle, and seven other crewmen. Their boat was spied leaving the beach at dusk but never returned to the ship. A second boat was sent out to investigate and reported dangerous tide rips and overfalls in the vicinity of where Thistle's boat had last been seen. The following day, remains of the boat were found but traces of its crew were never found. Flinders commemorated these men by naming Cape Catastrophe, Memory Cove, and eight small islands for each of the

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men who lost their lives - Thistle, Taylor, Smith, Lewis, Grindal, Little, Hopkins and Williams. Nearly 180 degrees of longitude from Cape Catastrophe lies Cape Horn and the Straits of Magellan. The British Hydrographic Office began surveying these straits in 1826 under Captain Philip Gidley King on HMS *Adventure* with the tender HMS *Beagle* under Captain Pringle Stokes. These ships and their crews encountered extreme weather during these surveys with the attendant dangers to both ships and boat crews. The dangerous nature of their survey work was noted in *The Admiralty Chart* by Admiral George Ritchie: "The extreme foulness of the weather was brought home to the *Adventure* when, only a month after operations began, Lieutenant Ainsworth was lost with two of his crew when high winds overtook him in the gig whilst crossing the Strait to Port Famine." The rigors of this survey were such that they caused Captain Stokes to commit suicide by shooting himself. He died in a delirium after twelve days , imagining that the *Beagle* was driving on a lee shore for the last and fatal time. Lieutenant Skyring temporarily took command of the *Beagle* before being relieved by Captain Robert Fitzwilliam Fitzroy – commanding officer of the *Beagle* during the famous cruise of Charles Darwin. Fitzroy also committed suicide, but nearly 40 years later by slitting his throat with a straight razor.

Although weather and waves killed many hydrographers, by far the largest number of fatalities occurred during the survey of 30,000 miles of African coast by Captain W. F. Owen on the *Leven* and the follow-on surveys. This survey is of near legendary status in the annals of British hydrography. These fatalities were almost always the result of disease as compared to boat accidents. It was nearly a death sentence for detached survey crews to be left ashore or sent up tropical rivers. A hydrographic party left in an accompanying tender called the *Cockburn* lost 13 of 20 men in 1823 when left at a shore camp at Delagoa Bay. Captain John Washington, a future head of the Hydrographic Office, wrote in 1838: "This gigantic survey, embracing the east and west coast of Africa, from the Isthmus of Suez round by the Cape of Good Hope to the Pillars of Hercules, may be said to have been drawn and coloured with drops of blood. Twice did Captain Owen change his whole crew and officers; those accomplished surveyors, Captain Boteler and Skyring, fell a sacrifice during its progress, and now, in the hour of conclusion, the crews of the *Etna* and *Raven* have all but shared their fate."

Returning to North America, the United States Coast Survey was not immune to the dangers of small boat work. Coast surveyors drowned in small boat accidents in the Kennebec River, Maine; Apalachicola Bay, Florida; Mobile Bay, Alabama; San Luis Pass, Texas; Tillamook River Bar, Oregon; Columbia River, Oregon; Jo Creek, Washington; numerous points on the Alaska coast; and numerous points in the Philippine Islands. Perhaps the most poignant of these was the occurrence at Apalachicola when two officers and four seamen were returning to the Coast Survey schooner *Silliman* from Sunday church services. They were under sail when a sudden gust of wind overturned the small boat. All six men drowned. Although Alexander Dallas Bache, the second superintendent of the Coast Survey, was eulogising three young men who died in the line of duty in 1852, the following is true of many of the surveyors noted in this article: "These officers have left little to their families but the inheritance of a good name."

The addition of engines and outboard motors, although mitigating the loss of life in small boat accidents, did not entirely end fatal accidents. On 26 September 1936, Lt. Marshall Reese and Quartermaster Max McLees left a shore camp on Unimak Island in a dory with an outboard motor to obtain supplies and communicate with the ship. The men remaining in camp, helpless to assist, saw the dory capsize and drift out to sea with the two men clinging to it. Two of the remaining men hiked to Dutch Harbour and notified the Coast Guard which immediately put to sea. However, a terrific gale had been sweeping the area and the remains of Reese and McLees were never found. The most recent fatal boat accident in the United States Coast Survey occurred on 13 August 2002, when Eric Koss, coxswain of a survey launch off the NOAA Ship *Rainier*, lost his life off Elrington Island. He, like many of those hydrographers worldwide who lost their lives in the line of duty, is commemorated by naming a coastal feature in his honour. Koss Cove joins the names imparted by Flinders on the Australian coast, those given by Owen on the African coast, and those given by other hydrographers on the coasts of the world in commemorating their fallen comrades. ◂

▲ *Figure 4:* Peirce *hydrographic launch approaching ship for pickup. November front had just passed whipping up wind and sea. Mike Briscoe on the bow hook. Strength and agility are the prerequisites. Lt. (j.g.) Victoria Barnum is OIC, K.P. Keene the coxswain. Ship making lee during approach; boat out of water within two minutes of photo.*

▲ *Figure 5: Setting the mark. Memorial to a fallen shipmate, Able Seaman Eric Koss.*

EvoLogics GmbH, Germany

Bionic Solutions for Underwater Communication

EvoLogics GmbH is a private high-tech enterprise with headquarters in Berlin, Germany. The company designs and manufactures underwater information and communication systems, as well as hydroacoustic sensors. Its core values are rooted in bionic concepts that combine state of the art engineering with the best ideas found in nature.

EvoLogics was launched in 2000 with a small group of scientists and R&D experts, aiming to develop innovative technologies for maritime and offshore industries. To solve the common problems of transmitting data underwater, the team turned to dolphins - the ocean's 'talking nation' - known to use a wide variety of acoustic signals to efficiently communicate in the most challenging underwater conditions. The resulting EvoLogics S2C spread-spectrum communication technology grew into a whole 'ecosystem' of products that now includes several series of underwater acoustic modems, underwater positioning systems (USBL, LBL, SBL), networking protocols and developer frameworks, as well as novel robotic solutions.

Flexible underwater exploration and monitoring system, suitable to access hard-to-reach or yet unexplored areas

EvoLogics Today

In 2016, EvoLogics remains a close-knit team of 32 employees. The company's main business is solutions for underwater communication, positioning, navigation and monitoring applications. EvoLogics S2C R and S2C M lines of underwater acoustic modems and positioning systems cater to various scenarios and provide a high degree of customisation as is shown in Figure 1.

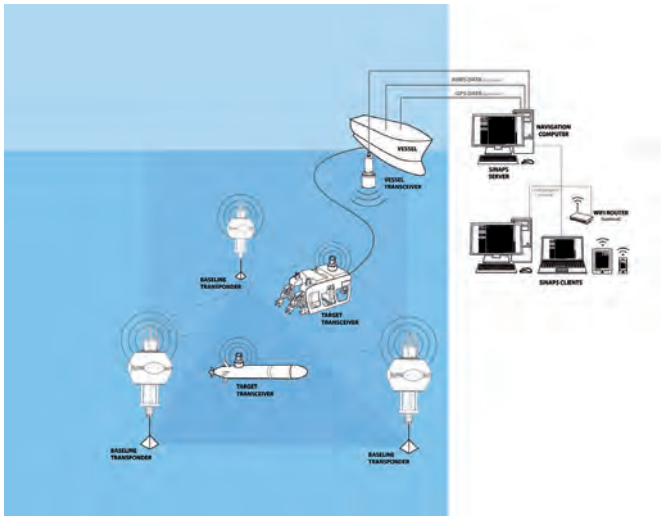
To offer cutting-edge technology, research and innovation have been an essential part of the EvoLogics DNA since the company's inception - the company is an active collaborator of several EU-funded R&D projects and encourages academic efforts of the employees. EvoLogics' range of hardware and software developer solutions includes an open-source framework for underwater networking and targets scientists and researchers worldwide. Current development is focused on intelligent integrated solutions extending the capabilities beyond communication and positioning into telecommunication centres and robotics.

▲ *Figure 1: EvoLogics underwater acoustic modems.*

Commercial Products

EvoLogics exports to international markets both directly and through its established distribution network. The company's key clients are offshore companies, fisheries, commercial service providers, state- and privately-funded research facilities and universities.

EvoLogics bestsellers are underwater acoustic modems that provide a highly reliable bidirectional data link along with acoustic positioning, broadcasting and networking. Applications range from retrieving data from subsea sensors and navigating unmanned underwater vehicles to deploying complex underwater sensor networks for monitoring and exploration. USBL and LBL positioning systems,



▲ *Figure 2: EvoLogics LBL positioning system.*

▲ *Figure 3: EvoLogics Sonobot USV.*

coupled with EvoLogics positioning software (SiNAPS), are gaining popularity among the clients, see Figure 2.
EviNS (the EvoLogics intelligent Networking Software) is the company's framework for developing, testing, debugging and implementing underwater acoustic network protocols and customer-specific applications. Besides seamless integration with EvoLogics underwater modem hardware, EviNS is fully compatible with EvoLogics modem emulator (available as an online service and as a hardware box) that makes it possible to work with a virtual network of underwater acoustic modems, significantly reducing time and cost for network protocol development.
EvoLogics is active in marine robotics - its communication technology is implemented in the company's unmanned surface vehicle, the Sonobot. Available as a commercial product since 2011, the Sonobot was initially developed as an easy-to-deploy bathymetric survey vehicle for inland and harbour waters. Equipped with EvoLogics S2C-technology echo sounder, the vehicle has since been tested for LBL baseline calibration and mini-ROV deployment (Figure 3).

Research and Development

EvoLogics' ongoing R&D efforts focus on underwater acoustic communication and positioning for distributed underwater networks. EvoLogics is part of the SWARMs (Smart and Networking Underwater Robots in Cooperation Meshes), an EU project focused on cooperative operation of unmanned underwater vehicles. Project collaborators aim to design a set of unified software and hardware components that will allow integrated operation of different UUVs, linked into a multimedia sensor network for various automated missions.
Another important project is WiMUST (Widely scalable Mobile Underwater Sonar Technology), where collaborators focus on engineering an intelligent distributed underwater array of marine robots for seismic acoustic surveys.
One of EvoLogics' recent R&D efforts in robotics is the BOSS (Bionic Observation and Survey System) project, a joint research effort, supported by the German Federal Ministry for Economic Affairs and Energy (BMWi). BOSS's goal is to create a powerful and flexible underwater exploration and monitoring system, particularly suitable to access hard-to-reach or yet unexplored areas with its unique functional properties.
Deployed in the target area for observation and survey, the BOSS system is a self-coordinating swarm of autonomous underwater vehicles (AUVs), all linked into a multimedia sensor network with the latest communication and navigation technologies. The AUV is the project's core innovation - engineered and built at EvoLogics, the experimental bionic vehicle is modelled after a Manta ray and can move through the water by wing-like movements of its 'pectoral fins'.

View on the Future

The EvoLogics philosophy of constant innovation defines the company's key directions for future development.
The team is working on expanding the functionality of EvoLogics underwater acoustic modems and positioning systems, and is soon to introduce atomic clock integration that will allow synchronisation with unprecedented accuracy. Constantly improving cost and time efficiency is the goal set for future hardware and software upgrades of the main product lines.
Underwater 'internet of things', allowing for intelligent cooperation between various vehicles and sensors, is the concept that guides EvoLogics' research and development team working on underwater networking protocols, a rapidly evolving field gaining momentum worldwide (Figure 4). ◀

More information
www.evologics.de

▲ *Figure 4: EvoLogics system deployment.*

Open Geospatial Consortium

The new **OGC Marine Domain** Working Group

OGC's new Marine DWG will investigate some critical issues surrounding the usefulness of marine data for purposes other than navigation. In doing this, it hopes to broaden the use of marine data and create demand for more thorough mapping of the oceans.

The Open Geospatial Consortium (OGC) Technical Committee meeting held in Dublin, Ireland in June 2016 saw the establishment of the new Marine Domain Working Group (DWG).

OGC DWGs provide a forum for discussion of key interoperability requirements and issues, discussion and review of implementation specifications, and presentations on key technology areas relevant to solving geospatial interoperability issues.

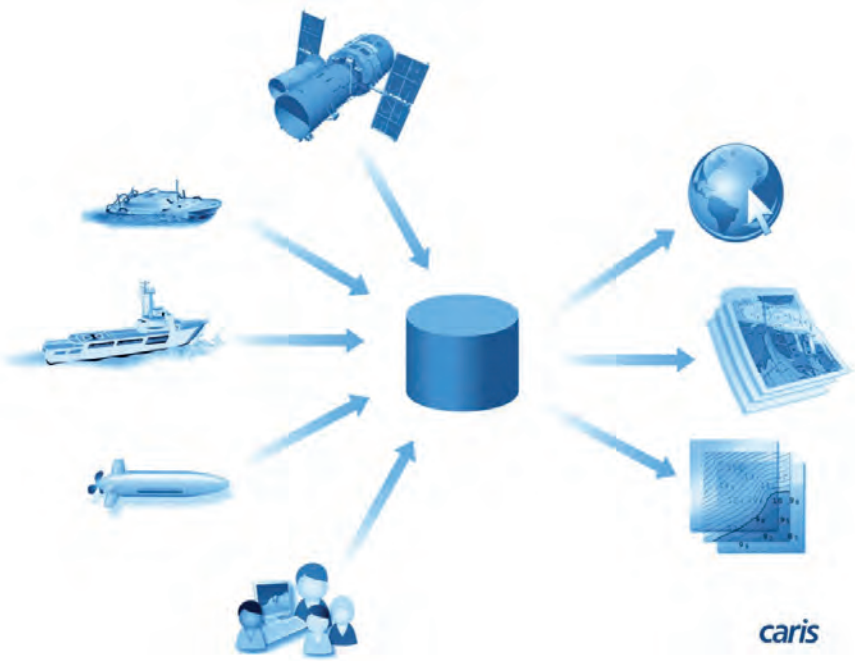
The Marine DWG will identify gaps in the current OGC baseline regarding marine geospatial data with an emphasis on ocean mapping to support smart exchange methods required for interoperability. The Marine DWG is motivated by the widening use of marine data for purposes other than safe navigation, which can be described as Marine Spatial Data Infrastructure (MSDI).

Data volumes are increasing as more sophisticated marine sensors are being used

Two thirds of the Earth is ocean; it is a source of food and energy, it governs our climate, and it is the main method for transporting goods around the world - yet only 5% of it has been mapped and charted at high resolution. In order to increase this meagre coverage it is important to reach a broader group of stakeholders, as it is unlikely that this percentage will increase dramatically purely for the purpose of safe navigation. By considering the wider use cases, we increase the potential for additional sources of funding for this important survey work.

To dramatically increase this coverage will require much technological advancement in order to create force multipliers around data collection sensors and devices, and new processing and production techniques. It is critical that the data collected, in increasing volumes by an increasing number of data sources, can be used effectively and in a standardised way by a much wider group of stakeholders to support a Blue Economy.

Geospatial data in the marine domain has been successfully standardised for navigational purposes by hydrographic agencies for many years. This has allowed mariners to safely navigate oceans, ports and waterways anywhere on Earth. However, the core data that support this activity is now in demand for a much wider



▲ *Figure 1: The Marine data flow: inputs and outputs.*

▲ *Figure 2: Leendert Dorst, from the Royal Netherlands Navy on behalf of the North Sea Hydrographic Commission, talked at the OGC's TC/PC meeting in Dublin 2016 on the need for better mapping of the oceans and interoperability of marine data with other data sources.*

range of applications (for example: environmental protection, emergency response, offshore energy, fisheries, etc.), and as such, interoperability of this data is more important than ever before.

The use of open standards and associated best practices in spatial data and spatial data systems creates a vital 'interoperability glue' that helps rapidly integrate technologies and diverse sources of information for wider use. For decades, OGC has been developing a comprehensive framework of open standards that significantly reduce the time, effort, and cost necessary to integrate new content sources and technologies, and support rapid innovation in emerging and established markets alike. The Marine DWG will investigate how best to use these standards to help add some 'glue' to these otherwise disparate sources of useful information.

For example, chart data modelled in S-57, S-101, or Int1 is a major source of information, but does not lend itself automatically for wider use due to specific portrayal and attribution characteristics and lack of standard metadata. The OGC Marine DWG will investigate methods and processes for extracting content from this kind of data for wider use.

Similarly, high-resolution bathymetric grids, point clouds, and seafloor sediment mosaics are captured by the IHO S-102 product specification for coverage data, but may require further standardisation to be interoperable with the broader geospatial community, which the Marine DWG will also investigate. This is further amplified with the increasing popularity of capturing water column data, HD camera mosaics of seafloor infrastructure, and also the appearance of new data structures for modelling bathymetry called 'variable resolution grids.'

The offshore oil and gas community are increasingly using the IOGP Seafloor Survey Data Model. This model has a GML schema for exchange called SeabedML. In order to support a concept of 'collect once, use many times' it is important to understand how data can be used effectively by the Oil and Gas industry, Hydrographic Offices, and the wider geospatial community.

In addition, data volumes are increasing as more sophisticated marine sensors are being used (e.g., sonar, bathymetric Lidar and laser scanners). More data sources are also being exploited (e.g. survey vessels, unmanned drones [AUVs, ASVs], satellite derived measurements, crowdsourced observations). To cope with the increasing data volumes and sources, research is required into efficient and standardised sensor processing and management techniques.

The Marine DWG will work closely with the IHO MSDI Working Group but will have a more technical focus. Some of the Marine DWG members are expected to participate in the IHO MSDI working group to ensure that the evolving IHO standards are brought to the attention of the OGC membership, and the OGC standards are brought to the attention of IHO members, in an effort to ensure best practice is being used and the latest technical approaches considered. The Marine DWG will aim to meet at OGC Technical Committee meetings and in addition as an extension to the annual IHO MSDI working group meeting, the next opportunity being at the MSDI meeting in Vancouver in early 2017. ◀

The use of open standards and associated best practices creates a vital interoperability glue

More information
www.opengeospatial.org/projects/groups/marinedwg

OCTOBER

Inmartech 2016
Bergen, Norway
→ 4-6 October
inmartech2016.imr.no

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

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

Flood Expo
London, UK
→ 12-13 October
www.thefloodexpo.co.uk

Unmanned Maritime Systems
Arlington, USA
→ 17-19 October
www.unmannedmaritimesystems.com

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

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

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

Danish Maritime Fair
Copenhagen, Denmark
→ 25-28 October
www.danishmaritimefair.dk/

NOVEMBER

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

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

San Diego BlueTech Week
San Diego, USA
→ 7-11 November
www.themaritimealliance.org/events/san-diego-bluetech-week

Ocean Energy Europe 2016
Brussels, Belgium
→ 8-9 November
http://www.oceanenergy-europe.eu/oee-2016

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

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

European Autumn Gas Conference
The Hague, The Netherlands
→ 14-16 November
www.theeagc.com

UK Marine Technology Show
Southampton, UK
→ 14-18 November
conference.noc.ac.uk/matshowcase

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

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

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- accuracy: up to 0.04 degrees

LBL POSITIONING SYSTEMS

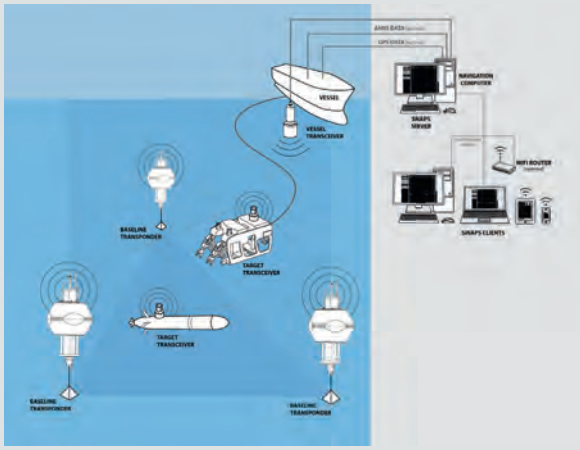
highly accurate, precise and stable performance, simultaneous positioning and data transmissions

- flexible SiNAPS positioning software
- reliable data transmissions
- range: up to 8000 m
- accuracy: better than 0.01 m

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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