Business Guide 2019

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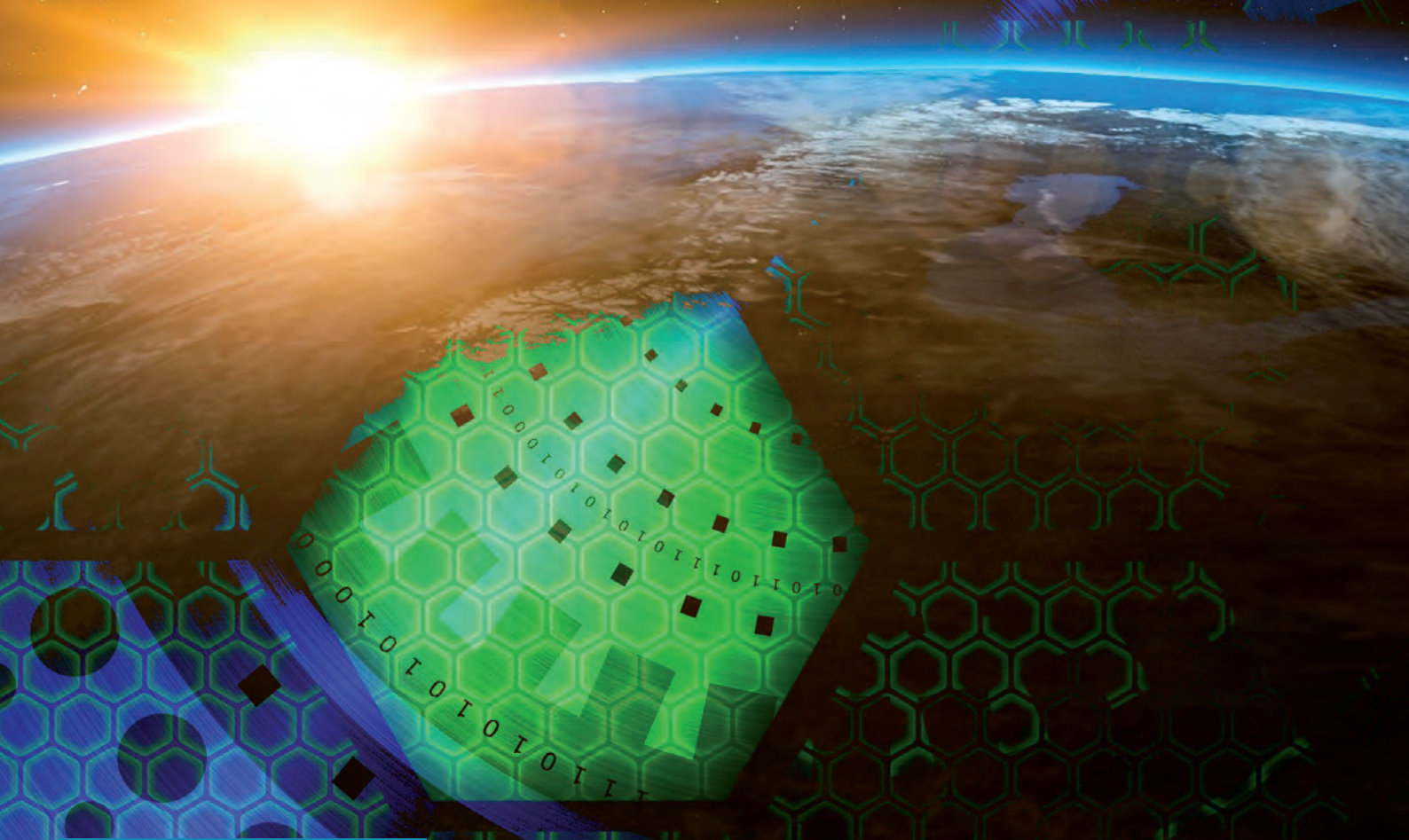
Hydrographic Surveying: Where Do We Stand

The Advancing Technology of AUVs

Emerging Trends in Bathymetric Lidar Technology

Unmanned Surface Vehicle Trends and Insights



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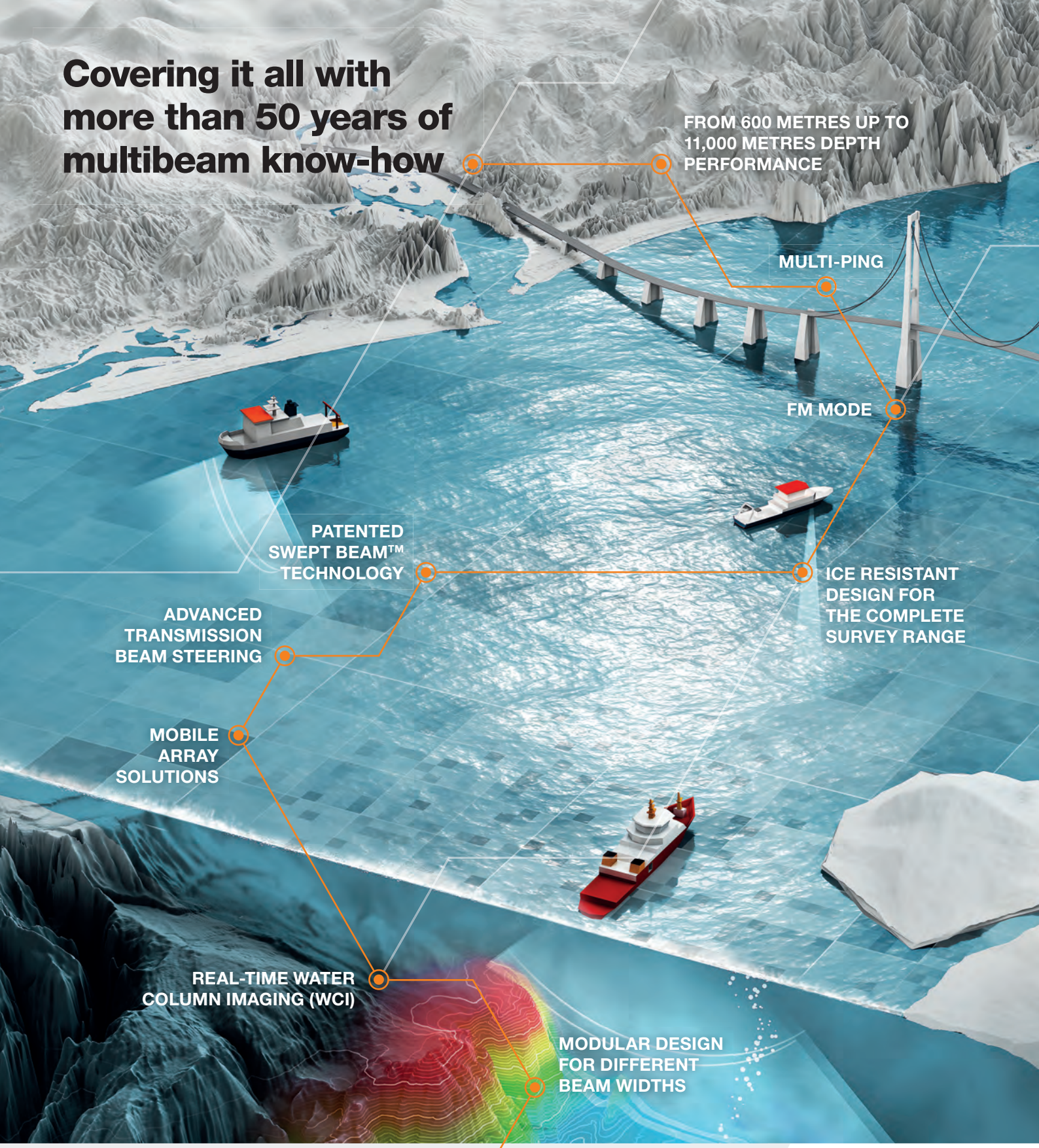

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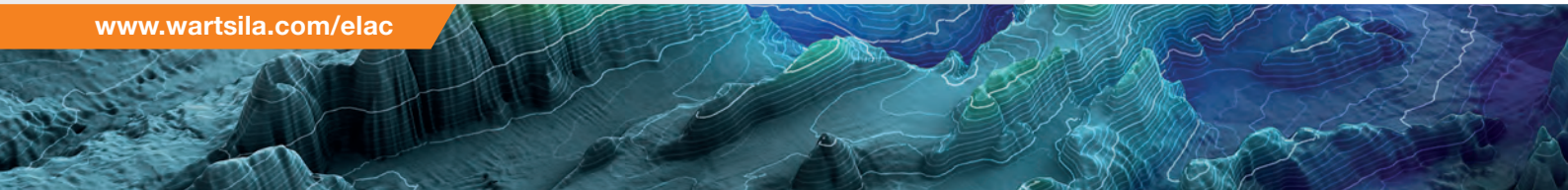

Hydro INTERNATIONAL

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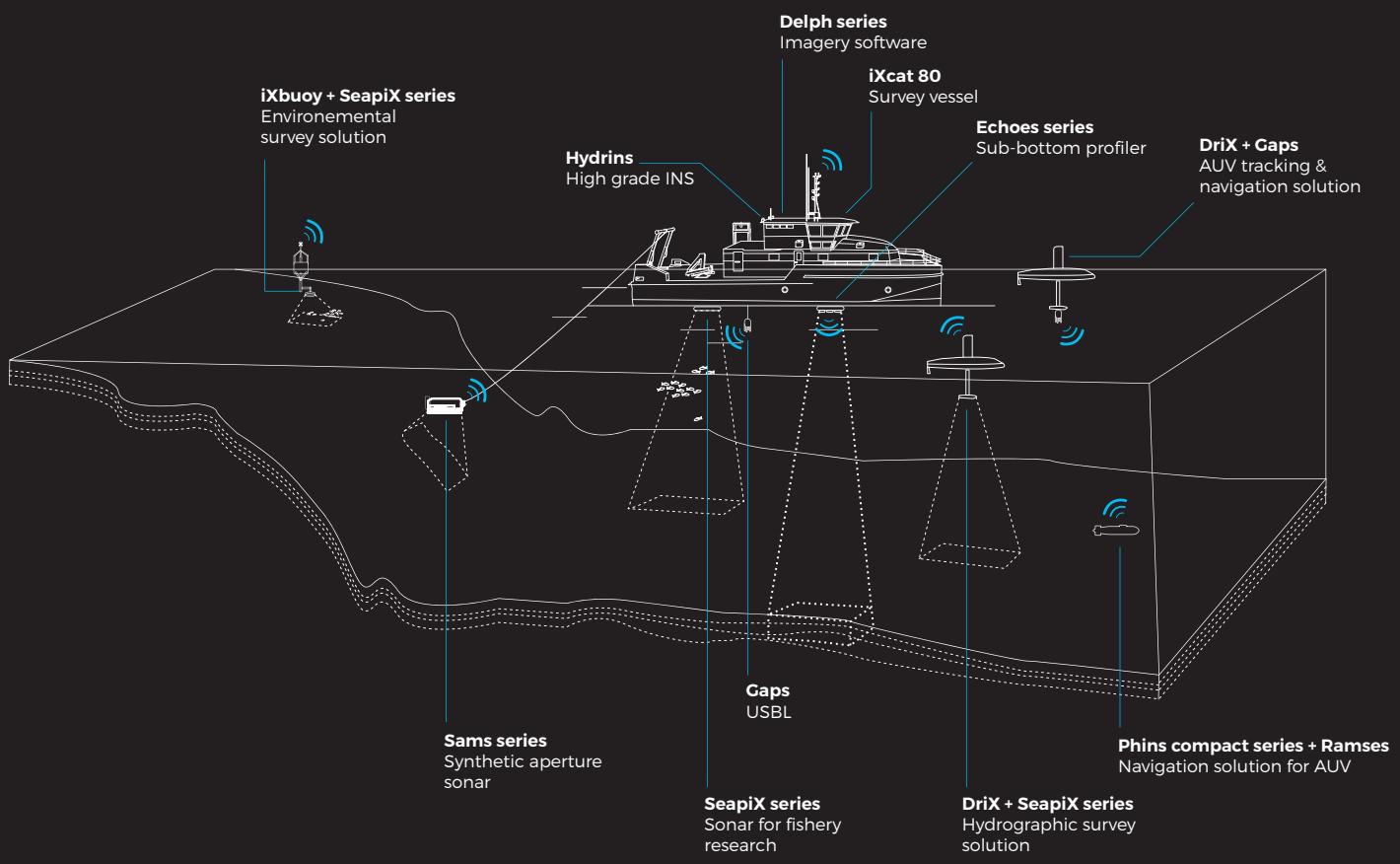
The *Hydro International Business Guide* contains a mix of articles that aim to help you to do better business in 2019! How will the hydrography sector develop in 2019 and beyond? This guide provides you with the latest insights gathered by our editorial team and other experts from the field.

From sensors to Vessels.

Solutions for marine survey



iXblue

Keeping your cool

▲ *Durk Haarsma.*

This 2019 edition of the *Hydro International* Business Guide gives a perfect overview of the current state of our business, while it attempts to give a glimpse of the future as well. Upcoming technologies like Autonomous Underwater Vehicles and bathymetric Lidar are fuelling the imagination of professionals in the hydrographic industry. But these entrepreneurs are also aware of the threats facing the business: the oil price is still at an all-time low, Brexit is around the corner and a trade war between China and the United States is troubling international business, while stirring prices. My hope for 2019 is that we will see an international arena that keeps its cool, giving plenty of opportunities for companies to invest and roll out new technologies, while those technologies don't just hold a promise for entrepreneurs, but also to gain more insights into our seas and oceans, ultimately resulting into a better, blue planet.

Durk Haarsma,
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Advancing the Industry in Challenging Times

▲ *Wim van Wegen.*

How do you put together a relevant Business Guide that can serve as a reference throughout the year? Fortunately, we can rely on a pool of experts from the hydrographic, maritime and oceanographic surveying industry, which has enabled us at *Hydro International* to provide professionals in our business with an interesting, exciting new edition. This edition contains a mix of articles that zoom in on various survey and mapping methods and technologies, such as bathymetry Lidar and AUVs. Our editor Huibert-Jan Lekkerkerk wrote an article giving an overview of the current state of hydrography (page 22). Where do we stand now, and what can we expect in the near future? Absolutely worth a read to get an impression of the industry, zooming in on topics such as multibeam, side-scan sonar, laser imaging, GNSS, acoustic positioning, inertial navigation, survey platforms and processing and other software. Lekkerkerk signals two major trends: the ever-increasing accuracy of sensor systems and the development of autonomous vessels, which is expected to lead to fully autonomous survey vessels over the coming decade. Exciting times ahead in the field of autonomous underwater vehicles.

Highlighting one of the categories of subsea and surface vehicles, the article Unmanned Surface Vehicle Trends and Insights (page 6) gives an analysis of the trends based on the behaviour of thousands of visitors of Geo-matching, a platform where hydrographic and geomatics professionals can find and compare relevant products and/or manufacturers for their projects. This data was combined with subjects that were clearly of most interest on the *Hydro International* website and represents some highly interesting and relevant insights regarding the growing demand for USVs, especially when we relate these findings to some noteworthy outcomes of market research.

Both these articles prove that the hydrographic industry is not in calm waters. On the contrary, exciting times are ahead, with lots of new technological developments. However, at the same time influenced by challenging market circumstances that are often beyond the control of the industry itself.

Wim van Wegen,
Content manager Hydro International

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A Geomares Data Analysis

Unmanned **Surface Vehicle Trends** and **Insights**

Advances in unmanned surface vehicle technology and increased demand are expected to drive the unmanned surface vehicles market over the coming years. Geomares, the publisher of *Hydro International* and Geo-matching, has analysed the user data and behaviour of thousands of members of the global hydrographic community. This article presents the findings of the analysis, identifying the latest trends and sharing insights on the outlook for unmanned surface vehicles.

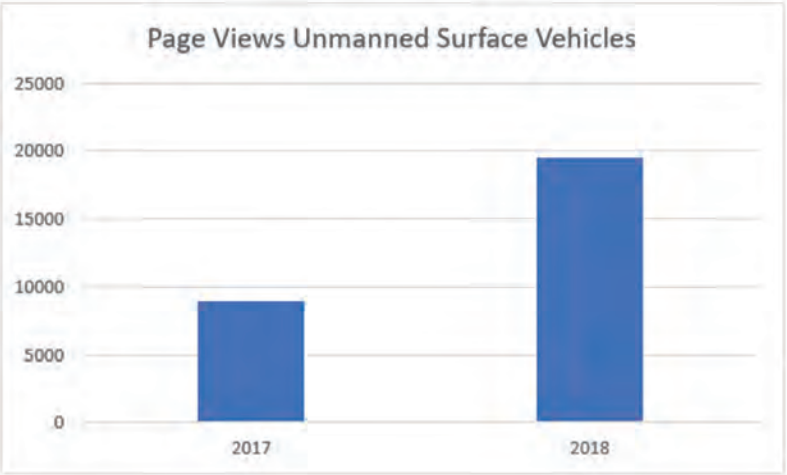
Unmanned surface vehicles combine the advantages of small survey vessels with those of unmanned survey platforms, giving them a range of applications varying from maritime security, protection of shallow waters and ports and ocean mapping [1]. Interesting applications include underwater topographic surveys in Antarctica [2] and long-term environmental monitoring for the Ocean Cleanup project [3].

Worldwide Growth in the USV Market

Market research shows that the unmanned surface vehicles market will grow significantly over the coming years, with North America being the sector leader. This is an exciting market forecast for unmanned surface vehicle manufacturers and it would be interesting to see if the website user behaviour for *Hydro International* and Geo-matching supports these findings.

The worldwide growing demand for USVs is related to a range of applications, such as ocean data and mapping, maritime security and protection of shallow waters and ports. When we zoom in on North America, it becomes clear that that the defence segment is the most important pillar of the unmanned surface vehicle market, with a strong focus on the autonomy and intelligence of USVs. In addition to the fact that North America is leading the global market, the US is considered to be the largest developer, operator and exporter of USVs.

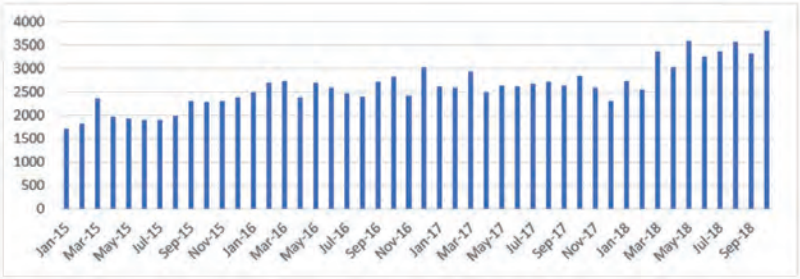
The European market shows significant growth as well, however, the applications that drive this increasing demand differ from the situation in North America. Scientific research and hydrographic surveying companies are employing USVs on a larger scale, however, there is a trend towards an increasing demand for maritime security in the European waters as well. The EU policy aims to achieve adequate maritime security to maintain the rule of law in areas beyond national jurisdiction and protect the EU strategic maritime interests. This encompasses new chances for manufacturers of USVs. The same can be said for other parts of the world with a strong interest in more secure seas and oceans, for example by China.



▲ *Figure 1: Geo-matching page views for unmanned surface vehicles in 2017 and 2018.*

Behaviour of Geo-matching Users

400,000 professionals visited the *Hydro International* and Geo-matching websites in 2018, and a large percentage of those online visitors were interested in unmanned surface vehicles. This puts Geomares in a unique position to analyse website behaviour to discover trends and insights related to unmanned surface vehicles. To provide a balanced overview, this analysis is based on a combination of Geo-matching website data, Google search statistics and market research. Data from the Geo-matching website shows a strong growth in interest in unmanned surface vehicles. Geo-matching is the world's largest product platform for surveying, positioning and machine guidance, listing more than 2,000 products from 500 manufacturers and attracting more than 250,000 users in 2018.



▲ *Figure 2: Google search terms for unmanned surface vehicles and related terms.*

▲ *Figure 3: Regional distribution of Geo-matching users looking for unmanned surface vehicles.*

Unmanned surface systems technology is one of Geo-matching's most important sections, featuring 38 products from 20 manufacturers. In 2018, the number of page views on the unmanned surface vehicles page more than doubled (see Figure 1).

Google Search Volume

Google keyword planner was used to study the search volume for unmanned surface vehicles worldwide (see Figure 2) from 2015-2018. Google statistics show a strong increase in search volume for unmanned surface vehicles. The searches for unmanned surface vehicles grew from 2,064 average searches per month in 2015 to 3,250 average searches per month in 2018 – a growth of 64% in 3 years. October 2018 was an absolute record with 3,798 searches.

These figures include searches for unmanned surface vehicles and related search terms such as unmanned surface vessel, unmanned survey boat, autonomous surface vehicles, unmanned maritime vehicles and so on, but do not include specific product names.

Geo-matching Profile of Typical Unmanned Surface Vehicle Users

User surveys shows that Geo-matching is primarily used as an information source and is important for product research. Product specifications can be compared on Geo-matching, and users can read case studies/watch product videos and can contact product manufacturers directly.

The user behaviour provides interesting quantitative information and can show general trends but the types of contact requests made through Geo-matching provides great insights into how, and for what purposes, unmanned surface vehicles are used. Geo-matching has seen enquiries ranging from major organisations like national armies to Hydrographic Offices and hydrographic surveying companies worldwide.

Enquiries have also come from universities across the world (oceanographic research), fire brigades (search and rescue), port authorities (port surveys) and naval organisations worldwide.

The Geo-matching user profile is in line with market research stating that rising demand comes primarily from hydrographic and oceanographic organisations, but that there is also a strong need from the defence and security sector and to monitor water quality.

Regional Distribution

Market research identifies North America as the dominating region in the market for unmanned surface vehicles, followed by Asia-Pacific and Europe. It is interesting to see that the Geo-matching user profile is a bit different. The largest group is from the Asia-Pacific region (37%), followed by Europe (27%) and the Americas (26%). The strong presence of Asia-Pacific users on Geo-matching could mean that a lot of users from this region are investigating unmanned surface vehicle technology, making it a strong indicator for a growing market share in 2019.

Payloads for Unmanned Surface Vehicles

The growing unmanned surface vehicles market is also driving the growth for payloads enhancing USV capabilities. It is possible to equip unmanned surface vehicles with cameras, sensors, sonars, X-band marine radars, visual systems, Lidar, echo sounders, and other payloads. Sensor payloads can be used to examine undersea cables and to classify a wide variety of chemicals in seawater and various other purposes.

Growing Demand for USVs in Asia

The growth in Asia-Pacific is expected to be primarily boosted by geo-political developments. China is establishing itself as a major power, investing in state of the art military and naval assets, thereby driving the unmanned systems market. Recently, countries such as Japan and India are also putting efforts into USVs and

▲ *ASV Global C-Worker 5 unmanned surface vehicle.*

related technology. In the Asia-Pacific region, the application of USVs is also used to protect maritime assets, including economic zones, maritime borders and territorial waters, but also for oil rigs and deep-sea mining activities. Obviously, these applications are not only limited to this part of the world.

Conclusion

Geo-matching website data, Google search statistics and market research all clearly show that the demand for unmanned surface vehicle technology has increased over recent years. Hydrographic and oceanographic research will further drive the rising demand for unmanned surface vehicles, but there is also a strong need from the defence and security sector and to monitor water quality. The unmanned surface vehicles market is expected to grow by 13.8% from 2018 to 2023, reaching a total market size of US $ 1,028 million by 2023.

Market research shows that North America will be the domination region in the market for unmanned surface vehicles, but Geo-matching user data shows that there is a strong interest for unmanned surface technology in the Asia-Pacific region. Geo-matching is primarily used for product research, so the increased interest in the Asia-Pacific region could be a strong indicator for a growing market in the Asia-Pacific region over the coming years. ◂

This article is based on various sources to provide general trends and insights related to unmanned surface vehicles. For more research data and/or a personalised report, please contact Sybout Wijma (sybout.wijma@geomares.nl).

▲ *Z-Boat 1800 USV in action on a mine pit in Australia with a single-beam depth sounder from Valeport.*

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[2] https://www.hydro-international.com/content/news/usvs-conduct-underwater-topographic-survey-in-the-antarctic

[3] https://www.hydro-international.com/content/news/autonaut-usv-accompanies-the-ocean-cleanup

Peter Tapken is content manager for Geo-matching – a leading product platform for surveying, positioning and machine guidance. He is responsible for the website content, product development and online marketing. He has a background in marketing management, having completed his Master of Business Administration at the University of Groningen and also gained a BBA in Management, Economics and Law from Saxion University of Applied Sciences in Enschede, both in the Netherlands.

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A View of the Autonomous Underwater Vehicle Market

The **Advancing Technology** of AUVs

Since the last autonomous underwater vehicle (AUV) review in 2016, the market has continued to grow. The biggest market for AUV systems remains the military. The world's most advanced navies own and operate low-logistic AUV systems for mine countermeasures (MCM) in very shallow waters. These systems can operate in confined areas where MCM vessels cannot. The same systems can also be used in search and recovery operations, hydrography and salvage. This market used to be dominated by a handful of AUV providers. However, the number of manufacturers is increasing.

Defence primes are also investing in these technologies through internal development programmes or acquisitions. In the commercial sector, the number of companies offering AUV services has grown too and new concepts of operations have been developed to adapt their use. As an example, Ocean Infinity operates multiple AUV systems from a single vessel, enabling faster data acquisition. The success of this application was demonstrated by the search for and discovery of the ARA San Juan submarine.

Technical Building Blocks

The growth in AUV use is in part driven by continuing improvements in AUV technology and capability. In the last two years, new AUV models have been launched and these can gather more data, over longer periods and more accurately. Many of these AUV systems are more compact than their predecessors despite their increased capacity.

Better endurance, improved communications, more accurate navigation, enhanced imaging, artificial intelligence and big data are all contributors. Recent advances in energy density, spearheaded by the mobile phone industry, have helped improve AUV endurance. In parallel, communications, navigation and payload instruments are becoming more effective. The latest advances in signal design are being used to make acoustic communications travel further and carry more data, using less power. Other techniques like free space optical modems are also enabling large amounts of data to be transferred through-water to AUV systems, using the visible light spectrum at distances of up to 150m. More than ten thousand times more data can be transferred this way than is possible with acoustics. In parallel, navigation performance is improving thanks to new inertial navigation systems that can dead-reckon with as much as twice the certainty of what was possible even two years ago. This is possible by combining latest generation gyros and acoustic aiding from Doppler velocity logs as part of a single instrument.

Video: https://youtu.be/5pGDMr1tryg

▲ *Low-logistic AUVs have become the survey tool of choice for expeditionary forces. Pictured here is the Bluefin-9 two-man portable AUV from General Dynamics Mission Systems.*

Better Understanding of the Environment

There are now many more options for AUV payloads. When thinking about a mission,

operators can choose from lasers, sonars and even stereoscopic high-definition video. Electronically scanned sonar systems are now manufactured in all sizes - even as small as a GoPro camera – for every application. Some produce stunning imagery at 5m range using high frequencies. Others, working at lower frequencies, can spot obstacles at ranges of over 1000m. For inspection missions, video and laser are combining to provide stunning pictures of the subsea environment as it has never been seen before; at centimetric resolution and in full colour. When it comes to survey, operators are not just limited to side-scan sonar imagery and multibeam bathymetry. There is now a new generation of multi aperture sonar systems capable of extending range and producing three-dimensional bathymetry. Synthetic aperture sonar has also proved popular for large AUV systems. This is an industry generating more data than ever before. Fortunately, it is at a time when storage solutions have become more prevalent, and machine learning and big data techniques are becoming wide-spread.
So, how are AUV systems being used? The following section explores some of their current uses.

▲ *C-Worker Unmanned Surface Vehicle and National Oceanography Centre ALR working together in recent trials demonstrating acoustic and optical communications.*

Military Roadmaps

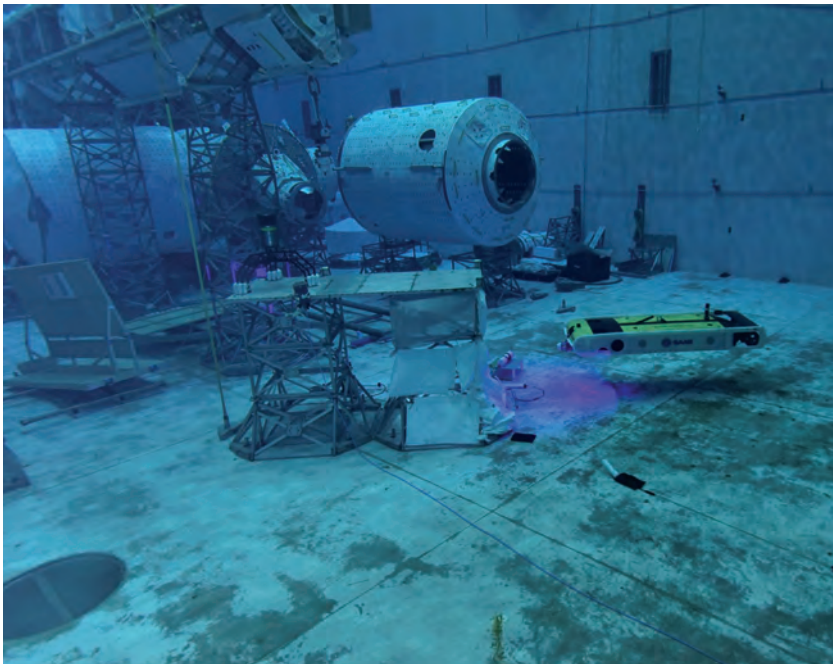
Cylinder shaped AUV systems with a diameter of approximately 9in-12in have become a common sight in MCM operations. These systems are typically equipped with side-scan sonar systems and high-grade survey systems. They are launched from small vessels or rigid hull inflatable boats and survey rectangular areas of the seabed in search of objects of interest. The data quality and speed of survey make them the ideal tool for this purpose. The number of working systems operated by navies keeps increasing and the number of navies adopting them is also increasing. They are also playing an important role in helping navies understand and learning to use autonomy. At the end of 2016, the UK hosted the Unmanned Warrior exercise in the UK. It was a showpiece for autonomous technology, with international participation from industry and foreign delegations. Following that exercise, governments realised that autonomous systems are indeed very capable and stand to revolutionise the way their navies operate. Leading the pack, the Belgian and Dutch navies are currently accepting bids for their next generation MCM vessels, which will be equipped with AUV systems and other autonomous assets as standard. This will be a world-first; traditionally, mine hunting vessels are equipped with towed or variable depth sonars. The UK's mine countermeasures and hydrographic capability programme and the US littoral combat ship MCM module follow a similar model. AUV systems may become the de-facto mine hunting tool.
Video: https://youtu.be/HrFWepU1iRk

Autonomous Submarines

The US Navy announced recently that it had awarded contracts to Boeing and Lockheed Martin to develop extra-large diameter AUV systems. These systems will replace submarines in many of their missions, deploying from shore and travelling thousands of nautical miles to conduct intelligence gathering, surveys or inspections. It is not just the military that is contemplating long-endurance AUV systems. The National Oceanography Centre (NOC) in Southampton, UK, has developed a range of systems named Autosub long range (ALR) which can travel for months and can conduct scientific missions across large distances. The most famous ALR, nick-named Boaty McBoatface, will be operated from the UK's flagship oceanographic vessel the RSS *Sir David Attenborough* when it launches. The ALR has already demonstrated the ability to operate 'over-the-horizon' by linking to an unmanned surface vessel and using it to establish a link to shore. It has also demonstrated the ability to detect leaks and seeps and its use for carbon capture inspections.
Extra-large diameter AUV systems can be deployed and recovered from shore, so launch and recovery is simpler and they can operate in a much wider set of sea states. They do, however, need a large battery pack and very accurate navigation. The promise of this technology is that it can deliver science at a fraction of the cost of a vessel and crew. Others may well follow NOC's designs.
Another future use for these systems in the military domain may be anti-submarine warfare (ASW) operations. The persistence of extra-large diameter AUV systems is also attractive for this purpose. They can monitor choke points or work together in the open ocean. Since ageing fleets of ASW vessels are nearing replacement and these AUV systems are seen as a cost-effective force multiplier, they may, in time, become the ASW force.

Oil and Gas Today

This sector has been using AUV systems commercially for many years for deepwater surveys. The last two years saw some new players enter the market and a renewed interest in autonomy from operators. The downturn in the oil price meant that operators had to seek more efficient ways to operate and AUV systems were and remain part of the solution. In this sector, the commercial use of AUV technology is still dominated by the deepwater survey market. There are also some systems available for surveys in shallower waters and a lot of work has been done with these in West Africa. Companies like Ocean Infinity are questioning the status quo and it will be interesting to see what happens. Other companies, like MMT, have banked on remotely operated vehicles (ROVs) capable of fast survey speeds. Interestingly, these fast ROVs look remarkably like an AUV but remain tethered to a surface vessel. Will there be a time when the tether is severed? Perhaps not for survey tasks. However, as far as



▲ *Saab Seaeye Sabretooth using BlueComm free space optical modem for wireless communications.*

subsea inspections are concerned people are asking when, not if, the tether will be severed. In this area, there is a race for dominance. Saab Seaeye introduced the Sabretooth product, a hybrid ROV/AUV for prolonged duration inspection missions, many years ago. Since 2011, i-Tech Services has been working on its autonomous inspection vehicle (AIV) offering for oil and gas inspections. Now, these companies are being joined by Oceaneering, with its Freedom concept, Saipem, with Hydrone and its FlatFish license, the Eelume snake-like AUV, and Houston Mechatronics' Aquanaut. IKM also offers a resident electronic ROV concept. While each system has its differences, they all mix remote operation with autonomous decision-making. Furthermore, they are all being built in response to operator demand. Companies like Equinor have made no secret of their vision for underwater intervention drones, a term they have trademarked. Recently, other companies including Aker BP have included AUV operations in their vision statements. This promises to be an exciting space to watch.
Video: https://youtu.be/fgv8j9pO4I0

AUV Swarms

Another development is the proliferation of low cost, small AUV units, which collaborate and work together for one common goal. This is typically referred to as a swarm of AUV systems. There have been some well publicised trials by several companies, and other work has been published but not discussed in the open media. More work is being conducted by companies which prefer to remain outside of the public domain while their technology is being developed, deployed and manufactured. The biggest commercial driver for this technology is thought to be for marine seismic applications. However, the military and oceanographic bodies are also keen to develop tools that enable them to cover larger swaths of the oceans. This is very much work in progress and it is hard to predict when the technology will become commercial. Crucial technical hurdles still need to be met: How does the swarm communicate? What payload sensors can it carry and afford while remaining commercially viable? How do we launch, operate and recover each and every AUV?

The Shell Ocean Discovery XPRIZE

While this article was being written, the final of the Shell Ocean Discovery XPRIZE was taking place in Greece. Many teams entered this competition with the ambition of being the first to provide a solution capable of launching from shore or air in order to explore the competition area, to survey it and to photograph a specific object. The competition area is up to 4000m deep. There is US $7 million in prize money to be won. Eight teams made it to the final, each with their own unique concept, from AUV systems supported by unmanned surface vessels for launch and recovery, to air-deployed ones.
The aim of this competition is to help increase our knowledge of the oceans. Today, only 5% of the ocean floor has been explored yet the oceans provide 50% of our oxygen. In fact, we know more about the surface of Mars than we know about our own seabed.

Academia and Native AUV Systems

Academia continues to use and develop AUV systems. Institutions such as the NOC, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography and Monterey Bay Aquarium Research Institute have lead these efforts. Now, many other programmes are being developed across the world. From South America to South East Asia, researchers are developing home-grown AUV systems to help advance their own understanding of the technology and to help adapt it to their own needs. This is evidenced by the diversity of teams that took part in this year's AUVSI Robosub, a high school and undergraduate AUV design competition. The top three teams were from China, Singapore and Canada, respectively - in a competition that took place in the US.

What Should We Expect to Happen Next?

Operating autonomously subsea is challenging: lack of communications, intense physical pressure, no ambient light and unchartered waters add up to make it one of the most difficult technical challenges for humanity to solve. Solutions have been found and over the last two decades the market has grown in ways which we never anticipated at the start of this journey. As new blue technology industries such as aquaculture, mining and renewables evolve, I expect AUV systems to play a part in their evolution. The successes of the last two years should help with the continued expansion of the AUV market. New successes to come will in turn fuel future market growth. Will the market be dominated by extra-large AUV systems, AUV swarms or extra-large AUV swarms? Most likely a combination of them all. ◀

Ioseba (Joe) Tena is tasked with shaping and growing Sonardyne's instrument business for marine robotic systems across all application domains including offshore energy, defence and ocean science. He works alongside his colleagues to ensure that clients' operational requirements are completely satisfied through the delivery of low-risk subsea technologies, products and services. He has been involved in developing smart solutions for the underwater vehicle industry for more than two decades and continues to lend his expertise to the engineering team.

5 Questions to…

Dr Martin Pfennigbauer, director of research, and James van Rens, strategic advisor, RIEGL

To gain real insight into today's hydrographic business landscape, *Hydro International* asked some of the sector's most influential companies for their opinions. This series of Q&As focuses on the current state of the industry from various perspectives, such as which technological developments will have the most impact on the market, which market segments are the most promising and which areas offer the most growth. Here, Martin Pfennigbauer and James van Rens from RIEGL share their views of and expectations for the business.

▲ *Martin Pfennigbauer.*

▲ *James van Rens.*

How do you expect the hydrographic market to evolve over the coming year?
Martin: We have seen excellent development in 2018, with more systems ordered and in operation worldwide. Furthermore, there have been a couple of very interesting new products introduced to the market. Drone operation of airborne laser bathymetry sensors seems to be the hot topic with a couple of announcements in 2018. RIEGL paved the way with its Bathycopter which was introduced in 2016. At Intergeo 2018 we presented the VQ-840-G, which features a form factor and weight suitable for UAV-borne deployment without having to significantly compromise performance. With this to come, I expect a thrilling 2019.

In what ways could the ocean technology industry benefit from artificial intelligence and/or machine learning?
Martin: Point classification and waveform analysis are complex and demanding processes, especially with respect to computational power. Machine learning has the potential to bring improvements and acceleration for both. It has already been successfully demonstrated for point cloud analysis and we will certainly see more applications in the near future.

How is your company addressing the market for autonomous vehicles?
Martin: Lidar is one of the key enabling technologies for ground-based autonomous vehicles (cars, robot carts). Autonomous UAVs currently rely on cameras only but will probably also use Lidar sensors, especially for higher speeds and larger ranges. RIEGL sensors are already used for such purposes and with the shrinking size of sensors the field of applications is going to increase.

What could governments do to support the new market for automated surveying?
James van Rens: The UN-GGIM (United Nations Global Geospatial Information Management Committee) has the important initiative on Global Geospatial Information Management. The initiative has 5 principles of Statistical Geospatial Framework (SGF). This policy framework is a critical structure for all surveying and mapping information. Governments need to adopt the UN-GGIM Framework and Sustainable Development Goals. This process will facilitate automated surveying to flow naturally into each nations geospatial information system and then globally. Good Policy is Good Government!

What is the main technological advancement to watch for the future?
Martin: When it comes to airborne laser bathymetry, UAV-based solutions seem to be the next greatest thing. Flexibility in deployment, low operational costs, and improved compact sensor equipment are the key factors that currently drive this field. Another quite interesting field is sensor data fusion – there are an increasing number of applications requiring the combination of Lidar data not only with RGB imagery but with all sorts of other data ranging from hyperspectral to radiation sensors.

5 Questions to…

Peter Stewart, director of marine products, Applanix

To gain real insight into today's hydrographic business landscape, *Hydro International* asked some of the sector's most influential companies for their opinions. This series of Q&As focuses on the current state of the industry from various perspectives, such as which technological developments will have the most impact on the market, which market segments are the most promising and which areas offer the most growth. Here, Peter Stewart, director of marine products of Applanix shares his views of and expectations for the business.

▲ *Peter Stewart.*

How do you expect the hydrographic market to evolve over the coming year?
I think we'll see the continued deployment of autonomous and remotely controlled platforms, using unmanned vessels as the so called 'force multiplier' to enable ever more efficient data collection. That said, successful deployment of unmanned platforms requires a workflow that is well defined and 'hands-off', and so I expect we will see tighter integration between the component parts of the survey puzzle – not just in hardware, as has been the trend already, but increasingly on the software side too.

In what ways could the ocean technology industry benefit from artificial intelligence and/or machine learning?
In a world where the survey sensors are creating vast amounts of data, automated decision-making and error detection are vital. Not only does this make the process more efficient, but also more consistent, taking the subjectivity out of processing. But, of course, one can never predict every eventuality, and a software environment where a level of machine intelligence exists to react appropriately ensures that the automated stage can cope with greater amounts of data, further increasing overall efficiency and data throughput.

How is your company addressing the market for autonomous vehicles?
Applanix has years of experience in creating solutions for autonomous applications. From the DARPA challenge, to agriculture, mining and on-road navigation, we are in a strong position to leverage this experience into many applications where robust and reliable positioning is paramount for successful autonomous navigation. For example, our Autonomy Development Platform enables automakers and their suppliers to accelerate development and production of autonomous vehicles of all types.

What could governments do to support the new market for automated surveying?
Many local and national governments already do much to promote the testing and deployment of autonomous platforms, providing areas where testing and development can be done. But there is always more that can be done, and perhaps by providing tax breaks for early adopters, or writing survey specifications which favour automated surveying will help to foster further innovation.

What is the main technological advancement to watch for in the future?
In the survey world, true sensor fusion, where data from a wide variety of complementary sources is combined in a synergistic manner holds much promise. For more than 30 years, Applanix has provided ever more tightly coupled inertial navigation systems, using GNSS and other sensors to ensure the most robust solution possible. Combined with machine learning, where the system of sensors can react to changing conditions in an intelligent way, or new sources of data can be added at will, future systems will be able to operate in as wide a variety of conditions as possible without human intervention.

5 Questions to…

Anders Ekelund, vice-president, Airborne Bathymetric Lidar at Hexagon Geosystems

To gain real insight into today's hydrographic business landscape, *Hydro International* asked some of the sector's most influential companies for their opinions. This series of Q&As focuses on the current state of the industry from various perspectives, such as which technological developments will have the most impact on the market, which market segments are the most promising and which areas offer the most growth. Here, Anders Ekelund from Hexagon Geosystems shares his views of and expectations for the business.

▲ *Anders Ekelund.*

How do you expect the hydrographic market to evolve over the coming year?
The hydrographic market is currently seeing an upside trend after a few years of downturn. Specifically looking at airborne bathymetric Lidar, more and more Hydrographic Offices are integrating this technology as the preferred solution for surveying very shallow zones (< 5 -10m). Using bathy Lidar before capturing data with traditional multibeam surveys offers large cost savings and a significant increase in efficiency. This is the result of using bathy Lidar in areas where multibeam capture is inefficient. Nowadays, bathy Lidar is accepted to IHO order 1A accuracy by many Hydrographic Offices.

In what ways could the ocean technology industry benefit from artificial intelligence and/or machine learning?
Artificial intelligence and digitalisation will have the same effect on today's society as the industrial revolution had in the 18th century. It will affect any industry, and completely change the way we live and work. The Internet of Things connects any device and/or built-in component. Technical problems that were impossible to solve a few years ago can now be solved after a few weeks of training using commercial off-the-shelf AI tools. Big data sources allow efficient machine learning of neural networks. It is a game changer, which offers our society a lot of opportunities. Within airborne Lidar, for instance, we already see AI-based classification of data, refining the number of classes identified and reducing human labour intensive parts from the process.

How is your company addressing the market for autonomous vehicles?
Autonomous vehicles are a natural development to increase efficiency. Within Hexagon, we offer several technologies supporting the autonomous vehicle market, such as smart positioning solutions, components and services for the engineering of autonomous vehicles, base maps and mapping solutions to direct such vehicles, simulation software, self-driving vehicles and fleet management software for the mining and agriculture industry, and machine control solutions for the construction sector, amongst other things. Along with strategic partnerships and acquisitions, such as the 2018 acquisition of AutonomouStuff, at Hexagon we are continuously striving to create technologies that harness the power of the IoT and leverage the vast potential of autonomous connected ecosystems.

What could governments do to support the new market for automated surveying?
It's necessary for any government to continuously adapt to change. I recommend governments to continuously monitor new technology in the market and have an open mind to update specifications for tenders such that modern technology can be used. When a government defines the problems to be solved, industry is good at providing the solutions.

What is the main technological advancement to watch for the future?
I believe that the digitalisation of society and the use of artificial intelligence will be a game changer. Global climate change and growing world population will also push environmentally friendly solutions. By using the technology available on the market, any organisation can help 'shape smart change' and drive the acceleration of new and innovative technologies.

What is on the Horizon for Airborne Lidar Bathymetry?

Emerging Trends in Bathymetric Lidar Technology

A surging interest in remote sensing and analytics has seen technology developments linked to these domains take off as we head into 2019. Airborne Lidar bathymetry (ALB) is no exception to recent innovations, especially with the growing recognition in the importance of high-resolution data to inform management of our oceans, seabed and coastal zone. In our recent discussions with ALB manufacturers and experienced operators, several significant new developments were revealed.

The new developments include:

- Lightweight ALB sensor alternatives driven by the proliferation of Unpiloted Aerial Vehicles (UAVs)
- Increased point density for ALB across all feasible depths for improved detail and feature detection
- Increased automation in the data-processing workflows for improved efficiency and faster delivery
- More data products requested by users due to their increased storage capacity, and improvement in cloud-based services. In many jurisdictions this is leading to increased data sharing and analytics using online platforms.

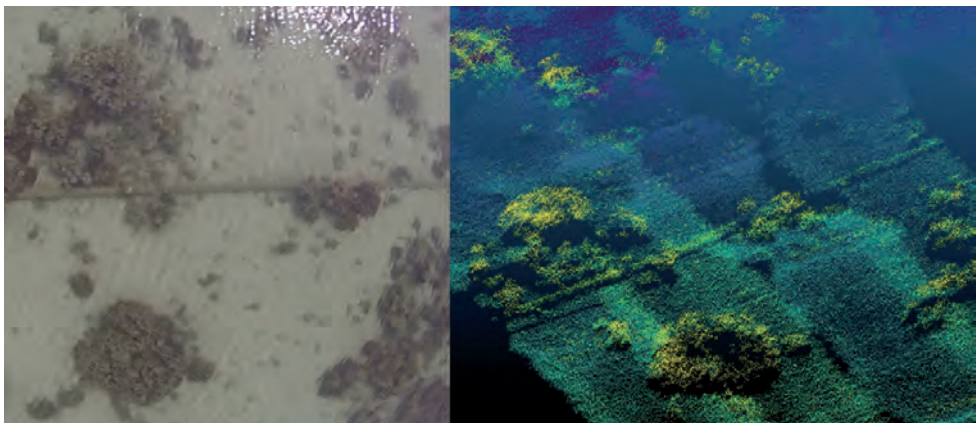
With the current focus on autonomy and automation, it is an inspiring time to be in seabed mapping, especially as a fan of ALB.

New Lightweight ALB Sensors for Unpiloted Aerial Vehicles (UAVs)

UAVs are providing a cost-effective alternative for remote, small and localised ALB surveys. With a surge in the number of UAV models and operators, Lidar manufacturers are developing lighter, more compact sensors suitable for this market (traditional sensors weigh 60-300kg). Until recently, ALB's size, weight and power consumption has not made it commercially viable for UAV operators. However, recent developments have seen a marked reduction in these system parameters enabling UAV flight and leading to increased flight endurance. It is worth noting that ALB sensors on UAVs are also being targeted at inland waterways and estuaries. Channel volume, shallow-water pools and thalweg identification are all important features ALB technologies are able to provide to assist waterway management. Turbidity is still a factor for depth performance and bottom detection, but with lower mobilisation costs end-users are more willing to test the performance in these environments.

Fugro, RIEGL and ASTRALiTe are all examples of companies which have recently developed sensors targeted at UAVs. These can be classed into two categories: lightweight (~15kgs) and ultra lightweight (~5kgs). Of the lightweight sensors there are RIEGL's VQ-840-G and Fugro's RAMMS (Rapid Airborne Multibeam Mapping System) sensors, which are both swath capable. The RIEGL VQ-840-G can be installed on larger UAV platforms for both coastline and shallow-water waterway mapping. It provides returns up to 1.5 x Secchi depths. The Fugro RAMMS ALB sensor has push broom technology which can be mounted on fixed wing UAVs with greater depth penetration of up to 3 x Secchi depths.

In the ultra-light category is the impressive ASTRALiTe topographic-bathymetric (topo-bathy) Lidar sensor which is also swath capable. It is aimed at the broader market having been mounted on the popular DJI Matrice 600 Pro. This first model targets shallow waters from centimetres to greater than 5m depth in clear waters (>1.5 x Secchi depth), which was recently demonstrated off the coast of Oahu, Hawaii. At its extremely high resolution it has mapped underwater features such as piers, vegetation, rocks, coral and narrow pipelines of



▲ *Figure 1: ASTRALiTe 15cm diameter pipe location in coral bed on Coconut Island, Hawaii; Left - GoPro image, Right - Lidar point cloud.*

only 15cm in diameter (Figure 1). Another example in this category is the RIEGL BathyCopter, which is being used for bathymetric applications including shorelines and profiles of inland waterbodies. It consists of RIEGL's RiCOPTER combined with their BDF-1 bathymetric depth finder. Although this does not have swath capabilities is does provide an ultra lightweight alternative for measuring profiles up to 1.5 x Secchi depths. To create dense point clouds these ultra-light sensors need to operate at slow speeds and low altitudes, and so are restricted to small areas and shallow depths.

Improved Depth Penetration and Higher Point Densities

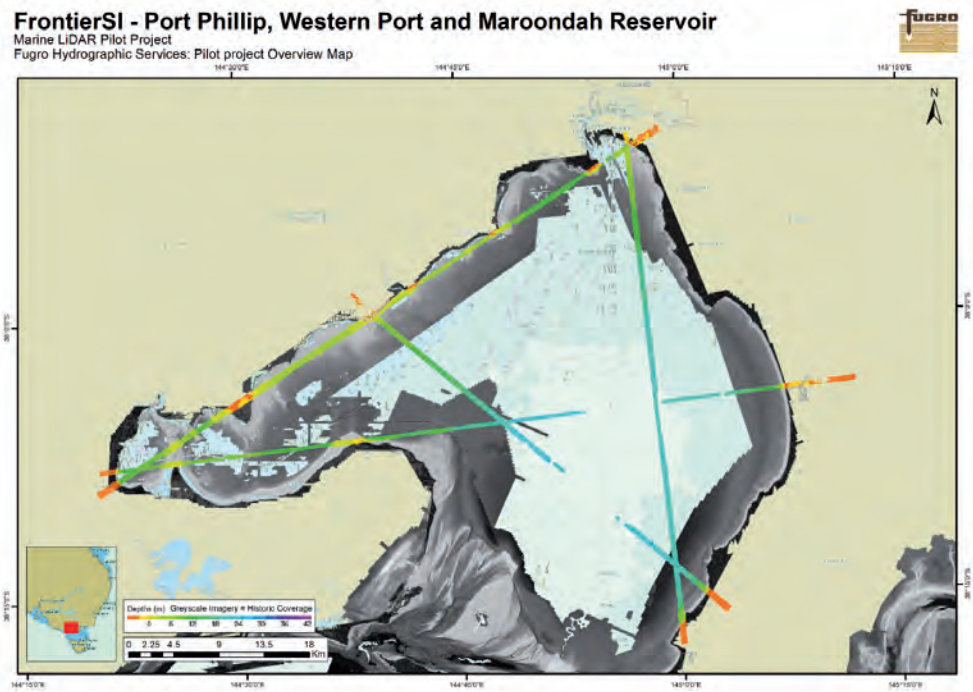
ALB sensor developments have seen point densities increase across manufacturers from the previous standard of around 1pt/25m2 (5m x 5m). Another improvement is in the depth penetration of some sensors which have been extended to 3 x Secchi depths, whilst not sacrificing their previously achievable point density. The traditional trade-offs between point density and depth penetration are starting to decrease, however, there is still some compromise required between sensors' laser power (laser energy per pulse?), depth penetration, coverage, data density and data quality.

Optech, Fugro and Leica have all been targeting improvements to their higher end ALB sensors at the 3 x Secchi Depth range. Of note is that the Fugro LADS HD and RAMMS can both achieve 3 x Secchi depths, with the RAMMS also achieving very high-resolution data, >6pts/4m2 (2m x 2m). The Leica Hawkeye III deepwater topo-bathy sensor can also achieve 3 x Secchi depths, with its point density capability discussed below. Teledyne Optech have recently developed the CZMIL Nova sensor which is typical of the current push for smaller and lighter, as it is 30% smaller, 25% lighter, and uses 15% less power than the previous model, with a 2.5 x Secchi depth range.

In terms of point density, systems are still divided into deepwater and shallow-water categories. The Fugro LADS HD and the Optech CZMIL Nova deepwater ALB sensors have progressed to 1pt/4m2 (2m x 2m). Leica Geosystems have recently improved their ALB sensor's point density by a factor of four, with the aptly named Leica 4X technology. The Chiroptera 4X (nearshore) and Hawkeye 4X (deepwater) sensors allow up to 50% in flight cost savings for typical end - user specifications, as 200% coverage is no longer required. Typical specifications of 2-4pts/m^2 can now easily be achieved in a single flight line. The Leica 4X technology has the same accuracy and same turbid water performance with 10% improvement on depth penetration.

In the shallow-water category, the RIEGL VQ-880-GII and the UAV-based VQ-840-G can achieve high point densities of more than 30 pts/m2. ASTRALiTe's UAV-based system can achieve densities as high as 3000pts/m^2 flying at extremely slow speeds of 1-2m/s from UAVs. Flying at a more reasonable speed for UAV-based shallow-water surveys still gives densities of about 1000pts/m^2 over very small areas such as shown in Figure 1.

It is important for users to note that the choice of ALB sensor for a project is based on a range of factors, and that these recent achievements in point density should not be used in isolation when selecting the best sensor for an ALB survey. Especially when you need to consider factors such as depth and flying speed.



▲ *Figure 2: Port Phillip Fugro LADS HD and RIEGL VQ-820-G Final Coverage Achieved.*

Automated Point Cloud Processing for Faster Delivery

Automation in ALB acquisition, data-processing, quality assurance and storage are improving efficiencies, delivery timeframes and costs. Investments across Lidar providers are being made in machine learning, and in particular deep learning using neural networks. Training datasets are being widely used by companies to improve point cloud classification. Not only is machine learning being used to classify features such as reef, rock, sand, pipelines, wrecks and fish etc., it is also being used to perform the data cleaning by identifying noise and artefacts in the point cloud. This significantly reduces the amount of manual processing within the ALB workflow. Machine learning is going to substantially change the quality achieved and insights gained from our ALB data, and through automation it is starting to result in faster data deliveries. Traditional ALB projects tend to have a minimum delivery timeframe of 4-6 weeks, with the larger projects often taking 3-4 times the acquisition period to process and deliver the final data. The use of machine learning is seeking to substantially reduce this processing time by up to a factor of four; which means we will all get our data faster.

Advancements within Recent ALB Projects in the Pacific Region

A few notable projects in our region include ALB surveys in Tonga and Niue by IX Blue and Geomatics Data Solutions, and in Papua New Guinea, New South Wales (NSW) and Victoria, Australia by Fugro. At FrontierSI, we commissioned an ALB trial in in Port Phillip and Western Port in Victoria. This project tested Fugro's LADS HD and RIEGL VQ-820-G ALB sensors over different coastal and inland water conditions. The test flights were conducted in combination with a series of Secchi depth readings across the flight lines (see Figure 2) prior to the flights. The Secchi depths conducted over the past year will enable us to plan the timing of future surveys, particularly when reviewing the impact of adverse weather. The results of these new sensors demonstrate an

5 Questions to…

Dr Jonathan Beaudoin, co-director of QPS

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▲ *Jonathan Beaudoin.*

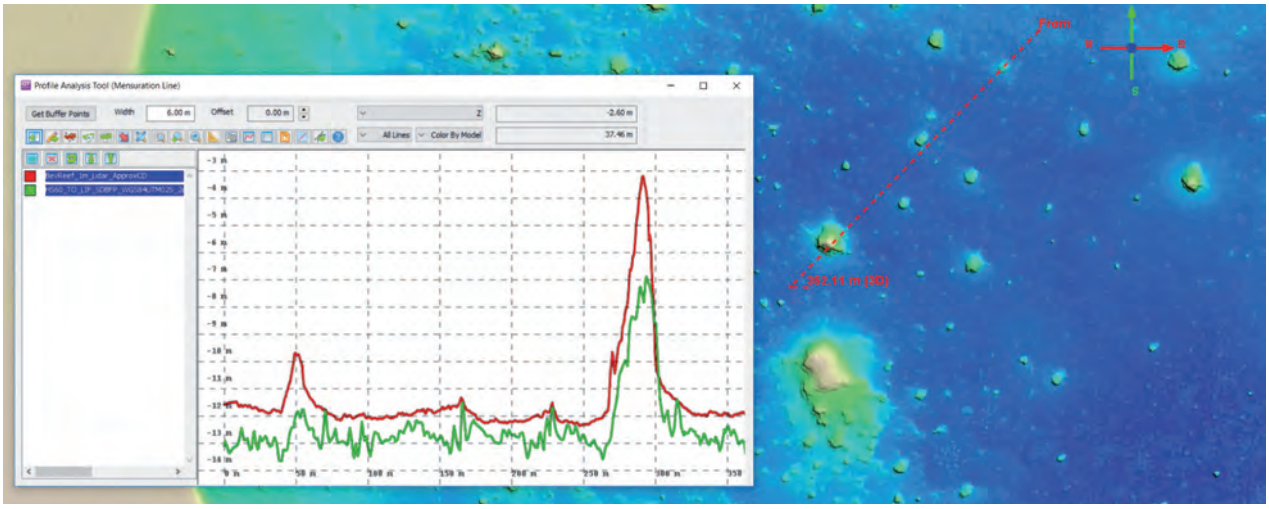
How do you expect the hydrographic market to evolve over the coming year?
As AUV and ASV platforms become more effective force multipliers, we'll see ever increasing leaps in autonomous surveying as companies strive to become more cost effective. Along with this will come many new AUV and ASV manufacturers. With increased global focus on climate change, together with instability in oil and gas due to geopolitical factors, we anticipate continued work going to support the renewable energy sector – most notably, offshore wind farms. This work has complex and multi-faceted requirements, which means a greater need for data fusion – specifically, the integration of multiple streams of temporally and spatially variant datasets to best aid decision-makers. Also, changes in sea ice conditions will open new trade routes and natural resource development areas, which together will bring about a new era of exploration.

In what ways could the ocean technology industry benefit from artificial intelligence and/or machine learning?
Autonomy can only get so far without artificial intelligence, otherwise it will only ever be unmanned as opposed to autonomous. Artificial intelligence is enabling technology that will facilitate and accelerate autonomy. Running a line plan is one thing, but it is the more sophisticated on-the-fly adjustments and decisions that have tremendous impact downstream. With these capabilities, companies will be able to meet the demand they'd normally be too resource-constrained to handle. Machine learning benefits most from big data, and with ever increasing data volumes collected there should come automated means of ensuring data quality and less of the tedious – and costly – human intervention that was necessary in the past.

How is your company addressing the market for autonomous vehicles?
QPS has provided autonomy in its survey software from the very beginning; it has always been our goal to let the machine work for you, instead of the other way around. The QPS philosophy of 'doing things right the first the time' is a good example of this. Our acquisition software QINSy has long since laid the groundwork with remote user interaction, system monitoring alerts, and data processing, gridding, and mosaicking – all in real-time. Since then we've achieved integration with several key autonomous survey vessel manufacturers, with such functionality to include mission planning, automation, systems interfacing, control and monitoring, as well as post-acquisition solutions. Most recently we've added an auto-survey function that dynamically adjusts line plans based on the real-time processed data of the adjacent line, thus the correct overlap of data is guaranteed and there are no data gaps. Altogether, our autonomous functionality combined with our real-time processing work to reduce both processing hours and precious ship time.

What could governments do to support the new market for automated surveying?
Be open minded and willing to work with industry. Governments can choose to foster growth, for example, by supporting R&D efforts in the academic and private sector, or by granting incentives for automated shipping that will naturally benefit the surveying industry. Adding autonomous solutions in public tenders would add further stimulus and result in more innovation. Additionally, there is the issue of net neutrality, and maintaining it will help keep the cost of data transmission low, which will facilitate remote connections to autonomous platforms while also promoting cloud processing.

What is the main technological advancement to watch for the future?
Hardware costs will decline, and autonomous turn-key solutions will proliferate. The role of a surveyor will change dramatically, shifting from the management of a single vessel to a whole fleet of autonomous vessels. Embedded smart algorithms will facilitate not just autonomous surveying, but in the setup, processing, management, and quality control of data as well. These will bring the art of hydrographic surveying to a wider base. Anybody could be a surveyor!



▲ *Figure 3: ALB Chiroptera 4X to SDB comparison; Red line - ALB, Green line – SDB.*

improved coverage over previous ALB surveys. There are still gaps in deep, turbid areas, however, these effects can now be factored into future ALB planning.

In NSW, Australia, Fugro have just conducted a large ALB survey of the entire coastline covering more than 7,000km^2 achieving depths in excess of 40m in some areas as compared with maximums of 30-35m in previous projects. To speed up delivery, they used their 'back-to-base' facility to transfer the data within hours back to their processing office. Utilising field to office data transfers on a daily basis means that companies are able to start processing their survey data sooner, speeding up the initial assessment whilst the field staff are still mobilised, and also moving the data into the full workflow sooner.

The Tonga and Niue ALB surveys were conducted by IX Blue and Geomatics Data Solutions for Land Information New Zealand (LINZ). This survey used the ideal combination of Satellite-Derived Bathymetry (SDB) in the planning phase and MBES to fill in the gaps. The planned use of all three technologies to complete the bathymetry acquisition expedited the ALB planning, enabled targeted ALB flight planning and provided a more cost-effective solution to the project. Most significantly, the vessel time and associated costs have been significantly reduced by having the ALB data acquired beforehand. With the ALB data the multibeam vessel was operated continuously at 9 to 10 knots in complete safety. The ALB surveys utilised the latest Leica Chiroptera 4X to achieve a high nominal point density of 9pts/m^2 in shallow water (Figure 3). The very high-resolution point cloud, also covering the topographic areas, is enabling local stakeholders to use the data for a range of applications.

Conclusion

So, what is on the horizon now for ALB? What does the future hold? For the time being, everyone is being very cagey about this. Which could mean we are on the cusp of some exciting new technology. We have seen the beginnings of machine learning for point classification, with further developments sure to happen in 2019. We are also sure to see the development of more compact and efficient ALB sensors capable of being mounted on UAVs, with ever improving point densities and depth penetration. We will likely see increased usage of cloud storage and processing as concerns about cost, speed and security are mitigated.
Our 'out there' prediction for ALB technology will be developments in edge analytics and near real-time visualisation, specifically targeted at UAV platforms. Edge analytics is the next evolution of cloud computing and could see automated data-processing and analysis occurring in real-time on the platform, rather than processing in the office. Edge analytics complimented by near real-time visualisations of ALB data would unlock time-critical applications which would previously have been thought inconceivable. ◀

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Gerald Thompson, ASTRA LLC
Anders Ekelund, Hexagon Geosystems

Nathan Quadros
Nathan Quadros is the Chief Commercial officer at FrontierSI. In 2008, he completed his PhD investigating issues with airborne Lidar in the coastal zone. After completing his doctorate he worked for the Victorian Government, Australia to manage major airborne bathymetric and topographic Lidar projects. In 2011, he joined the Cooperative Research Centre for Spatial Information (now known as FrontierSI) as a research fellow in remote sensing. Nathan has since managed and advised on numerous Lidar projects around Australia and the Pacific. In particular, designing and coordinating the delivery of bathymetric and topographic Lidar to Tonga, PNG, Vanuatu and Samoa for sea level rise planning. In 2015, Nathan presented this project at the United Nations Lighthouse awards at Paris COP21.

Jessica Keysers
Jessica works at FrontierSI in the role of project manager and technical support. She has a broad range of skills and experience, focusing on topographic and bathymetric Lidar, the management of software development and research projects, and providing technical GIS support. She graduated from Melbourne University in 2006 with Honours in Geomatic Engineering and Geography. Over the past seven years Jessica has quality assured numerous topographic and bathymetric Lidar projects, including being involved in the development of the QA4LiDAR software for the automated quality assurance of Lidar projects.

Ever Increasing Accuracy of Mapping the Surface Waters

Hydrographic Surveying: Where Do We Stand

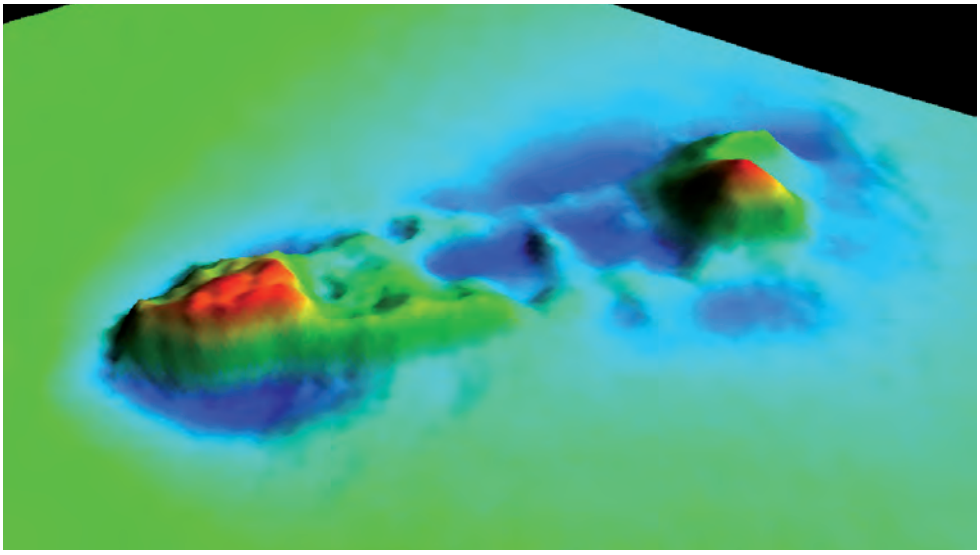
Hydrographic surveying is highly specific and requires a suite of advanced acquisition and positioning sensors attached to a mobile survey platform as well as sophisticated software to allow the correct combination of all the data. For those within the industry, the advances over the last decade may feel more like an evolution rather than a revolution. If we look back one, two or even three decades we can see the enormous leap that hydrographic surveying has taken. Where do we stand, and what can we expect in the near future? In this article we will look at the present compared to the past and will try to give an insight into the near and more distant future.

Multibeam

When it comes to data-acquisition, hydrographic surveyors have always first and foremost been involved in bathymetric data. Coming from the lead and line, the acoustic single-beam echo sounder became the standard in the 1920s and 1930s. In the late 1980s, we saw the introduction of the first commercial multibeam systems such as the Simrad (now Kongsberg) EM100 and Reson (now Teledyne Reson) 9001. Single-beam echo sounding was still the standard and multibeam a very expensive tool. Over the last decade multibeam has replaced single-beam echo sounders on many projects. At the lower end of the market we now see cost-effective multibeam solutions that more than exceed those early multibeams whereas at the higher end of the market we see new multibeams with higher performance.

Besides the main development of cost reduction for entry level multibeam systems, many multibeam systems now offer backscatter, side-scan sonar like data and water column imagery. These allow the user to not just map a bottom depth but also to map the intensity of both bottom returns as well as any return in the water column. The introduction of ever smaller beam widths, higher frequencies and larger swath angles means the hydrographic surveyor can capture more and more detail.

A modern, high-end, multibeam echo sounder easily generates 50,000 depths per second in shallow water and at maximum settings with millimetre resolution. Compared to, say, the original Reson Seabat 9001 with its 900 depths per second under similar conditions this is a more than a 50-fold increase in roughly 3 decades. In the same time the beam angle has decreased from around 1.5 degrees to around 0.3 degrees; an increase in detail of around 5 times.



▲ *Figure 1a: Early multibeam image of a wreck (Simrad 950).*

Side-scan Sonar

A side-scan sonar accompanied most bathymetric surveys three decades ago to scan between the sounding lines for any objects such as wrecks. With the greater use of multibeam echo sounders the side-scan sonar is still around for those wishing to generate high-resolution imagery of the ocean floor or objects on it. But the side-scan sonar has also gone through a development making it capable of producing higher detailed imagery at speeds that are twice to three times those of the old days. Frequencies have also increased allowing even higher resolution imagery at the cost of shorter ranges. Finally, many side-scan sonar systems now also generate bathymetry, making

the distinction between multibeam and side-scan sonar even smaller than before. As a result, the choice between a multibeam or a side-scan sonar can become a matter of discussion within any survey company.

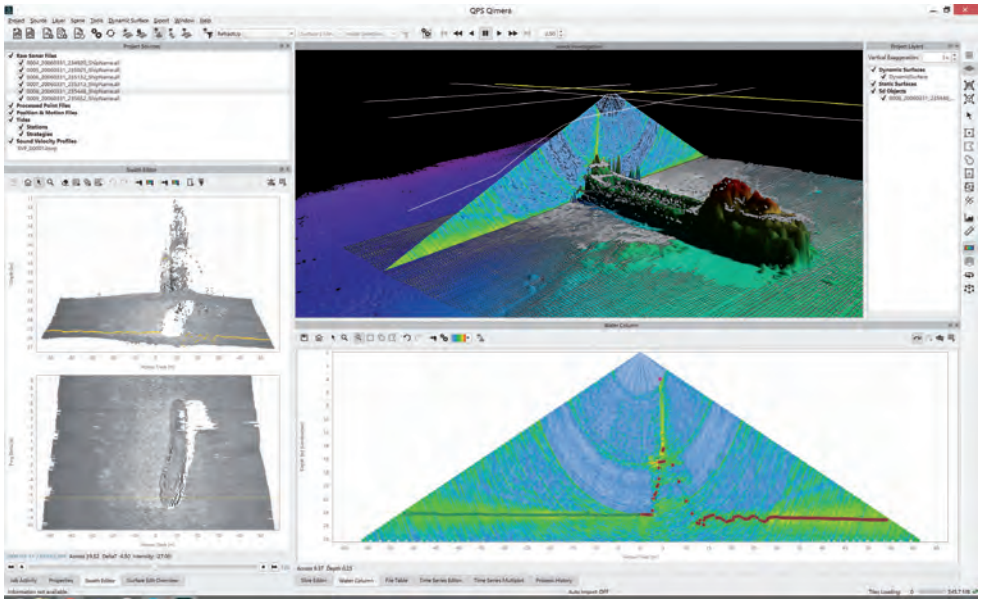
Laser Imaging

The early 1990s saw the introduction of the first bathymetric Lidar systems while we now see the next step in laser scanning. A recent development is the use of underwater laser imaging systems. These systems are comparable to the terrestrial laser scanners and are mounted on an ROV or set-up using a tripod on the bottom. They generate high-resolution images of underwater objects such as pipeline valves or wrecks. Just as bathymetric Lidar they are still restricted to clear water but the use of different colours of laser light has improved the achievable ranges somewhat for these systems.

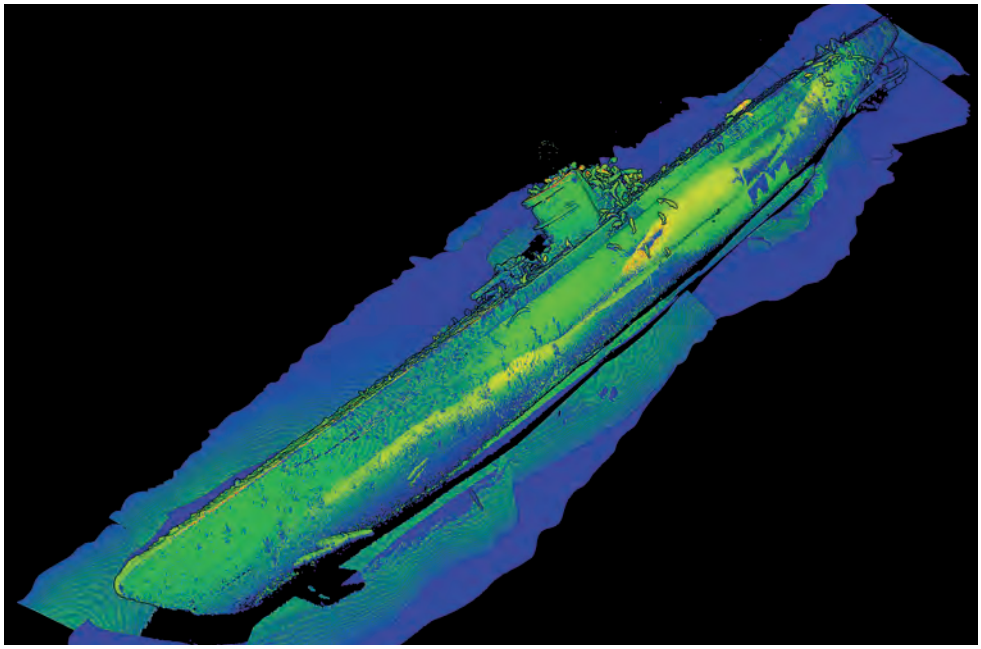
GNSS

For centuries positioning was performed using a sextant nearshore. With the introduction of electronic navigation systems, the sextant was slowly replaced on many projects but could still be found in use in the early 1990s. Three decades ago GPS was introduced into the hydrographic survey industry. The workhorse of many hydrographic companies back then was the Sercel NR103, a ten channel, parallel differential GPS receiver. The mid 1990s saw the first introduction of carrier phase techniques such as RTK into the inshore / onshore surveying business. Surveyors used RTK together with their own base station. Offshore surveyors were happy to achieve a few metres of accuracy whereas inshore a few centimetres were achievable. Alternative positioning systems such as Hyperfix or a dedicated total station were still in use but slowly being phased out.

Over the last decades, GPS has become just one of four Global Navigation Satellite Systems (GNSS) together with Glonass, Galileo and Beidou. The accuracy of the techniques of old has slowly but steadily improved and is now about twice as good as 10 years ago for similar techniques. A modern GNSS receiver will have a few hundred reception channels but essentially still do the same but at greater speeds. Initialisation has come down from tens of minutes to just seconds and the output rates have gone up to tens of hertz instead of once a second.



▲ *Figure 1b: Modern multibeam data of a wreck [Source: QPS].*



▲ *Figure 2: Laser scan of u-boat [Source: Eiva].*

In the early 2000s, the first Precise Point Positioning solutions became commercially available. In the offshore surveying industry these are now the standard in most projects giving offshore survey vessels a positioning accuracy of a decimetre horizontally and slightly more vertically.

Acoustic Positioning

GNSS does not work underwater. As a result, acoustic techniques were developed starting in the 1930s (Radio Acoustic Ranging). In the 1960s, acoustic positioning techniques as we know them today came into play. Over the years these systems have evolved into the current generation of systems which are much more resilient to noise and have improved measurement accuracies.

Inertial Navigation

Three decades ago Inertial Navigation was something for submarines or a cruise missile. We were happy with heave compensators for the single-beam. With the introduction of multibeam the motion sensor became a standard. Over the last decade we have seen the motion sensor develop in three directions. The first is that since using MEMS techniques they have become much smaller and can now be used for many other applications such as

▲ *Figure 3a: Early Sercel NR103 GPS receiver.*

▲ *Figure 3b: Modern Trimble SPS855 marine GNSS receiver [Source: Trimble].*

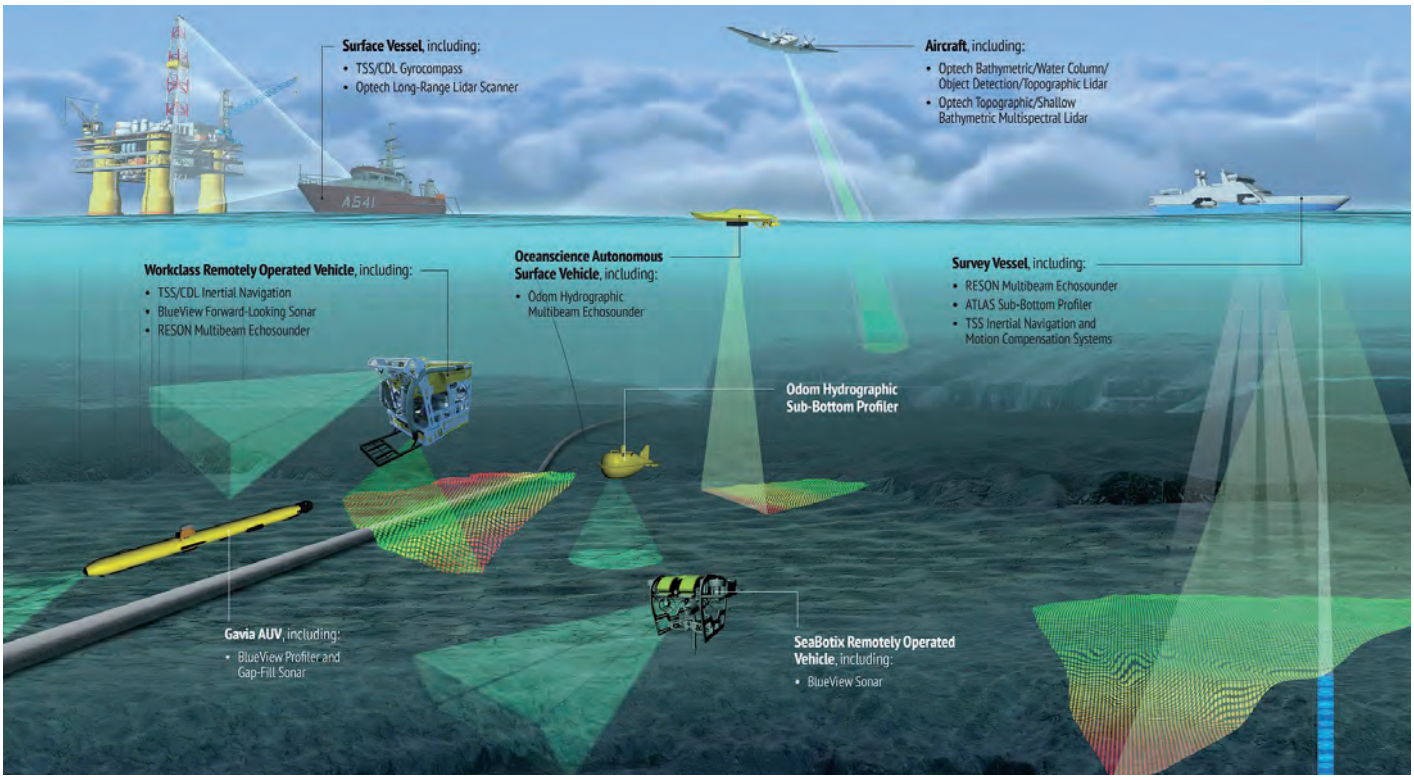
drone positioning. The second is that they have become much more accurate (without decreasing size), now giving routine accuracies of less than 0.1 degree for roll and pitch.

The last development is the full use of inertial navigation systems in hydrographic surveying, both for underwater positioning as well as for surveying in difficult areas such as under bridges. The deployment of Inertial Navigation into hydrography started with the introduction of GPS and Attitude measuring systems such as the original TSS Pos-MV (now Teledyne) and the Kongsberg Seapath systems. Although these systems had some inertial capacity they were mainly designed for accurate and stable heading computations. Nowadays, we see full Inertial Systems with high-quality inertial motion sensors and aided by GNSS, ADCP or underwater positioning systems.

Survey Platforms

For centuries hydrographic surveys were performed from a manned survey vessel; large or small. In the 1960s, the tow fish was introduced, mainly for side-scan sonar. The tow fish was, however, not suitable for inspection around objects such as offshore platforms. Around the 1980s, the hydrographic industry saw the introduction of the Remotely Operated Vehicle (ROV), allowing the sensors to be brought closer to the bottom and, most importantly, allowing control over where they went. As with the tow fish, it was still connected to the mother ship but due to its controllable thrusters it could manoeuvre anywhere its umbilical cable allowed it to go.

Around two decades ago the first Autonomous Underwater Vehicles (AUV) were introduced. Instead of requiring an umbilical cable the AUV is free swimming and is programmed in advance to follow a certain survey pattern. As a result, the mother ship can do other work while the AUV is surveying, or as we see more and more, the mother ship can have a 'swarm' of AUVs in the water at the same time.
Today, the manned surface vessel, ROV and AUV



▲ *Figure 4: Overview of survey platforms and sensors [Source: Teledyne Reson].*

are joined by the ASV, the Autonomous Surface Vessel and, in coastal areas / inshore by the UAV or Unmanned Aerial Vehicle. The latter, commonly known as drone or aerial drone, can now be found in the toy store but is also used in the dredging industry. The Autonomous Surface Vessel, an unmanned surface vessel, is now beginning its entry into the hydrographic industry.

Software

Where processing software and mapping programmes were struggling with the data load of the early multibeams we now see that processing power has reached a level at which it is no longer the limiting factor in data collection. The amount of data to be processed has, however, increased marking the introduction of more and more automatic data cleaning routines necessary to allow an efficient data collection process for most projects. Water column bathymetry adds even more data and the current generation of software is slowly adapting to these massive amounts of data.

While in the past the end of any hydrographic project was the generation of a 'paper' map (often as a pdf), we now see more and more integral data management where data is stored in databases. These databases allow the distribution and creation of products at will but have also introduced more rigorous information management techniques into hydrographic surveying. The addition of object and attribute data together with the more traditional bathymetric data have spurred the use of Geographic Information Systems (GIS) as part of the hydrographers toolkit for more than the creation of a final chart.

Into the Future

As shown, over the past decade(s) we can see two major trends. One is the ever increasing accuracy of the sensor systems; more data at greater accuracy at higher speeds is something that does not seem to have come to an end yet and we can foresee this development continuing over the next decade or so.

What can also be seen is that the technological developments are now catching up with some of the base information. The development of PPP is, for example, showing that the current geoid models are lacking in accuracy and resolution; especially at sea. As a result, the technique cannot be used to its fullest. Over the next decade we will probably see more and more accurate geoid models being developed. The raw data is already being collected; what awaits is for this data to be made into a model by geodesists.

Similarly, the development of autonomous vessels is just starting. Over the next decade or so we will see further developments making these vessels completely autonomous, allowing them to make on the spot decisions on where to navigate but more importantly where to survey; even in shallow or restricted waters. However, current regulations on the water, as on land, are not yet suitable for this development. ◂

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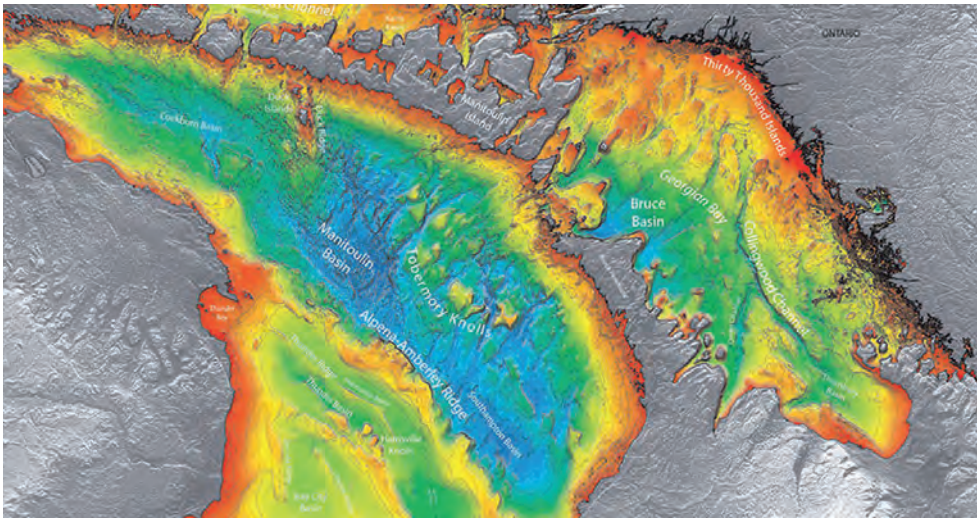
What is the Difference Between a Bathymetry Chart and a Hydrographic Chart

The Study of **Mapping the Seafloor**

This article will immerse us into the deep water of bathymetry. It explains in detail what a bathymetry map is, what it shows, what methods we use to collect the bathymetry data and last but not least, how to create a good quality bathymetry map. It will also cover the difference between a bathymetry chart and a hydrographic chart and the techniques our ancestors used in the past to collect and record depths.

What is Bathymetry?

Bathymetry is the study of mapping the seafloor. Bathymetric maps represent the ocean (sea) depth as a function of geographical coordinates, just as topographic maps represent the altitude of Earth's surface at different geographic points. On topographic maps, the lines connect points of equal elevation. On bathymetric maps, they connect points of equal depth (Figure 1). The name derives from the Greek words: βαθύς (bathus), 'deep', and μέτρον (metron), 'measure'. The general purpose of producing Bathymetric (or hydrographic) charts/maps is supporting safety of surface or sub-surface navigation and usually displaying seafloor relief or terrain as contour lines called isobaths. A bathymetric chart differs from a hydrographic chart in that accurate presentation of the underwater features is the goal while safe navigation is the requirement for the hydrographic chart. A hydrographic chart will obscure the actual features to present a simplified version to aid mariners in avoiding underwater hazards. Illustrating the depths on a bathymetry map combines different methods such as using a Digital Terrain Model (DTM) or artificial illumination techniques. [1] Like geographical maps of the surface of Earth, bathymetric maps are designed also in cartography projection. Generally, the projection used most often in bathymetric maps is the Mercator projection. It has been used for a long time to produce sea charts that are used for sailing in all latitudes except Polar ones.



▲ *Figure 1: A bathymetric image of Lake Huron. In the same way that topographic maps represent the three-dimensional features (or relief) of overland terrain, bathymetric maps illustrate the land that lies underwater. (Source NOAA)*

What is the Bathymetry Data Used For?

Bathymetry data is used for various purposes including:

- Charting and navigation purposes
- Harbour constructions
- Determination of marine boundaries
- Fishery management
- Environmental management
- Alternative energy assessment
- Investigation into coastal process (beach erosion, sea level rising and subsidence) and ocean currents (tsunami modelling)
- Valuation and identification of environmental geohazards, such as underwater landslides
- Providing useful forensic evidence in court when certain types of crimes involving the sea are committed
- Treasure-seekers when investigating the seafloor to identify the most likely areas to seek sunken ships (HMS *Titanic* in the 1980s)
- Biological oceanography, defining the habitat for benthic (bottom-dwelling) organisms.

How did We Collect the Bathymetry Data in the Past?

There are various methods to collect bathymetric data. The first officially recorded depths and shallows were entered into log books and sailing guides ('rutters'), and then in 1584 the first chart with depths on it was produced by the Dutch. Early techniques used pre-measured heavy rope or cable deployed manually into the water (Figure 2). The crew of

▲ *Figure 2: Hydrographic survey by lead line. (Source NOAA)*

▲ *Figure 3: Hydrographic survey using a drag wire. (Source NOAA).*

the ship had to 'feel' when the rope hit the seafloor and then record the current depth. That method was quite inefficient, incorrect and incomplete because the rope often did not travel straight to the seafloor but was shifted by currents. The surveyors were also measuring the depths only to a single isolated point at a time and thus, until the next measuring, missing possibly significant features like underwater hills or trenches.
For instance, the most important structure in the Atlantic Ocean, the Middle-Atlantic ridge, was discovered and began to be investigated only after World War II. This method is also subject to steady movement of the ship (heaving, rolling) due to waves and currents and therefore also quite inaccurate. For safe navigation, all that is needed is the minimum depth, so at the beginning of the 19th century drag wires began to be used in coastal waters (Figure 3). A drag wire is strung between two vessels, with supporting buoys in between, that are at a known depth. If this can be taken safely along a channel, then it is known that the minimum safe depth for navigation is the depth of the drag wire.

From the beginning of the 19th century, European States also started setting up national Hydrographic Offices to provide charts to support their navies, as they had poorer charts than merchants who bought charts from commercial publishers. [2]

What Techniques Do We use Today to Collect Bathymetry Data?

Nowadays, the data used to make bathymetric maps are derived from modern devices such as:

1) Single-beam echo sounders (SBES)
- Starting in the early 1930s, SBES produced a single line of depth points directly under the equipment. During a bathymetric survey, the echo sounder system is mounted on the hull of a survey vessel and measurements are made while the vessel is moving to identify general seafloor patterns or fish schools (Figure 4). The sonar system sends out multiple soundwaves that bounce off the seafloor and return to the ship. The delay between sending and receiving the signal provides a measurement of ocean depth. These measurements are then used to produce a map charting the seafloor (bathymetric map).

2) Multibeam echo sounders (MBES)
- Most commonly used method. The principle is the same as the SBES, except that equipment uses hundreds of very narrow adjacent beams arranged in a fan-like swath of typically 90 to 170 degrees across to acquire multiple depth points over an area. This method produces high-resolution data and accuracy (Figure 5).

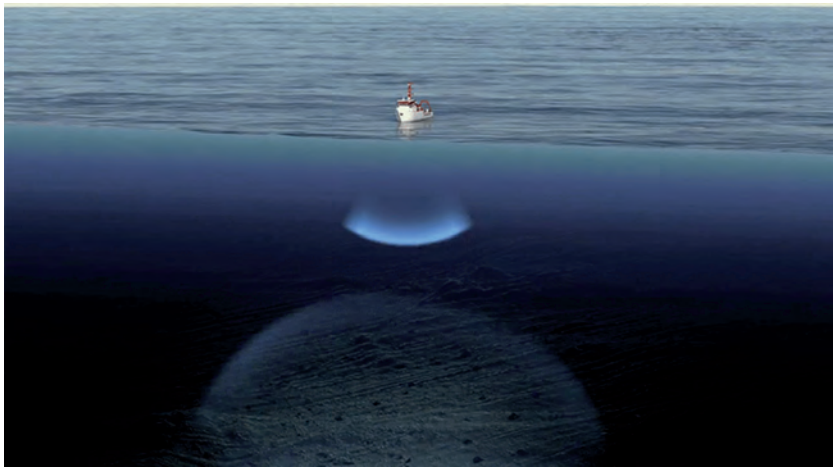
3) Satellite-derived bathymetry data
Satellite-derived bathymetry (SDB) is actually an umbrella term for a number of very different approaches to producing bathymetric data, which only have in common their dependence on satellite data. This method produces maps at low resolution, therefore showing only general features over a large area (Figure 6). Satellite altimetry measures the height of the ocean surface. If there are hills/mountains on the seafloor, the gravitational pull around that area will be greater and hence the sea surface will bulge. [3]

Generally, the higher the frequency, the better the resolution of the data, because the higher frequencies create better returning signals

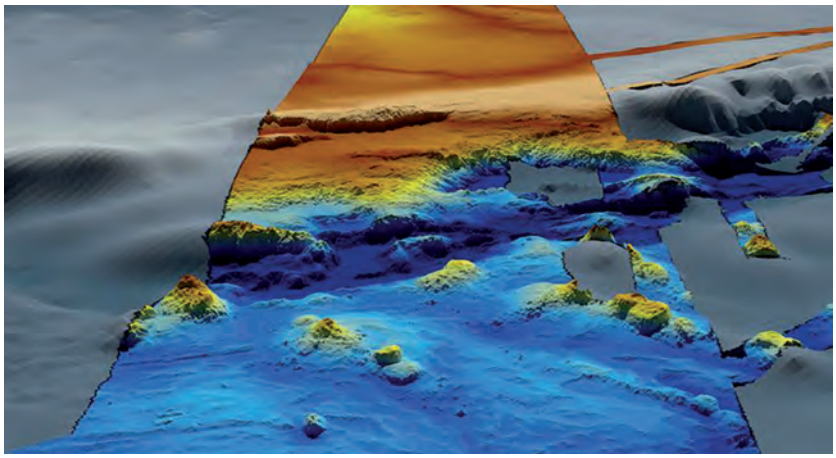
4) Light detecting and ranging (Lidar)
- Like the MBES, it derives the data by acquiring multiple depth points through a wide swath angle, but it is mounted on an airplane. The amount of time it takes for the sound or light to travel through the water, bounce off the seafloor, and return to the sounder informs the equipment of the distance to the seafloor. [3] As with the MBES method, the Lidar technique obtains very high-resolution and accurate datasets.

5) Hydrographic survey by crowdsourcing
- This method is quite new and relies on public volunteer vessels recording position, depth and

time data using their standard onboard navigation instruments. The data is then further uploaded to crowdsource organisations such as OpenSeaMap, TeamSurv or ARGUS and further post-processed for tidal corrections or speed of sound. This approach does not require a specific survey vessel, or professionally qualified surveyors to be on board but it cannot substitute a rigorous systematic survey, where this is required. Nevertheless, the results are often more than adequate for many requirements where high-resolution or high-accuracy surveys are not required or are unaffordable. [6]



▲ *Figure 4: The sonar system mounted on the hull of the vessel sends out sound waves that bounce off the seafloor and return to the ship.*



▲ *Figure 5: Image of the seafloor in the same location as Figure 2 but showing a strip of high-resolution data (in colour) where multibeam data has been acquired. (Source: Australian Government, portal Geoscience Australia.)*

What Else is Important to Create a Good Quality Bathymetry Map?

To the various different methods, we have to add some extra bathymetry equipment that helps acquire more accurate and reliable data. Gyrocompasses with an accurate heading provide information to correct for vessel yaw, and attitude sensors help correct roll and pitch on the ocean surface. The modern MBES systems have an integrated motion sensor fixing the correction errors and a mounted GNSS that positions the soundings with respect to the surface of the Earth. During the surveying process, supplementary measurements for factors such as water salinity, sea temperature and ocean depth need to be made due to the refraction of 'ray-bending' of the sound waves owing to non-uniform water column characteristics. These factors affect how quickly sonar waves travel through the water. The most significant device that measures the propagation velocity of the acoustic wave within the water column is called Sound Velocity Profiler (SVP).

In general, sound travels faster as temperature, salinity and pressure increase. The ocean has different currents, with different temperatures and salinities. A sensor recording that data is named CTD (Conductivity, Temperature, Depth). When processing multibeam bathymetry data, corrections for those factors need to be made in order to get high-quality data.

When processing multibeam bathymetry data, corrections for those factors need to be made in order to get high-quality data

To construct a precise map of the region it is necessary to perform surveying in such a manner that map stripes, obtained in different vessel tracks, are as close to each other as possible, or even overlap.

During the acquisition of the data, the surveyor can choose different operating frequencies - low or high frequencies. Generally, the higher the frequency, the better the resolution of the data, because the higher frequencies create better returning signals. However, high frequencies (greater than 100kHz) usually dissipate faster within the water column and therefore we use low frequencies (less than 30kHz) in deep waters. The greater the water depth, the worse the resolution of the data. That is due to two main factors:

1. In deep waters we use low frequencies instead of high frequencies, so that the acoustic waves reach the seafloor. The low frequencies do not produce a good resolution of the data though.
2. The deeper the water, the greater the area the beam covers. That is due to the swath opening angle. However, the outer beams of the swath create poorer returning signals and therefore lower resolution data.

▲ *Figure 6: Image of the seafloor mapped using satellite data. (Source: Australian Government, portal Geoscience Australia.)*

Finally, hydrographic processing software processes all the data. The resulting sounding measurements are then processed either manually, semi-automatically or automatically (in limited circumstances) to produce a bathymetry map of the area. After performing such surveying, all data are joined together, and the map of the entire region is constructed. [4]

The Hydrographic Processing Software

As mentioned above, after data has been collected, it has to undergo post-processing. The amount of data collected during a hydrographic survey is massive, often with several soundings per square metre. Depending on the goal for which the bathymetry map will be created (for example, navigation charts, Digital Terrain Model, volume calculation for dredging, topography, or bathymetry), this data must be reduced. The data will also need to be corrected for errors (i.e. bad soundings,) and for the effects of tides, waves/ heave, water level and thermoclines (water temperature differences). The final output of charts can be created with a combination of specialty Hydrographic Processing Software or a computer-aided design (CAD) package. Hydrographic Processing Software is software designed to process hydrographic data, Hydrographic Acquisition Software. This software allows for the creation of bathymetry maps, target detection, a difference analysis between new and old surveys as well as many other features for a wide variety of applications such as removing outliers, plotting field sheets, exporting data to CAD, computing volume quantities, generating contours, creating side-scan mosaics, etc.

From Paper Facsimiles to a Digital Chart

It must be remembered that no map is a real model of the world, but has been created to meet the needs of the intended user. Bathymetric nautical charts are no different in this respect. Firstly, they are mostly planned for the safety of navigation showing the shallowest depths in an area, which is great for navigators but does not meet the needs of many other users who want a more balanced view of the depths. Secondly, they were constructed and intended for marine sailors to plot their tracks on, which means that the amount of information shown beyond that needed for safe navigation is limited.

Digital charts would overcome the problems of displaying less data on the paper maps, but most digital charts are still basically just facsimiles of the paper charts and have yet to use the benefits that a digital approach could offer. This may change with the S-100 series of standards for digital charts, but these have not been implemented in commercial products yet. [5]

Finally, whilst the preponderance of GPS for positioning means that most charts have now been redrawn to the WGS84 horizontal datum, vertically charts refer to a local sea level. Nowadays, there is still a big variety in choosing the right vertical datum. Some States are still using datums like Mean Lower Low Water (MLLW) in the USA and not the recommended by International Hydrography Office (IHO) Lowest Astronomical Tide (LAT) or Mean Sea Level (MSL) in areas with minimal tidal ranges. However, this is not a big issue for navigation, but makes it difficult to set any sort of global mapping to a common vertical datum.

Conclusion

The taking and analysing of bathymetric measurements, as well as the creation of bathymetric maps is one of the core areas of modern hydrography, and a fundamental component in ensuring the safe transport of goods worldwide.

Overall, very little is known about the seafloor; less than 8% of the Earth's waters have been mapped. Even the surface of Mars and Venus has been better mapped than the Earth's seafloor. The existing maps of the seafloor are often low-resolution maps, mostly derived from satellites and only provide a general indication of water depth. Therefore, great efforts will need to be made in the future to change this. ◀

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5 Questions to…

Michael King, business development manager of Bibby HydroMap

To gain real insight into today's hydrographic business landscape, *Hydro International* asked some of the sector's most influential companies for their opinions. This series of Q&As focuses on the current state of the industry from various perspectives, such as which technological developments will have the most impact on the market, which market segments are the most promising and which areas offer the most growth. Here, Michael King, business development manager of Bibby HydroMap, shares his views of and expectations for the business.

▲ *Michael King.*

How do you expect the hydrographic market to evolve over the coming year?
Not sure we'll see a huge amount of evolution in a 12-month timeframe. There are various autonomous technologies on the market that will gain traction over the next year, but it will take time for them to be adopted, and it will be a while before they are commonplace.

In what ways could the ocean technology industry benefit from artificial intelligence and/or machine learning?
AI/machine learning has two major advantages:
1. Firstly, it removes a lot of the human element from some tasks. This has the potential to improve HSE performance, by reducing exposure hours in challenging and potentially dangerous environments. The technologies also have the ability to remove human subjectivity from the data analysis. This will allow data businesses to homogenise their results and provide more streamlined deliverables in a shorter timeframe.
2. Secondly, it will increase the effectiveness of hardware across the industry. By completing certain tasks 'artificially', it frees up hardware and software to concentrate on other things while the AI/machine learning takes care of basic tasks.

How is your company addressing the market for autonomous vehicles?
Bibby HydroMap have already invested in a market-leading autonomous survey solution – DriX. Developed by iXblue, we consider it to be the best autonomous tool available today for hydrographic survey. We have signed a development agreement with iXblue to assist them in improving this, and future, versions of DriX, and we expect to be at the forefront of autonomous hydrographic surveying across a range of industry sectors.

What could governments do to support the new market for automated surveying?
The main restriction to autonomous operation is the regulatory aspect. The Government and the IMO need to be clearer in their roadmap for publishing and supporting regulations for autonomous crafts. Too much of the focus is on the 'future' of autonomous shipping and large-scale solutions. What seems to have escaped some people is that companies are already using autonomous vessels in a commercial setting, with little to no regulatory support or guidance available.

What is the main technological advancement to watch for the future?
In our industry, the combination of autonomous deployment and new connected technologies (IoT, databases, communication between autonomous devices) will lead to a step-change in how the hydrographic industry operates. Proper autonomy and the ability for autonomous devices to interact with each other can potentially lead to huge improvements in productivity and affordability of survey services.

In-depth Hydrography Articles for You!

As the world's leading hydrography media brand, it is *Hydro International's* mission to keep you up to date on the latest trends and developments in the industry. We've selected the most read articles on bathymetry, AUVs, deep-sea mapping, new survey methods, electronic charts and other hydrography-related topics for you. Simply open the short URL in your browser and read the full story!

Research-driven Tools for Ocean Mappers

In a world where artificial intelligence plays a key role in our everyday life, it is disappointing when the everyday routines of an ocean mapper or cartographer involve solutions that are crudely manual, repetitive and error prone. Although the root causes of this situation might be debatable (e.g., constraints from abstruse formats, obscure algorithms, obsolete specifications, or a combination) the advantages to the ocean mapping community catching up with current-era technologies and moving towards smarter and more automated solutions are not.

▸ ***https://bit.ly/2PwqpTT***

▲ *The SmartMap WebGIS provides direct access to the Quality Factor values based on RTOFS forecast data for the next seven days.*

A Fully Autonomous Hydrographic Survey

During September 2017, one of the world's first autonomous hydrographic survey was performed. 'Autonomous' means not by remote control, but rather that the autonomous surface vehicle (ASV) used guidance from survey software to run pre-planned survey lines or automatically generated lines based on sonar coverage, with human interaction possible but not required. The Channel Coastal Observatory (CCO) commissioned 4D Ocean to undertake a hydrographic survey of the seabed offshore of Hurst Spit, Western Solent, using a SeaRobotics ASV 2.5. The pilot survey was supported by the Maritime & Coastguard Agency (MCA) and UK Hydrographic Office (UKHO).

▸ ***https://bit.ly/2G91XbW***

▲ *The SeaRobotics ASV 2.5.*

The Making of *RV Kronprins Haakon*

Norway is a maritime country with a very long coastline, and on top of this it is also very much a polar nation with 80% of its sea territory and 45% of its land mass north of the Arctic circle. It is the only country with territorial claims both in the Arctic and the Antarctic. In spite of this, Norway has not had a purpose built polar research vessels since Roald Amundsen's *Maud* (1917), instead relying on converted commercial vessels for these purposes. This is about to change when *Kronprins Haakon* comes into service in 2018.

▸ ***https://bit.ly/2RPIxtP***

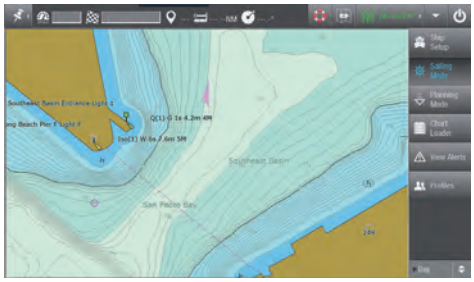
▲ *Kronprins Haakon has been designed to carry two helicopters.*

Mapping the Deep Ocean with Multiple AUVs

Ocean Infinity's seabed mapping campaign commenced in the summer of 2017. The Ocean Infinity team is made up of individuals from multiple disciplines, who have gained vast experience with deep-sea exploration operations in the past. Their combined knowledge and insight led to the idea to undertake deep-sea mapping operations using up to eight autonomous underwater vehicles (AUVs), paired with eight unmanned surface vessels (USVs). This novel concept is explained in more detail in this article.

▸ ***https://bit.ly/2RR5tZV***

New Challenges for Digital Chart Production



▲ *High Density Bathymetry ENC in ECDIS.*

Hydrographic Offices have realised that bathymetric data is not sufficiently represented in Electronic Navigational Charts (ENCs). A few aspects of this topic have already been touched upon in the presentation *Innovative approach in automated contour generation …* that was presented at Hydro 2017. This article focuses on the challenges of high-density bathymetry chart production and introduces a new approach to cope with it.

▸ ***https://bit.ly/2C3szqH***

A GIS Case Study from the Atlantic

Mapping the world's oceans is a tremendous task that would benefit from a prioritisation strategy. In this article, an in-depth presentation of one such approach is given: a GIS-based analysis that identified potential target areas for future mapping efforts in the North Atlantic Ocean. The authors of this article state that more knowledge about the seafloor could be significantly accelerated if all bathymetric data were publically available.

▲ *Result map showing the suitability of the study area and the three selected target areas.*

Bathymetric ENCs in Confined Waters

▲ *The Australian Hydrographic Office (AHO) published HD bathymetric electronic navigation charts (bENCs) for two ports.*

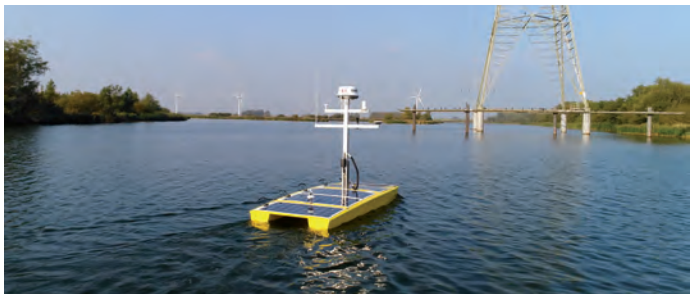
Electronic charts with greater scale and bathymetric content than any Hydrographic Office's ENC (equivalent to a paper nautical chart) are not a novelty for many ports around the world. Such charts are normally produced by Port Authorities and are used by marine pilots on the Portable Pilot Units (PPU). The Australian Hydrographic Office (AHO) has experimented with, and now published, High Density (HD) Bathymetric Electronic Navigation Charts (bENCs) for two ports, with more under development. These ENCs – like any other official ones – are available both to ships' crew using ECDIS and to Marine Pilots' PPUs. Why are High Density Bathymetric ENCs so important for the conduct of vessels in confined waters? Why is it so important that these ENCs become available to both ECDIS and PPUs? Before answering these two questions, it is necessary to understand the background of the Australian approach.

▸ ***https://bit.ly/2xHcgiU***

Streaming Data Processed Live to the World Wide Web

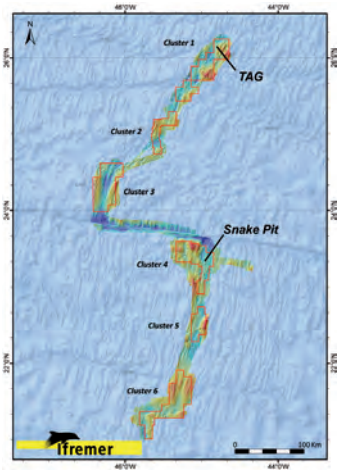
The Dutch government is currently focusing on autonomous technologies. Autonomous cars can already be found on Dutch highways and now Rijkswaterstaat (The Ministry of Infrastructure and Water Management) has also started to automate survey processes on rivers, together with the company Aquatic Drones. The use of autonomous vehicles creates new opportunities for traditional surveys. Equipped with hydrographic instruments, the vehicles can collect data remotely in increasing volumes, in challenging environments and with less risk to personnel.

▸ ***https://bit.ly/2EpKomb***



▲ *Aquatic Drones with multibeam survey suite.*

Understanding Deep-sea Minerals and Ecosystems

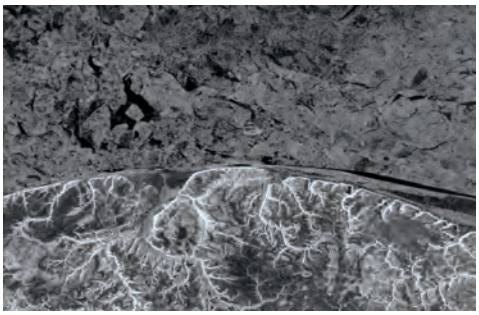


▲ *Map of the French exploration contract for polymetallic sulphides on the Mid Atlantic Ridge.*

France and Ifremer have had a long involvement in the discovery and study of deep-sea mineral resources and their associated ecosystems. With a rather unique position in the marine research landscape, Ifremer is actively involved in the deep-sea both as a contractor with the ISA and as an integrated marine science research institute. The HERMINE 2017 exploration cruise on the French polymetallic sulphides exploration contract is an example of combined mineral exploration and scientific investigations. The last two decades have seen a renewed interest for these potential sources of minerals sparked by factors such as the rise of metal prices, the development of low-carbon technologies increasing the demand for some minerals and geopolitical issues. Exploration of the three types of deep-sea mineral resources has therefore been an item of increasing interest on the international agenda.

▶ ***https://bit.ly/2C9dxQJ***

Mapping the Seafloor with Remote Sensing and Satellite Imagery



▲ *Northwest Passage sea ice contrasts with the coast of Baffin Island, Canada, in this ALOS-PALSAR image taken 8 March 2011. (Courtesy: JAXA, METI).*

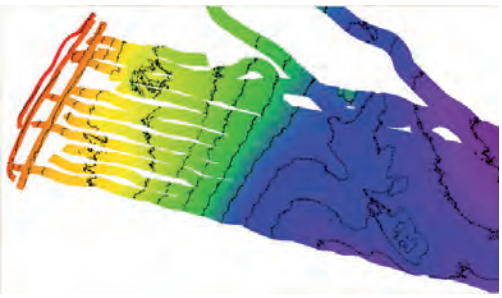
0% of the Earth is covered by water, but so far just 7% of it has been surveyed (Mars, Venus and the Moon are better surveyed). Hydrography as a science has changed dramatically since the first measurements were made by Alexander Dalrymple and James Cook with lead lines and sextants. Singlebeam echosounders were invented in the 1920s – a technology still used today for mapping the seafloor. This method of using echosounders can produce very high-resolution bathymetric data but the high operational costs and the slow working process make it economically unsuitable for covering large areas. However, with the ongoing expenses of the offshore industry over the last decades, scientists and engineers had to develop better and more effective technologies to map the seafloor, namely airborne technologies. Over the past decades there has been increasing interest in airborne and satellite-derived bathymetry data. This article explains the methods of remotely mapping the seafloor in detail and their advantages and disadvantages.

▶ ***https://bit.ly/2G9UNnC***

Subsea Cable Route Surveying

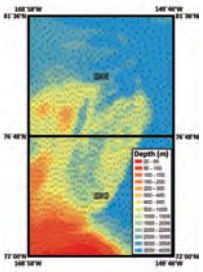
Ninety-nine percent of international data is transmitted by around 265 subsea cable systems connecting the world. The total length of subsea cables exceeds 1.6 million kilometres and they can be found as deep as 8,000m. The cables, which can cost hundreds of millions of dollars, must generally be run across flat surfaces of the ocean floor and care is taken to avoid coral reefs, wrecks, environmentally and politically sensitive areas and general geological obstructions. Diameters are generally no thicker than an average garden hose. Cable laying is an expensive operation and is a function of the total length of cable, water depths and required protection and resulting cable types.

▶ ***https://bit.ly/2Uw7E6R***



▲ *Multibeam data coverage in shallow water.*

Automated Depth Area Generation for Updating NOAA Nautical Charts



▲ *Tool output for two new charts covering Chukchi Plateau.*

National Oceanic and Atmospheric Administration's (NOAA's) Marine Chart Division (MCD) is currently revising production efforts using an 'ENC-first' approach to provide seamless and tiled geographic coverage. Currently, ENC production workflows within MCD require cartographers to manually manipulate data in the Nautical Information System (NIS) to update navigation products. This MCD addressed this production bottleneck by developing a tool to derive depth area, contour and sounding vector data directly from gridded raster bathymetry surface data.

▶ ***https://bit.ly/2SJpbqb***

Applanix

Applanix Corporation, a wholly owned subsidiary of Trimble, designs, builds, delivers, and supports products and solutions designed specifically for the hydrographic survey industry. Even in the harshest marine environments, our products and solutions provide robust, reliable, and repeatable positioning and motion compensation solutions from moving boats and vessels. Marine-based mobile mapping and positioning with Applanix technology not only cuts costs associated with marine surveys, it also delivers tremendous accuracy with faster times to completion and improved quality of data.

POS MV

POS MV blends GNSS data with angular rate and acceleration data from an IMU and heading from GNSS Azimuth Measurement System (GAMS) to produce a robust and accurate full six degrees of freedom Position and Orientation solution. POS MV comes in 4 models:

- POS MV SurfMaster / SurfMaster One
- POS MV WaveMaster II
- POS MV OceanMaster
- POS MV Elite

All POS MV models are designed for use with multibeam sonar systems, enabling adherence to IHO standards on sonar swath widths of greater than ± 75 degrees under all dynamic conditions. Benefits of POS MV include:

- More robust georeferencing in the most difficult GNSS environments
- Robust heave in a wide dynamic range
- Increased productivity
- Accurate attitude in all dynamics
- No timing errors

To learn more about Applanix and our products and services, visit our website at www.applanix.com or email marine@applanix.com.

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Bibby HydroMap

Bibby HydroMap are experts in the acquisition, interpretation and presentation of highly accurate and precisely positioned seabed and sub-seabed data.

Established in 1997, Bibby HydroMap has flourished into a leading marine survey business in the UK and Europe. Part of the Bibby Line group since 2012, the company prides itself on its commitment to quality and innovation. With its client-led approach and continuous investment in custom-build survey vessels and equipment, Bibby HydroMap is an award-winning partner of choice.

Working with clients from a range of industries, core competencies include: hydrographic survey, marine engineering geophysics, shallow marine geotechnics, UXO survey and detection, ROV and AUV survey and inspection, asset integrity surveying, maritime archaeology, benthic sampling, engineering geology, metocean and oceanography. From a fleet of 6 vessels, the company provides a true inshore to offshore survey capability, supplemented by land and autonomous technology to service project requirements.

With a focus on innovation, the company has recently taken steps to develop autonomous survey capability in association with iXBlue. Providing a stable platform, DriX is an Autonomous Surface Vessel capable of 24hr acquisition with a maximum duration of 7 days. Over traditional survey vessels, DriX offers efficiency gains whilst reducing personnel exposure, and is ideally suited to windfarm monitoring activity.

The combination of knowledge, experienced personnel and innovative solutions are all key requirements for a successful project when working in challenging marine environments.

Contact us for more information about the survey solutions we can offer you: enquiries@bibbyhydromap.com or visit our website: www.bibbyhydromap.com

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Phone: +44 (0)151 328 1120, enquiries@bibbyhydromap.com, www.bibbyhydromap.com

CHC Navigation

CHC Navigation is a publicly listed company that creates innovative GNSS-based navigation and positioning solutions. With a global presence and distributors in over 80 countries and more than 1,000 employees, CHC Navigation is today recognised as one of the fastest growing companies in Geomatics technologies.

CHC Navigation develops advanced geospatial technologies and provides a wide range of state of the art solutions for land surveying, construction, GIS, hydrography and bathymetric survey, deformation monitoring, precision farming, and 3D mobile mapping for mass data acquisition.

Our Marine Survey Solutions

The Apache 3 is a portable unmanned survey vessel and provides a cost-effective USV solution for achieving accurate results for bathymetric surveys in channels, shallow draft riffles and inland rivers and lakes.

The Apache 5 is a new USV concept for high-resolution hydrographic surveying with integrated single or multibeam echo sounders. Its absolute linear technology ensures seamless surveys, even in strong sea or river current.

The P3DT GNSS is a dual antenna GNSS sensor for heading and RTK positioning applications.

With real-time data output up to 50Hz, the P3DT GNSS Sensor is designed to answer the requirements of high-dynamic positioning applications.

CHCNAV
Make your work more efficient

CHC Navigation, 599 Gaojing Road, Qingpu District, Shanghai, China, 207102. Phone: +86-21-51508100, sales@chcnav.com, www.chcnav.com

EvoLogics

EvoLogics GmbH is a German high-tech enterprise founded in 2000 by a group of leading international scientists and R&D experts. The company is on a mission to develop innovative technologies for maritime and offshore industries through interdisciplinary cooperation between engineering and life sciences.

EvoLogics' core values are rooted in bionic concepts that combine state of the art engineering with the best ideas found in nature. The team took a bionic approach when solving the common problems of transmitting data in the dynamic underwater environment.

The resulting S2C spread-spectrum communication technology became the basis for the company's commercial products. Over the past 8 years it grew into a whole 'ecosystem' that includes several lines of underwater acoustic modems, positioning systems and novel robotic solutions.

Research and innovation remain the cornerstones of EvoLogics - the company is active in multiple national and international R&D projects that drive development of novel technologies.

Advanced communication and positioning - the S2C technology

EvoLogics offers highly reliable, flexible and cost-effective solutions for multiple underwater communication, positioning, navigation and monitoring applications.

EvoLogics' acoustic telemetry provides an independent bidirectional data link with simultaneous positioning, broadcasting and networking.

S2C-based systems have been carefully designed for operations in harsh underwater conditions and are enhanced with special algorithms for signal processing and data management. The company's extensive experience with sensor integration makes turnkey solutions possible for customers. These range from accurate positioning systems for subsea assets to underwater acoustic sensor networks for monitoring multiple environmental parameters and remotely controlling complex processes from the surface.

EvoLogics

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Fugro Marinestar

Marinestar high-performance positioning products and services delivered to you by Fugro Satellite Positioning are able to meet a varied range of applications in dredging & marine construction, wind farm installation, cable laying, and naval and hydrographic/oceanographic surveys.

Marinestar services deliver up to 8cm (vertical, sigma 2) accuracy in high availability using eight overlapping L-band satellite beams.

With GPS, GLONASS, Beidou and Galileo constellations, redundancies as well as precision gains are made available. One of our most recent developments is the fixing of ambiguities of the GPS constellation leading to the G2+ or G4+ L-band service.

Our redundant infrastructure and 7x24 global customer service makes this precise positioning service the exact tool you need!

When positioning counts…….count on Marinestar!

www.fugro.com/marinestar

MARINESTAR

Fugro Marinestar, Dillenburgsingel 69, 2263 HW Leidschendam, The Netherlands. Phone: +31 70 3170960, marinestar@fugro.com, www.fugromarinestar.com

Geomares

Geomares supports businesses that want to grow by devising smart marketing campaigns and executing them until you reach your goals! With our enthusiastic team of dedicated, knowledgeable marketing advisors and content professionals, and the largest global database of decision-makers in the geomatics and hydrographic community, we form the link in the interaction between professional buyers and businesses.

One of the publications of Geomares is *Hydro International*, the high-quality leading source of information in the field of hydrography. With in-depth articles, groundbreaking case studies, jobs and much more, the website, e-newsletter and printed magazine reach the largest global audience in the field of hydrography.
Hydro International goes straight to the desk of key decision-makers in the international hydrography arena and is directed at commercial, academic and government professionals all over the world, people at the leading edge of managing, implementing and procuring hydrographic equipment and services.

Geomares, P.O. Box 112, 8530 AC Lemmer, The Netherlands. Phone: +31 514 561854, info@geomares.nl, www.geomares-marketing.com

INNOMAR

INNOMAR Technologie GmbH has been providing innovative and high-quality underwater acoustic survey equipment and associated software for the marine and offshore business for more than 20 years.

INNOMAR's main product line, the narrow-beam parametric sub-bottom profiler (SBP) series 'INNOMAR SES-2000' provides unequalled high-resolution sub-seafloor data achieving excellent penetration both laterally and vertically. This product line covers all depth ranges and can be used in water depths between less than one metre and full ocean depth (11,000 metres). Applications include the geophysical imaging of sediments and sub-seabed structures for dredging purposes, for route and offshore site surveys and to map buried pipelines/cables.

The 'INNOMAR SES-2000' series of parametric sub-bottom profilers (SBP), with more than 400 units sold, comes with a software package comprising a user-friendly data-acquisition software, a data export tool to convert INNOMAR data formats to SEG-Y, XTF and ASCII data formats and a dedicated post-processing software. All data are recorded digitally, but analogue outputs are available too. Transmit pulse characteristics can easily be adjusted by the user to fit specific survey requirements. The receiver settings are adapted automatically to match the transmit pulse used. Transducers are available for over the side pole-mounting as well as for installation in the vessel's hull including optimised shock absorbers to avoid vibrations and optional transducer protection for ice-going vessels.

There are also 'INNOMAR SES-2000' models incorporating a narrow-beam parametric sub-bottom profiler and a dual-frequency side-scan sonar for simultaneous operation. Multi-transducer SBP models for both surface vessel and underwater vehicle operation provide high data density suitable for 3D sub-seafloor visualisation, boulder and UXO detection as well as tracking of buried pipelines or cables. The latest shallow-water model 'INNOMAR SES-2000 smart' is perfectly suited for small boats and ASV/USV integration.

INNOMAR's quality management has been certified by DIN EN ISO 9001 for more than 15 years.

INNOMAR Technologie GmbH, Schutower Ringstr. 4, 18069 Rostock, Germany. Phone: +49 (0)381 44079-0, info@innomar.com, www.innomar.com

iXblue

iXblue is a global leader in the design and manufacturing of innovative solutions devoted to navigation, positioning and underwater imaging, as well as shipbuilding. Using its unique in-house technology, the company offers turnkey solutions to its Civil and Defence customers to carry out their sea, land and space operations with optimum efficiency and reliability.
iXblue is recognised throughout the industry for its pioneering work on the development of fibre optic gyroscope (FOG) technology which has revolutionised inertial navigation systems in the last decade, providing unequalled performance and cost of ownership benefits.
Employing a workforce of 600 people worldwide, iXblue has a global footprint and conducts its business with over 35 countries.

iXblue - 34 rue de la Croix de Fer, 78105 Saint-Germain en Laye, France. Phone: +33 1 30 08 88 88
contact@ixblue.com, www.ixblue.com

Leica Geosystems

Leica Geosystems, part of Hexagon, recently revolutionised bathymetric surveying by introducing the Leica Chiroptera 4X and Leica HawkEye 4X, a new high-resolution technology delivering four times the point density and increasing data collection efficiency by up to 50%.

4X Bathymetric Point Density

The higher point density allows customers to deliver high-resolution products at reduced operational costs. Flight cost savings of 50% can be achieved for typical bathymetric Lidar end-user specifications. The depth penetration increases up to 10% with the new technology while not affecting the turbid water performance or accuracy.

Seamless Data from Sea to Land

By integrating multiple sensors into the survey systems, Leica Geosystems has optimised the survey efficiency and performance. For everyday nearshore surveys, the Chiroptera 4X will collect seamless data from land to a water depth of 25 metres. When fitted with the HawkEye III deep bathymetric module, the survey water penetration depths can be increased to 50m.

Integrated Processing of Lidar data

The Leica Lidar Survey Studio (Leica LSS) software allows simultaneous processing and quality assurance of all sensor data, therefore increasing productivity. Users can quickly create coverage plots, check accuracy and point density, visualise the data in 3D, and review and extract Q/A reports. Tools such as automatic calibration, data classification, water refraction correction, data cleaning, turbid water enhancement, point cloud colourisation, point cloud matching, import of reference points, and quality assurance statistics analysis are integrated.

Contact us to find out how you can increase your data collection efficiency.

Leica Geosystems, part of Hexagon, Geospatial Content Solutions Division, Klubbhusgatan 15, 553 03 Jönköping, Sweden.
Phone: +46 361 966 80, info.gsd@leica-geosystems.com, www.leica-geosystems.com/chiroptera-4x

QPS

QPS BV (Quality Positioning Services) makes industry leading software for all phases of ocean mapping. Our solutions are used for a variety of applications including hydrographic surveys, offshore and nearshore construction, wind farms, oil and gas, precise navigation and Electronic Navigation Chart (ENC) production. Our technology is highly geared towards automation and autonomous solutions. We maximise the value in the integration of our products to increase efficiency, while also offering the utmost modularity for client workflow flexibility. We integrate seamlessly with ArcGIS for Maritime, for further efficiency gains in maritime-related businesses.

- QPS QINSy is a software suite supporting multi-sensor and multi-object survey planning, acquisition, and real-time processing.
- QPS Qimera is an evolution in multibeam data processing, simple to use but at the same time with the most advanced functionality.
- QPS Fledermaus is interactive 4D geospatial processing and analysis software – the ultimate tool for data fusion and communication.
- QPS Qarto is ENC production software built for rapid and automated product generation and used in some of the world's busiest ports, ensuring timely product delivery.
- QPS Qastor is precise navigation, piloting, and docking software – with real-time server updates, Qastor ensures safety of navigation and optimal situational awareness for mariners.

We also offer various services, such as having our engineers come on-site to ensure optimal installation and setup, customised to your configurations, including intensive training. Expect a powerful and fully integrated workflow that your crew will be confident to operate, resulting in products of the highest quality that have been generated in a timely fashion.

QPS is a software company that has been headquartered in the Netherlands since 1986 and now has subsidiary offices in the USA, Canada and the UK. In 2012, QPS became a member of the SAAB (Sweden) group of companies (Traffic Management division).

QPS, Handelsweg 6-2, 3707 NH Zeist, The Netherlands. Phone : +31 306 941 200, sales@qps.nl, www.qps.nl

RIEGL Laser Measurement Systems

RIEGL is an international leader in providing cutting edge Waveform-Lidar technology for airborne, mobile, terrestrial, and unmanned laser scanning solutions. RIEGL's innovative hardware and software products provide powerful solutions for multiple applications in surveying.
For combined hydrographic and topographic surveying RIEGL offers the fully integrated airborne laser scanning systems VQ-880-G II and VQ-880-GH – the new, further improved successors of the proven VQ-880-G. Providing a water penetration of 1.5 Secchi depth, they are ideally suited for coastline and shallow-water mapping, river bed profiling, measurement of aggradation zones, hydro-archaeological surveying, etc. These turn-key surveying systems include a high-end IMU/GNSS unit and an RGB camera and are fully calibrated off-factory. The integrated improved infrared laser scanner complements the data from the green laser scanner and supports the detection of the water surface. The compact and robust housing is compliant with typical aircraft hatches and stabilised platforms. Additionally, the VQ-880-GH's form factor with reduced height is specifically optimised for helicopter integration. Additionally, RIEGL announces the new topo-hydrographic laser scanner RIEGL VQ-840-G, a compact and lightweight Lidar system to be installed on various platforms including UAVs.
The BathyCopter, the world's first small UAV-based surveying system for bathymetric surveying completes RIEGL's topo-hydrographic portfolio. It is capable of measuring through the water surface and it is ideally suited for generating profiles of rivers or water reservoirs. The robust and reliable platform design integrates the RIEGL BDF-1 bathymetric depth finder - with tilt compensator, IMU/GNSS unit, control unit, and up to two digital cameras - on RIEGL's RiCOPTER.

RIEGL Laser Measurement Systems GmbH, Riedenburgstrasse 48, 3580 Horn, Austria. Phone: +43 2982 4211, office@riegl.com, www.riegl.com

SBG Systems

SBG Systems is a leading supplier of compact, high-performance & cost-effective MEMS-based inertial motion sensing solutions. Our Motion Sensors and Inertial Navigation Systems are ideal for hydrographic applications, ship motion monitoring, Lidar and Buoy orientation and positioning; ROV & AUV control; camera stabilisation, and antenna tracking.

NEW: QINERTIA, The Next-generation INS/GNSS Post-processing Software

For more than 10 years, SBG Systems has been designing inertial navigation systems from the internal Inertial Measurement Unit to the filtering with GNSS data. Expert in real-time data fusion, the company takes another step in the surveying industry by unveiling Qinertia, a fully in-house Post-Processing Kinematic (PPK) software. After the survey, this full-feature software gives access to offline RTK corrections, and process inertial and GNSS raw data to further enhance accuracy and secure the survey.

Two Product Lines Dedicated to Hydrographic Survey

The Ekinox 2 Series is a line of survey-grade compact inertial sensors that shows an impressive performance/price ratio. This second generation is twice as accurate as the initial one, now providing a Roll and Pitch accurate to 0.02°, additionally to Position, Heading and Heave.
The Apogee Series is the most accurate line of inertial navigation systems based on the robust and cost-effective MEMS technology. It provides a Roll and Pitch accurate to 0.005° in real-time, Heading and Heave. Depending on the model, the Apogee integrates or connects to a tri-frequency GNSS receiver that receives RTK, Marinestar, OmniSTAR, TerraStar, Veripos, etc.

SBG Systems S.A.S., 1, avenue Eiffel, 78420 Carrières-sur-Seine, France. Phone: +33 1 80 88 45 00, sales@sbg-systems.com, www.sbg-systems.com

Seabed

Seabed (founded in 2004, and based in Amsterdam, The Netherlands) is a company specialised in equipment for surveying and dredging. Our highly qualified engineers develop and produce products for the offshore as well as the onshore industry.
With our complete team of developers, support engineers, hydrographic surveyors and the sales team we aim for the right balance in Sales, Support and Engineering. This, together with dealerships of well-known global brands offering equipment of a very high standard, makes Seabed a reliable partner for all your needs. We offer the following products: positioning solutions, Sonar/Bathymetry, mobile mapping, underwater sensors, hydrophones, density probes, bottom sampling, crane systems, software solutions, telemetric solutions and cables, connectors and housing.
All these products are available for rental as well. In addition to the standard product line, Seabed is also very strong in system integration based on specific customer requests. Seabed organises demo days yearly in September, where all the latest equipment is demonstrated. If you wish to attend, please mail rsvp@seabed.nl. For more information check out our Seabed Gazette or visit our website: www.seabed.nl

Seabed, Asterweg 117, 1031 HM Amsterdam, The Netherlands. Phone: +31 20 6368443, sales@seabed.nl, www.seabed.nl

Teledyne CARIS

For over 35 years, Teledyne CARIS has been making software designed for the marine GIS community. Not only renowned for its products, but also for outstanding customer service, Teledyne CARIS offers a comprehensive level of support through training sessions and consulting, online technical support, email, and multilingual telephone support.
Developed in cooperation with hydrographic clients and universities, the CARIS toolset provides clients with resource optimisation and a true operational advantage. Known for the Ping-to-Chart™ solution, we offer a comprehensive portfolio of products, from the processing of the echo sounder ping to the production and distribution of the chart.
The newest product in the toolset, CARIS Onboard, is a near real-time and autonomous data- processing package that has been developed with autonomous underwater vehicles (AUVs) and unmanned surface vehicles (USVs) in mind. This solution acts as a force multiplier when used on survey vessels by fitting seamlessly into the Ping-to-Chart suite of software, and reducing the overall product creation timeline.
Find out why CARIS software is selected by national mapping and charting agencies, survey companies, port and waterway authorities, oil and gas companies, and academic institutions worldwide by visiting www.teledynecaris.com.

Teledyne CARIS, 115 Waggoners Lane, Fredericton, NB E3B 2L4, Canada. Phone: +1 (506) 458-8533 , caris-info@teledyne.com, www.teledynecaris.com

Valeport

Valeport is a leading British manufacturer of hydrographic, hydrometric and oceanographic instrumentation including: Sound Velocity Probes / Sensors, Altimeters, Radar Level Sensor, Current Meters, Tide Gauges, Fluorometers, Wave Recorders, CTD's, Multi-Parameter CTD's and GPS Echo Sounders.
With leading edge technology, lifetime product care approach and a strong commitment to putting the customer first, Valeport has supplied the subsea sector since 1969 and continues to innovate and lead the way in supporting the hydrographic and oceanographic survey sector.
Valeport products benefit from an industry-leading three-year warranty. All deepwater subsea products are manufactured to the highest standards using titanium for maximum durability.
The dedicated service facility and modern calibration laboratories at Valeport provide a responsive repair and calibration service to our global customer base and we offer a unique 12-month warranty on all Valeport serviced products.
Our latest probe, the SWiFTplus, combines the power of the SWiFT SVP and a turbidity sensor offering a highly accurate probe with a string of benefits suited to multiple applications.
The new SWiFTplus uses Valeport's world leading high-accuracy sensor technology which incorporates turbidity observations with sound, speed, temperature and pressure sensor technology to also provide computed conductivity, salinity and density.
Designed from the outset with the intention of a seamless workflow, the handheld profiler has an integral GPS to geo-locate every profile and provides high-quality profiles in a compact, robust and portable package.
The turbidity sensor within the SWiFTplus is effectively two sensors in one. Both a 'classic' turbidity sensor for low turbidity levels and a second sensor using OBS optical backscatter arrangement at higher turbidity levels.
Using the Valeport Connect app, data can be quickly downloaded and reviewed wirelessly via Bluetooth, and instantly shared in industry standard formats through email and cloud services.
Valeport's work with MBES manufacturers and OEMs has allowed interesting interfaces of SV sensors and Valeport's new ultraSV is designed for simple integration and easy exchange where required for both shallow-water and deepwater transducer applications.
To learn more about Valeport, our products and services visit: www.valeport.co.uk or email: sales@valeport.co.uk

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Wärtsilä ELAC Nautik

Wärtsilä ELAC Nautik is a market leader in hydroacoustic systems for survey, naval and commercial applications. With more than 50 years of multibeam know-how we offer highly innovative integrated survey solutions, including project management, research and development, software and hardware design as well as extensive training and logistics tailored to our customer's needs.
Our products are developed and manufactured in Kiel, Germany and are renowned for their high reliability, robustness and advanced technology. We are specialised in equipping new vessels with innovative products, and developing customer-specific modernisation solutions.
No matter what the challenges are – Wärtsilä ELAC Nautik delivers.

Wärtsilä ELAC Nautik, Neufeldtstrasse 10. 24118 Kiel, Germany. Phone: +49 431 883 0, marketing@elac-wartsila.com, www.wartsila.com/elac

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- low power consumption for autonomous operations
- advanced data delivery algorithms, addressing and networking, remotely configurable settings
- extendable platform with multiple configuration options: power-saving Wake Up module, acoustic releaser, additional sensors, custom solutions, OEM versions available

USBL POSITIONING SYSTEMS

simultaneous positioning and communication - no need to switch between positioning mode and modem mode

- flexible SiNAPS positioning software
- reliable data transmissions
- range: up to 8000 m
- accuracy: up to 0.04 degrees

LBL POSITIONING SYSTEMS

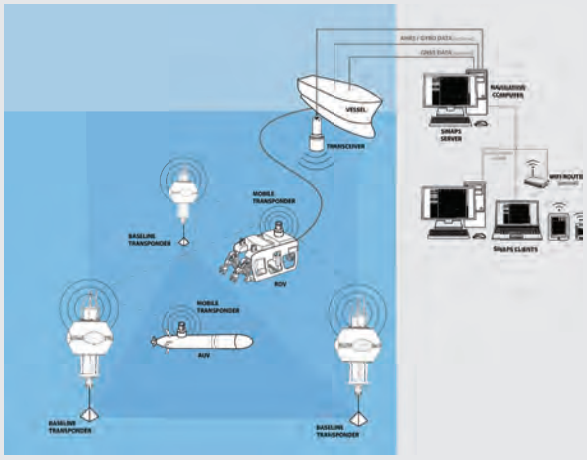
highly accurate, precise and stable performance, simultaneous positioning and data transmissions

- 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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