MARINE TECHNOLOGY REPORTER

November/December 2022
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Ocean Observation

IFREMAR New Energy, New Directions
Interview **Carl Trowell,** Acteon
Methane Stepping on the Gas
Lander Lab #5 **Batteries**

Volume 65 Number 8

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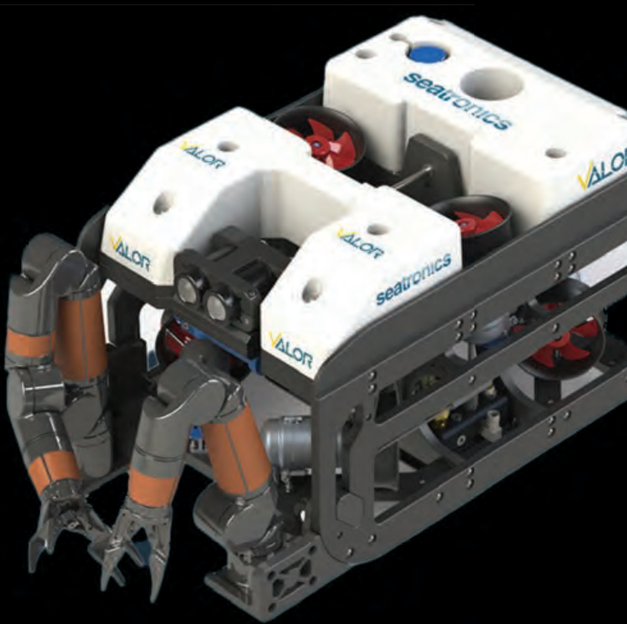

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On the Cover

Inside IFREMER – l'Institut Francais de Recherché Pour l'Exploitation de La Mer – or "French Research Institute for Exploitation of the Sea", France's premier ocean science research institute.
Image courtesy IFREMAR

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Editorial

As 2022 winds to an end, it's fascinating to see how so many technology trends simultaneously are conspiring to literally upend this industry are coming to fruition. Matters of ESG and emission monitoring and reduction are taking firm hold across this sector, with multiple projects centered on alternative fuels and the emission signature of entire systems and projects coming under close scrutiny. Digitalization and the effective, efficient use of data plays a part in that conversation too, but in a much broader context the manner in which we extract information from our world's waterways and, in turn, process and put it to meaningful use is a top two agenda item for all.

But while much of our talk in print and online tends to focus on the tech side of the business, an ultimate limiting factor to 'how far, how fast' this industry moves comes down to a familiar foe: bureaucracy.

I was pleased when Rear Admiral (ret.) **Tim Gallaudet**, PhD and Commander (ret.) **Victor Vescovo** reached out to me – literally as we were going to press – to gauge my interest in publishing an op/ed entitled *"The Biggest Barrier to Advancing the Ocean is Bureaucracy – Let's Fix it Now*," which serves as our *"The Final Word"*. Both author's credentials stand on their own and it was a no-brainer to engage and offer a platform for their insights. I won't steal their thunder here, but the impetus for the article was the *denial* of Caladan's request to mark the 80th anniversary of the Battle of Midway with a dive in the Papahanaumokuakea National Monument, using the Deep Submergence Vehicle (DSV) Limiting Factor to image the aircraft carrier wrecks sunk during the famous World War II naval battle. Read their rationale and insights on how bureaucracy can effectively stifle innovative subsea exploration, starting on page 60.

Gregory R. Trauthwein
Associate Publisher & Editor

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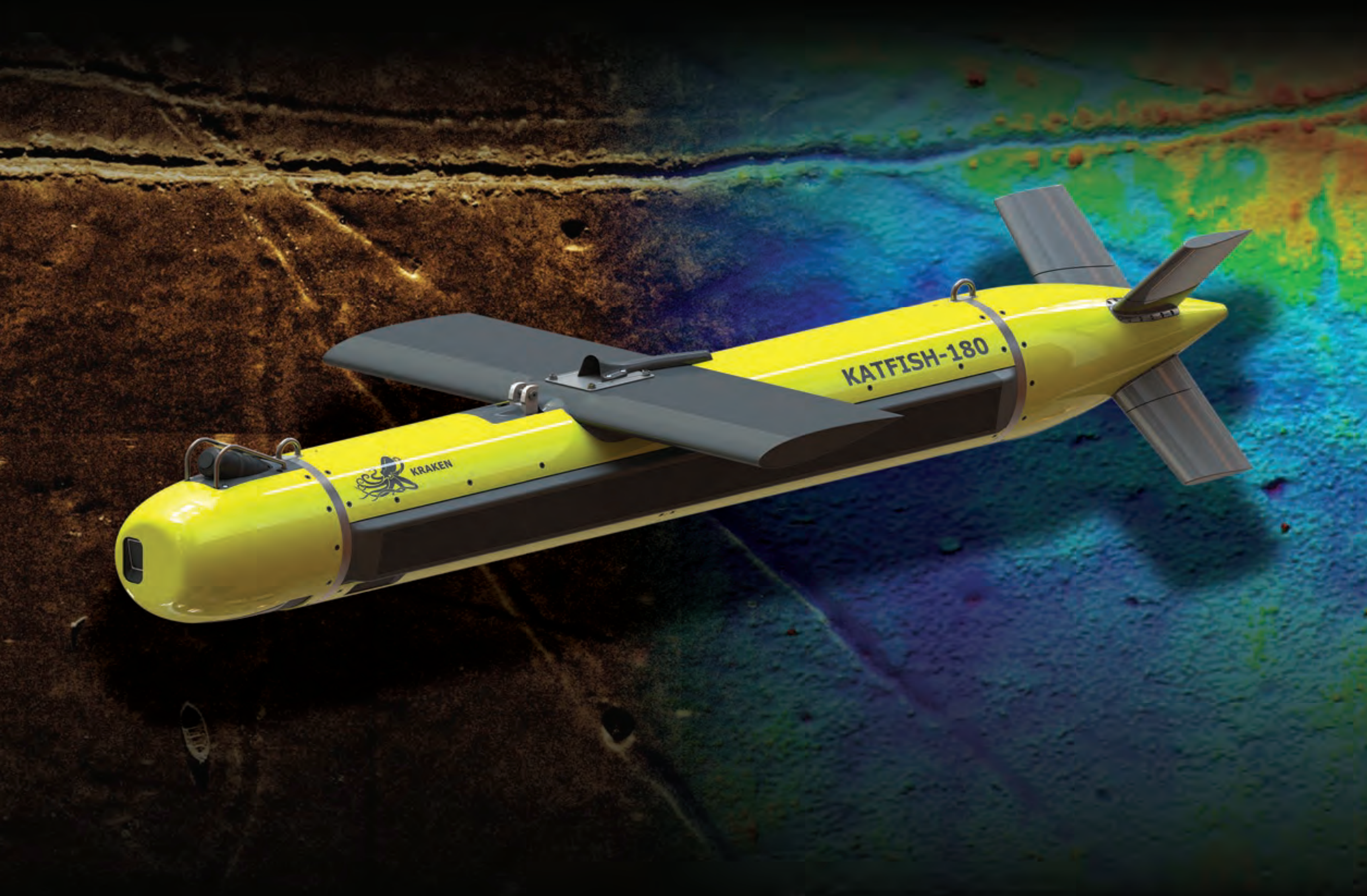

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SAS Robustness Against Yaw	±10° over 50 m track length
SAS Robustness Against Sway	±0.2 m/s

info@krakenrobotics.com

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Commander (ret) Victor Vescovo is a former intelligence officer in the U.S. Navy. He is the owner and chief submersible pilot of Caladan Oceanic, LLC, a co-founder of Insight Equity, and recipient of the 2020 Gold Medal of The Explorer's Club.

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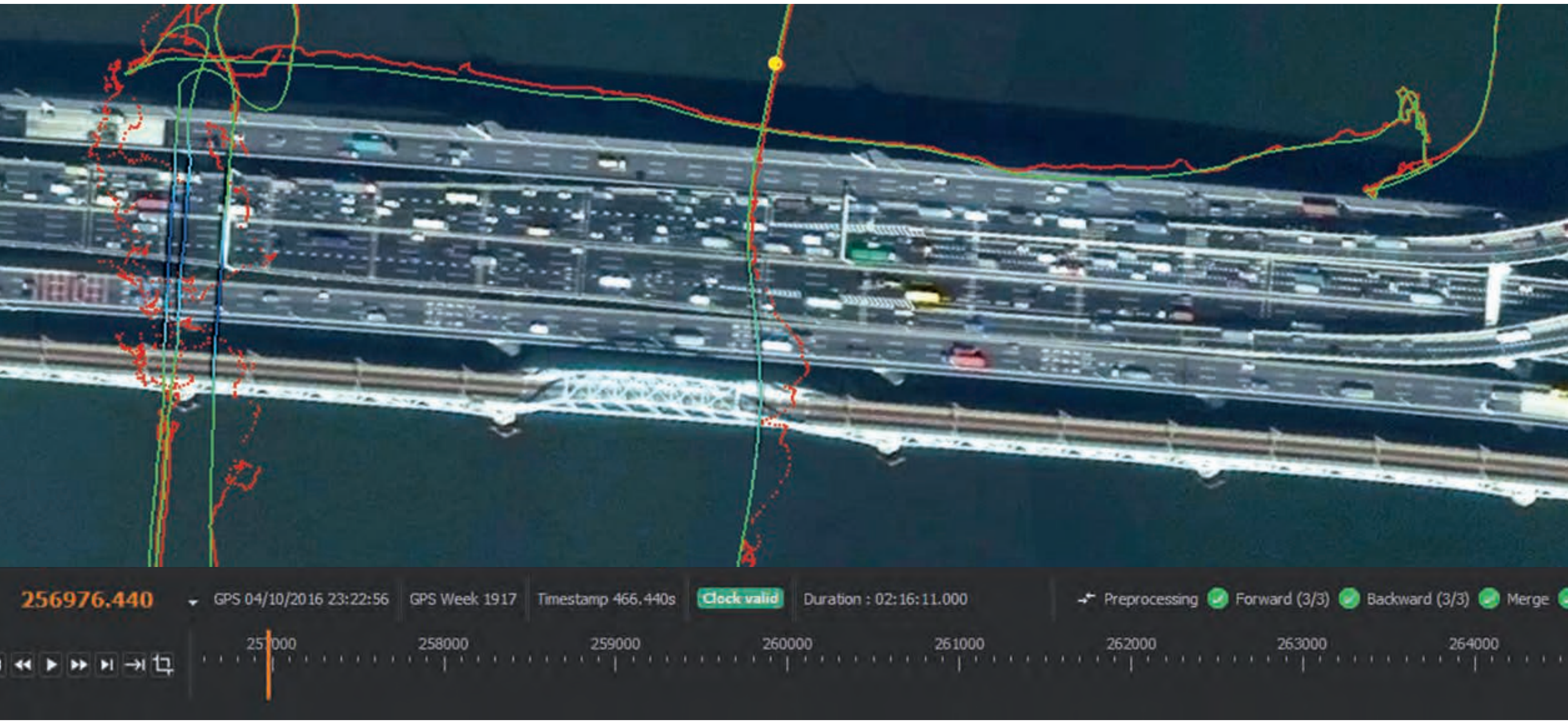
Data Sheet



Quality: *Green -> centimetric position; Blue -> decimetric < 30cms; Red -> Raw GNSS data*

SURVEYING UNDER BRIDGES MADE EASY

This survey has been done with an APOGEE INS under very challenging conditions for the GNSS receiver (red dots).

The boat is crossing multiple times three large bridges including one made of steel.

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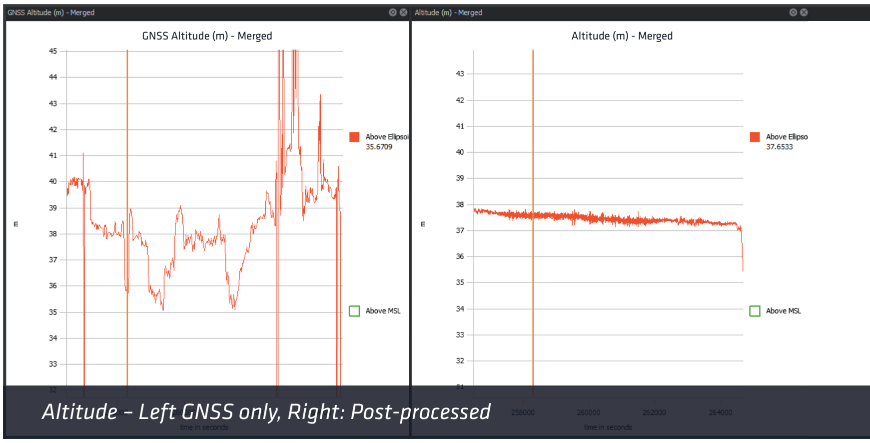

Altitude – Left GNSS only, Right: Post-processed

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Many thanks to Hydro Systems Development (HSD Japan) for their kind collaboration.

Full data available upon request at marketing@sbg-systems.com
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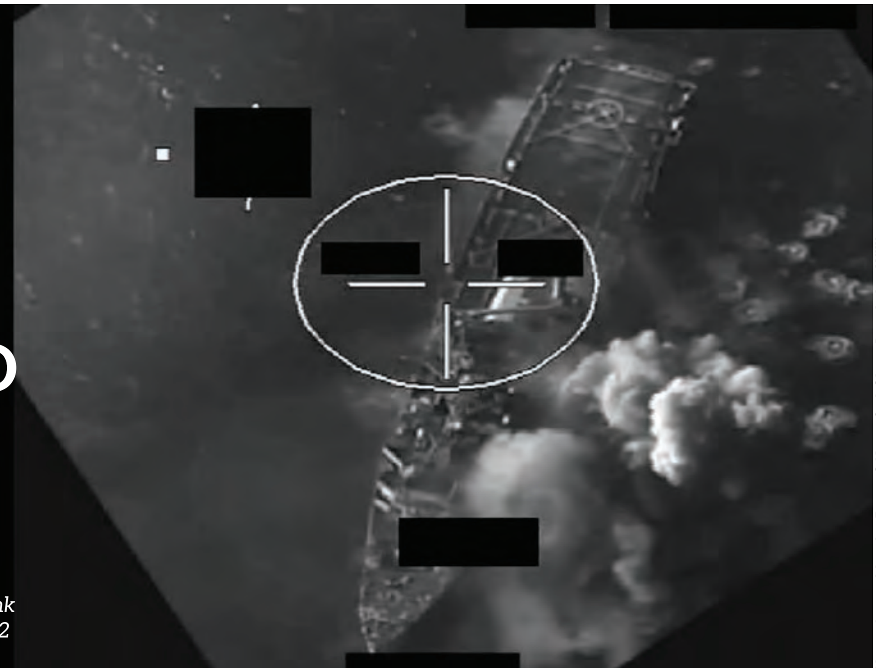
SBG SYSTEMS

Ex-USS Denver still served until sunk



Ex-USS Denver is sunk during RIMPAC 2022

Photo from video by Petty Officer 3rd Class Demitrius Williams

Explosive charges aboard the ship enabled battle damage assessment (BDA) teams to respond to actual damage

By Edward Lundquist

The former Austin-class amphibious transport dock USS Denver (LPD 9) was sunk in a blaze of glory as a target ship during the recent Rim of the Pacific (RIMPAC) Exercise 2022. The 9,600-ton, 561-foot Denver, which was commissioned in 1968 and served until being retired in 2014, had been stored with other inactive ships at Pearl Harbor, Hawaii, before being sunk about 50 miles north of Kauai in about 15,000 feet of water.

Before going down on July 22, Denver made one more valuable contribution to the Fleet. Navy salvage and repair experts set explosive charges aboard the ship that enabled battle damage assessment (BDA) teams to respond to actual damage.

According to Jamie Koehler a Naval Sea Systems Command spokesperson, the event exercised the capabilities and limitations of an expeditionary group of Reservist and Regional Maintence Center (RMC) Sailors for emergent repair when paired with an emergent repair container capability.

"The event provided the opportunity to survey realistic blast damage and conduct planning to utilize the Emergent Repair Capability afforded by the Emergent Maintenance and Repair Container (EMARC) along with Surge Maintenance (SURGEMAIN) Navy Reservist Sailors to plan and execute emergent repair," Koehler said. "Divers were offered a realistic training environment to learn how to assess battle damage and how to effectively repair the ship."

"The training simulated exactly how a ship would look after an attack or casualty and offered Mobile Diving Salvage Unit One and Pearl Harbor Naval Shipyard divers a chance to work as a team to assess, repair and return the vessel back to sea," Koehler said. "Opportunities like this also identify future manning requirements, equipment shortfalls, and medical response preparations that can be measured appropriately."

Koehler said a similar training opportunity, the Repair Technology Exercise 2022 (REPTX), was conducted in Port Hue-

Battle Damage Assessment Training aboard ex-USS Denver

- Commander, Navy Regional Maintenance Center (CNRMC) coordinated the availability of the EMARC containers.
- Hawaii Regional Maintenance Center provided Sailors an Engineering Assessment team support to the repair planning effort.
- SURGEMAIN provide Sailors and three Officers to support the assessment, planning and execution of repairs.
- MDSU-1 conducted Battle Damage Assessments (BDA) and notified PHNSY of their findings. Their knowledge of salvage equipment and techniques were used to complete the BDA evolution.
- PHNSY conducted Battle Damage Repair (BDR) and patch work to fix the damaged vessel based on MDSU-1's recommendation. Our knowledge of patches and repair techniques were used to complete the BDR evolution.

neme, Calif., from August 22 to September 2, 2022. Southwest Regional Maintenance Center (SWRMC) participated in the REPTX and demonstrate their new Diving Support Vehicle as well as their underwater drone technology.

Technical demonstrations and field experiments were conducted aboard the Navy's Self Defense Test Ship, the ex-USS Paul F. Foster (DD 964), an asset of Naval Surface Warfare Center Port Hueneme Division (NSWC PHD).

According to a news release from NSWC-PHD, REPTX offers a unique opportunity to evaluate innovative products and services that could potentially help sailors carry out the repairs needed to keep them underway.

During the SINKEX, Denver was pummeled from land, sea and air. A U.S. Third Fleet press release said, "F/A-18 Hornets from Marine Fighter Attack Squadron 232 (VMFA-232), Marine Air-Ground Task Force 7 (MAGTF-7) used Joint Direct Attack Munitions (JDAMs) against a ship, the ex-USS Denver (LPD 9), during a sinking exercise (SINKEX) as part of Exercise Rim of the Pacific (RIMPAC) 2022. VMFA-232 coordinated the strike against the environmentally clean, decommissioned naval vessel in cooperation with the U.S. Navy and the U.S. Air Force. During SINKEX execution, four U.S. Marine Corps F/A-18 Hornets from VMFA-232 also fired High-Speed Anti-Radiation Missiles (HARM), followed by a Harpoon (AGM-84), and JDAMs. The F/A-18 is unique within the U.S. Marine Corps for its ability to employ a diverse array of air-to-surface and air-to-air weapons."

"From the land, the Japanese Ground Self-Defense Force and U.S. Army shot Type 12 surface-to-ship missiles and practice rockets," another press release said.

"SINKEX is more than the end result. It takes a team of capable, adaptive partners from different nations and disciplines to come together to find, fix, track, target, engage and assess with the agility and precision required to put the right ordnance in the right place, at the right time, every time,“ said Royal Canadian Air Force Brigadier-General Mark Goulden, commander of the RIMPAC Combined Force Air Component Command. "The SINKEXs at RIMPAC provide us with a uniquely complex and challenging environment for partner forces to hone those important skills. Being able to work together was our goal, and SINKEX is a demonstration of our success."

In addition to Denver, the ex-USS Rodney M. Davis (FFG 60) was also sunk as a target during RIMPAC.

The two ships were towed from Pearl Harbor to the designated target area by USNS Grasp (T-ARS 51).

VESSEL AUTONOMY IN OFFSHORE WIND

Scaling up operations through technology and regulation

By Elizabeth (Liz) Kretovic, ABS Director – Business Development North America Offshore Wind

Autonomous technology is adding value to the offshore wind (OSW) industry, its supply chains and government policy with the potential to deliver benefits such as increased operational efficiency and safety, and reductions in human error and operational costs. With the unique needs for wind leases and their relative close proximity to shore, a wider group of systems and technologies can be deployed.

A DEVELOPING REGULATORY LANDSCAPE

Autonomous technology is the result of rapid advancements in sensors and imaging, vessel connectivity, machine learning, and more. However, regulation, engineering and mind-set all present challenges as significant as the development of technology itself.

The IMO's Maritime Safety (MSC), Legal (LEG) and Facilitation (FAL) Committees have all completed their separate Regulatory Scoping Exercises on autonomous operations.

From the review of the various instruments by the Maritime Safety Committee (MSC), the scoping exercise identified a list of 11 common potential gaps and/or themes which needs to be addressed to advance the development of regulations for autonomous operations. From this list, the IMO has identified four potential gaps and/or themes as high-priority issues that cut through critical IMO instruments and may require a policy decision or determination to progress further.

The IMO has embarked on plans to develop goal-based requirements for autonomous operations with the target of publishing these requirements by January 1, 2028.

MOVING FORWARD

Industry mindsets are changing. Conversations about 'fully autonomous' vessels to autonomous and remote control functions, will have a big role to play in future OSW operations.

There is potential for fully autonomous vessels to be used in specialized tasks and fully autonomous vessels are likely to be limited to smaller units operating in controlled areas such as port waters, or perhaps on local, point-to-point voyages.

However, vessel owners and operators see the possibility for autonomous functions to be applied to conventional commercial vessels in the near future to improve seafarers' work and duties to help relieve their workloads, as well as to improve situational awareness. Good situational awareness happens when crew have a complete picture of their vessel's position in relation to nearby ships and/or other risks. For autonomous navigation, autonomous collision detection and collision avoidance functions should be able to monitor and analyse their surroundings with a high level of accuracy and make changes when necessary based on the analysis of precise data.

While simulation techniques for determining how autonomous functions will operate in practice are growing in sophistication, the recent test onboard Prism Courage was significant for being the first case to be undertaken on a vessel in actual operations. The Prism Courage voyage demonstrated that the continuous improvement of navigational safety in the future will require improved situational awareness and far more exchange of navigational and voyage data between vessels and shore.

SUBSEA AUTONOMOUS OPERATIONS

Autonomous operations have a critical role to play in subsea operations. This includes site investigation to support conducting survey operations, mapping ocean floors, through to passive acoustic monitoring to assess protected species and natural resources. In order to be granted a permit to develop wind farms, extensive environmental due diligence is required. Autonomous operations can help to provide further benefits to this sector of the renewables industry.

ABS continues to provide the necessary verification and certification for this process. The role for Class in Third Party assessments is to support risk evaluations and to help qualify autonomous and remote control tools before wider deployment and adoption. Class review and approval frameworks are critical in achieving industry confidence of safe working practices in offshore operations with the need for very high system reliability.

The success of these new technologies is dependent on thorough testing and verification to prevent potential failures, covering comprehensive, diverse and critical situations for both normal and abnormal operational conditions.

As technology continues to evolve and autonomous functions are increasingly applied to more vessels used in the OSW industry, there are several issues that will require continual focus, including connectivity, the use of augmented reality, human factors and cyber security. Continuous and reliable communication and connectivity between the vessel and the remote operator station is a key enabler.

ABS collaborated with Sea Machines and Foss Maritime to advance adoption of autonomous operations at sea by issuing approval in principle (AIP) to their vessel autonomy system, the SM300, that provides autonomous navigation and collision detection and collision avoidance (CDCA). Foss is to install Sea Machines' SM300 system on board its harbor tug Rachael Allen to enhance safety and efficiency of operations. Overall, the system will function for routine transit and standby operations with the goals of enhanced safety and alleviating crew fatigue.

Going forward, ABS believes the OSW industry will see an increasing number of projects focused on addressing the challenges of autonomous and remote-control functions. Interest is already growing in uncrewed survey systems, seabed analysis and collecting underwater acoustic data. By providing support to industry through certification with Approval In Principle (AIP), and ABS's Technology Qualification, it paves the way for operators to qualify autonomous systems and their operations to improve their safety, competitiveness and productivity.

Projects addressing the testing and validation of these technologies and testing the interoperability between these functions and existing conventional vessels will be a particular focus as the OSW industry embraces an increasingly complex range of offshore autonomous and remote control functions.

Image courtesy Acteon

Acteon Gears Up for a "Mega-Cycle" of Investment

INTERVIEW:

CARL TROWELL, CEO, ACTEON GROUP

*Striking a balance between traditional offshore oil and gas and renewable markets is neither straight nor clear. **Carl Trowell, CEO, Acteon Group** discusses his company's strategy to capitalize on what he sees as resurgence offshore oil and gas investment premised on energy security concerns, plus a "mega-cycle" of investment in offshore wind energy in the long term.*

By Greg Trauthwein

"There's going to be more infrastructure going into the sea in the next decade from offshore wind than went in throughout the whole lifetime of oil and gas. If you just look at the number of units, the number of installations, when you start moving to floating wind, it's going to be off the scale of the number of moorings. We're at the beginning of what will be a mega cycle of investment."

Watch the interview on OETV

~ Carl Trowell, CEO, Acteon Group

When you look at the industries you serve, what do you consider to be the key technologies that are central to your future?

I'll pick three to emphasize. One of our divisions specializes in survey work, both ahead of installation of in-sea infrastructure and then post installation for ongoing integrity and inspection monitoring; that technology is an area that we are going to emphasize going forward, as there's going to be such a huge amount of infrastructure going in the sea over the next few years. Where we see real technological advancement is in putting sensor packages on autonomous vehicles, surface or subsurface.

Another area where we're putting a lot of innovation is around geotechnical site investigation, particularly with the building need for the installation of big offshore wind farms where the foundations are getting more complicated. So rock soil parameters are important, and to give you one example, we've developed a new remotely operated sea floor drill specifically for shallow water, unconsolidated sands relevant to the renewables market. We've been doing this for years in the deep water for oil and gas, but we've particularly developed a new product for the renewables market.

The third are where we are putting a lot of time and effort into is new foundation technologies and techniques, particularly, again, for renewables. We're taking techniques that have been developed in the oil and gas world and now applying them as the offshore wind market begins to move away from areas where it's easy to just put in simple monopiles to where you're going to have to do more complex foundations, hard rock, difficult substrates. But also the fact that the turbines are just getting bigger and bigger, which means the foundations are getting more challenging.

Can you point to one technology, one capability where you sit back as a CEO and just think, "wow, we actually do that?

Our ability to engineer and store complex foundations would have been what I picked until a few weeks ago, but then I sat through a review with our engineering group where we're building a digital twin for an offshore floating wind installation. We've helped the operator engineer and model the whole floating system from the turbine through to the semi-sub and the anchoring systems, and come up with a digital monitoring system. We're building a digital twin so that you can then use it to predict failures, problems and downtime on the other units in the field. I've seen a lot of PowerPoint presentations on it, but I actually saw it for real and I saw it on a live project. I did step back and say, "Wow, we can do that." So that's a nice question with nice timing.

Has the most recent offshore oil and gas crash from 2014 to '21 fundamentally changed the needs of your clients, and as a result, your company?

Historically Acteon saw itself as an oil field services business, when in fact actually, if you step back, it's an in-sea infrastructure company. To some extent, a lot of the services we provide are somewhat agnostic as to whether they work for oil and gas, renewables or other nearshore infrastructure projects. But the heritage of the company came from the oil and gas side and it still remains a big leg, one of the key legs for us

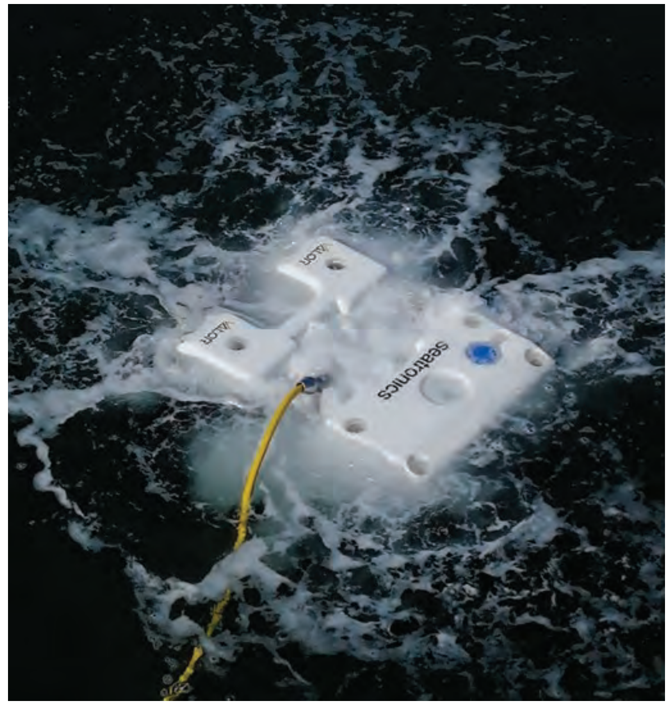


Image courtesy Acteon

on the stool. But as you say, the downturn from 2014 onwards was quite drastic. (Personally) I've been through maybe three or four big downturns in my career and this one felt very different from most, if for no other reason the duration.

What we saw is a couple of things. We saw from our customer base a real entrenchment and a focus on cash flow, cash flow generation, return back to shareholders rather than pumping money back into lots of new projects. As a consequence, we saw a lot of our customers focus on investment in existing infrastructure, existing bases and existing projects. Accordingly, we cut our business to match that. I think Acteon now versus where it was in 2014 is much more focused on oil and gas services that are related to the installed base. So helping with existing optimization with late life extensions, with intervening on infrastructure to add additional capacity or extra wells. So you're getting more from the install base all the way through to decommissioning. And so our business in the oil and gas is much more focused now late life and decommissioning than it was in 2014.

I think we will see a resurgence in some of the green field new developments, but I think in general that will still be biased a bit more onshore than it is offshore. And in the offshore arena, I think that we will still bias our services towards that existing infrastructure services.

The other thing is part of our customer base started to seriously get focused on the energy transition. As we've seen their focus change, we've been moving with them.

It's going to be very interesting now to see how much the focus on energy security, and the need for oil and gas in the interim, how much that really drives a wave of investment. We're seeing it, but is it sustainable?

How do you balance offshore oil and gas work with emerging markets like offshore wind?

The challenge is a bit less consequential for us because a lot of what Acteon does is within servicing in-sea infrastructure, somewhat agnostic as to whether that's oil and gas infrastructure, renewables or other structures. It means for all of our services, it's a move or a nudge over in that direction, or it's a repurposing or dual-use of some solutions.

I can give you an example of that in what we have within our moorings and anchors business unit, InterMoor. There, we developed a SEPLA anchor, a suction embedded plate anchor which was used in the oil and gas industry in many places all

Image courtesy Acteon

Image courtesy Acteon

around the world for certain anchoring purposes. It turns out, it's incredibly applicable to floating wind. So we've slightly re-engineered it, we've looked at a deployment technique, and we have a product which is equally applicable in both spaces.

Then 2H, our engineering group, specializes in risers and umbilicals. In the energy transition they've been successful taking that expertise and applying it decarbonization of the oil and gas industry.

So they're taking that expertise, reversing it and coming up with engineered solutions to, for example, do cold-water cooling on FPSOs, reducing the energy requirements because (by using seawater for the cooling). They're doing something similar to provide air conditioning into airports and hospitals by using deep water.

Overall, there are a lot that companies and individuals that grew up engineering in the oil and gas business (now able to address the challenges associated with the energy transition.)

The attitudes have changed quickly and I think that's driven a lot by following the money.

I think there's something that everyone has to think about, which is there's going to be more infrastructure going into the sea in the next decade from offshore wind than went in throughout the whole lifetime of oil and gas. If you just look at the number of units, the number of installations, when you start moving to floating wind, it's going to be off the scale of the number of moorings. If you're in this sector you should be turning your eyes to this because we're at the beginning of what will be a mega cycle of investment.

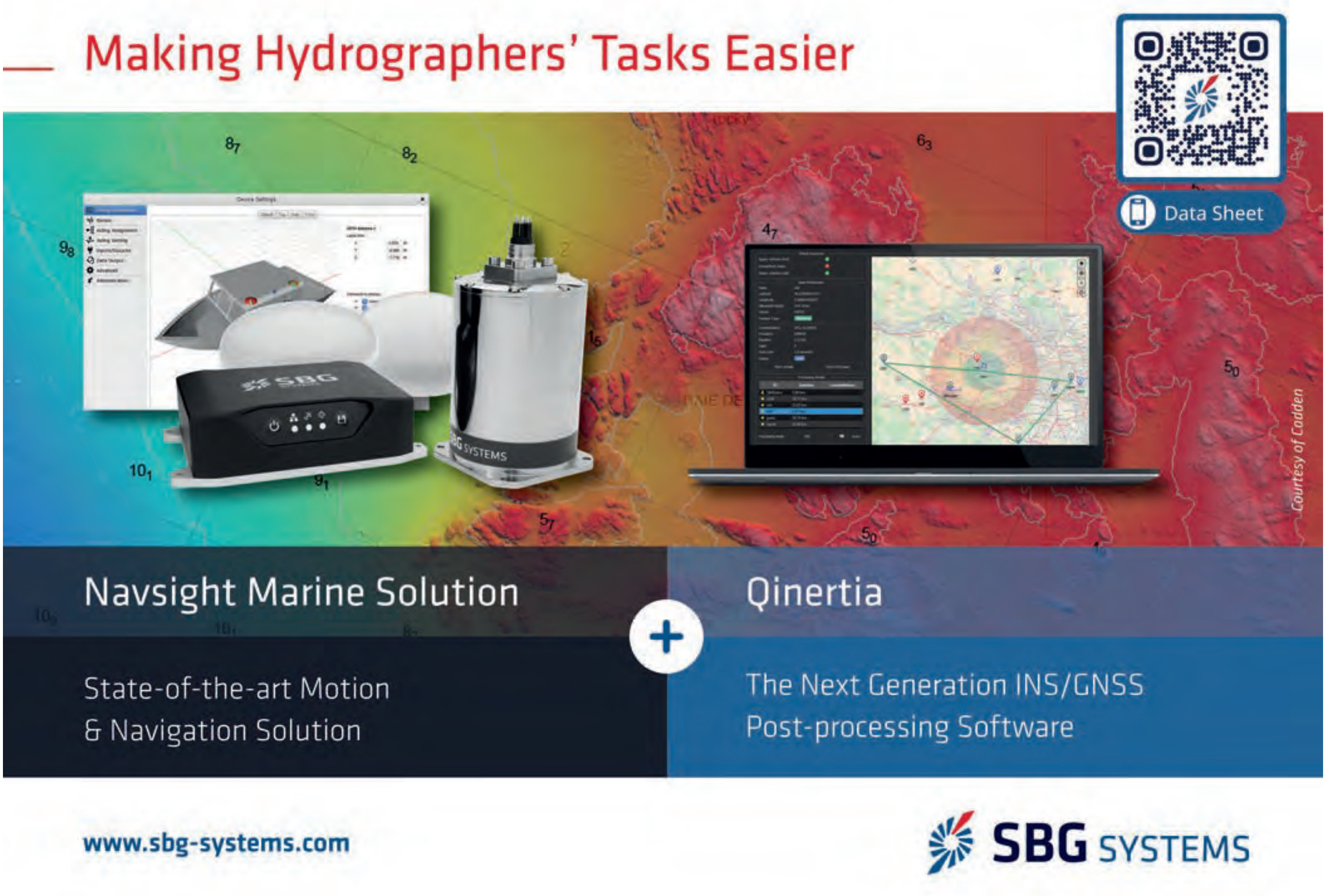
Acteon Group has built and acquired a family of brands across the marine and the energy industries. What's next?

For us, we have a new structure, working with three divisions now on a global scale. That's been the latest evolution, and we see the benefits of further integration both from technology synergies and probably new product development, from bringing those companies closer together. But I think there is a mega cycle coming of investment and where that lies between offshore wind and oil and gas, we'll have to see. I think there's room for further consolidation amongst the supply chain. But on the back of the last oil and gas downturn, we have a lot of smaller subscale oil field services business and I think there's going to be some consolidation there.

With respect to the renewables, you've got this huge investment cycle coming. We did a recent piece of work and we found out that on a typical offshore wind project, you've got almost 10 times as many companies independently contracted in the supply chain than you do in an equivalent oil and gas project. So we think logic would tell you that there's a need there from an efficiency and delivery point of view for consolidation. And there's also room for there to be big global offshore service companies focused on the offshore wind developed because we're only at the beginning of this evolution. So you could see the need for bigger companies to service the industry on a global scale developing. And we see ourselves as a platform for future M&A, be that bolt in to our structure or if we take part in some of the bigger combination.

Image courtesy Acteon

Image courtesy Acteon



Olivier Dugornay/IFREMAR

New Energy, New Directions

*In September, **Marine Technology Reporter** was part of a select group of journalists invited to attend the Sea Tech conference held every two years.*

Tom Ewing reports from Brest, France.

Brest is an ancient maritime city on France's Atlantic coast, its history rich in all things shipping and maritime, from commercial vessels to nuclear subs to newly built wooden sailing vessels to post-graduate oceanic research and training.

The opportunity to attend Sea Tech included an invitation to visit selected sites focused on maritime challenges. The full Sea Tech program covered almost four days. Its broad theme focused on "Maritime Transport: Towards Smarter & Greener Solutions." The agenda ranged from adapting to climate change to sustainable polymers to electronic navigation to polar exploration.

Not surprisingly, one top thematic focus, across the entire conference agenda and within posters and exhibits, was on efforts to decrease maritime related CO_2 emissions. Approximately 100,000 ships cross the seas every day, responsible for 3% of the world's C02 emissions, as well as 13% of SOx and 15% of NOx. Policy makers and their scientific and technical allies in France, and, indeed, in all of western Europe, are homed in on breaking this maritime-CO_2 connection and that big changes can and will result from new digital applications, new propulsion (or old, depending on how you view sails) and, of course, new technologies and hardware.

Another Sea Tech message, particularly from Brest: big imaginations wanted, welcomed and supported. There is a deliberate and thoughtful maritime cabal in Brest to attract research, support it, attract commercial interests and establish a glidepath to move to commercial production. As energy generation changes, Brest – part of the Brittany region of France – wants to be in the forefront of every change and economic development. Officials want their hometown and region to reap the benefits from new investments in a new energy economy.

"A CAUDAL FIN"

Bluefins is one project that exemplifies and showcases the big-picture thinking that characterizes teamwork in Brest right now. Bluefins exemplifies creative, out-of-the-box ideas. But not wild-eyed ideas. Rather, ideas focused and grounded on ways to support shipping and vessels as they operate today, ideas that can maintain large scale, efficient maritime operations. Potentially, Bluefins could cut CO_2 from vessels by 20% without impacting a vessel's standard operations and practices.

On one level, Bluefins is a singular start-up, the brainchild of a naval architect and a mechanical engineer with a combined 40 years of maritime experience. On another level, Bluefins highlights the supportive infrastructure established by French industrial and business associations, established specifically to connect new ideas with money, research and business expertise to create new energy tools – again, workable projects at scale, not laboratory R&D. Finally, there's a third level: French governmental and public institutions are all-in with supporting these initiatives. The result is a rich, deep and well-connected economic and creative milieu to select and foster promising projects and help them advance.

Olivier Guisti is Bluefins' CEO, a naval architect and expert in hydrodynamics. Dominique Leroux is CTO, a mechanical engineer who spent 20 years at IFREMER, the French re-

Olivier Dugornay/IFREMER

search institute. His work focuses on designing mechanical and hydraulic systems meant for oceanographic exploration.

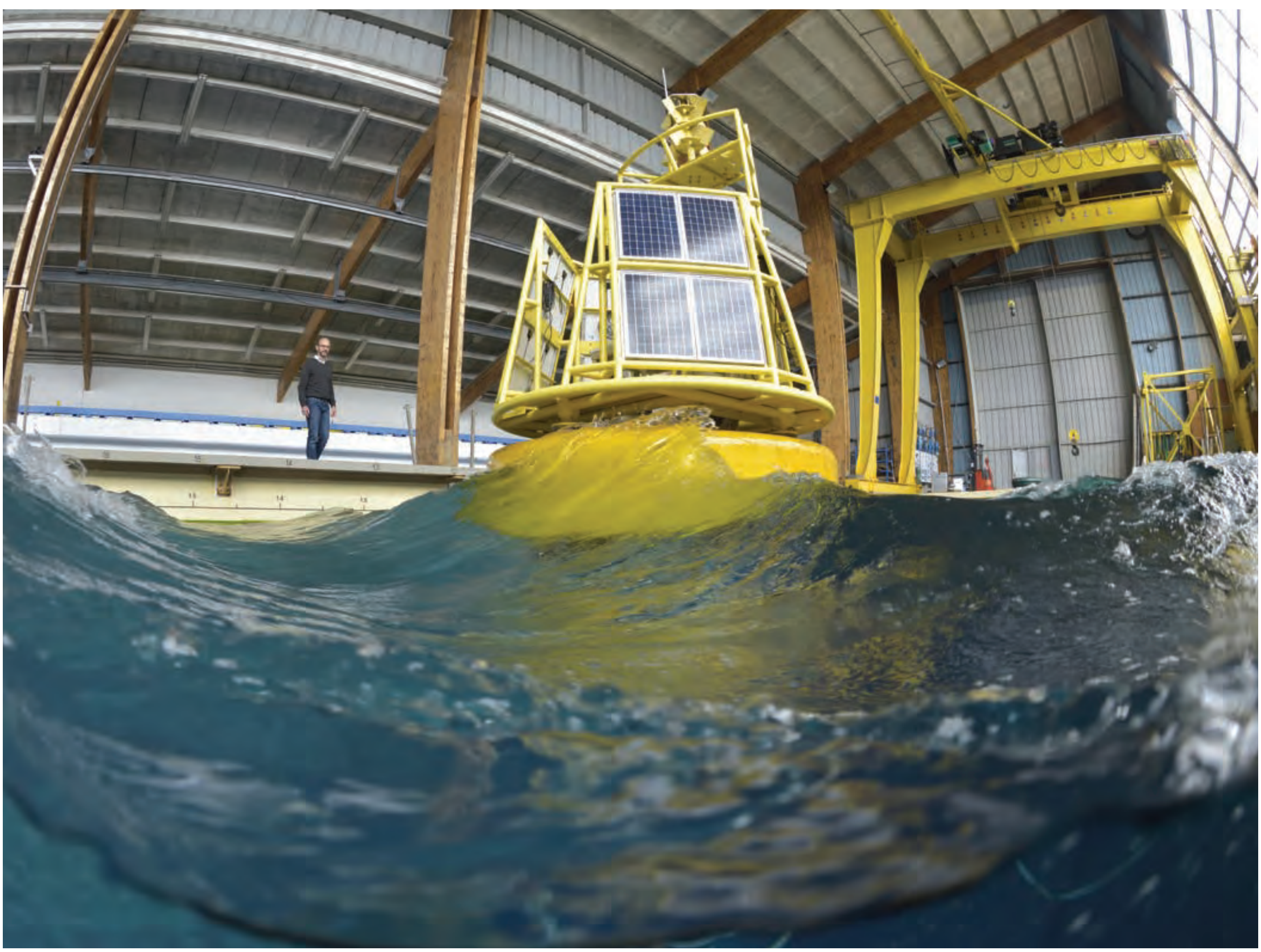
IFREMER – l'Institut Francais de Recherché Pour l'Exploitation de La Mer – or "French Research Institute for Exploitation of the Sea" is France's premier ocean science research institute, established in 1984, a merger of existing marine fisheries and oceanography agencies. Its programs are international in scope. IFREMER manages the French Oceanographic Fleet. Its budget is 240M€ annually and it operates under the joint authority of the French Ministry for Higher Education, Research and Innovation, the French Ministry for the Ecological and Solidary Transition, and the French Ministry of Agriculture and Food. Its vision is to advance science, expertise and innovation in three broad areas:

- *Protect and restore the ocean;*
- *Sustainably use marine resources to benefit society; and,*
- *Create and share ocean data, information & knowledge.*

During a meeting at the Bluefins' lab and development site, Guisti explained that the germ of the Bluefins idea, and its working concept, are based on propulsion dynamics observed in whale tail fins. Bluefins seeks to design a zero fuel auxiliary propulsion system that converts energy from waves. In its construct, the Bluefin will consist of a hydrofoil attached to a ship's stern through a set of mechanical articulations. "Just like a whale's tail fin propels the animal forward," Guisti said, "our hydrofoil converts the pitching motion of the ship into forward propulsion." He further referred to the invention as a "caudal fin."

In addition to fuel savings – and CO2 reduction – the external device will reduce vessel pitch. Container ships, LNG carriers, tankers and bulk carriers are expected future markets. Controls will allow maximum gains in varying wave and wind conditions. Importantly, the fin can be raised out of the water and set securely when sea conditions are not favorable, and the lifted position allows mooring configurations and emergency towing.

Guisti cites advantages vis-à-vis other alternate propulsion ideas. External mounting means Bluefins can be retrofitted; it's not a device just for new vessels. External placement does not impinge on cargo space, such as alt-fuels like LNG or



Olivier Dugornay/IFREMAR

maybe even hydrogen. It won't interfere with loading/unloading operations. And it doesn't demand fundamental vessel redesign and new piloting skills, issues that add complexity and challenge to new wind-sail technologies and systems.

Guisti said potential clients and partners include shipowners and charters. Preliminary outreach is underway with Asian shipyards. "It's a trendy topic," he commented. Next steps include a model vessel in 2023, field trials in 2024 and, hopefully, commercialization in 2025.

It's important to note Bluefins' developmental context. Its website lists five partners:

- *BPIFrance, a French Sovereign Fund that invests in startups;*
- *Greenpact, a "start-up studio dedicated to ecological transitions;"*
- *CITEPH, a group of 15 large engineering and energy companies, which itself is part of a much larger group called EVOLEN that includes 250 energy companies working towards "carbon neutrality by 2050."*
- *The French Government; and,*
- *IFREMER.*

Bluefins partnered with IFREMER in 2021, which holds the hydrofoil patent. Development is within the IFREMER facility in Brest. For a start-up like Bluefins, location is critical.

The IFREMER facility includes an ocean-wave simulation lab referred to as the Technological Research and Development (RDT) unit. The test basin is 50m long, 20 m deep and 12.5 m wide. Researchers can program specific wave shapes and wave lengths that flow along the channel. Waves can range from predictable to chaotic, or what Guisti calls "rogue waves." It can generate regular and irregular swells with a maximum peak-trough amplitude of 45cm. There are two traction bridges, 25-tonnes and 5-tonnes, for models and associated material handling.

This equipment allowed Guisti and his colleagues to confirm Bluefins numerical modeling. "In our case," he commented, "for such an innovative technology, it was important to have an experimental proof." Guisti estimated there are just four such wave labs in France, none as large as the IFREMER facility, and, he added, likely available only at a cost to the researchers. The point is, as an incubator, Brest is unique. It would be hard for a startup like Bluefins to start somewhere else. Brest officials want to make sure people know that.

Bluefins was a winner of a "Concours Innovation" competition which IFREMER started in 2021. Project reviewers include investors, incubators, scientists and entrepreneurs. Startup awards are around 250k . Alexis Mareschi, an IFREMER spokesperson, explained that priority interest is given to projects "which can develop a startup (company) and can become a solution either from the ocean, e.g., marine renewable energy, biotechnologies, or for the ocean, i.e., addressing climate change, pollution or overfishing."

For selected projects, IFREMER does not set a time-to-market deadline. Two recent awards show this wide flexibility, in interest and timeliness. One award went for a new communication system for scuba divers, expected to be market ready in a few years. Another, a biotechnology project using deep sea micro-organisms to produce hydrogen, is expected to take much longer – about 10 years. Importantly, for those applicants not chosen as an IFREMER winner, IFREMER still helps applicants establish alliances with other funding partners. Good ideas are redirected, not rejected.

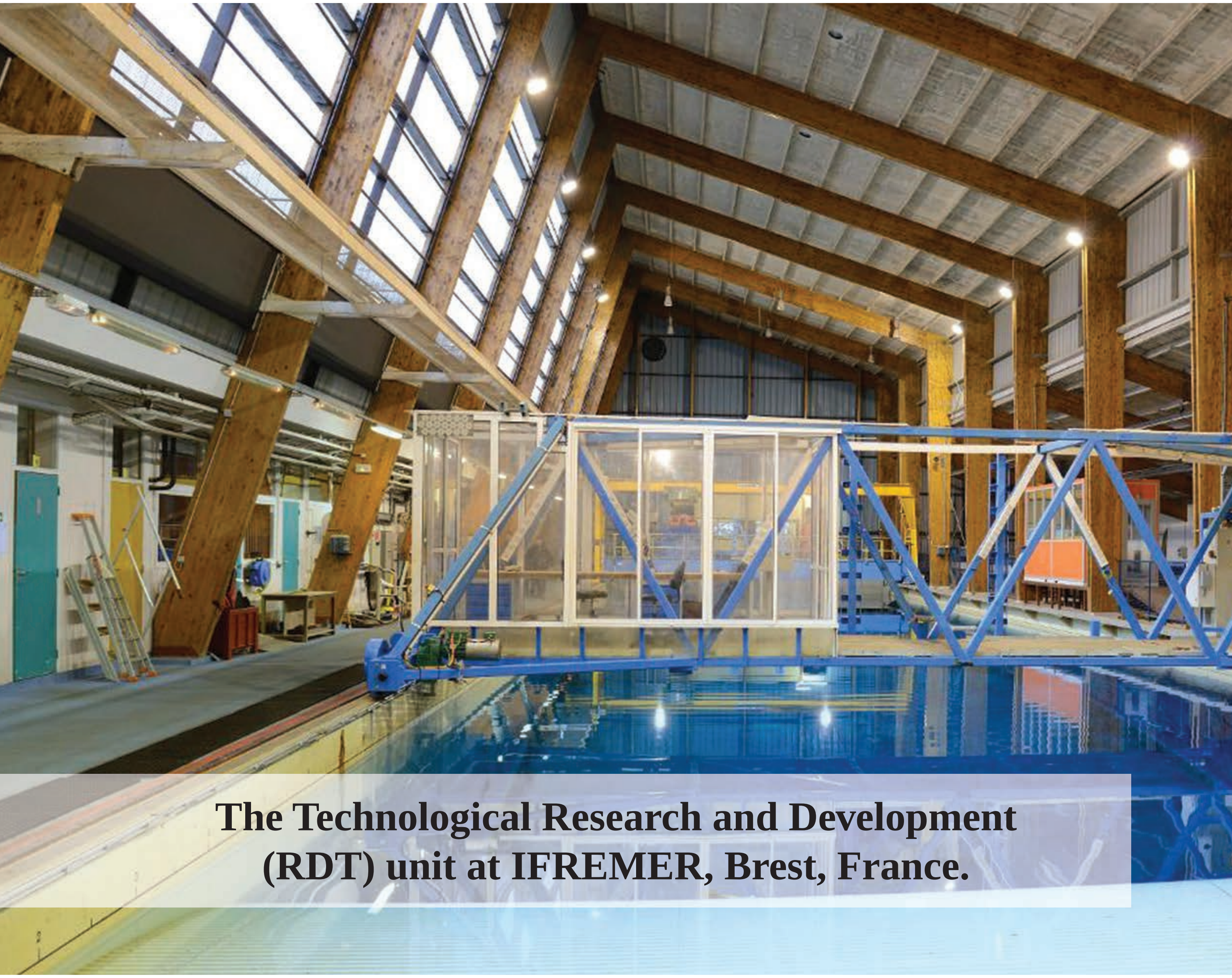
Guisti was asked about making the jump from laboratory to factory, turning Bluefins into an actual product for sale and installation. He said current partners will help facilitate that transition. One partner in particular, Greenpact, has specialized experience in "deeptech projects, with a track record in taking early stage technologies to the market." Guisti said Bluefins is on the lookout for manufacturing and integration expertise, and they are looking to hire additional staff.

"WORLD CAMPUS OF THE SEA"

As important as IFREMER's efforts are to advance startups like Bluefins, IFREMER's work itself is coordinated within a larger organization in Brest called the "Campus Mondial de la mer," or World Campus of the Sea. In fact, the Sea Tech conference is a product of the Campus Mondial, which might be thought of as an incubator of incubators.

The Campus keeps what otherwise might be distant players working closely. It seeks to establish complementary efforts among regional academic, scientific, economic and institutional organizations involved in marine science and technology and the maritime economy. It is the first such maritime and marine association in France. Its scope includes the tip of the Brittany region – Brest and the nearby cities of Roscoff, Morlaix, Quimper and Concarneau. Its governing board includes individuals from the French Navy to SHOM – France's hydrographic and oceanographic service – to the IRD, the French Institute for Development as well as business, academic and engineering groups. These regional partners contribute funding, currently 350k€ per year.

One Campus goal is to "be the crucible of forward thinking." Another is to "animate and support the community," again, with a focus on maritime activities. It is upfront regarding one bottom line outcome: "to ensure that this concentration



The Technological Research and Development (RDT) unit at IFREMER, Brest, France.

of knowledge in Brittany in the field of marine science and technology leads to more business and job creation."

Success is never guaranteed, of course. But chances go way up when more and more people, working from the same playbook, are on the lookout together. If something can succeed, people in Brest will likely spot it first, and help it grow. As the world's energy demands change, Brest will be leading, not following.

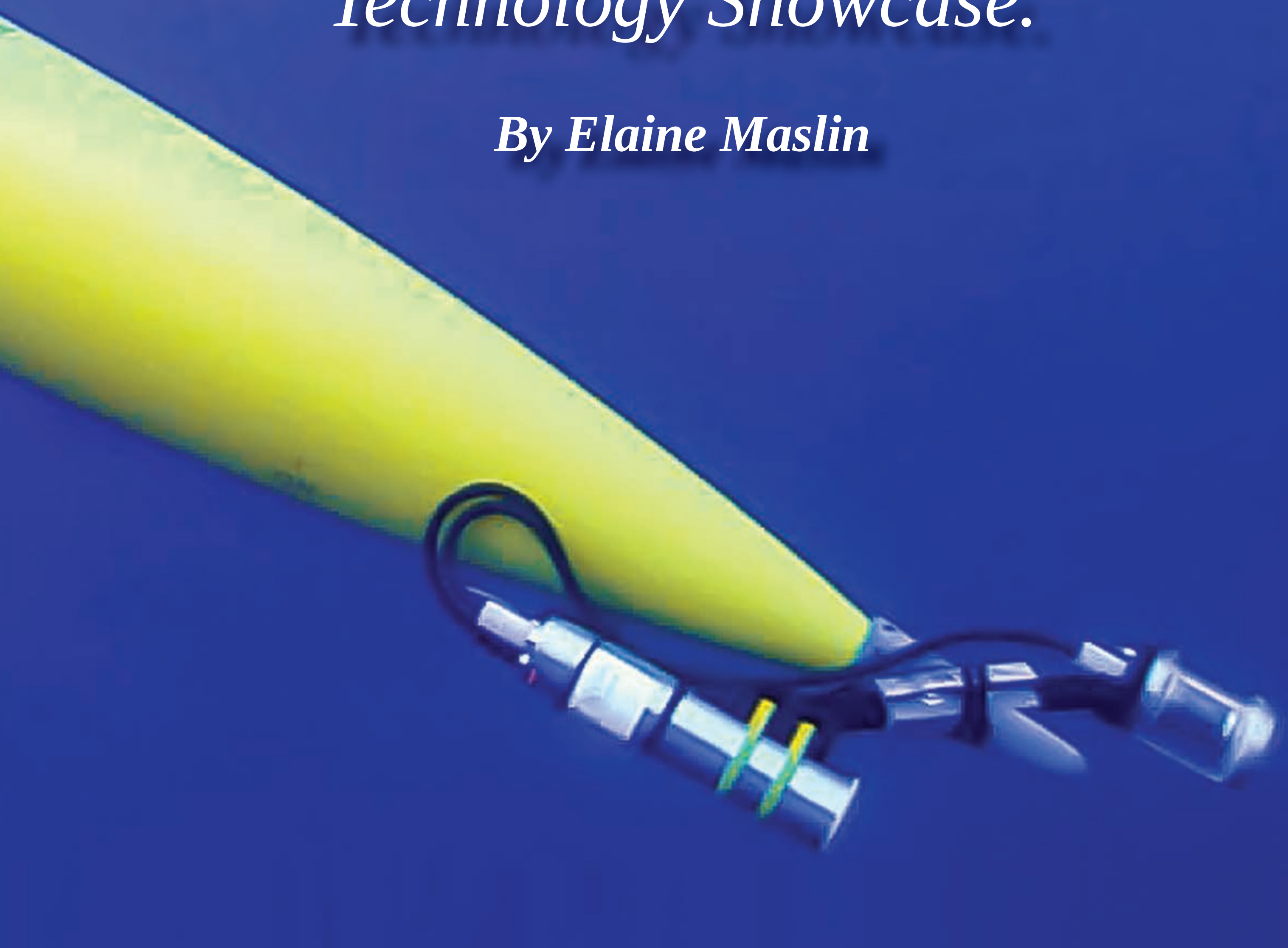

Olivier Dugornay/IFREMAR

New Tech Frontiers for Ocean Gliders

Image by Ehsan Abdi for CSCS

Expanding the amount of work that gliders can do was a key topic at this year's Marine Autonomous Technology Showcase.

By Elaine Maslin



Building useful datasets that allow a better understanding ocean of ocean variables has long been a challenge. It's not that long ago that ocean temperature data was limited to surface temperature and the same goes for many other parameters.

But an increasing number of players, across science, defence and industry, are now able to access an increasing number of ways to gather data in the ocean, not least using gliders.

With around two decades of their use now banked, users are now looking at how much more these vehicles can do, from carrying biological sensing payloads or towing towed arrays, the Marine Autonomous Technology Showcase (MATS), held at the National Oceanography Centre in Southampton and online heard early November.

BLUE OCEAN

Blue Ocean Marine Tech Systems is one of those who have been using gliders for some time. Initially this was in the energy sector, with parent company Blue Ocean Monitoring doing tasks such as marine mammal monitoring during seismic acquisition campaigns. But Blue Ocean Marine Tech Systems is now also working in the defence realm, including developing a towed array system for gliders under the UK Royal Navy's Project HECLA.

James King, Managing Director UK at Blue Ocean Marine Tech Systems, says buoyancy driven gliders lend themselves to monitoring applications, thanks to their low noise footprint. Also, because they're buoyancy driven, they use a small amount of power, so they can stay deployed for months at a time.

That lends them well to tasks such as submarine hunting, something that the Royal Navy has been trialling under Hecla, including deploying Slocum gliders in the North Atlantic for months at a time to gather various ocean data, including salinity, sound velocity and temperature – useful information (dubbed "tactical hydrography, meteorology and oceanography") for operating submarines – and send it back to shore by surfacing.

However, what if they could also tow an array to detect human-made noise, i.e. vessels? This was what the Hecla Project tasked Australia-based Blue Ocean Marine Tech Systems' UK team with. For the project, they chose to trial Seiche's

Blue Ocean Marine Tech Systems' towed array deployment under the Royal Navy's Project HECLA.

Image from Blue Ocean MTS

Raw data showing the Minke Whale vocalisation.

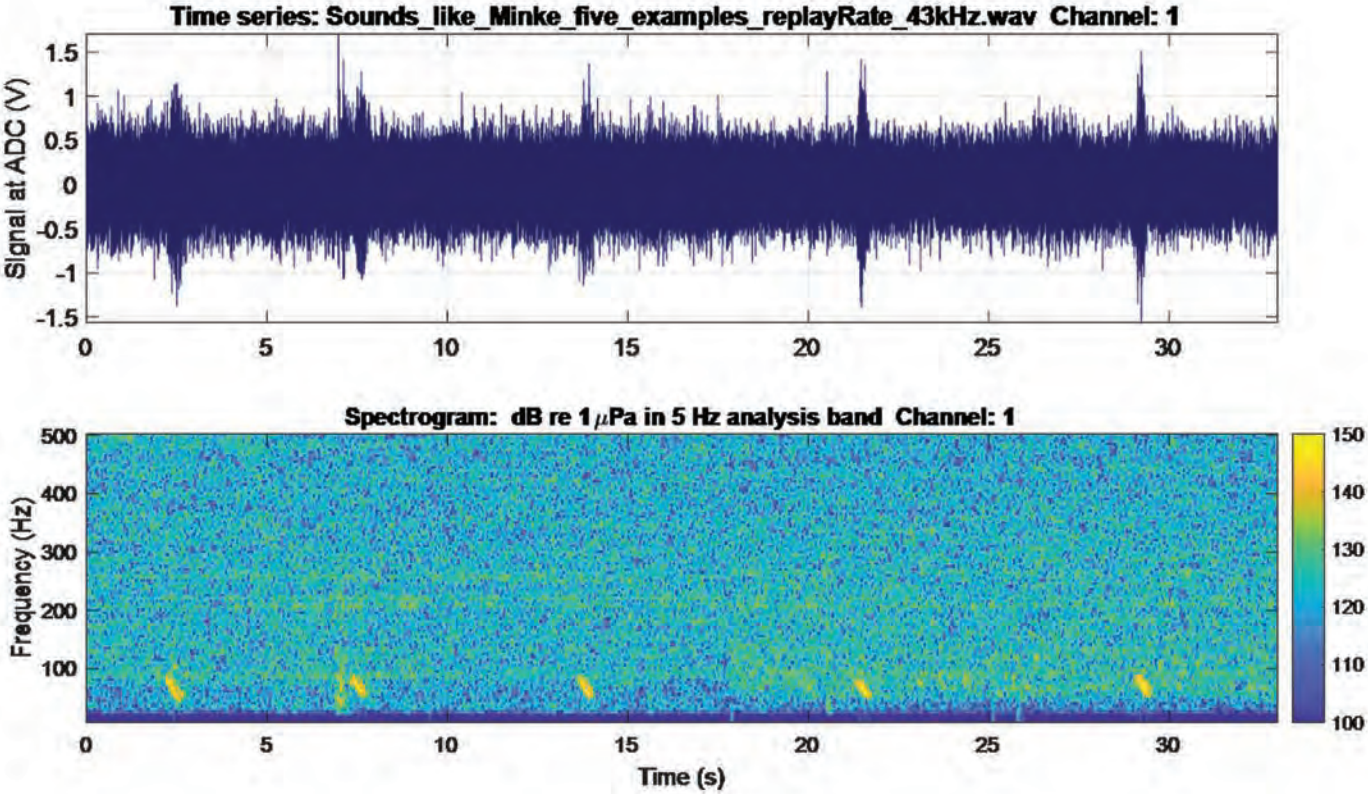


Image from Blue Ocean MTS

Digital Thin Line Array, a miniaturised (20mm), low power towed passive acoustic array, King told MATS. It's already been trialled with traditional autonomous underwater vehicles (AUVs) or uncrewed surface vessels (USVs), that hosts eight digital hydrophones (and can be configured to take up to 32). As the glider is a slow platform, operating around 1kt, drag was a critical factor.

"We set out to determine if a buoyancy driven vehicle can tow an array given that it is a finely ballasted vehicle," says King. "Can an array be used for marine acoustic data collection and how can the data be used?"

Blue Ocean MTS ran three trials out of Plymouth, where tidal variations and vessel activity offer a challenging test area for the system, initially using a dummy array, to prove the tow-ability. Then, once they'd proven that, working out that with the addition of a thruster, they'd be able to improve control, they moved to a real system, containing four active hydrophones. While there were issues with plastic in the ocean jamming the thruster and rudder, the trial proved the ability to gather acoustic data. Mark Burnett, Director at Seiche, who also spoke at MATS, says the glider's self-noise was such that the array could pick up other signals, including a vessel passing close to the array, proving it could pick up anthropogenic (man-made) noise. Through processing they were able to correlate signals to marine mammal noise, specifically, minke whale, so that meant biological noise could be detected too.

On the third trial, more adjustments were made, including to the thruster guard and how the towed array – now 10m-long with eight hydrophones – was coupled to the glider to make controlling the glider better. This time the glider stayed within a planned operational area. They also used a known source, a D11 transducers to mimic machinery noise, and tracked AIS so they could correlate it with acoustic data from the hydrophones and the glider's location data.

The broadband D11 Sound Source the Blue Ocean MTS project used.

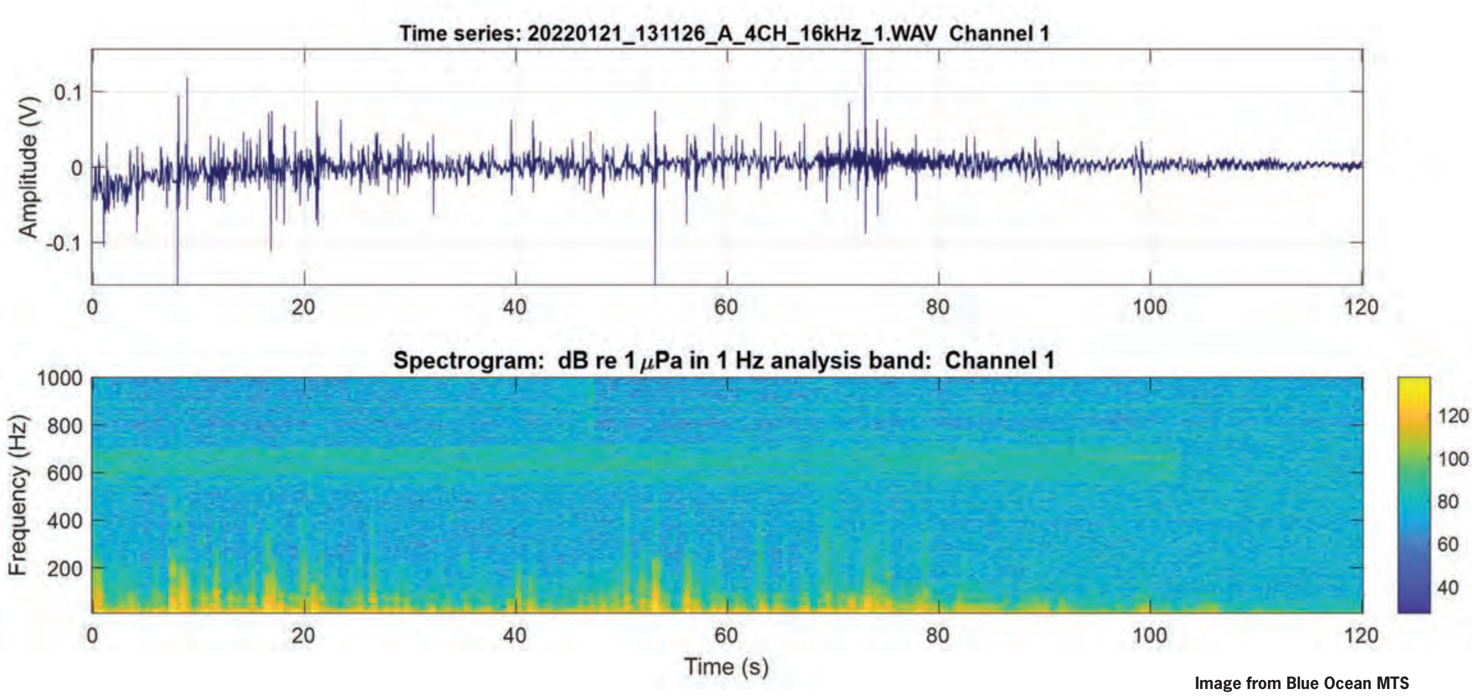


Image from Blue Ocean MTS

Burnett says one of the goals was real-time processing to get real-time information about what's in the water. This meant signal processing and software integration into the glider, but, with the longer array, also improving the power supply to reduce noise.

"We were able to correlate with AIS and could see a cargo vessel passing within 2.45nm of the array," says Burnett. "We were also able to collect biological data. We observed a pod of common dolphins from the vessel we were on so could time stamp the data and had good corroboration. We could also see machinery start up noise (in the data). In parallel, we developed signal processing, as part of a three-year knowledge transfer partnership with the University of Bath, using a low power, low footprint FPGA (field programmable gate array) to process data in real time."

They then looked at the initial four hydrophones and processed the data to beam form and get three beams – forward, aft and broadside, to get automated detections – proving this capability. The idea is that information is then sent to the vehicle command and control system so it can get a better bearing on the target and or surface to communicate that it's made a detection. More trials are expected to be carried out in the new year.

BIOGLIDER

One project is looking to endow gliders with biological sensing capability. Bioglider is a two- and half-year Horizon 2020 ERA-NET Cofund MarTERA project ending next September.

Yves Ponçon, Bioglider project coordinator, based at ENSTA Paris, part of the Institut Polytechnique de Paris research institute, says more biological sensors need to be deployed in order to measure ocean variables and that gliders, operating autonomously, could help.

"Autonomy is a game changer as they can stay at sea for months," he says. As well as gathering oceanic data as they "yo-yo" through the water column, they could also be used to acoustically gather and then transmit (once at the surface) data from remote underwater moorings that are otherwise hard to reach. As well as for research work, this capability to track biological elements could also be used in fisheries or in oil and gas, he says (ConocoPhillips is among the financial supporters of the project).

To date, putting biological sensors on commercial gliders hasn't been done, he says. Scripps Institution of Oceanography had developed the Zooglider, which takes images and acoustic measurements of zooplankton (a key element of the aquatic food chain), but this was a research project and nothing has been developed in the commercial realm.

A project, called Bridges, which ran 2015-2019, had focused on miniaturising instruments for use on to gliders. This included the UVP6 (Underwater Vision Profiler 6, an imaging sensor with strobe lights to take pictures of zooplankton). A DeepEcho module - a blackbox that allows for easy integration of the WBT Mini, a miniaturised version of Kongsberg's EK80 multibeam echosounder, into the gliders – was also developed.

The Bioglider project was set up to apply these on to three commercially available gliders: a Huntington Ingalls Industries (HII) SeaGlider, a Teledyne Slocum and an Alseamar SeaExplorer. A key part of this is software; the echosounder was developed to work horizontally, but gliders go up and down all the time.

The Seaglider has been on two missions, one in May 2022, then again in October 2022, on the Polar Front campaign in the Lofoton Islands area. The Slocum

WBT Mini integration is in progress on the G2 and G3, with the first mission targeted in June 2023, also as part of the Polar Front mission, with discussions ongoing around work on the SeaExplorer. The UVP6 has already been used on the SeaExplorer.

Initial data looks really promising, says Ponçon. "We can have an echogram with very good acoustic measurements," he says. "We can see phytoplankton blooms and on the glider we can go to 1,000 m water depth and profile and couple that with the UVP6 to give more precision to the biomass we deliver." All while still having existing payloads, such as CTD and oxygen sensors, he says.

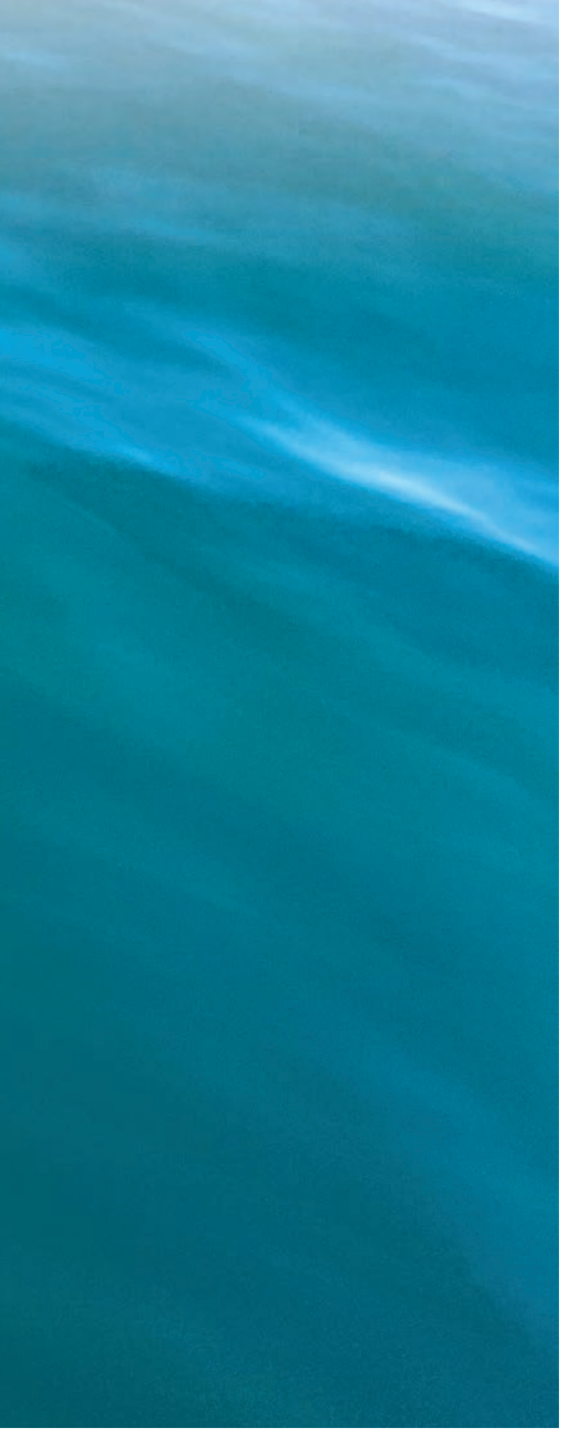
"For moderate cost we can have this all in one platform that can be autonomous and be at sea multiple months to 1,000 m water depth and bring some really great data," says Poncon.

In addition, the platform could gather data from scientific

A closeup of the Common Dolphin visually corroborated during the trials.

Image from Blue Ocean MTS

moorings that are otherwise hard to reach. Therefore, the project is also looking to integrate modems onto moorings and on the glider to acoustically communicate with moorings and retrieve their data. First trials for this element are expected in Sprint 2023, with field tests in summer 2023.



All images: University of Rochester/John Kessler

Dr. Thomas Weber (front left) and other scientists deploying hose to pump ocean water for analysis.

STEPPING ON THE GAS

Rochester researchers team up to tackle methane emissions

By Celia Konowe

With global temperatures rising, oceans warming and ice caps melting, carbon dioxide attracts the bulk of the blame throughout media, public discourse and academia. All too many—save some scientists and researchers—neglect methane, the second biggest greenhouse gas that's influenced by human activity. Often associated with livestock production and ruminant flatulence, methane has both natural and anthropogenic sources and is garnering more attention as science strives to understand the holistic effects of the warming planet.

Researchers at the University of Rochester have embarked on a mission above and below the blue waves to better understand natural sources of methane and how a changing climate may impact these stores. Professors John Kessler and Thomas Weber of the Department of Earth and Environmental Sciences set sail on a research cruise this past summer onboard the R/V Hugh R. Sharp, continuing a project that first took to the seas in 2019, only to be delayed by the pandemic. While the two scientists led different roles on board and in the lab (Kessler gathering large field data sets and Weber developing machine learning models), both had done previous work with methane emissions, inspiring the current collaboration.

SEAS-ING AN OPPORTUNITY

Methane poses a threat to the environment as it traps heat in the atmosphere, contributing to global warming. Sources that are unexposed to the atmosphere are less of a concern unless they become destabilized. Methane hydrates, which form on the seafloor when significant amounts of gas meet high pressure and low temperatures, are a solid that typically remain stable, although past research sought to determine if they contributed to climate change as oceans warm. "We've more or less debunked that, which is great," said Kessler. "But in doing so, we realized that the closer you got to land, in the coastal oceans, methane concentrations went super high." The uncertainty of the data in these areas was also high due to relatively few sampling points, pointed out Weber, who realized machine learning modules could help generate informative maps. Thus, the marriage of measurement science and artificial intelligence (AI) was born.

A unique aspect of this summer's research cruise was that it built on a previous expedition conducted in 2019 onboard the R/V Rachel Carson, leveraging knowledge of what worked well and what didn't. The pandemic provided the team with two years of being landlocked in Rochester, N.Y., during which they tweaked equipment and sought ways to continue their work on the nearby Great Lakes. The greatest inhibitor though was the size of the equipment, which was too big to place on anything smaller than a research vessel. The solution? "We looked to miniaturize it," Kessler stated. "Let's look at every component that we have, and can we do this in a way that's smaller, cheaper, easier—where we can literally get it on a kayak? And the answer to that is yes." In addition to lightening the equipment and decreasing its size for convenience, the team made the instruments more reliable in continuously collecting data with less researcher oversight.

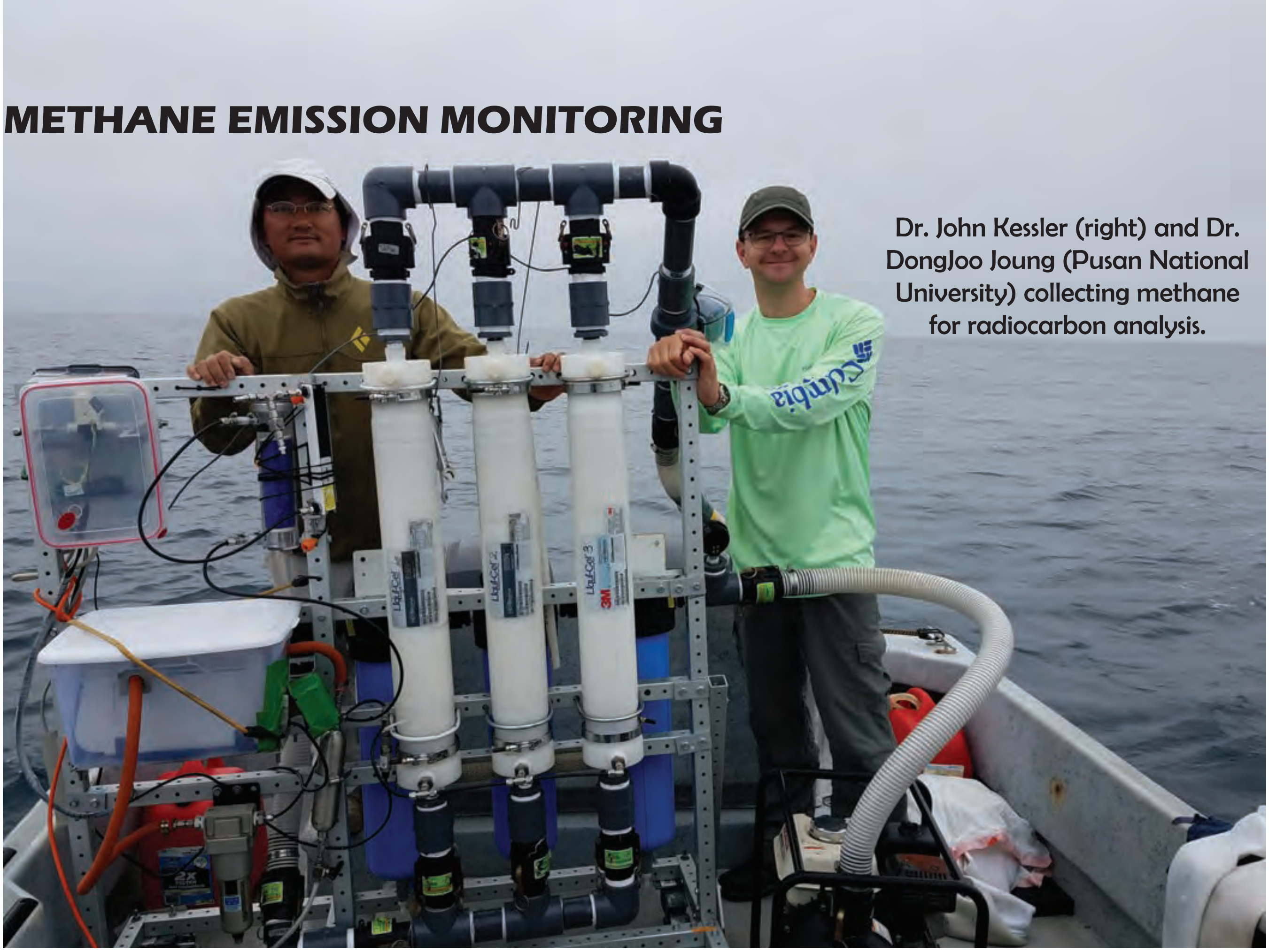
A HULL OF A RESEARCH CRUISE

The cruise spent 26 days on the water, leaving Delaware to travel down the east coast of the United States, around Florida, into the Gulf of Mexico and back. The boat "ping ponged" along the coast, getting as close to the shore as possible and then sailing out across the shelf, all while continuously collecting data from a series of instruments. While the measurements were taken autonomously, the crew had many tasks at hand, like monitoring the equipment. A pump was mounted off the side of the ship that continually diverted water through spectrometers to measure gases and then other instruments to measure variables like temperature, nitrate, chlorophyll, salinity, pH, and turbidity.

Two additional experiments, conducted by the researchers directly, took place alongside the autonomous data collection. "We keep talking about methane sources and methane emissions. There are microbes in the water that eat methane… we're very interested in that process. Not only are we interested in the sources, but the sinks," commented Kessler. Monitoring the microbes involves incubation, so the team took water samples to the lab and measured how methane was consumed as a function of time. They also radiocarbon dated methane in the coastal oceans as they sailed. The process, far from autonomous, involved collecting between 1,000 and 40,000 liters of ocean water, which Kessler described as ridiculous. "We've developed a way where we deploy a 3-inch diameter hose down to anywhere from the surface to 500 meters; we pump water up at about 200 liters a minute. As it's flowing up, we suck off all the dissolved gases, which we compress into a metal oxygen tank and bring home." The team is looking specifically at tracing methane bubbling up from the seafloor from hydrate forms decomposing in warmer waters, he added. Radiocarbon dating allows them to see how far up the water column methane from the seafloor travels: "Does it make it to the surface? Is it emitted to the atmosphere? Is it dissolving in the deeper waters?"

Continuous and autonomous measurements also allowed the team to do a preliminary analysis of the data while on the waters. "The nice thing about making measurements this way is we don't have to wait until we get back to Rochester to learn something—we're learning something literally as it comes off the screen," Kessler observed. If the incoming numbers presented a unique feature or surprising occurrence, the ship could turn around to gather more information in that area, allowing for the most data collection.

Machine learning, a branch of AI that focuses on "teaching" processes how to leverage data to perform a task, is playing an enormous role in modeling the methane distribution data



Dr. John Kessler (right) and Dr. DongJoo Joung (Pusan National University) collecting methane for radiocarbon analysis.

All images: University of Rochester/John Kessler

collected at sea. "Models like artificial neural networks are essentially pattern-recognition tools—it's essentially the same technology as facial recognition software and the algorithms that predict your political leanings based on things you like on social media," explained Weber. "For us, the pattern recognition tool is used to identify pattern similarities between variables that we have little data for (like methane) and other variables ('predictors') that we have lots of data for, like temperature and chlorophyll that we can measure from satellites." After training the models using the information collected at sea, they can begin to predict methane concentration under any combination of variables, so long as data is being measured continuously. These predictions will derive continuous maps of surface methane, which will aid in emissions research and fill any knowledge gaps that currently exist. "Of course, our predictions will never be 100% correct and we have to be very careful about keeping track of uncertainties in our predictions," Weber added.

OLD QUESTIONS, NEW TACTICS

Methane emissions research holds huge potential as scientists and policymakers scramble to better understand the ocean's story. What are the fluxes—natural or anthropogenic—that exacerbate the warming climate? In what quantities does methane travel from coastal waters into the atmosphere? If the process is natural and values are stable, there is less concern to be had. However, if direct or indirect human influence over time is significant, what industries or activities are the contributors? Referencing the Deepwater Horizon oil spill and recent Nord Stream gas leaks, Kessler pointed out that past environmental crises have long indicated the need to better understand the dynamics of methane emissions.

This urgency and current lack of data are well answered by the implementation of machine learning models, although their application in the earth sciences is not new, shared Weber. Within oceanography alone, AI is helping to "estimate air-to-sea carbon dioxide and nitrous oxide exchange, quantify organic carbon fluxes in the biological pump, and map poorly sampled trace element distributions." What makes this project special, both researchers agreed, is that it's one of the first known direct collaborations between large field data measurement and machine learning model development. Not only is data collection efficiently sped up with autonomous and continuously working instruments, but he added, "It gives us the ability to ask exactly what type of data, and in what locations, we would need in order to improve the model predictions, and then go out and gather that data."

TWO FIELDS, ONE GOAL

In a continuously changing climate and with global discussions fast approaching, including the 27th United Nations

Dr. DongJoo Joung and Dr. Mihai Leonte (University of Rochester) deploying equipment for methane sampling.

Framework Convention on Climate Change (better known as COP27), every moment of data collection is crucial to better understand the oceans and their fluxes. Methane, often discussed less than carbon dioxide, plays an indisputable role in the climate—yet there exists few maps and little information about their path from coastal oceans to the atmosphere. Current collaborations, including the University of Rochester one, should help close the gaps and yield better predicting methane emission patterns, which can in turn aid scientific analysis and policy design.

“This marriage of big data and AI with fundamental measurement science shows two fields that don’t normally work together. Having that connection has opened doors that we wouldn’t have been able to do and allowed us to explore things in real time,” Kessler concluded. It’s a partnership that could very well change the way scientists collect and analyze data, and it may be just the start.

A feature about technologies, strategies and use of Ocean Landers

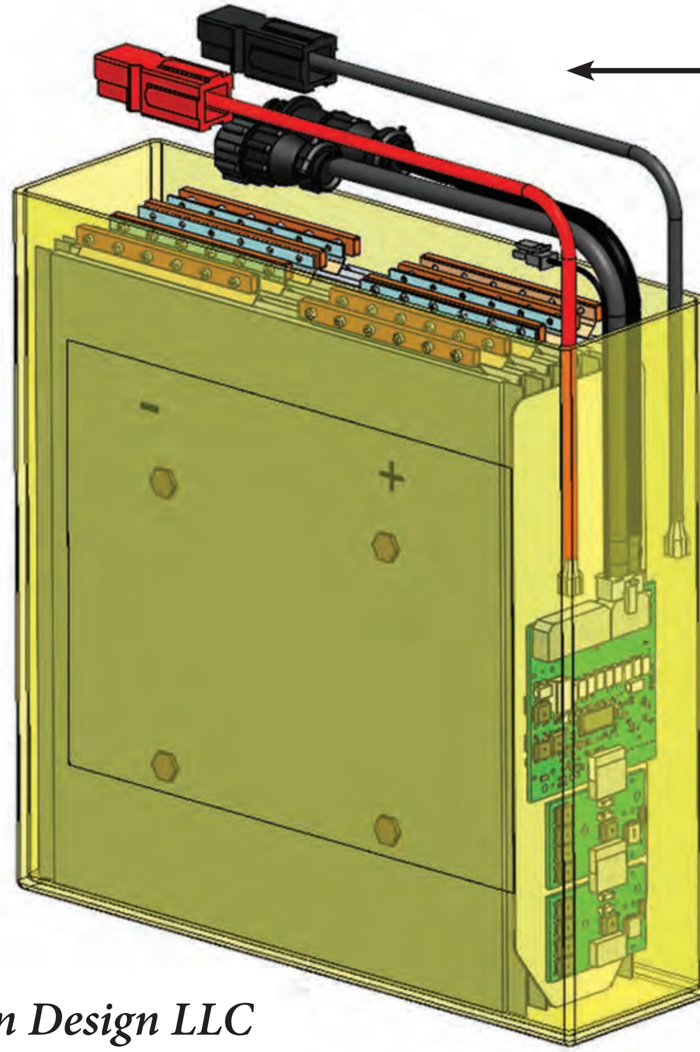


Photo used permission from Leon Adams, SWE, Houston, TX

LITHIUM POLYMER BATTERIES

By Kevin Hardy, Global Ocean Design LLC

Lithium-Polymer batteries offer a safe and robust option for portable electrical power. As we collectively have gained experience, application parameters have been refined, defined and improved. Though ubiquitous in everyday life, their acceptance has not quite outrun a troubled past.

LiPos have now flown on crewed Space-X spacecraft and are installed on the International Space Station. The global automotive industry is undergoing dramatic change with new battery developments that follow the personal computer and cell phone industries. The Tesla Powerwall, which uses a stack of LiPos, allows homes to get off the grid when the grid goes down. WHOI's DSV ALVIN, James Cameron's DSV DEEP SEA CHALLENGER, and Triton Submarine's TRITON 36,000/2 (DSV Limiting Factor) submersibles are powered by pressure compensated LiPo battery modules. In 2019 and 2020, Japan launched two new diesel-electric submarines, Taigei, or "Great Whale," and Toryu, or "Fighting Dragon," equipped with lithium-ion batteries, making the submarines capable of cruising silently submerged for longer.

Like different animals at the San Diego Zoo, it is important to recognize LiPo's are simply different than lead-acid or alkaline batteries. They have their own distinguishing behaviors. I admit to some apprehension when I began studying, then learning-by-doing with LiPos. I started out with LiPo batteries inside of fireproof charging bag, on a concrete floor within a small cinderblock bunker 6-feet away from everything else. I moved to a big clay garden pot with a clay drain pan for a lid. I monitored temperature, and voltage. I read everything I could. I followed up on promising leads. It was DreamWorks' "How To Train Your Dragon". I needed to know. Safety remained paramount, as I began to get a handle on the technology a lot of others were already using.

I have now used LiPos for several years in a variety of at-sea applications. The more you learn, the more successes you have, and the more possibilities present themselves. I respect their energy density, but also their willingness to do a job.

There is a large body of work describing fundamentals of LiPo cells and their application. This article will cite some of them.

In brief, always treat LiPo's with the respect they deserve. It is crucial to stay within the industry recommended operational parameters. The terrible tales of weekend RC enthusiasts can

Figure 1

A look inside a Southwest Electronic Energy SeaSafe II pressure compensated Lithium Polymer battery shows placement of the prismatic LiPo cells, the individual Battery Management Systems PCBs, and the Power Booster boards for intelligent control of the output.

partly be blamed on those end-users straying outside the prescribed boundaries to gain a few more minutes of flight time, or trying to get one more flight in by fast-charging above the recommended max rate. Sometimes it's a lousy battery they got at a cheap price. Sometimes they don't have the right devices to protect and maintain the batteries as they should be.

SOME BASICS ON LI-ION AND LIPO BATTERIES

Lithium-ion and Lithium-polymer batteries are rechargeable, secondary cells with similar chemistries. They can be used for the same high-power applications. They are distinguished by different electrolytes and packaging.

Lithium-ion and Lithium-Polymer are completely different from primary, non-rechargeable lithium cells. For one, lithium polymers use an intercalated lithium compound for their electrodes, not metallic lithium, and therefore are more stable. They are also not hazardous if exposed to water.

Lithium-ion cells use a liquid electrolyte, and are encased in a cylindrical stainless-steel housing. The well-known 18650 cell is an example.

Lithium-polymer (LiPo) cells use a gelled electrolyte and are vacuum sealed inside a soft plastic pouch. This is known as a "prismatic cell". There are several LiPo chemistries, but the most common for prismatic packs is Lithium Cobalt Oxide. The chemistry is specified in the MSDS for that battery. A stack of prismatic cells maybe be bound together using a shrink wrap, for lightweight applications, or inside an injection molded hard plastic casing to provide puncture resistance.

Compared to alkaline cells, LiPo's have lighter weight, higher capacity, higher discharge rate, and are less affected by cold temperatures as may be found deep. Cycle life can be 100's before battery capacity is reduced to ¾ of its original capacity.

A LiPo configuration is specified by the number of prismatic cells, and how they are connected, that is the numbers of cells in series and in parallel. A "6S1P" means there are 6 cells in series, and only 1 stack, with none in parallel. Virtually all prismatic batteries are wired with all cells in series, and so the configuration is simply referred to as "6S", with the "1P" understood.

About voltages: The nominal voltage of a battery is the number of cells x 3.7v/cell, the mid-point voltage of a battery pack. A 6S battery is described as 6 cells x 3.7v/cell = 22.2v, though a full charge is 25.2v.

LiPo batteries have four key voltages to know:

- **Max voltage:** 4.2V/cell (6S x 4.2v/cell = 25.2vdc)
  - o (Managed by the BMS, explained below)
- **Storage voltage** (50% of full charge): 3.85V/cell (6S x 3.85v/cell = 23.1vdc)

Capacity (%) vs. voltage tabulated by # of LiPo cells in series

%	1	2	3	4	5	6	7	8	9	10	11	12
100	4.20	8.40	12.60	16.80	21.00	25.20	29.40	33.60	37.80	42.00	46.20	50.40
95	4.15	8.30	12.45	16.60	20.75	24.90	29.05	33.20	37.35	41.50	45.65	49.80
90	4.11	8.22	12.33	16.44	20.55	24.66	28.77	32.88	36.99	41.10	45.21	49.32
85	4.08	8.16	12.24	16.32	20.40	24.48	28.56	32.64	36.72	40.80	44.88	48.96
80	4.02	8.04	12.06	16.08	20.10	24.12	28.14	32.16	36.18	40.20	44.22	48.24
75	3.98	7.96	11.94	15.92	19.90	23.88	27.86	31.84	35.82	39.80	43.78	47.76
70	3.95	7.90	11.85	15.80	19.75	23.70	27.65	31.60	35.55	39.50	43.45	47.40
65	3.91	7.82	11.73	15.64	19.55	23.46	27.37	31.28	35.19	39.10	43.01	46.92
60	3.87	7.74	11.61	15.48	19.35	23.22	27.09	30.96	34.83	38.70	42.57	46.44
55	3.85	7.70	11.55	15.40	19.25	23.10	26.95	30.80	34.65	38.50	42.35	46.20
50	3.84	7.68	11.52	15.36	19.20	23.04	26.88	30.72	34.56	38.40	42.24	46.08
45	3.82	7.64	11.46	15.28	19.10	22.92	26.74	30.56	34.38	38.20	42.02	45.84
40	3.80	7.60	11.40	15.20	19.00	22.80	26.60	30.40	34.20	38.00	41.80	45.60
35	3.79	7.58	11.37	15.16	18.95	22.74	26.53	30.32	34.11	37.90	41.69	45.48
30	3.77	7.54	11.31	15.08	18.85	22.62	26.39	30.16	33.93	37.70	41.47	45.24
25	3.75	7.50	11.25	15.00	18.75	22.50	26.25	30.00	33.75	37.50	41.25	45.00
20	3.73	7.46	11.19	14.92	18.65	22.38	26.11	29.84	33.57	37.30	41.03	44.76
15	3.71	7.42	11.13	14.84	18.55	22.26	25.97	29.68	33.39	37.10	40.81	44.52
10	3.69	7.38	11.07	14.76	18.45	22.14	25.83	29.52	33.21	36.90	40.59	44.28

YELLOW = Practical Limits, RED = Danger, DARK GREEN = Storage/Recommended Discharge, TEAL = Full When Cold

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Chart courtesy of Mark Forsyth, RCGroups.com

Figure 2

State of Charge versus LiPo Pack Voltage

Photo by Brian Hardy, Global Ocean Design

Figure 3

The author with a 440Wh car battery that floats!

Gens Ace

Figure 4

A Gens Ace Tattu LiPo battery. The LiPo battery characteristics of voltage, capacity, configuration, and max current rating are shown. More background information on GensAce/Tattu LiPo batteries may be found at <*https://www.genstattu.com/bw/*>.

o (Charge battery, then discharge with CBA V Pro to this value. Explained below.)

- **Shipping voltage** (30% of full charge): 3.71V/cell (6S x 3.71v/cell = 22.26vdc)
  o (Charge battery, then discharge with CBA V Pro to this value. Explained below.)
- **Min voltage** (Absolute): 2.9V/cell (6S x 2.9v/cell = 17.4vdc)
  o (Managed by the BMS, explained below)

Using a 10" polyamide sphere, I've made a positively buoyant 22v/20Ah (440Wh nom) rechargeable battery. That's a car battery that floats.

LiPo quality varies between consumer and commercial grade batteries. Commercial grade batteries are made by paying attention to quality at every step, including selecting cells that match the characteristics of others in a stack. Consumer grade batteries are made by paying attention to cost. The difference is like buying batteries from Duracell versus Harbor Freight. Two commercial brands I tend to use are Gens Ace Tattu and Turnigy Graphene. One list of the top LiPo manufacturers can be found at <https://www.grepow.com/blog/best-rc-lipo-battery-for-2020.html>.

Because prismatic cells are vacuum sealed in a soft plastic pouch, they are pressure tolerant. There are no compressible materials on the interior so the rate of chemical reaction is unaffected by pressure. The matching BMS protection circuitry is likewise made of pressure tolerant components (See next section). I have immersed both in bags filled with mineral oil and tested them to 18,000-psi. They held up fine.

Placing a pressure compensated LiPo battery outside the hull means you only subtract the water weight from the buoyancy budget, rather than the air weight when it's inside the hull. Just a SWAG, but for the same amount of buoyancy, a craft may be able to carry an additional 25% power.

For more background details on LiPo's, see Battery University <https://batteryuniversity.com/>; "A Guide to Understanding LiPo Batteries" <https://www.rogershobbycenter.com/lipoguide>; and "The care and feeding of LiPo packs" <https://www.promodeler.com/askJohn/How-To-Care-for-LiPo-Packs>.

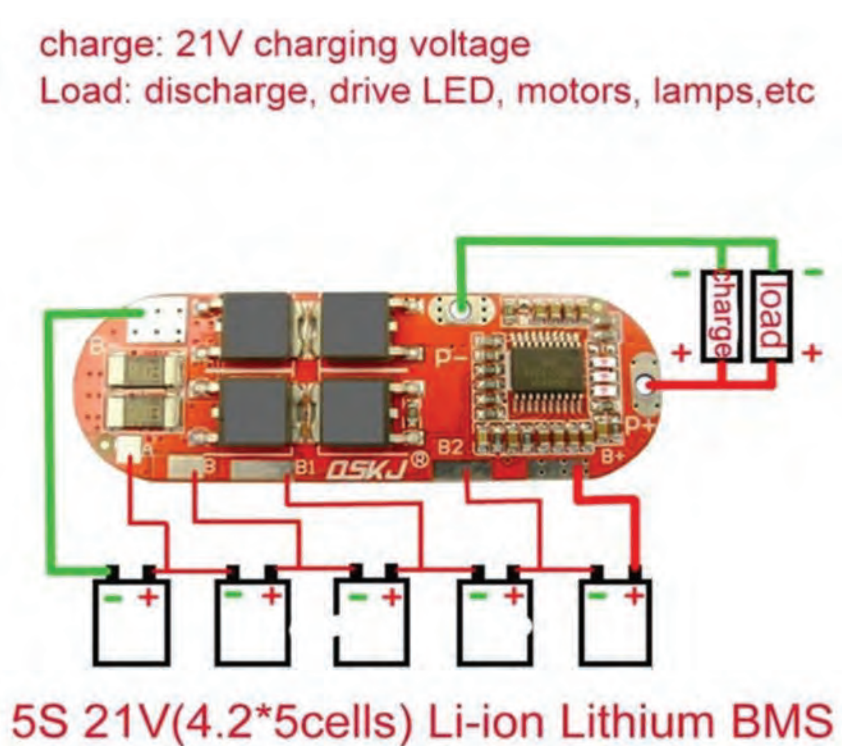
Follow your curiosity and you'll find others.

LIPO PROTECTION CIRCUITRY

Here's where I diverge from normal RC practice.

It is very important to balance charge a LiPo battery. This is because some cells have slightly higher internal resistance than others, allowing some to overcharge, while others undercharge, if not regulated. You'll find a plethora of "balance chargers" that work fine. BUT, it is also important to balance discharge to prevent one cell from discharging faster than the rest for the same reasons, and plunging too low. A low voltage cut-out is not enough, as that measures the total voltage of the pack. One cell, hiding within the total voltage of the battery pack, can be depleted to the point of ruin, taking the whole battery with it. When that battery is placed on a balance charger next time, it will find the one that's bad, and cancel the charge.

The solution is a BMS: Battery Management System, a board



QSKJ Power Module Experts

Figure 5

A LiPo protective circuit "Battery Management System" (BMS), protects individual cells in a LiPo pack during charge and discharge. A 5S LiPo battery is shown.

designed to protect every cell in your LiPo pack by keeping it inside safe operating regions. In addition to a charge/discharge balancing function, a BMS features over-charge protection (high voltage cutout), over-discharged protection (low voltage cutout), short circuit protection (disconnect the load), and over-current protection (selectable 20A, 30A, 40A). The better BMS designs draws less than 200uA.

Another great advantage to the BMS is multiple identical batteries, each with its own BMS, can be tied together, positive-to-positive, negative-to-negative, in what is called a "voltage bus". The parallel arrangement provides the battery rated output voltage, while adding the Amp-hour capacity together. The BMS also provides the ability to recharge the battery from a single power port without opening the housing. If a second battery pack for a deployed lander is on-hand, it can be charged slowly, which will extend the life of the cells.

Look closely at the SMT components used in assembly of the BMS board. Chances are good they are all pressure tolerant. Good news, this means a pressure compensated LiPo can have its side car BMS along for the ride.

Safety: A polyamide sphere is sealed with a vacuum. In the unlikely event any gas is generated, the sphere will simply fall apart. If submerged, saltwater will discharge the battery, but will not react with the polymer. If using a glass sphere from Nautilus Marine Service (Vitrovex): Pull the cap off the self-sealing purge port. The check valve will hold the interior vacuum, but pop out if there is an internal overpressure. Be sure to replace the purge port cap when done. If in a cylinder, a safety measure for outgassing is to remove the screws holding the endcap to the housing. An internal vacuum will hold the endcap on, and internal overpressure will push it out. If fitted with a self-sealing purge port, remove the cap. The internal check valve will hold the interior vacuum, but pop out if there is internal overpressure. Be sure to replace the purge port cap when done. Alternately, a Pressure Relief Valve (PRV), like those made by Deep Sea Power & Light or Prevco, could be used. A PRV should be placed at the bottom of a pressure case, similar to an entry hatch to an undersea habitat. When a PRV is open, it is open directly to the sea. PRVs have a cracking and re-sealing pressure, at which point water can dribble in if the PRV is pointing up. Another reminder for engineers is to be careful of dissimilar materials corrosion between the PRV and the end cap. We'll discuss Housings more in a later issue.

CHARGERS

Since each battery has its own BMS to balance charge individual cells, a smart unbalanced charger designed for LiPos is needed. These are notable in that they do not have the LiPo balance plug connector port.

A smart unbalanced LiPo charger provides LiPo under-voltage protection, so that if the LiPo battery's voltage is <15.12V, the charger will not charge the battery as one or more cells are likely damaged. It also offers a second level of protection to the BMS for output short circuit protection, over-temperature

Illustration courtesy of AA Portable Power Corp.

Figure 6

An unbalanced smart LiPo charger. Universal input allows use in any country or ship of opportunity.

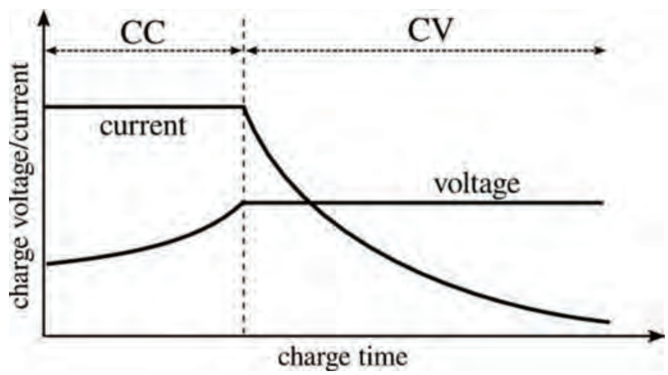


Illustration courtesy of Witold Maranda, PhD, Lodz University of Technology, Poland

Figure 7

An unbalanced smart LiPo charger provides Constant Current (CC) initially, then shifts to Constant Voltage (CV) to complete the charge.

Progressive RC

Figure 8

The ESR (Equivalent Series Resistance) Meter Mark II.

protection, over-voltage protection, and reverse polarity protection. The smart unbalanced LiPo charger provides a constant current/constant voltage charging cycle.

IMPORTANT INSTRUMENTS TO HAVE

1. DVM, of course, then it gets interesting.

2. The **LiPo ESR** (Equivalent Series Resistance) Meter Mark II. Easily the next most important LiPo diagnostic tool to have in the tool chest.

Internal resistance (IR) is the best predictor of battery condition. IR is measured in milliohms (mΩ). The lower the resistance, the less restriction there is current flow. High resistance causes the battery to heat up and the terminal voltage to drop under load.

The **LiPo ESR** (Equivalent Series Resistance) Meter Mark II is the best meter on the market for judging the quality of lithium battery packs.

The ESR meter provides the internal resistance of individual cells when removed from the battery stack, or an integrated measurement of the entire pack, including the BMS. The BMS adds a fixed offset to the battery IR. The ESR provides a direct readout of the Internal Resistance and Max Current the pack can deliver at the moment the measurement is made.

The manufacturer advises measurements be made at the same temperature.

($150, Progressive RC <https://www.progressiverc.com/>

3. The Computerized Battery Analyzer V Pro (CBA V Pro)

I'd definitely get this one, too. It's used to test battery capacity and to accurately and automatically discharge a battery to a specific voltage for storage or shipping.

The Storge and Shipping voltages are obtained by first charging the battery, then discharging to the specified voltage using the CBA V Pro Battery Analyzer. Specify the end voltage and the CBA will automatically stop when it reaches that voltage.

The CBA (Computer Battery Analyzer) V can also determine the actual capacity of the battery at different discharge rates. It can also test the Low Voltage Cut Out function (LVCO) of the BMS.

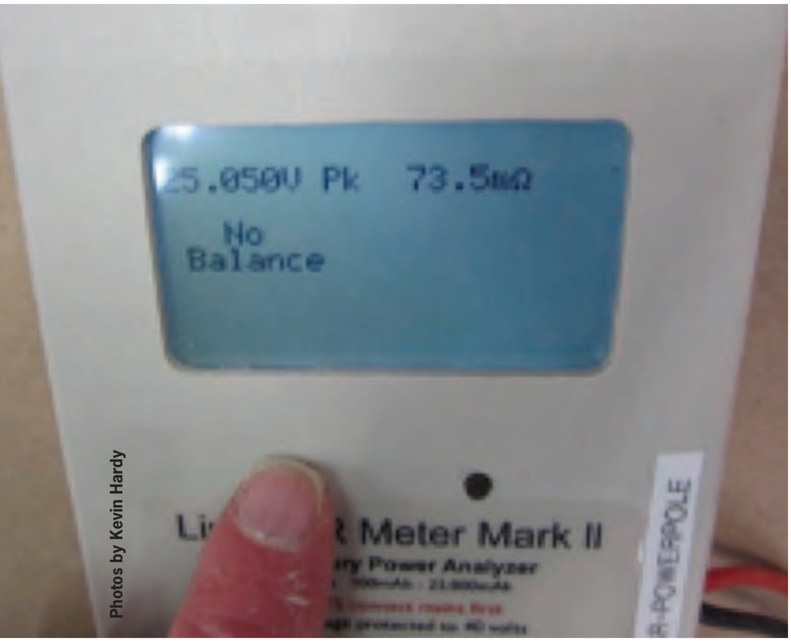
To test a battery's capacity at cold temperature, place it in a refrigerator and run the leads out to the CBA V. An indoor/outdoor thermometer will provide temperature. ($229, from West Mountain Radio <https://www.westmountainradio.com/>)

4. A 5-in-1 Cell Meter to test cell voltage:

This meter measures voltage of individual cells and total battery voltage through the balance plug.

The Tenergy 5-in-1 Cell Meter can display the estimated remaining capacity based on unloaded terminal voltage for LiPo battery packs. Use this meter to quickly check if your battery requires charging before use. It can also display the voltage of each individual cell, confirming balance condition.

For LiPo and Li-ion battery packs, this cell meter will display the internal resistance of each individual cell, providing a quick evaluation of the health of the battery. I would use this



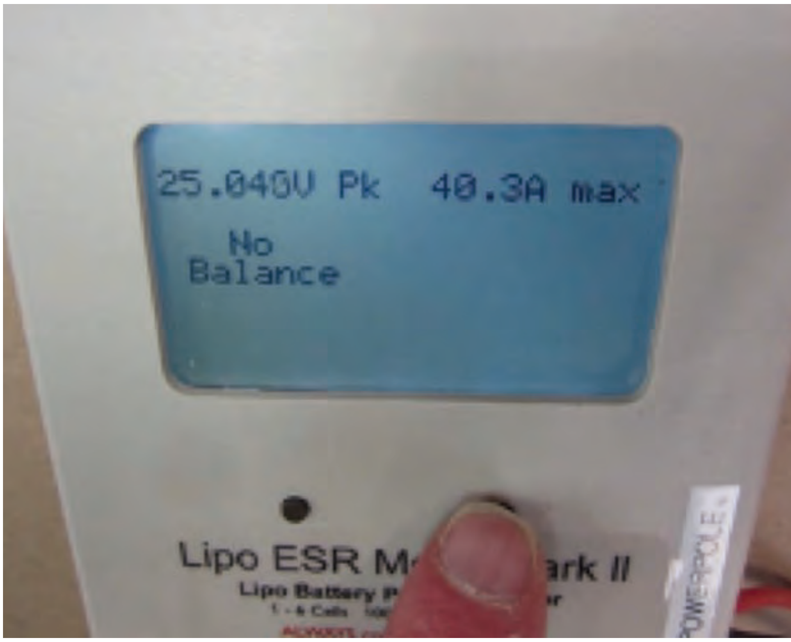


Figure 9

The Internal Resistance (left) and Max Current (right) can be measured and recorded for a new battery. These photos show a measurement of the condition of the full battery with BMS. If the estimated load is under 40A, this battery is fine. It is not necessary to hook-up to the balance plugs of the LiPo battery to make a general assessment, though it presumes the BMS is doing its job of balancing each cell. Should the net IR value increase from the initial measurement over time, the battery may need to be replaced.

meter as a check against the ESR, but would trust the ESR as a better instrument for this important task. ($19, at Tenergy Power <https://power.tenergy.com/>)

UNOLS ON SHIPBOARD LIPO SAFETY

Four University-National Oceanographic Laboratory System (UNOLS), WHOI and USN documents maybe found at <https://www.unols.org/documents/batteries>.

Scripps Institution of Oceanography has a similar document at <https://scripps.ucsd.edu/sites/scripps.ucsd.edu/files/basic-page-ships/field_attachment/2015/SIO.ShipboardLithium-BatteryGuidelines.Nov-2014.pdf>

SHIPPING:

IATA UN 38.3 restrictions apply. Good tip: Do not modify the LiPo batteries in anyway, and the UN 38.3 test certification document the manufacturer used to ship them to you still applies. They are required to give you a copy if you ask. FedEx and UPS publish their guidelines based on IATA Rules. If you ship the LiPos inside of a housing, they are qualified to be transported under UN3481, which is less restrictive. This is because the housing protects the battery from incidental puncture. For more information in IATA rules, see Battery University <https://batteryuniversity.com> and search for "BU-704a: Shipping Lithium-based Batteries by Air".

If you find IATA shipping is too restrictive, don't worry: you designed unmodified batteries into your battery pack! Pull the batteries out, and ship the housings empty. Order a new set of LiPos to be delivered to your agent in the foreign port of operation. Open and reassemble the battery pack there.

CONCLUSION

I haven't tried charging LiPos under pressure, as one might with a cable-to-shore network, but I suspect they will perform normally.

I hope this was helpful and you'll explore the cool things LiPos can do for you.

OTHER RESOURCES, BOOKS

"Batteries in a Portable World", Isidor Buchmann, 2016, (ISBN 978-0-9682118-4-7)

"DIY Lithium Batteries", Micah Toll, 2017, (ISBN 978-0-9899067-0-8)

FUTURE

IEEE Spectrum (October 2022) reported on Mercedes-Benz prototype Vision EQXX sedan. It will sport a "high silicone

West Mountain Radio

Figure 10

The Computerized Battery Analyzer V Pro

battery anode…which can squeeze more range from batteries, <and> are widely expected to be popularized over the next decade." Marine technology often benefits by crossover technologies whose development was paid for by larger markets. In a decade, who knows?

OTHER SHOP TALK

Make Magazine, Vol 83, just out, features "2022 Boards Guide", includes its annual Make: Guide to Boards comparing 79 of the hottest microcontrollers, single-board computers, and FPGAs — with an emphasis on those you can actually get your hands on.

ACKNOWLEDGEMENTS

Thanks to Douglas Alden, R&D Engineer 5, and Dr. Paterno Castillo, Scripps Institution of Oceanography, for engaging the wider Scripps community in a conversation on Lithium batteries through the on-campus Scripps Technical Forum. Thanks also to Chad Collett and Brent Lackey, SubC Imaging (Clarenville, NL, Canada), for their interest and ongoing conversation on undersea LiPo design. The author acknowledges his gratitude to Dr. Peter Worcester, Institute of Geophysics and Planetary Physics (IGPP) at Scripps, recognizing his insatiable curiosity, encouragement, trust in his team, and willingness to try new ways to advance his science.

READER FEEDBACK

Your comments and shared experiences are always welcome. Please send your thoughts, stories and photos to: Kevin Hardy <khardy@marinelink.com>. You may find yourselves in print!

COMMERCIAL UNDERWATER LIPO BATTERIES

- **Southwest Electronic Energy Corp.** (www.swe.com) offers SeaSafe II pressure compensated Lithium-ion battery solutions for subsea vehicles, control systems, and oceanographic equipment. They also post their very good collection of conference presentations to their website. <https://www.swe.com/technical-presentations/>

- **SubC Imaging** <https://www.subcimaging.com/> offers a BMS protected LiPo battery sphere as part of an autonomous camera system.

- **Ictineu Submarine** (Barcelona, Spain), (http://www.ictineu.net), offers a wide variety of pressure-tolerant LiPo batteries.

- **Develogic** (Germany) <http://www.develogic.de> offers refillable pressure protected battery containers that fit side composite, aluminum or titanium cylinders. Battery options include alkaline, Li-ion, and primary lithium.

- **SubCTech** (Kiel, Germany) <https://subctech.com/ocean-power/> offers a line of pressure protected Li-Ion batteries for undersea applications.

- **General Dynamics** offers the "Bluefin Robotics 1.5 kWh LiPo battery"

Photo by Kevin Hardy

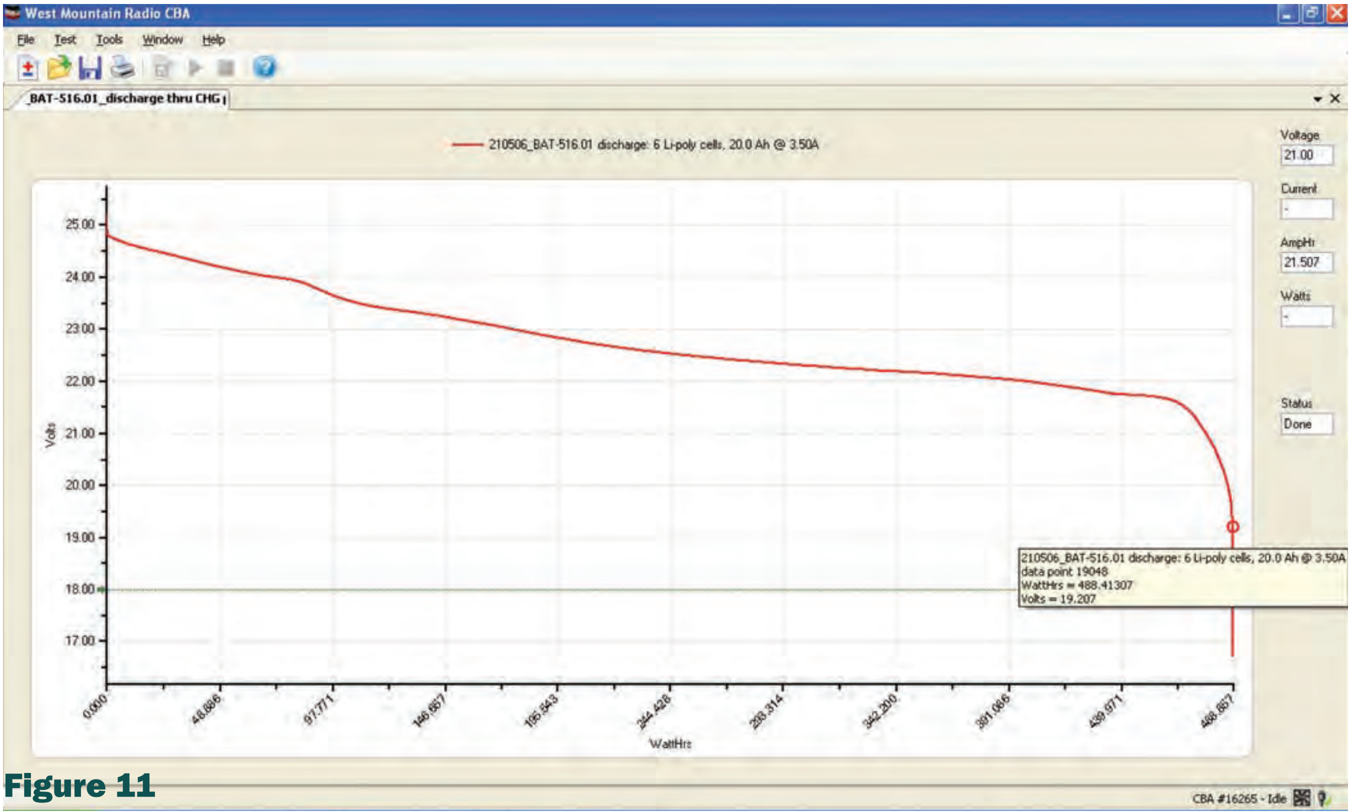


Figure 11

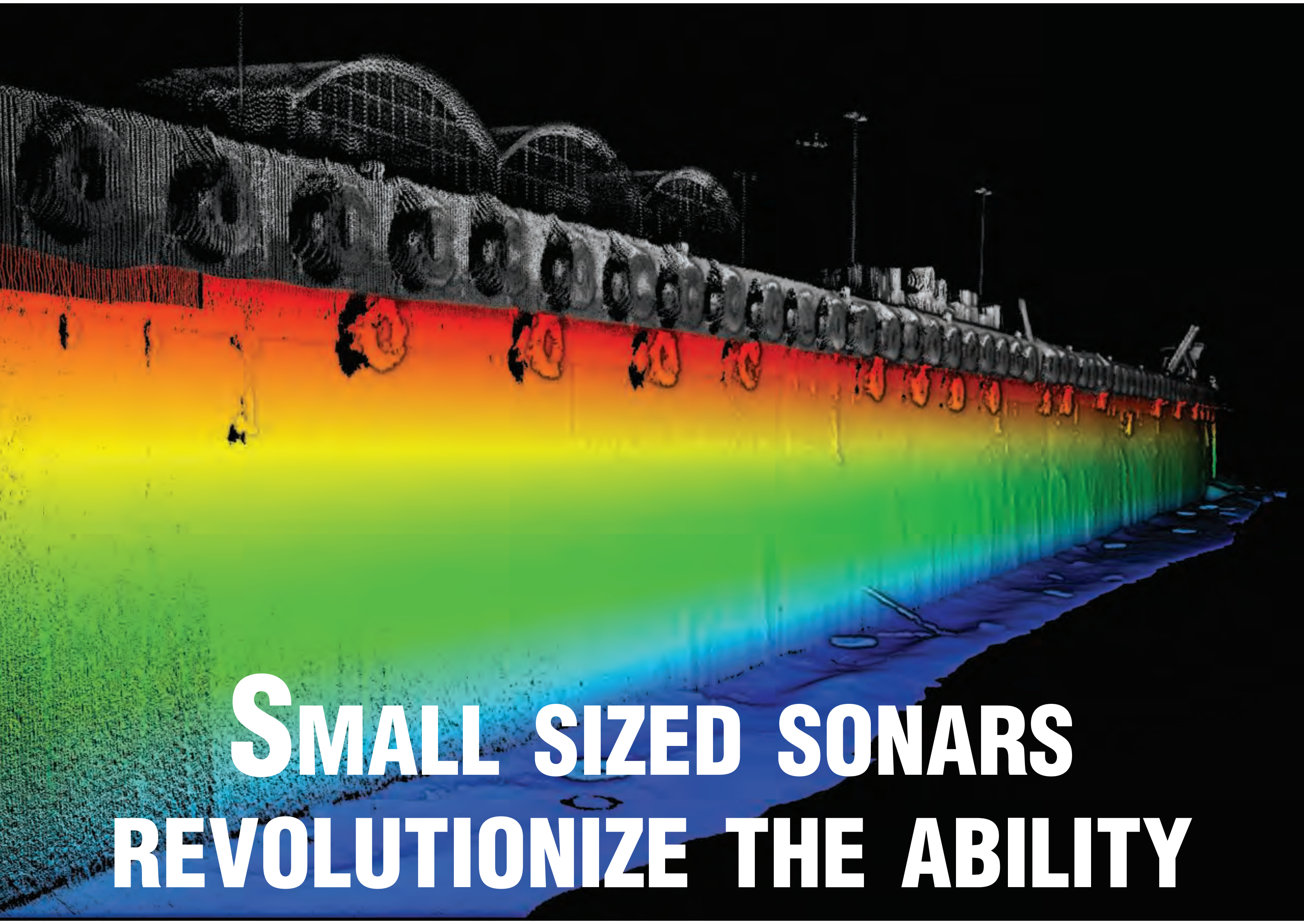
The CBA provides a true discharge curve and capacity of your battery. Here, the green horizontal line at 18.00 v is the preset limit to shut off the discharge of the 6S battery (3.0v/cell). Instead, the BMS low-voltage cut-out (LVCO) kicked in at 19.20v (3.2v/cell).

Figure 12

Tenergy Power

The Tenergy 5-in-1 cell Meter

All images courtesy Norbit



SMALL SIZED SONARS REVOLUTIONIZE THE ABILITY TO PERFORM UNDERWATER INSPECTIONS UTILIZING UNMANNED SURFACE VEHICLES

Across the globe companies have the need to perform accurate hydrographic surveys to ensure their marine assets are properly maintained and any issues quickly discovered and acted upon. Traditionally inspection work has been performed from medium sized and manned vessels. Utilizing the small size, weight, and power consumption of the NORBIT WINGHEAD i77h it is an ideal match with unmanned surface vehicles (USVs). This ensures that maintenance of quay walls, bridges, and subsea structures in general, can be done in a cheaper, safer, and more environmentally friendly manner than before.

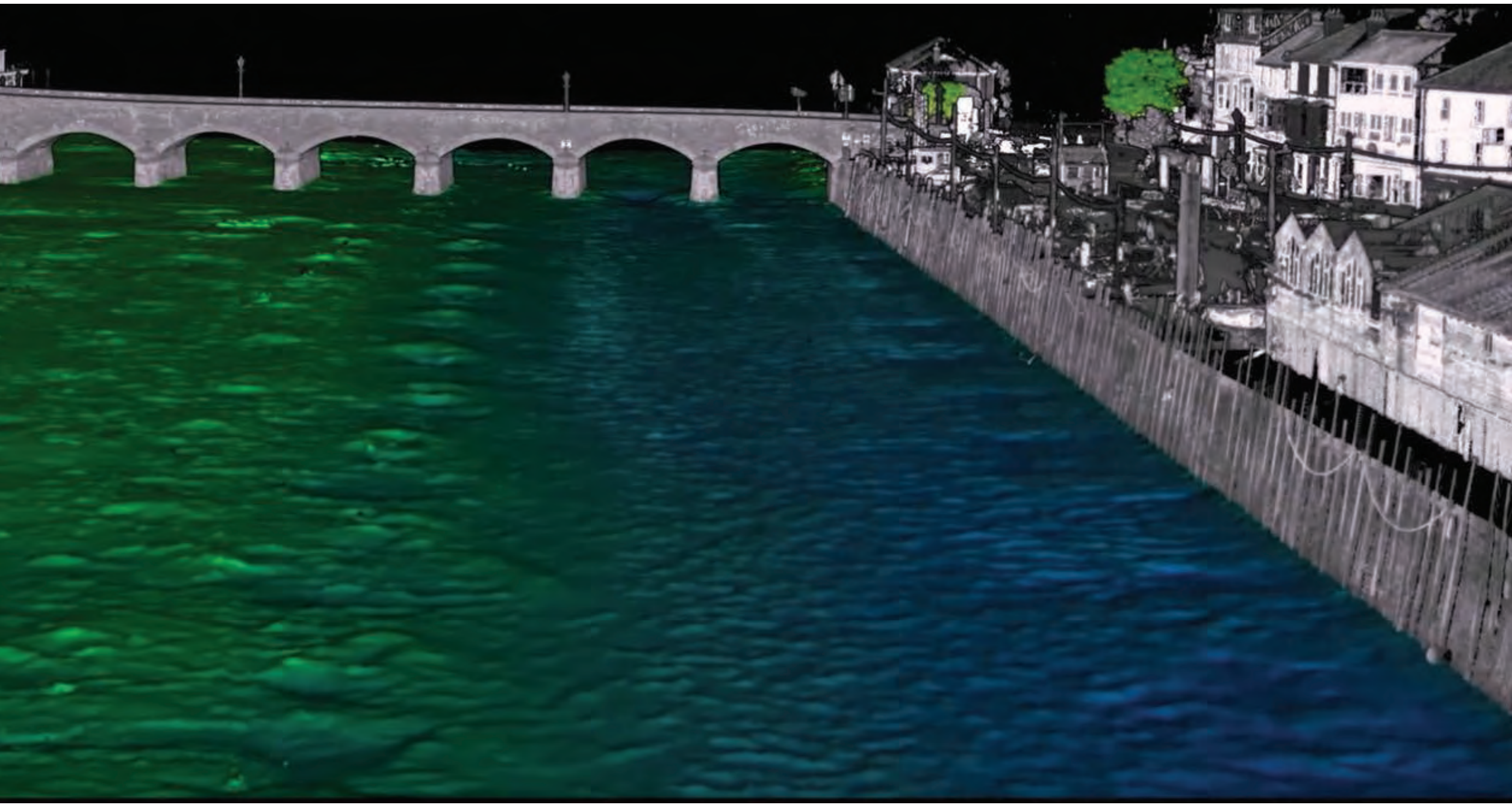
In past years NORBIT´s small sonar systems have allowed us to utilize unconventional vessels to test our equipment, including kayaks and jet-skis. We have done this to ensure systems are user friendly and easy to handle. In recent years, with the growth of USVs, combining our sonars with these vessels is the next step in ensuring the NORBIT sonars can be utilized in a simple, cost-efficient, safe, and environmentally friendly manner. The NORBIT WINGHEAD is specifically developed for high-resolution inspections on any subsea structure, including quay walls, bridges, oil platforms and so-on. USVs are typically small, lightweight with limited power and endurance.

To maintain efficiency most of these need a multibeam system which does not increase draft and drag, and a system with as low power consumption as possible. The NORBIT WINGHEAD complies with all these requirements and has become a preferred choice for many USV manufacturers and operators.

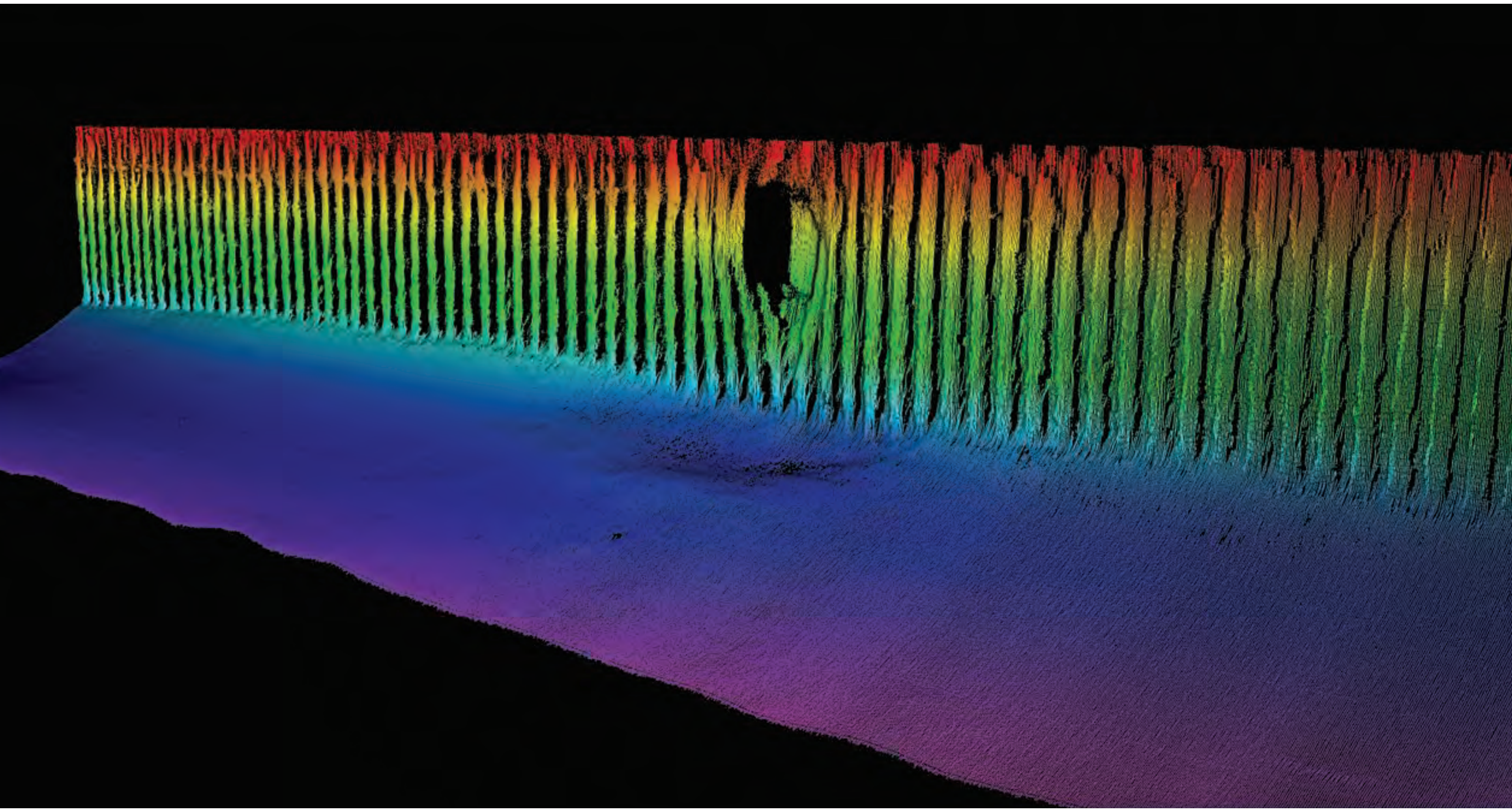
When looking at utilizing USVs to undertake various inspection and hydrographic surveys, NORBIT recognizes that small and easy to use systems are crucial for success. A USV operator is busy controlling the vessel, monitoring survey progress, looking out for other boats etc., so the sonar needs to be virtually autonomous and not require a lot of attention. NORBIT have put a significant effort into the WINGHEAD-family, creating a virtually hands-free system. This allows the operator to focus on other tasks than fiddling with advanced sonar controls. The NORBIT WINGHEAD is also designed to be extremely portable and to allow for rapid mobilization on any platform. It is delivered in a single pelican case ready for easy transportation and safe to transport in the aircraft hold. It comes with several optional features such as full motion stabilization (roll, pitch, and yaw). In addition, the system can be combined with an optional LiDAR, which, when the two are combined gives a full picture of the infrastructure, a seamless surface of the topography below and above the waterline. This provides context for the multibeam data, and aids interpretation of the results.

Collaboration with Ultrabeam Hydrographic

One company which specializes in delivering high-quality hydrographic and geophysical survey services to a wide range of clients, is Ultrabeam Hydrographic. From day one they have focused on specific and revolutionary methods of conducting hydrographic surveys utilizing USVs to perform these specialist surveys and inspections. They deduct that using USVs is much more efficient than many traditional methods, and especially safer when operating in hazardous conditions.



All images courtesy Norbit



Ultrabeam Hydrographic operates two unique amphibious survey platforms, the “Argonaut” and “Axolotl”. They both use NORBIT sonars for their underwater surveys. Ultrabeam Hydrographic’s USV platforms are very small and thus they need an equally small form factor, yet high-performance, multibeam sonar to allow them to run quality surveys without running out of power or sinking the USV.

How a Quay Wall Inspection has Changed

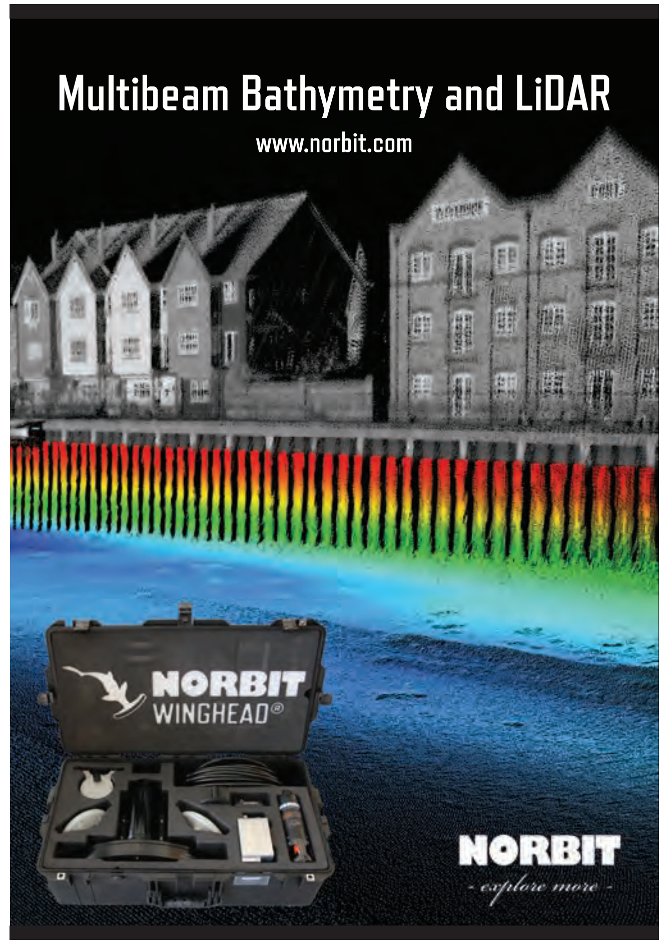
A quay wall is the border between water and land and to ensure safe docking, unloading and navigation it is crucial to ensure that such walls are stable. Wear and tear over time, collisions, debris are just some of the issues which can cause problems. Traditionally underwater inspections have often been carried out by divers, going underwater to do visual checks of the quay walls, or assessing the conditions of subsea infrastructure. Using divers alone, is not always the most ideal solution. Issues such as poor visibility, access to divers, underwater conditions etc. can cause problems. Therefore, we have seen an increase in underwater surveys utilizing acoustic technologies over the past 20 years. Now, more recently the wish to undertake these inspections easily and swiftly has prompted the focus on how sonars can be attached to USVs. Combining these two technologies allows us to utilize them as the only source of an inspection, or when needed as a pre-inspection followed by divers once areas of interest has been pin-pointed. This has significantly improved efficiency by being safer, faster, and cheaper.

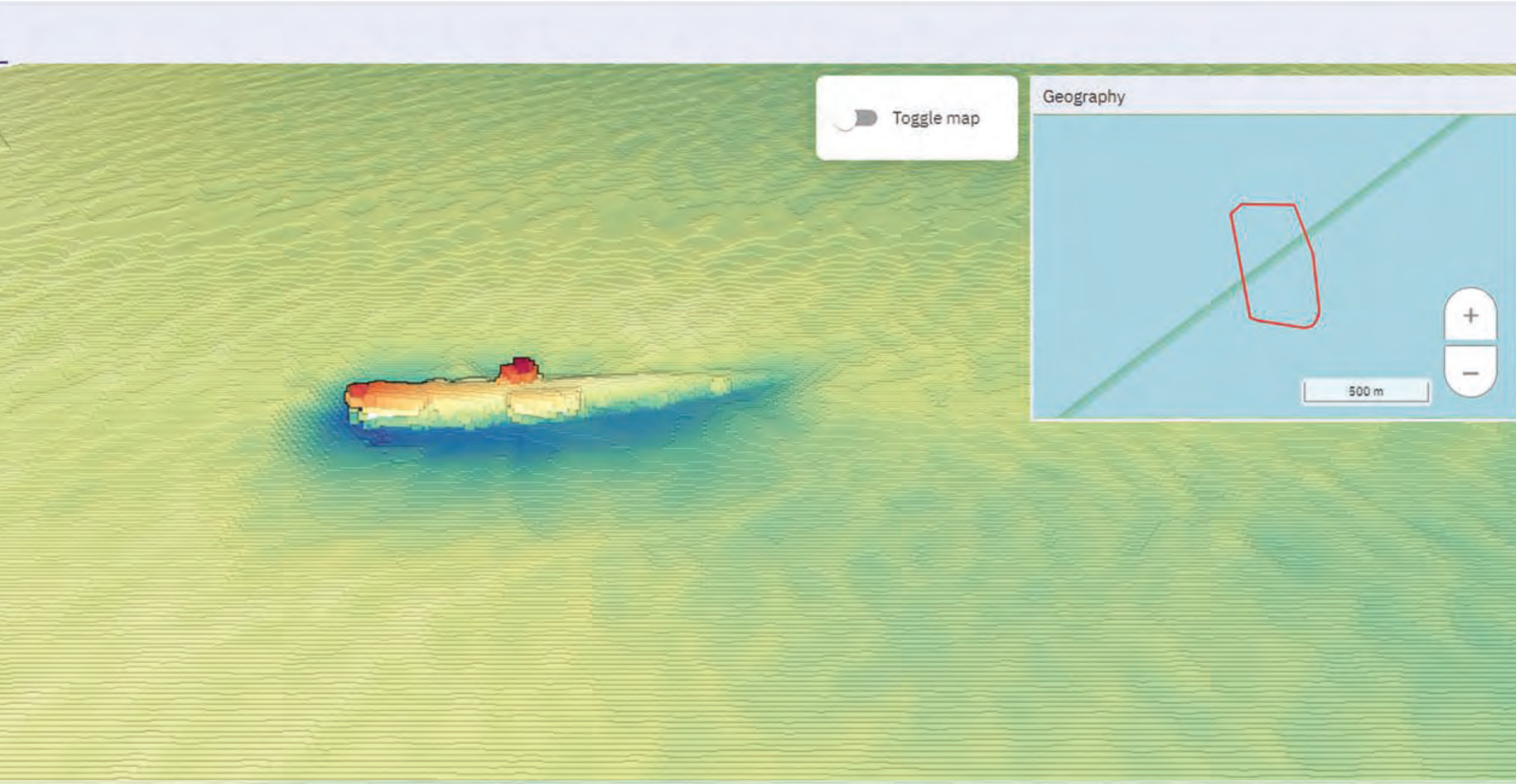
New Innovations Allow Seamless Inspections

High resolution point cloud data is essential for accurate infrastructure inspection. The level of detail we can detect is fundamentally determined by the sonar beam width resolution. The combination of NORBIT’s 0.5° beam widths and curved array technology makes it ideal for inspection work. The curved array provides consistent beam width resolution across the swath compared to traditional flat array systems. Furthermore, it is not necessary with curved arrays to physically rotate the sonar for vertical structure surveys, so it is more suited for quay wall detection than traditional systems.

The NORBIT WINGHEAD generates up to 1024 true beams per ping, providing ultra-high-sounding density on, for instance, quay walls, which is essential for reliable inspection work. The WINGHEAD offers 0.5°x0.9° beams at 400khz, providing extremely high-resolution data. The new technology combined in the WINGHEAD gives a dense point cloud dataset which aids inspection and enables us to detect smaller objects during a survey.

In summary we see that the utilization of new technology and combining existing technology now allows for accurate quay wall and harbor monitoring. Combining this with USVs allows our clients to conduct inspections systematically, efficiently and safely and in a whole new way than before. The portability and flexibility of the WINGHEAD also allows for quick and easy inspection after any incident, thus ensuring any subsea structure can quickly be inspected and any issues dealt with promptly.

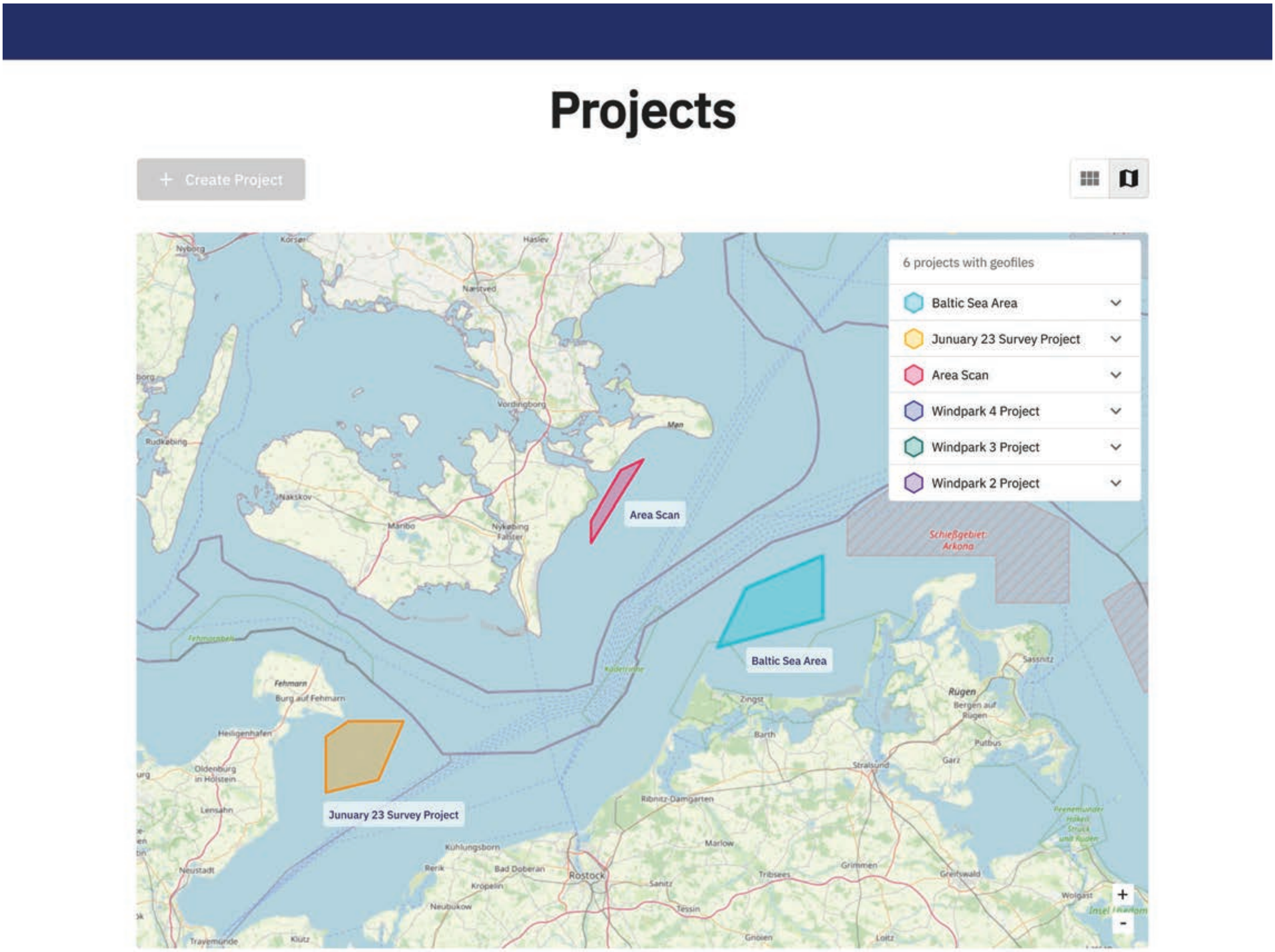




OFFSHORE 2.0

How ambitious expansion targets for offshore wind are driving digital transformation in the maritime industry.

By Thomas Sprenger



Under the impact of global climate change, Germany wants to triple the pace of renewable energy expansion, especially offshore wind. Skeptics point to obvious hurdles such as bureaucracy, sluggish grid expansion, fragile supply chains and shortages of ships and skilled workers. Another factor is overlooked: digitalization. It could slow down the energy transition or, on the contrary, trigger an offshore boom far beyond wind power. Unnoticed by the general public, but closely watched by American venture investors, a new generation of start-ups is working together with European technology companies on a maritime industry for the data age. Among them are many pioneers from Germany.

The German government could not have chosen a more appropriate date for the resurrection of the energy transition. In April 2022, the cabinet passed the amendment to the Renewable Energy Sources Act. The “Easter package” had it all: by 2030, the share of renewable energies in Germany’s gross electricity consumption is to almost double. In this decade, 80 percent of our electricity would be generated in a climate-friendly way. Today it is just under 50 percent. To achieve this, Germany wants to triple its pace in the expansion of renewables. Especially in solar energy and offshore wind. Currently, there are wind farms with a capacity of 7.7GW off the German coasts in the North and Baltic Seas. In less than eight years, there should be at least 30GW - 50 percent more than in earlier federal plans. By 2045, the federal government plans an installed capacity of 70GW off our coasts - ten times more than today.

Daniel Esser, Nicola Offshore GmbH

Frithjof Hennemann, TrueOcean

Soren Themann, Subsea Europe Services GmbH

THE PLUG PULLED ON OFFSHORE 1.0

Unlike the first wind power boom 15years ago, the euphoria in the industry is still limited. Caution is more the right word: 2022 was a good year for installed wind turbines, which generated 18 percent more electricity than in the previous year and, at 122 terawatt hours, made the largest contribution to green electricity production in Germany. Nevertheless, the expansion of wind power has been in the doldrums for years.

The decline began in 2018: suddenly, only half as many onshore and offshore wind turbines were built as in the previous year. New capacity fell from 6.5 to not even 3.4GW. And it fell further to 1.7GW by 2021. In the current year 2022, just 352MW of new wind capacity were connected to the grid. The causes can largely be attributed to politics, which in the last decade cut wind power subsidies, reduced tendering areas, piled up new bureaucratic hurdles and slept through the expansion of the electricity grids for the transport of energy to the industrial regions in the south. The result was a wave of bankruptcies in the young boom industry, many thousands of skilled workers lost their jobs. The ambitious expansion targets from the Easter package are now relying on an industry that has almost dissolved in this country.

OFFSHORE 2.0: SMALLER, (MORE) DIGITAL & (MORE) NETWORKED

That's why Daniel Esser doesn't want to grow in the traditional sense by hiring more staff and buying new ships, i.e. betting on the upswing with a lot of capital: "We're scaling on the technology side, in the efficiency of our processes and in productivity."

His company, Nicola Offshore, northwest of Hamburg, sends ships packed with state-of-the-art measurement technology and engineers out onto the continental shelf. There, his small fleet collects sensor data to map the seabed, detect World War II munitions storage sites or check submarine cables. Among his most important customers are energy companies that have to draw up plans, build foundations, operate and continuously maintain turbines for more offshore wind farms than ever before.

Esser's company belongs to a new generation of start-ups whose business models address a weak point of the maritime sector: costs. Especially the costs caused by data.

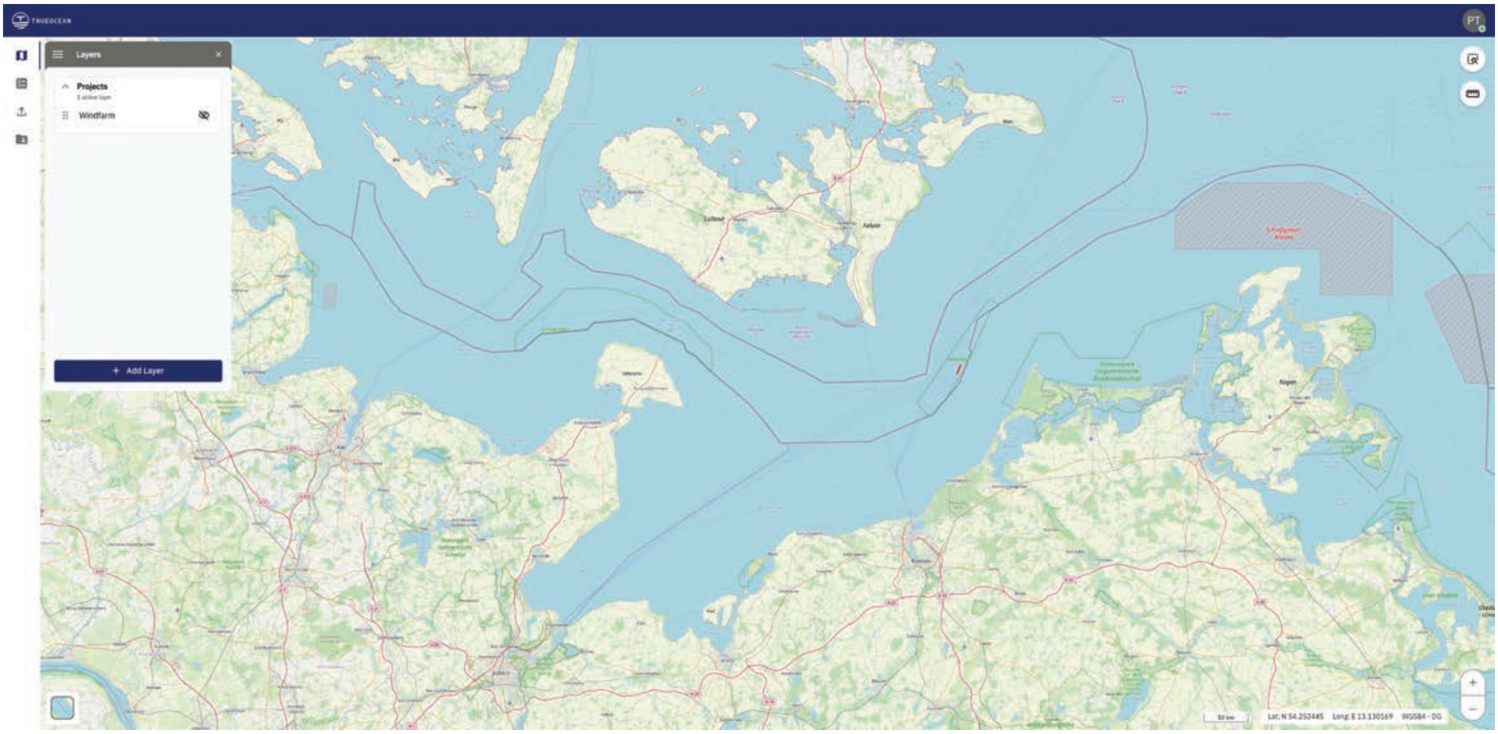
In the case of an offshore wind farm, these are already incurred on a large scale before construction begins. Its planners have to scan the construction site for the foundations to check the suitability of the seabed, ocean currents and stones and munitions remnants. What would be done quickly on land sometimes takes weeks at sea and costs tens of thousands of euros - per day.

"Not only expensive special technology is used on our reconnaissance trips. On board, highly qualified measurement engineers and technicians control the entire sonar campaign, check the incoming raw data and prepare it for later analysis," explains the economist and former submariner.

Compared to much larger competitors, Nicola Offshore, with four of its own survey vessels, including three fast catamarans, specializes in near-shore exploration missions, rapid deployment and high data quality. "We are literally the fast boats in the business. We keep our operations as lean and compact as possible and offer all digital data handling as a package," says Esser.

There is great interest in the maritime industry: subsidy reductions and competitive tendering procedures are forcing operators of capital-intensive offshore wind farms in particular to relentlessly reduce their costs and achieve efficiency gains. As a result, the price of wind power has fallen drastically in recent years. Today, wind turbines are more profitable than polluting coal and gas-fired power plants, even on the high seas.

In the long term, Esser hopes that technology will bring the marginal cost of collecting a new set of data at sea closer to zero. A second company in which he has a stake is also working on this and represents a new stage in offshore data collection.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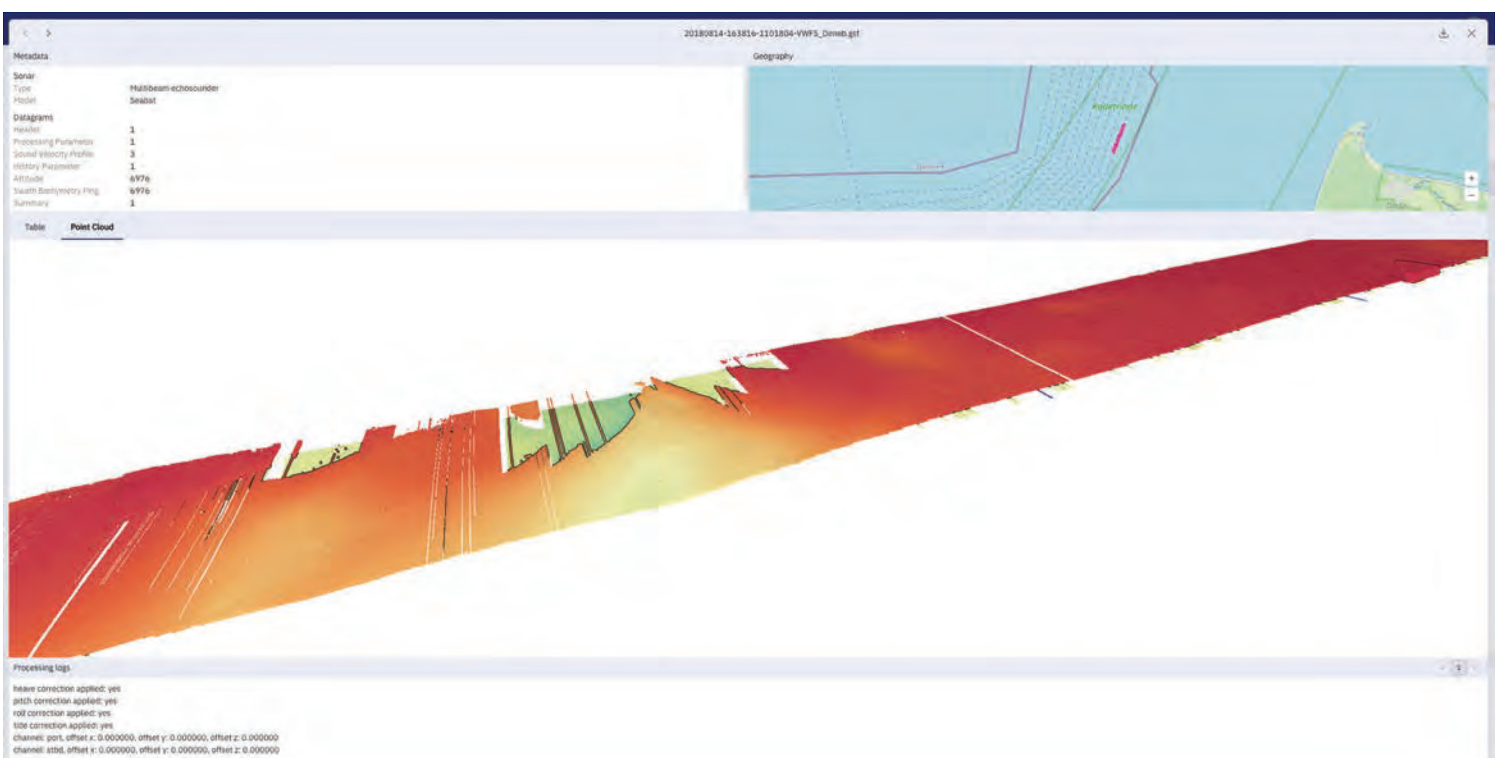
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THE NEXT STAGE OF EVOLUTION AT SEA: AUTONOMY & AI

New technologies such as autonomous surface and underwater vehicles, artificial intelligence (AI) and smarter hydroacoustic systems promise to further accelerate and streamline marine surveying. Subsea Europe Services GmbH, also based around Hamburg is heavily involved in these areas, with an ultimate goal of providing solutions that enable the cost of marine data to reduce to such a level that survey companies can go out and acquire it without a client commission, and only charge when it's required.

Managing director Sören Themann soon wants to send out entire swarms of autonomous vehicles to carry out even complex measurement campaigns without risk to human crews and at significantly lower costs: "These swarms can be launched and serviced from larger autonomous ships or from any manned vessel. We have successfully tested the use of autonomous sonar drones in combination with manned 'mother ships' and can cover a larger area and collect high-quality data faster under different conditions. The concept works," says Themann.

The ability to operate several vehicles simultaneously with a mother ship at the center of the network represents a paradigm shift in offshore surveying, says the marine geologist and economist: "In the future, the use of small, flexible and autonomous vehicles will reduce the cost per data package to such an extent that we will be able to carry out surveys when conditions are optimal - even without a prior client order. This has the potential to fundamentally change the way end users look at buying and using marine data."

Specialists such as Nicola Offshore and Subsea Europe are continually optimizing the physical side of data acquisition. But the data itself and the way it is handled also offer great potential for innovation in the maritime sector.

A CLOUD PLATFORM FOR THE OCEANS

The five oceans of the world may all be connected, but the data of maritime industries is not. Their owners lock data away in private silos and on local servers. The exchange is done cumbersomely over land, not infrequently still by sending hard disks by post.

One reason is the confusion of proprietary and outdated data formats and IT systems. Many techniques and methods for processing and analyzing data date back to the 20th century.

TrueOcean is filling this gap: the start-up from Kiel's Science Park, just a stone's throw from the Unicampus, has built a cloud just for marine survey data. The platform offers industry-specific tools to store and manage sensor and metadata and share it with approved partners internally, and if desired, externally. The aim is to dissolve data silos in an organisation and make marine survey data available on one platform, without the need to licence expensive, data format specific software for every single user or stakeholder.

There is still no standard format for different sensor data, said Frithjof Hennemann, managing director of TrueOcean: "A multibeam echo sounder from manufacturer X stores its raw data in a different format than the echo sounder from competitor Y."

Some measurement data is still stored in formats that were developed decades ago for storage on magnetic tape drives. "Reading out each format requires its own special software, which costs additional licence fees and bloats the local IT," says the lawyer and economist.

This also makes the use of non-industry cloud platforms uneconomical. Here, maritime customers first have to laboriously download their data back to local systems for each processing step because the proprietary software programs are only available there. But every data transfer on a public cloud costs money.

And dealing with maritime data is also demanding and unwieldy on the content level, as Subsea Europe Services founder Sören Themann knows: "When we record the coordinates of a measuring point in the sea, for example, the altitude relative to a local reference point is relevant in addition to the geographical longitude and latitude. But since the Earth is not an ideal rotational ellipsoid, but has humps and dents, every thorough measurement requires a local correction factor, the so-called 'datum'."

For an error-free and uniform database, therefore, even today highly paid experts have to manually reconcile and prepare raw and metadata. Such processes cannot be automated, not to mention the subsequent analysis of the data - at least until now.

Because the TrueOcean Cloud creates a uniform database for the first time by converting all raw sensor data into a universal open-source format. This not only makes expensive special software for reading out the data superfluous. Processes for quality control and refinement of raw sensor data can be automated and also simplify subsequent analysis with AI algorithms.

Soon, the start-up also wants to offer specialised applications for analysing the data directly on its platform. "Customers will then be able to book analysis modules as software as a service, for example generic statistics modules, visualisation filters or interactive maps with geolocations, all the way to complex, AI-based procedures that become more and more powerful as the data volume and quality grows and are also transferable to other use cases," says Hennemann. The TrueOcean CEO and his colleagues already have their sights set on the next development step.

Jann Wendt, TrueOcean

Prof Sandkuhl, University of Rostock

Rainer Straeter, IONOS

THE OCEANS BECOME A DATA SPACE

TrueOcean's cloud is embedded in the future European data ecosystem Gaia-X. "This will also allow our customers to connect external clouds and data sources to our platform via interfaces, without compromising on data sovereignty and user-friendliness," says Hennemann. The compatibility with the emerging European data infrastructure offers customers even greater cooperation opportunities with project and business partners for their data, adds Hennemann.

The idea behind Gaia-X is for cloud providers and data owners to join forces in data rooms. Here, user companies can combine cloud services at will and exchange data securely and sovereignly according to European rules and data protection standards. Unlike today's cloud market, the ecosystem is intended to provide transparency and comparability in the actual service attributes of each offering: such as the location of the data, accessibility by external personnel, permitted data use by third parties, certification level according to existing standards or the applicable legal framework.

Europe's largest cloud provider IONOS SE is one of the founding members and drivers of Gaia-X. The IT company from Montabaur also supplies the physical infrastructure for the TrueOcean cloud. Rainer Sträter, who is responsible for the cloud business at IONOS SE and played a major role in the Gaia-X standards, wants to improve the economic efficiency of digital processes through industry-wide data rooms: "Without common rules, a company has to define the exchange of data, its use and conformity with applicable data protection rules bilaterally in a contract with each individual cooperation partner. This creates an insane amount of work and drives up the costs of digital cooperation. Gaia-X creates for the first time a universally valid framework for the entire European Union."

The initiators of Gaia-X include IT service providers, as well as user companies from fourteen sectors, NGOs, research institutions and associations from all over Europe. Together with the Gaia-X organisations, they are gathering requirements, developing technical concepts, including the reference architecture for Gaia-X and basic services for the data economy in the EU and beyond.

MAKING MARINE DATA A PRODUCT

The federal element in Gaia-X is typical for Europe. This is because the data spaces are organised along themes, value chains and sectors. The pilot projects for the maritime data space, for example, are running under the name Smart Maritime Sensor Data Space X, or Marispace-X for short. The founding members include cloud provider IONOS, TrueOcean and north.io.

The project participants are developing rules and procedures for the secure and trustworthy handling of data in a maritime data ecosystem. "We want to make maritime data usable, refine it partly already on site, i.e., under water and at sea, and link it securely with data from other sources. To this end, we are working out and defining the requirements of our industry and bringing them into the design of a European cloud ecosystem," says Jann Wendt, initiator of Marispace-X.

Marispace-X comprises four application-oriented pilot projects that are being driven forward together with various partners: "We are looking at the management of underwater data for offshore wind farms, the data-based and AI-supported search for old munitions in the North Sea and Baltic Sea, the optimised cultivation of seagrass meadows as a natural CO2 store, and even the Internet of Underwater Things (IoUT)," says Wendt. Wendt does not yet know what new business models will result from a maritime data space: "This is a learning process: Marispace-X creates the conditions for sharing data with each other in a sovereign manner in the first place. In this way, the maritime players get to talk to each other and find out together how their data can be utilised when it is no longer locked away in their own treasure chests."

Professor Dr Kurt Sandkuhl has been researching digital business models for years. The holder of the Chair of Business Informatics at the University of Rostock sees data spaces and a European ecosystem of data spaces as a prerequisite for digital business models to develop on a broad scale at all: "Silicon Valley relies heavily on monopolies when it comes to creating value from data. The alternative is an open ecosystem in which data owners share their information and market it to third parties. This also gives start-ups and SMEs the chance to build digital business models in cooperation with others. Especially in niches like the maritime sector, this approach offers opportunities for innovation."

According to Sandkuhl, the entry into data-based business models triggers an evolution in the affected industries: Companies would have to find their role in the newly emerging data markets. "Like farmers, cooperatives, dairies and traders in the dairy industry, new roles are forming in data-based markets for data collectors, data refiners as well as data brokers. Companies will blend their data with that of trusted partners to distil more valuable products," says Sandkuhl. In the end, he says, there has to be a place where supply and demand come together. "How else do I know who is offering relevant data in the first place?" asks Sandkuhl.

But work is already underway on this development step as well: In the long term, Frithjof Hennemann plans to expand the TrueOcean cloud into a marketplace for data products. Driven by the offshore wind industry's rapidly growing demand for more efficient data solutions, maritime start-ups are transforming the role of digital data from cost driver to catalyst for new business opportunities.

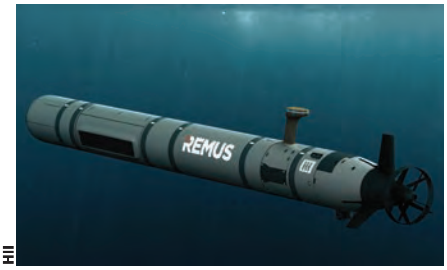
Innovative new products, technologies and concepts

BOREAS D70

Advanced Navigation debuts the Boreas D70, a fiber-optic gyroscope (FOG) inertial navigation system (INS). According to the manufacturer, the technology is well suited to surveying, mapping, and navigation across subsea, marine, land and air applications. Boreas D70 combines closed-loop DFOG and accelerometer technologies with a dual antenna RTK GNSS receiver. These are coupled with Advanced Navigation's AI based fusion algorithm to deliver accurate and precise navigation. The system features ultra-fast gyro compassing, acquiring and maintaining an accurate heading under the most demanding conditions. While D70 does contain a GNSS receiver, it's not required for gyrocompass operation.

Based on DFOG technology, D70 delivers a 40% reduction in size, weight, power and cost (SWaP-C), when compared to systems of similar performance.

- 0.01° roll and pitch
- 0.1° secant latitude heading (gyrocompass)
- 0.01° /hour bias instability
- 10mm position accuracy



HII

REMUS 620 UUV

HII's Mission Technologies division debuted a new medium-class unmanned underwater vehicle (UUV): REMUS 620, sporting a battery life of up to 110 hours and a range of 275 nautical miles. Built to support current and next-generation naval and special operations forces operations, REMUS 620 features a modular, open architecture design to facilitate seamless payload integration and HII's Odyssey suite of advanced autonomy solutions for intelligent, robotic platforms.

REMUS 620 is the same size and weight of the first and only full-rate production medium UUVs: the MK 18 Mod 2, Littoral Battleship Sensing-Autonomous Undersea Vehicle (LBS-AUV) and LBS-Razorback systems operated by the U.S. Navy's Mine Countermeasure Squadrons, U.S. Naval Oceanographic Office and Submarine Forces, respectively. Multiple REMUS 620s operating collaboratively can be deployed from submarines, small manned or unmanned boats, amphibious ships, surface combatants and helicopters. REMUS 620 can also be used as a platform to launch and operate other unmanned vehicles or payloads from beneath the sea.

ISS360HD Sonar

According to Impact Subsea, the ISS360HD offers a 1° acoustic angular resolution, 2.5mm range resolution and a distance measurement range in excess of 100 m/328 ft. The sonar is depth rated to 6,000 m/19,685 ft. The manufacturer said the ISS360HD has a wide operational acoustic bandwidth capability; 600 to 900kHz which is fully used through CHIRP (Compressed High Intensity Radar Pulse) technology, designed to provide a resolution of 2.5mm when using the full bandwidth.

A narrow acoustic beam, combined with a very short range resolution allows for high definition imagery.

While designed to provide big imaging results, the form factor of the sonar has been kept compact, small enough the company claims for even the smallest of observation class ROVs.

The ISS360HD also benefits from an inductively coupled transducer. This means there are no slip rings within the sonar – so there are no components to wear out and require periodic replacement.

Glosten © 2021 MBARI

Sonardyne's Ranger 2 USBL

Monterey Bay Aquarium Research Institute (MBARI) selected Sonardyne's deepwater positioning tech for 50-m long R/V David Packard, its new scientific flagship. Once operational, the ship will accommodate up to 18 researchers and will enable MBARI's continued exploration of the deep sea, from the midnight zone to the abyssal seafloor. The R/V David Packard will be the command center for the ROV Doc Ricketts, MBARI's deep-diving remotely operated vehicle. The new research vessel will also be capable of deploying a variety of autonomous underwater vehicles (AUVs). Underpinning this deep-water capability will be Sonardyne's Ranger 2 Ultra-Short BaseLine (USBL) system, with an HPT 7000 transceiver, which will be integrated into the vessel via a Sonardyne deployment machine. The ship, designed by Glosten, is being built at the Freire Shipyard in Vigo, Spain.

“World First” Resident Subsea Contract

What is being called ‘the world’s first resident subsea contract’ has been awarded to Modus by Equinor Energy for the autonomous deployment of a Saab Sabertooth underwater robot, which will remain docked on the seabed between tasks. The Saab Sabertooth will remain at a subsea docking station for charging and data transfer between missions at the Johan Sverdrup oil field, Norway. Over-the-horizon mission management will come from Modus’ Command and Control Center at its UK head office. A key challenge was achieving, while underwater, millimeter precision tasking from a remote location. This was achieved by circumventing latency with Saab’s iCON intelligent control system. The 3000m rated Sabertooth was seen by UTF as achieving a world first after proving the potential for marine autonomous systems to take a greater role in underwater inspection, repair and maintenance methodologies. Modus sees the project demonstrating the major benefits of resident underwater intervention drones.

SEA-KIT International

Zero Emission Hydrogen USV Design

SEA-KIT International secured funding through Round 2 of the Clean Maritime Demonstration Competition (CMDC) to design a hydrogen powered, zero emission Uncrewed Surface Vessel (USV). SEA-KIT worked with Bramble Energy on a CMDC Round 1 project to marinize a Printed Circuit Board (PCB) Hydrogen Fuel Cell. This latest funding win will see the two companies continue their collaboration, implementing Round 1 outputs into a proof-of-concept USV design that meets the performance, reliability and cost saving challenges of a fast-growing, global marine autonomy market – with zero carbon emissions. The ‘Zero Emission H-Class Ocean USV’ project, scheduled to start in January 2023, represents a significant step towards the commercialization of clean fuel vessel technology.

Bureaucracy

The Biggest Barrier to Advancing the Ocean is Bureaucracy – Let's Fix it Now

By Rear Admiral (ret.) Tim Gallaudet, PhD & Commander (ret.) Victor Vescovo

The U.S. government is the world leader in advancing the world's oceans. Whether scientific study, protection, conservation, restoration, or sustainable use, the U.S. sets the gold standard in preventing and responding to the many causes of environmental degradation in the sea. At the vanguard of federal agencies contributing to this worthy effort is the National Oceanic and Atmospheric Administration (NOAA). Between 2017 - 2021, the authors led or partnered with NOAA in efforts to map and explore the ocean, clean up marine debris, conserve and restore coral reefs, expand existing and add new Marine Protected Areas (MPAs), combat illegal fishing, sign international ocean conservation agreements, and advance ocean science and technology.

Furthering such scientific pursuits was the purpose behind an agreement between NOAA and Caladan Oceanic, LLC signed by the authors in 2020. The first year of the collaboration yielded extraordinary results, such as the survey of over 1 million square kilometers of previously unmapped seafloor which directly supported the 2020 U.S. national strategy and plan to map, explore and characterize the U.S. exclusive economic zone (EEZ). This included the mapping of the Aleutian Trench for the first time and making the most precise depth measurement of Challenger Deep in the Marianas Trench, the deepest point in the world's ocean through a series of eighteen dives there over three years, nine times more than the only previous descents in 1960 and 2012.

These accomplishments gave us confidence that NOAA would welcome another audacious exploration effort by Caladan. To mark the 80th anniversary of the Battle of Midway in June of this year, Caladan proposed diving in the Papahanaumokuakea National Monument using the record-setting Deep Submergence Vehicle (DSV) Limiting Factor to image the aircraft carrier wrecks sunk during the famous World War II naval battle. The monument is the final resting place for the USS Yorktown, as well as the Imperial Japanese Navy (IJN) ships Akagi, Hiryu, Soryu, and Kaga. Documenting underwater cultural heritage (e.g. shipwrecks) in MPAs is an active NOAA mission that both authors have conducted.

One can only imagine the disbelief we felt when NOAA disapproved Caladan's permit request. The issue stemmed from the 2016 proclamation by President Obama that prohibited "… placing, or abandoning any structure, material, or other matter on the submerged lands…" in the monument. The cause of the permit denial was that Caladan intended to discharge two to four tons of steel ballast in the monument required to safely operate the DSV Limiting Factor.

Even greater than our disbelief was our disappointment. Midway is the site of one of the U.S. Navy's finest hours where it turned the tide of the War in the Pacific through a remarkable combination of raw courage, superior strategy, and game-changing intelligence. The media attention that the expedition was expected to generate would have been fitting for such a monumental milestone in our nation's history.

The Japanese government also showed support, approving four media personnel from the Japanese National Broadcaster NHK to document the dives and recognize the thousands of fallen IJN sailors with a wreath-laying ceremony. Considering China's increasing assertiveness in the Indo-Pacific region, such a visible reinforcement of the U.S.-Japan alliance would have been a powerful postscript on President Biden's visit to Tokyo in May.

We believe that several mechanisms could have led to our permit's approval. First, another clause in Obama's proclamation provides an exception for scientific instruments left on the seaflor. Acknowledging that the DSV Limiting Factor is one of the greatest deep-sea scientific instruments ever constructed, NOAA could have considered ballast weights as a necessary "leave-behind" part of the scientific system.

Another section states "…this proclamation shall not restrict scientific exploration or research activities by or for the Secretaries" (Secretaries of Commerce and Interior, with NOAA acting on behalf of Commerce). Thus, NOAA could have simply characterized the expedition as scientific exploration under the 2020 Caladan-NOAA agreement.

Lastly, we point out that before the 2016 proclamation, the regulations governing the monument allowed the release of material so long as it causes no injury to the resources of the monument.

The wrecks of Midway lie in the abyssalpelagic zone of the deep ocean where the likelihood of ecological harm from a modest amount of steel ballast would have been near zero. Also, bear in mind that the wrecks themselves measure in the hundreds of thousands of tons of steel. Unfortunately, our permit request was subject to the ambiguous language in the proclamation rather than new implementing regulations because NOAA has failed to update them over the last six years.

The U.S. is not unique in possessing burdensome bureaucracy. In completing 25 global expeditions over 4 years to conduct over 100 dives in seventeen of the world's deepest ocean trenches, Caladan requested 16 permits from 11 countries. Three were not approved outright, and all of these denials came just before the commencement of an expedition resulting in significant financial cost and lost research opportunities.

All permits, even those approved however, faced extraordinary data request burdens and many were only approved shortly before expedition start dates when the risk of expedition abandonment at great cost was very real. The multitude of highly scrutinized approvals needed for marine scientific research, primarily due to extremely detailed environmental reviews of minimally impactful operations, stands in stark contrast to the utter lack of oversight or sanction of commercial vessels that accidentally dump over 1,000 containers a year into the ocean, including into the Papahanaumokuakea National Monument.

Our purpose here is not to criticize environmental regulations or regulators. Rather, we wish to illustrate how inefficient processes, excessive organizational inertia, and a lack of good faith assumptions for established research organizations can stifle innovative and transformational advancements in our ocean understanding.

Most of the world's oceans have yet to be explored. At this time where global geopolitical events tend to generate nothing but troubling and tense headlines, international ocean expeditions like those conducted by Caladan and others like them can give our world good news by casting a light on our undiscovered ocean and serving as sorely needed beacons of hope and unity. Shame on us if we let bureaucracy black them out.

About the Authors

Rear Admiral (ret.) Tim Gallaudet, Ph.D., is a former acting undersecretary and assistant secretary of commerce, Deputy Administrator of NOAA, and oceanographer in the U.S. Navy. He is the CEO of Ocean STL Consulting, LLC and fellow at The Explorer's Club.

Credit Tamara Stubbs-Chip

Commander (ret) Victor Vescovo is a former intelligence officer in the U.S. Navy. He is the owner and chief submersible pilot of Caladan Oceanic, LLC, a co-founder of Insight Equity, and recipient of the 2020 Gold Medal of The Explorer's Club.

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