MARINE TECHNOLOGY REPORTER

January/February 2022
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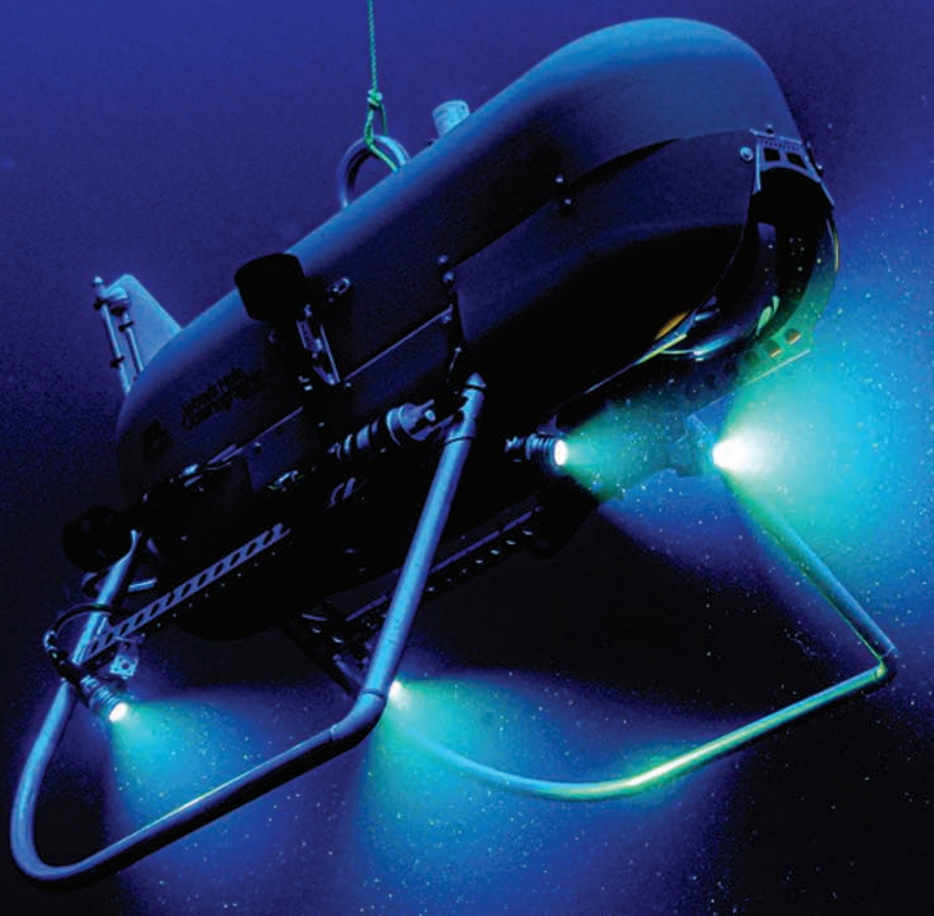

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Volume 65 Number 1


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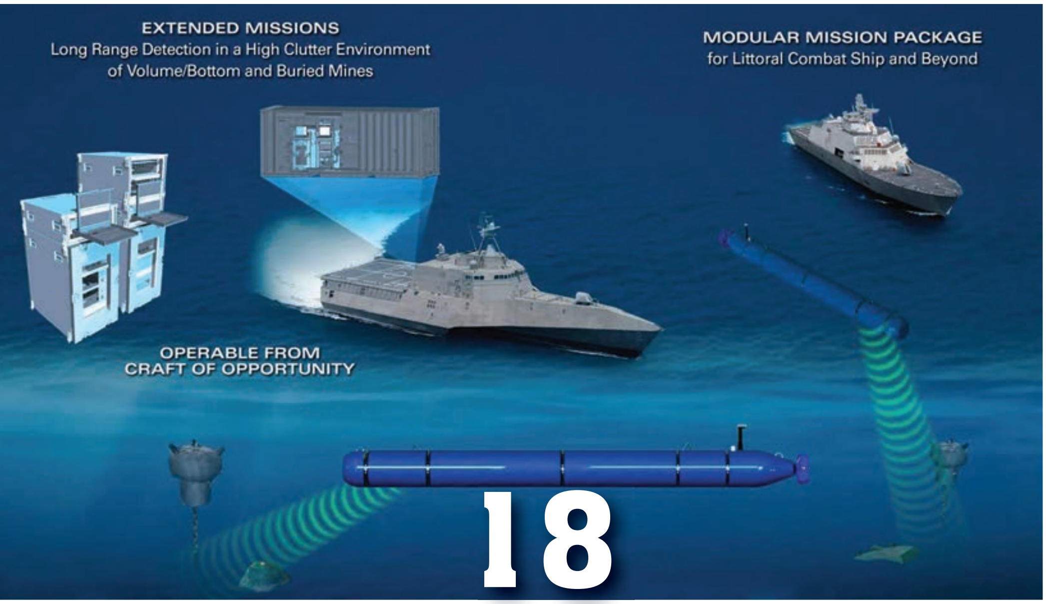

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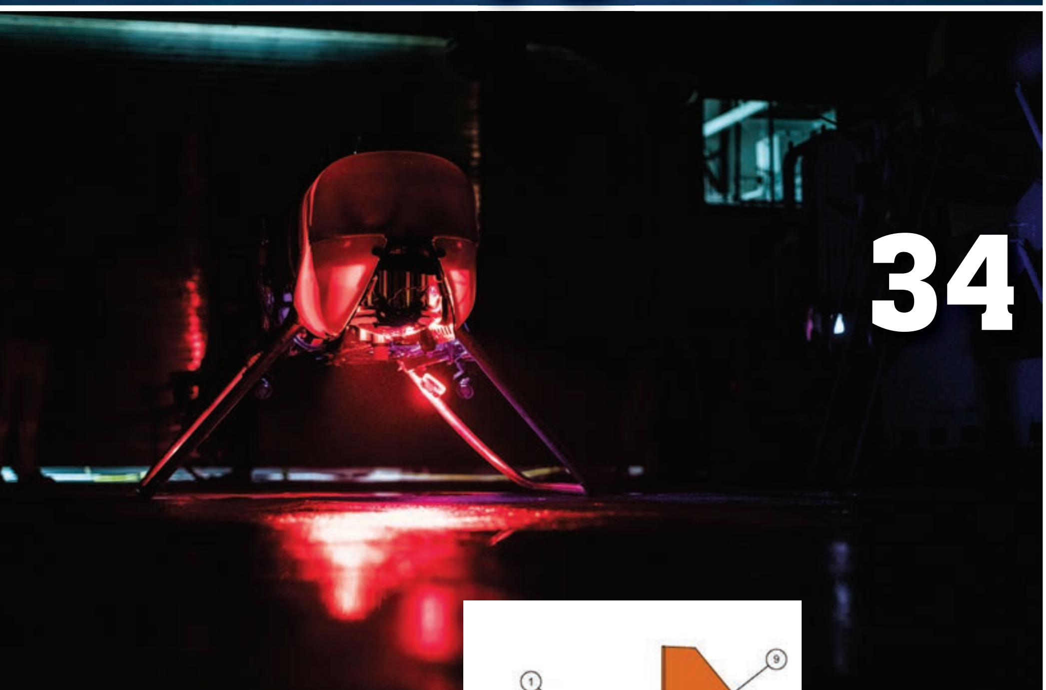

Image by Luis Lamar, courtesy of OceanX Media

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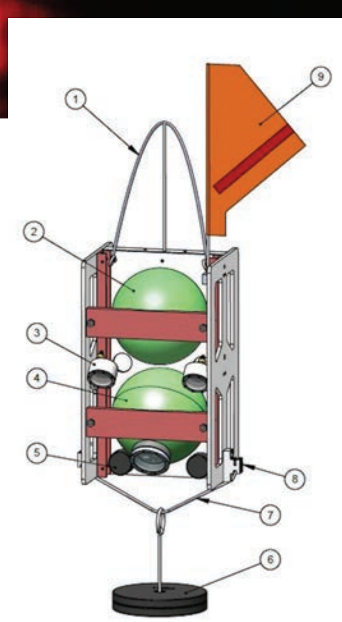

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On the Cover

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Editorial

There is no better way to start 2022 than with our 'Vehicles' focus, and in this regard Elaine Maslin starts us off on the right with her traditional technical insight wrapped in engaging prose with a pair of stories. The first is a revisit with the UK's National Oceanography Center and its Autosub AUV development over a quarter of a century, a program which has effectively introduced and refined many of the technologies that define the AUV market today. Her second story on Woods Hole Oceanographic's Orpheus AUV looks at tomorrow's technology today, with a focus on how the outer space and subsea worlds have become somewhat collaborative in the design, build and outfit of vehicles that are designed to work in and under some of the harshest conditions on this and other planets, surviving, thriving and bringing back new information sets.

This month I am also pleased to begin Kevin Hardy's column on Ocean Lander technologies, an often-overlooked class of unmanned undersea vehicles. The column, *Lander Lab*, starts on page 42 of this edition and is planned to be a regular feature in our pages. A many of you know, Hardy is retired from the Scripps Institution of Oceanography and founder of Global Ocean Design. Working with colleagues globally he has designed and built ocean landers that have dove ocean trenches, abyssal depths and near-shore zones out to the edge of the continental shelf, from large ships and small fishing boats. He will bring that experience to this column to educate and enlighten *MTR* readers to the possibilities of ocean landers in their field of research and enterprise. The column will have elements of history, hacker-maker experimentation, crossover tech, and good seamanship. The column will certainly evolve to include on-line video and open-source design, operational tips from the field, people, useful products from around the world, and input from his fellow 'Landerians.'

Gregory R. Trauthwein
Associate Publisher & Editor

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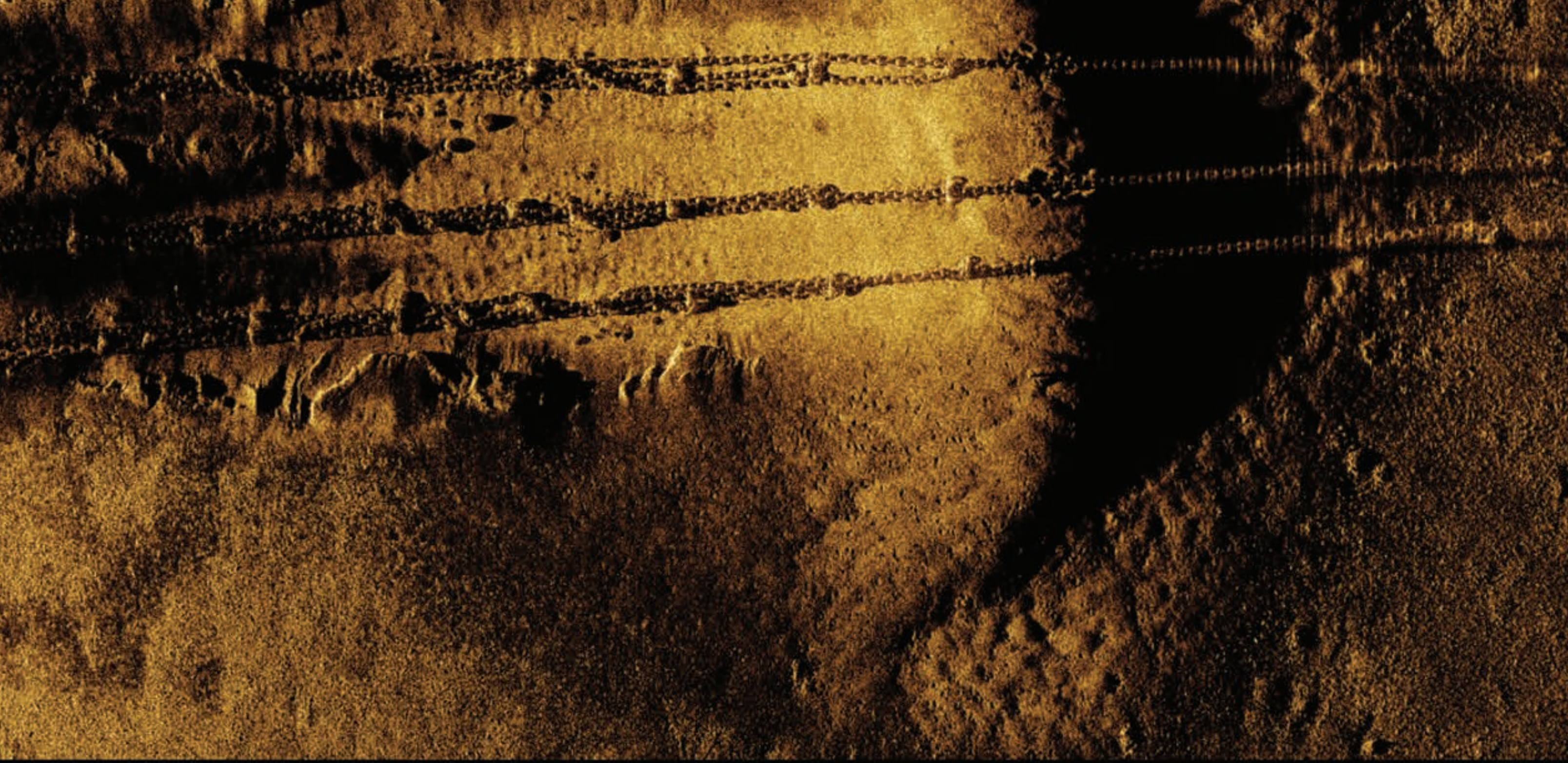

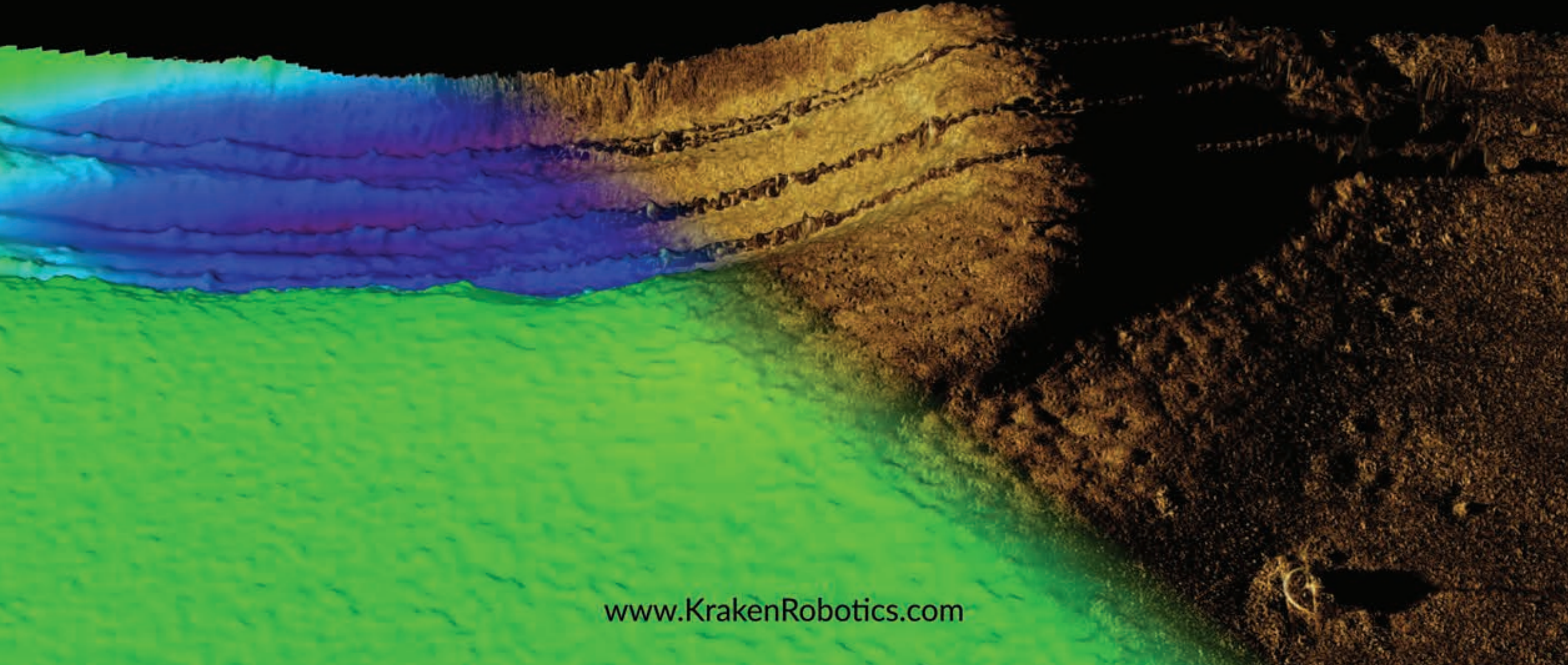
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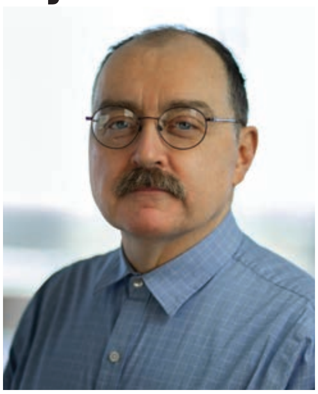

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Konowe

Lewis

Lundquist

Maslin

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Hardy

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ADVANCED NAVIGATION

Offshore Wind Development Gains Speed in the United States

As of the end of January 2022, there were over 45 projects in development representing a $136 billion capital expenditure and $4.4 billion annual OPEX opportunity that are forecast to be brought on stream within this and early in the next decade.

By Philip Lewis, Intelatus Global Partners

What a difference a year makes. This time last year there was still some uncertainty around the federal offshore wind permitting process, the timing of offshore wind projects and certainty for the supply chain.

At the beginning of 2022 the situation is more positive. The final investment decision has been made for a major offshore wind project which has also reached financial close, 12 OCS projects are under final federal permitting review, 17.5 GW of project capacity has secured offtake commitments, 16.5 GW of new federal offshore leasing activity in the northeast, South Atlantic and California is underway, turbine component, foundation, and cable factories are being built in the U.S., awards for at least six Jones Act compliant wind farm support vessels were announced in the last quarter of 2021 and offshore wind port development is accelerating.

Our forecast and report accounts for 55 projects, 46 of which will install 43 GW of capacity in this and the next decade – and will require CAPEX amounting to $136 billion to bring onstream, a recurring annual OPEX of $4.9 billion once delivered, and $19 billion of decommissioning expenditure at the end of commercial operations

These are the findings shared in a recent report on the U.S. offshore wind market in this decade by Intelatus Global Partners (IGP).

The report examines the latest developments likely to drive offshore wind project development in the U.S. within this decade, forecasts the number, CAPEX, OPEX and timing of projects, and provides a roadmap to understanding and accessing these market opportunities.

Exhibit 1 CAPEX, *Annual OPEX and DECEX Forecast by Final Investment Decision Timing*

Forecast ($ billion)	GW	CAPEX	OPEX/yr	DECEX
FID made	0.8	3.0	0.1	0.4
0-18 months	0.1	0.5	0.0	0.1
18-36 months	17.5	61.1	1.8	7.9
36-60 months	11.1	34.0	1.1	5.0
Over 60 months	13.7	36.8	1.4	6.2
Total	43.2	135.5	4.4	19.4

Source: Intelatus Global Partners

So, what has changed?

The excitement surrounding U.S. wind is founded on two power supply and demand drivers. On the supply side, federal leases containing over 20 GW of project capacity have been awarded – the last in early 2019. And more federal leasing is underway. On the demand side eight Northeast and Mid-Atlantic states have established offshore wind procurement targets and/or procured offshore wind capacity from developers operating federal offshore wind leases. Two Pacific coast states are also working through the process to establish offshore wind goals.

But those with a long memory of U.S. wind will remember the false dawn of the Cape Wind project. Initially proposed in 2001, Cape Wind secured the first commercial offshore renewable energy lease in the United States in 2010. The project's construction and operations plan (COP) was approved initially by federal authorities in 2010 and revisions further approved in 2014. However, in the face of objections to the wind farm, Cape Wind relinquished the lease in 2017.

In 2021, three things changed and have created a more solid foundation for the U.S. offshore wind industry.

The first piece of the jigsaw was the

White House initiative released in March 2021 to "catalyze offshore wind energy, strengthen the domestic supply chain, and create good-paying, union jobs". The White House program included an offshore wind deployment target of 30 GW by 2030 and an aspiration to achieve 110 GW of offshore wind by 2050. The practical upshot is that developers and tier one suppliers, most with European wind industry backgrounds, have the visibility of demand needed to make domestic U.S. investments – including key component factories and port developments. This in turn will create employment opportunities for "tens of thousands of workers."

Secondly, Federal agencies, led by the Bureau of Ocean Energy Management (BOEM), have shown a renewed impetus to progress offshore wind projects.

The 800 MW Vineyard Wind project was approved in July 2021 and reached financial close in September 2021. The project has broken ground, components are being manufactured, first power is expected in 2023 and the project will be fully commissioned in 2024. BOEM has approved the environmental impact assessment of a second wind farm, the 132 MW South Fork wind project and expects to complete final permitting of the project in January of this year.

Exhibit 2 shows the clear pathway to project capacity permitting by the month and year when BOEM expects all permitting to be complete. Most project capacity will be fully commissioned three to four years after final permitting.

The Department of the Interior has confirmed that BOEM will potentially hold up to seven new offshore lease sales by 2025. The first auction consists of six New York Bight leases. Other leasing will be held for sites in the North and South Atlantic, the Pacific and the Gulf of Mexico. This sets a clear foundation for long-term offshore wind activity in the U.S.

The third piece of the jigsaw is linked to state procurements and new federal leasing requirements– in simple terms developers must commit to significant supply chain infrastructure investment and make good on these commitments. As a result, developers are executing investments in offshore wind manufacturing and port infrastructure that were agreed as part of the capacity awards with the states. Further, the current New York Bight federal leasing contains domestic supply chain development incentives aligned to the supply chain development activities of New York and New Jersey. In its March 2021 statement, the White House targeted "one to two new U.S. factories for each major windfarm component including wind turbine nacelles, blades, towers, foundations, and subsea cables". At the time this seemed somewhat optimistic, yet through state procurement requirements multiple key component factories are now being built and will provide ongoing opportunities to the domestic supply chain.

One piece of the jigsaw is missing – Jones Act Vessels

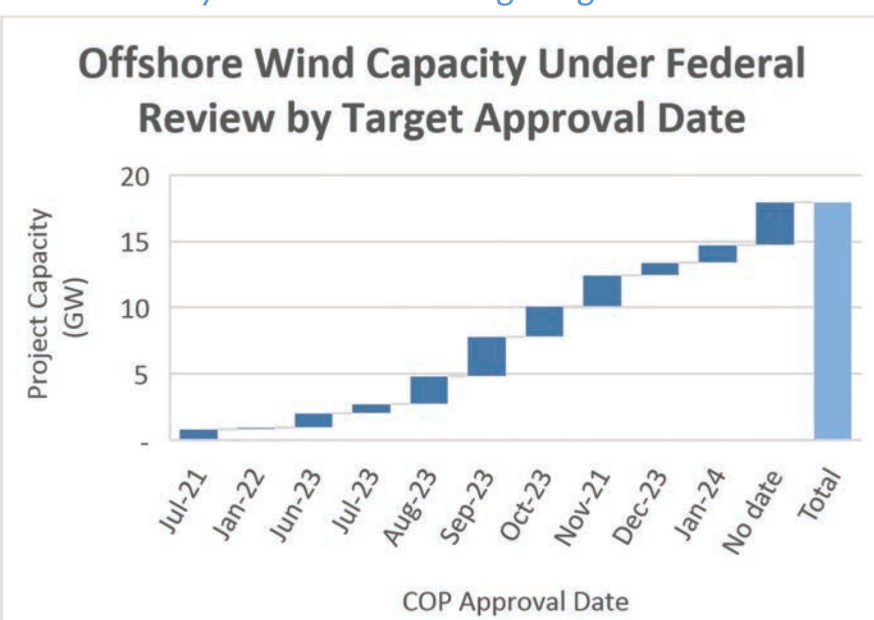
In the March 2021 White House statement on offshore wind, one ambition was to achieve "the construction of 4 to 6 specialized turbine installation vessels in U.S. shipyards, each representing an investment between $250 and $500 million." Achievement of this goal is currently behind plan.

Till now only one Jones Act wind turbine installation vessel has been committed and is under construction – owned by Dominion Energy and under construction at Keppel Brownsville. Without additional domestic supply, developers will need to secure installation vessels from the international market – as Vineyard Wind has done for its project. However, although international supply of wind turbine installation vessels is growing, supply will be stretched in the global market around the middle of the decade – at the same time U.S. offshore wind installation activity is expected to peak.

Recently, Great Lakes Dredge & Docks announced that it is moving ahead with the construction of the first Jones Act compliant wind farm scour protection/rock installation vessel. The Ulstein designed vessel is being built at Philly Shipyards and is due to be delivered in late 2024. Great Lakes Dredge & Dock and Philly Shipyard have agreed an option for a second vessel to be declared at a later date.

One would expect there to be a signifi-

***Exhibit 2** U.S. Offshore Wind Capacity by BOEM Permitting Target Date*



Source: Intelatus Global Partners

cant amount of construction of service operations vessels (SOVs) and crew transfer vessels (CTVs). Both are used in the long-term operations and maintenance phase of a wind farm and will need to be Jones Act compliant. Till now one SOV has been announced as under construction – although the indications are that others are in the pipeline. In the CTV segment, three vessels, owned by Atlantic Wind Transfers and WindServe, are already operating on the Block Island wind farm and the Coastal Virginia Demonstration project. Five CTV awards have been announced recently awarded to two yards -- Blount Boats and Gladding Hearn shipbuilding. Despite the building activity, the domestic supply and SOVs and CTVs is significantly below our forecast for demand.

Floating Wind Advances

Many eyes are attracted to the potential of California's offshore floating wind potential, with BOEM expected to auction two areas for development in 2022. But four floating wind projects are already currently being progressed in the Atlantic and Pacific – three in state waters and two in Federal waters.

Floating wind requires a different supply chain approach to the bottom-fixed of the current northeast and Mid-Atlantic pipeline.

First moves are being made on port infrastructure, but little movement has been made on the Jones Act vessels required to install floating wind projects – supply of the asset classes required in limited presenting a construction opportunity for domestic yards.

For more information about the U.S. Offshore Wind Market Forecast, please visit ***www.intelatus.com*** or contact Michael Kozlowski at +1 561-733-2477or Philip Lewis at +44 203-966-2492

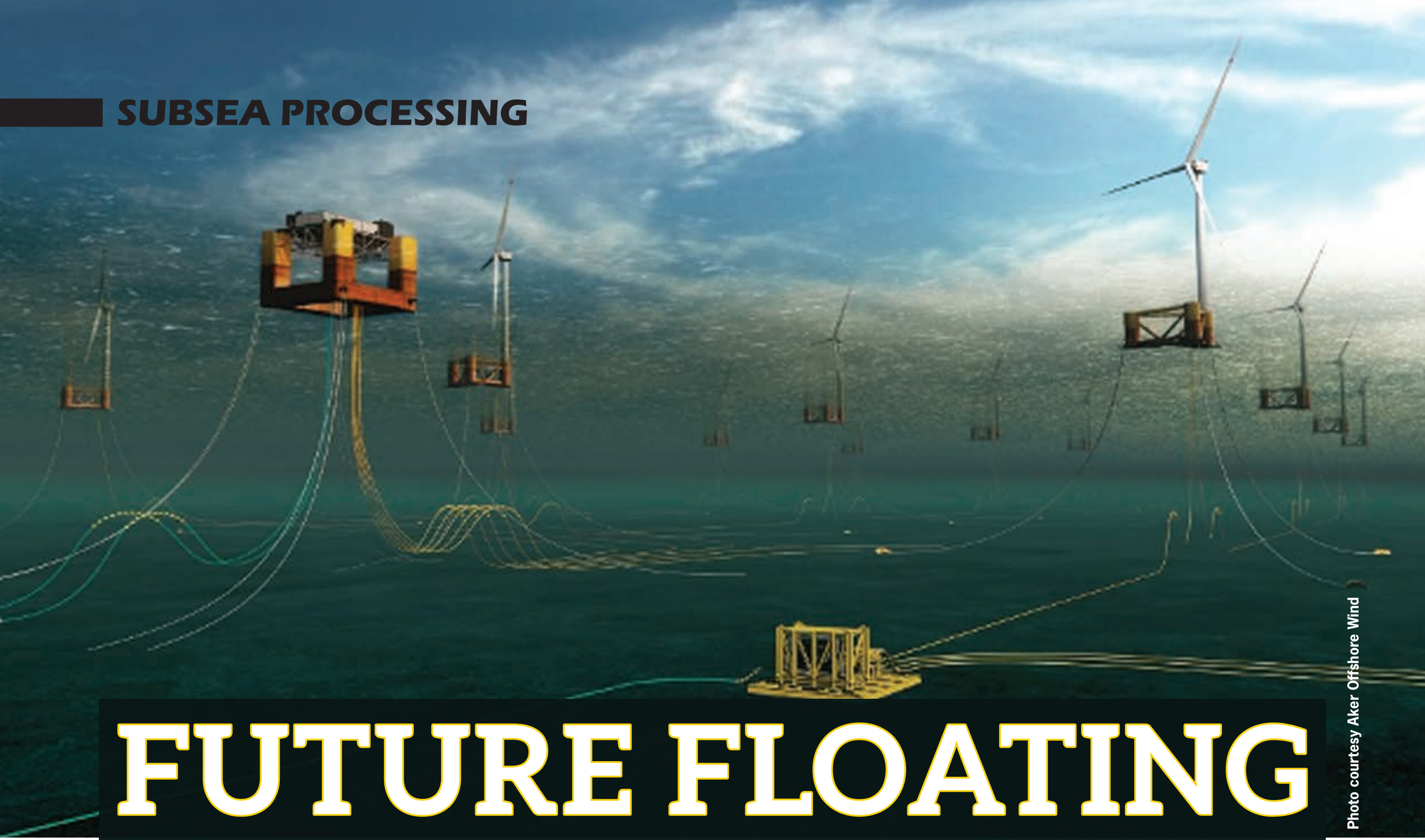


Photo courtesy Aker Offshore Wind

FUTURE FLOATING POWERHOUSES

From being an ugly duckling, floating offshore wind is now the Cinderella of the offshore renewables world. Attention is now being paid to floating and even subsea substation concepts to help bring this power to shore. ***Elaine Maslin reports.***

Over the past year, expectations around the growth in the floating offshore wind development have grown, significantly. Many are piling into the market, seeing that it could give them a chance to ramp up renewables capacity quickly, with 15MW turbines on the horizon and the possibility of GW-scale projects looming by the end of the decade.

Much has been said about the different floating turbine concepts. However, there's also thought going into floating and seabed substations, to help corral and then boost the voltage of the power to a level useful enough to export it to where it's needed.

Consultant Justin Jones at engineering firm Petrofac says: "Floating wind farms are going to be a major contributor to the carbon free energy mix, initially close to shore, within 20-30km, but the next stage will be significantly bigger in scale and in deeper water. Once you go to 100m water depth, it's expected that floating substations will be used to collect, convert and transmit high voltage power to shore because, at those water depths, fixed structures will become relatively large and heavy. Because of the increased wave load, they will need a bigger footprint and the natural period of the structure and fatigue become more important."

For countries like Japan and the US west coast, where depths drop to 700 – 900m quickly, floating will be a necessity, if they want to build out offshore wind at scale. In fact, Japan has already trialed a small, 25MVA, 1,00-tonne floating transformer at the Fukushima Forward project. Installed in 2013, a decision was recently taken to decommission the structure – a sort of spar – over the profitability of running it and the three demonstration turbines it collected power from.

Others are looking at floating concepts, too, such as Newfoundland and Labrador, where there's been a study into these types of structure for offshore wind. Meanwhile, subsea substations are also being proposed, including for the current ScotWind floating offshore wind round. Some of those working on concepts are building on their experience from the oil and gas industry where transformers, seabed and topsides, have been developed and delivered for the oil and gas industry for some time.

Kenneth Simonsen, SVP for Offshore Wind, at Aker Solutions says its floating substation design is focused on serving wind farms ranging from 250MW to 1.3GW and 220KV, and is based on the standardized building blocks it's developed and proven in oil and gas. "The simple hull is based on our design for the Blind Faith (Aker Kværner designed semisubmersible production) platform that has been in operation for over a decade (in the US Gulf of Mexico), and the Njord platform (semisubmersible, built at Kværner Stord and installed in 1997), which we've used as a reference for the flat top deck, has been operating for 20 years," he says, with HV electrical equipment from an original equipment manufacturer whose systems have been proven in an operating environment. The design will likely be fairly similar, but may, for example, require more enclosures in the North Sea, compared to more temperate locations like the Mediterranean or western US.

In 2018, power and automation group ABB said it had joined French floating wind foundation designer Ideol and STX Europe Offshore Energy to develop a floating substation design. The idea was being developed under a research and development project called Optiflot, which also involved French industrial process firm SNEF, and was based on Ideol's damping pool concept. In June this year, BW Ideol (having had BW Offshore as a shareholder since February 2021) said it was working with Hitachi ABB Power Grids on "scalable floating substations", using Ideol's shallow-draft floating platforms. BW Ideol said this collaboration follows the Optiflot project, which had now completed. ABB wasn't able to provide an update.

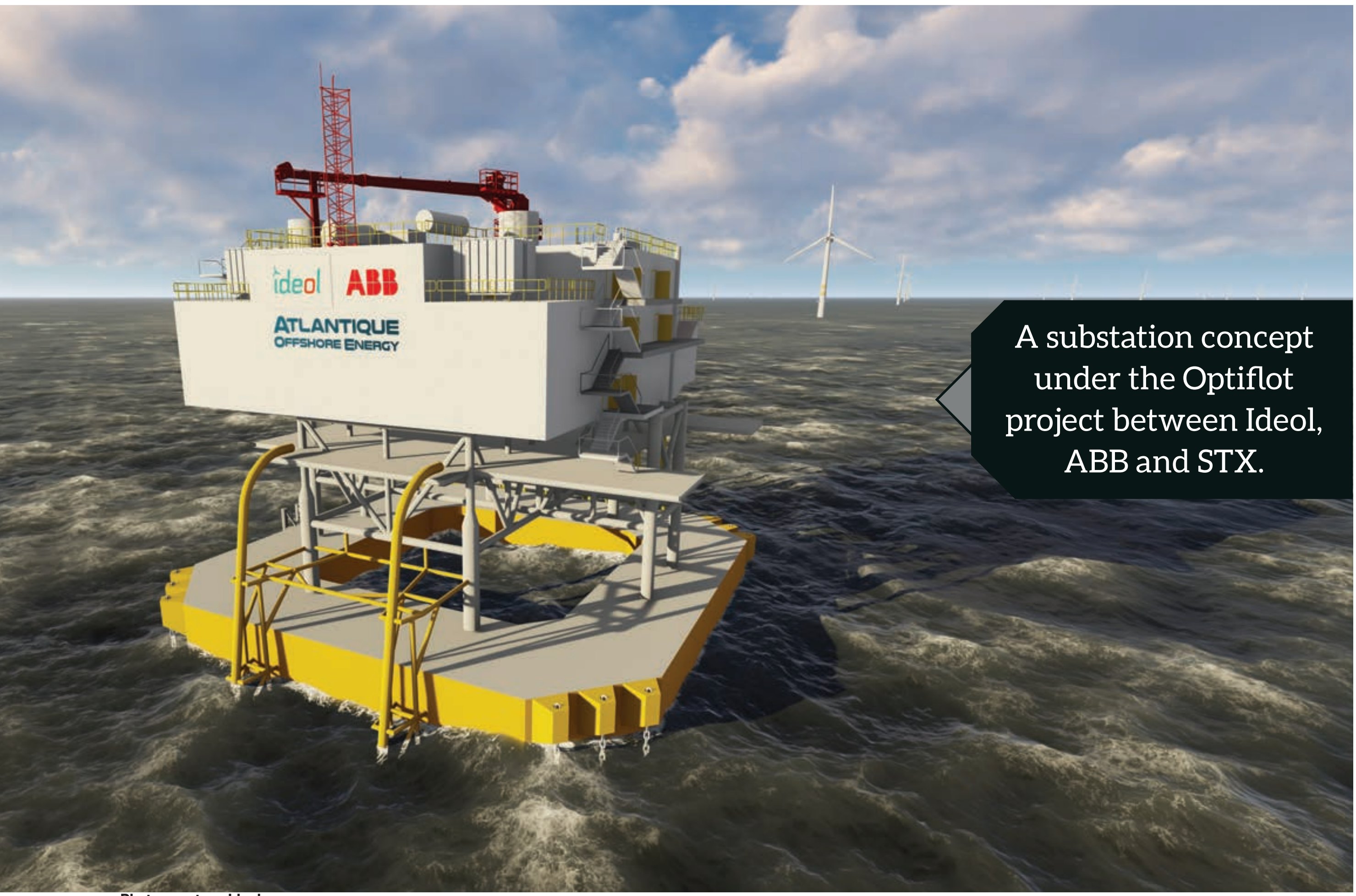
Earlier this year, construction engineering company Linxon and its parent companies Hitachi ABB Power Grids and SNC-Lavalin/Atkins partnered to "make floating substations for offshore wind a reality". Daewoo Shipbuilding & Marine Engineering and Korea Electric Power Technology Company have also said they're working on offerings for the floating offshore wind substation market for both deep and shallow waters.

Petrofac has been doing some detailed work on floating substation concepts. As projects scale up from 250MW pilot scale projects to GW-scale farms, and from high voltage AC to DC transformers, Jones says there will be different design requirements. For pilot projects, HVAC will be used. As projects ramp up to gigawatt scale far from shore, they will need HVDC substations. For HVDC projects, floaters will be larger, because DC takes up more space, due to more equipment and the requirement to keep the high voltage DC equipment adequately separated. They are also sensitive to accelerations, so a semisubmersible is a good solution, says Jones. "A deep spar could be a problem when you need that topside mass and footprint. There are other options, such as a tension leg platform (TLP), but it would need a similar hull size to the Hutton TLP."

For an HDVC solution, Jones said you'd be looking at a 66m x 70m footprint, on a four-column semisubmersible with a stressed-skin topsides, for strength and stiffness. In fact, this is just the type of structure – in the form of drilling rigs or floating production units – that's been laid up in the downturn and could potentially be converted, subject to many caveats, not least related to fatigue, but it's feasible, says Jones.

HVAC substations have a smaller footprint and are lighter weight than HVDC for the same capacity, which makes semisubmersibles less attractive; they're only really optimal once the structure has a topside footprint above 50m by 50m, says Jones.

For GW-scale projects Petrofac came up with a deep-draft semisubmersible design, giving low motion, but retaining shallow draught for transportation and maintenance, with a minimal braced topside structure. "The design has the added advantage that the cable outlet is well below the water surface, giving reduced cable fatigue," he says. The first projects with substations may have a capacity closer to 250MW, connect-



A substation concept under the Optiflot project between Ideol, ABB and STX.

Photo courtesy Ideol

ing 20-25 turbines. "Our concept for a pilot-scale substation is a minimum structure TLP facility, which has a really quite efficient weight structure, and good motion vertically, but increased cost of moorings. The early commercial HVAC substation projects will need some innovative thinking to achieve the most efficient design," he says.

The dynamic export cable is a critical element that will be needed to get the power from a floating structure to shore. These cables, at about 300 mm diameter at 220kV or more, will need a low fatigue environment and currently no cables exist that could do the job. Jones thinks there are solutions within the oil and gas industry that could fit the bill. But even then, floaters would need to be designed by the requirement to minimize the fatigue loading on the cable, he says. "You may want to pay, up front, higher capex to have a design in which the cable motion, and therefore cable fatigue, is lower to reduce the likelihood of cable failure over the 25-year life," he says. "You might want to go for a deeper, lower motion floater and have the cable outlet lower beneath the surface, where wave loads are lower."

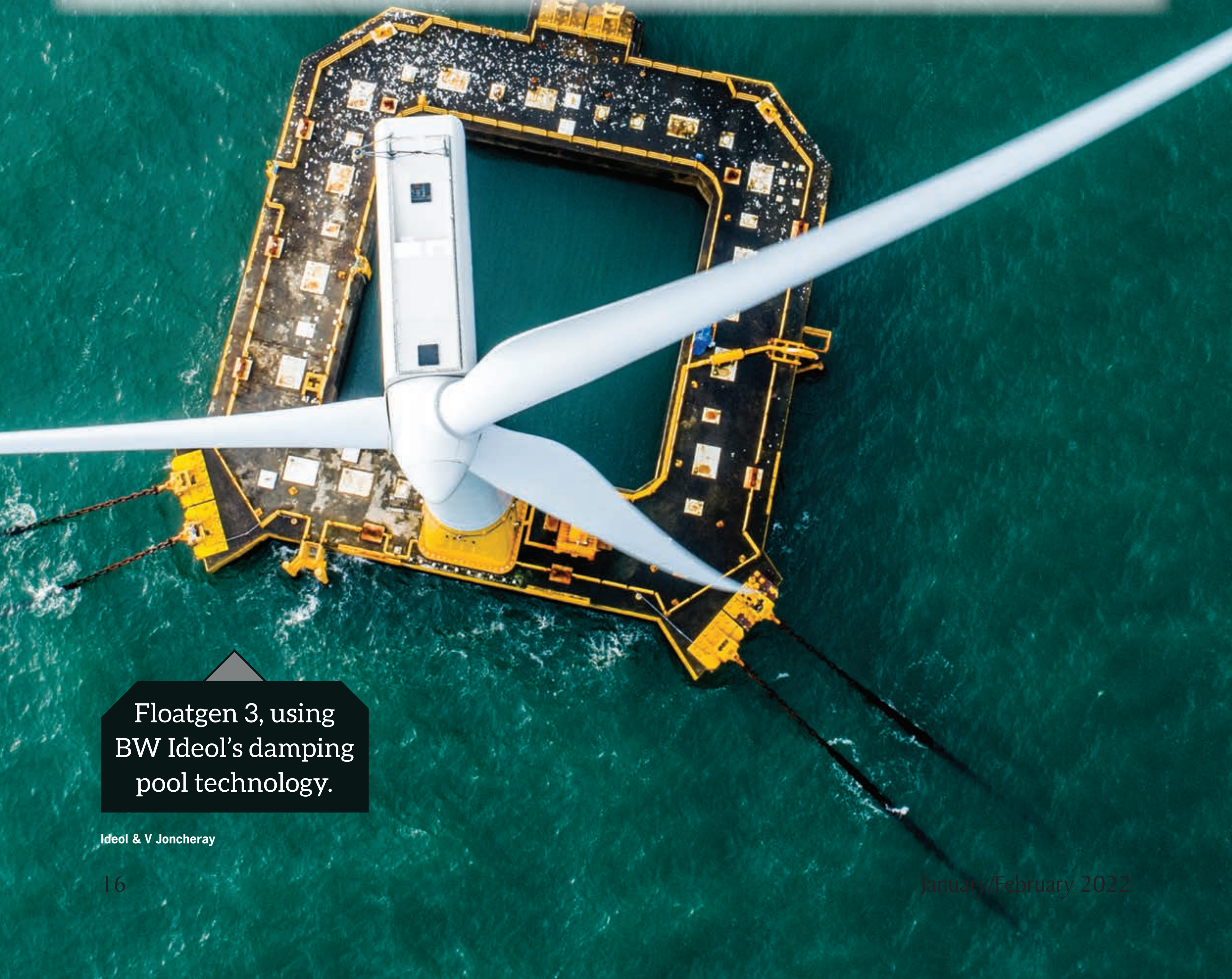
Kristin Nergaard Berg,
Senior Principal Consultant and JIP Project Manager, DNV

Collaborating to set industry standards

DNV is hoping to launch a joint industry project to align best practice in this space so that technology development can happen and scale-up faster. The organization says there's a standard for offshore substations (DNV-ST-0145), but that with a trend towards floating wind, it wanted to develop rules for floating substations.

More than 20 companies took part in an initial workshop and 29 partners are now interested, with kick off is expected in Q1 2022. "The whole value chain from developers, technology suppliers, sub-suppliers, integrators and infrastructure owners are on the list," says Kristin Nergaard Berg, Senior Principal Consultant and JIP Project Manager. "The core scope is on design and qualification of new technology, getting the right design and qualification requirements into the standards to reduce risk of taking these systems into use. We expect to see the main gaps related to HV power equipment and dynamic cables, but there may also be other areas we need to address."

While much of the equipment is the same, there are differences between floating and fixed substations that need to be considered. "The main difference is the movement and accelerations of the floater, combined with the high-capacity specifications the power equipment will see, and the dynamic capabilities required of the cable, combined with high voltage," says Berg. "There are experiences to build on from power equipment onboard ships, but not to the specifications required for this equipment. There are also experiences for dynamic power cables from oil and gas, but this is limited compared to what we need in order to take floating substations into use, and for both AC and DC applications. Smaller projects may require less of the equipment and as such represent less of a technical gap. Some floating wind farms may even be able to use bottom-fixed substations, when the water is not too deep. However, for big commercial windfarms in deep waters and far from shore you need a substation of high capacity – either floating or subsea."



Floatgen 3, using BW Ideol's damping pool technology.

Ideol & V Joncheray

Going subsea

Others are developing subsea substation solutions, which wouldn't need dynamic export cables. ABB unveiled its subsea power system back in 2019. While developed to meet oil and gas requirements, they also saw its applicability to offshore wind. The 100 MW capacity, 3000m water depth system comprises of a subsea transformer, switchgear and subsea power distribution up to 600km. This year ABB added offshore wind to an agreement it has with Aker Solutions around seabed solutions, while Aker Solutions has unveiled a subsea substation concept for floating wind.

Egil Birkmore, VP, HV infrastructure, Renewables, Aker Solutions, says, "Subsea transformers have been used since the 1990s, with no failures to date, and it means we don't need dynamic export cables." Putting the transformer subsea could be 50-70% less capex compared with putting it in on a semi-submersible, he says, but this isn't a one size fits all solution – there are sweet spots, depending on water depth and how much power needs to be transmitted, he says. There's also an opportunity to share infrastructure with oil and gas facilities, electrifying existing facilities, which could allow a phased approach to wind farm development. ABB and Kellas Infrastructure Partners are working on this idea, Birkmore says.

Developer Aker Offshore Wind has said it will deploy a subsea substation if it wins its ScotWind bids – a major licensing round in Scotland, the winners of which will be announced next year. Leif Holst - SVP Projects - Aker Offshore Wind says, "It's an innovation we're taking from the energy sector and applying to offshore wind." He says having it on the seabed has a number of benefits, including using the natural cooling offered by the seawater, having it entirely unmanned and easier to maintain. "This is an area we've seen where we can push the LCOE down further and where we have technology in the (Aker) group that we can leverage," he says.

However, depending on the water depth, these might face challenges, i.e. very deep waters with long power cables will challenge economics, says Ralph Torr, program manager, at the UK's Offshore Renewable Energy (ORE) Catapult.

What you can't see can hurt you

Getting to the bottom of mine warfare's top challenge

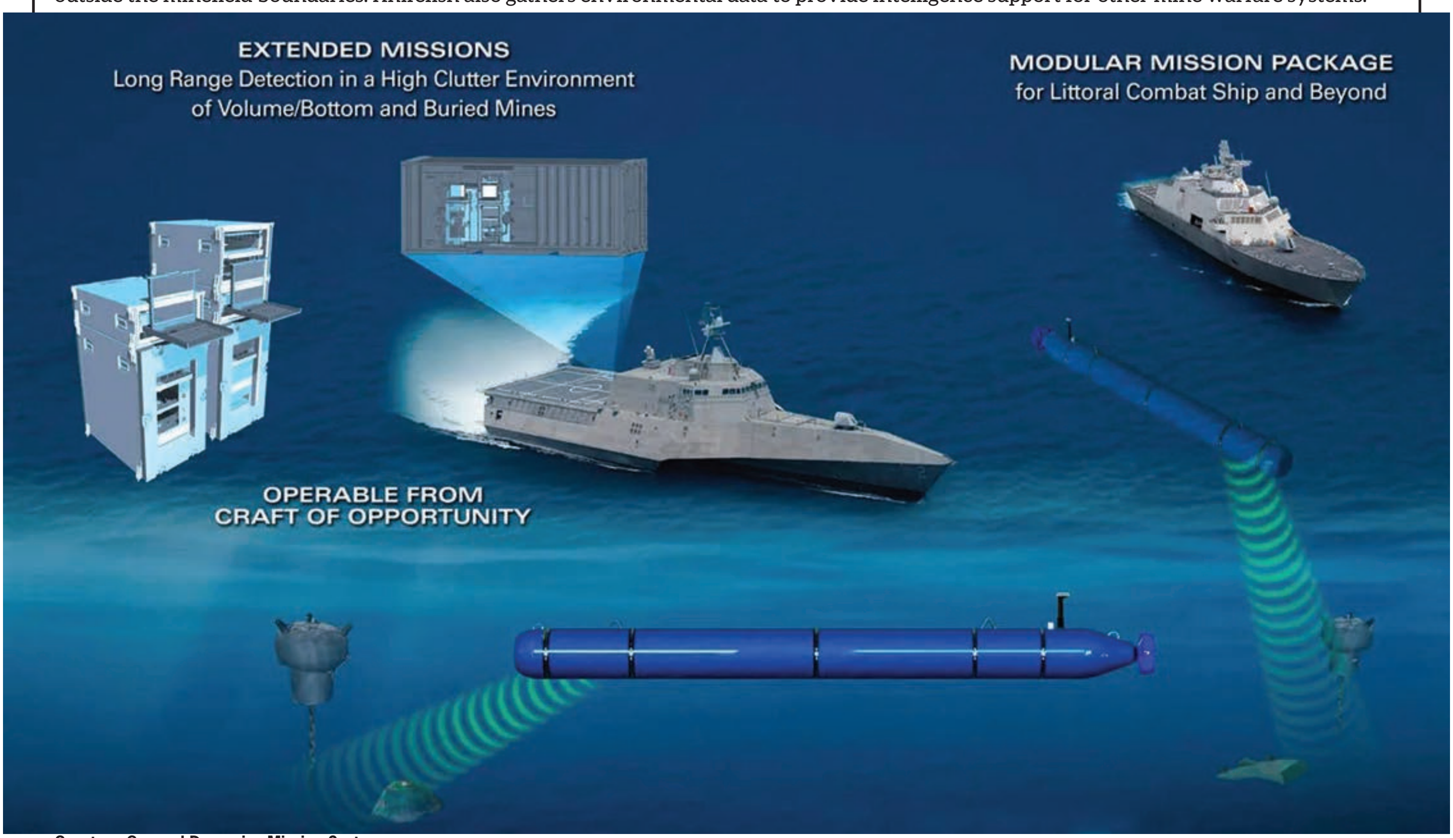
To find the mine warfare challenge with the highest degree of difficulty, start at the bottom.

By Edward Lundquist

Lurking unseen below the surface, naval mines pose a serious problem. They're cheap, relatively easy to deploy and can inflict heavy damage against even the most sophisticated warships. They can be hard to detect and difficult to counter. What you can't see can hurt you. And the most difficult mines to find and eliminate are bottom and buried mines.

Navies have developed ships to hunt for mines in the water column so they can be avoided or destroyed, use influence sweeps to detonate them; or cut their moorings so they surface and can be destroyed. Aircraft can also tow systems to find or induce mines to detonate. Unmanned systems can help find mines in the water column or see objects on the bottom that

The General Dynamics Mission Systems Bluefin Robotics Knifefish UUV detects, classifies and identifies volume, proud and buried mines in high-clutter underwater environments, and is a critical element of the LCS Mine Countermeasure (MCM) mission package. Knifefish's job is to detect, avoid and identify mine threats, reducing the risk to personnel by operating in the minefield as an off-board sensor while the host ship stays outside the minefield boundaries. Knifefish also gathers environmental data to provide intelligence support for other mine warfare systems.



Courtesy General Dynamics Mission Systems might be mines. But seeing mines that are flush with or buried under the sea floor takes sophisticated technology. Unmanned underwater vehicles (UUVs) can perform this mission, but they must be vehicles with the right combination of power, propulsion, sensors, data collection and analytics that can help a trained operator with the right tools can find those mines with a high degree of confidence.

Even if one suspects the presence of buried or bottom mines, searching for them is likely to be a lengthy process. Vehicles must be stable, with excellent position keeping so the location of any mine like objects detected can be accurately marked for further investigation, neutralization or avoidance. The vehicle may have to conduct prolonged and methodical search patterns, and that may require a vehicle with a lot of power and endurance, which translates to a lot of batteries, and thus a bigger vehicle for those larger search areas. The size of the vehicle also has bearing on the size of the sensor package, although sophisticated sensors are becoming smaller and smaller, and can also fit on smaller vehicles. Vehicles must be recovered and recharged or batteries swapped out. Some UUVs are fully flooded, with the payloads and batteries in small, pressurized modules. Others are fully pressurized but have to be depressurized before they can be opened and the batteries or hard drives removed. There have been prototypes of underwater fixtures that can download data to be sent back to the mother ship and recharge the batteries, either through induction or a physical connection. This “underwater garage” has to be put in place and is susceptible to environmental factors such as corrosion and bio fouling.

In most cases, vehicles must return to the host platform to have the data storage device physically removed and connected to the computers for processing the data. That means a launch and recovery cycle. Some vehicles can do processing on board, which means less time is required on the host ship. Automatic Target Detection and Recognition (ATF/ATR) and the ability to compare target data with known mines using a library such as the U.S. Navy’s Mine Warfare and Environmental Decision Aids Library (MEDAL), can alert a host platform that a possible mine has been found, and shortening the decision-making cycle required to act on that specific threat. That presupposes that the underwater vehicle can communicate with a surface buoy or surface and send a message by satellite or other means; but, if that’s the case, a launch and recover cycle can be avoided or delayed.

U.S. NAVAL RESEARCH LABORATORY

The Naval Research Laboratory (NRL) is a scientific and engineering command dedicated to research that drives innovative advances for the U.S. Navy and Marine Corps from the seafloor to space and in the information domain. NRL is located in Washington, D.C. with major field sites in Stennis Space Center, Mississippi; Key West, Florida; Monterey, California, and employs approximately 3,000 civilian scientists, engineers and support personnel. **https://www.nrl.navy.mil/**

Penetrating problem

Mines laying on the seabed can be hard to detect among the clutter of rocks, seaweed and waste. "The more objects you detect, the more time you need to make a proper classification," said Cmdr. Herman Lammers of the Royal Netherlands Navy, director of the NATO Naval Mine Warfare Centre of Excellence in Ostend, Belgium.

"Buried mines lie completely under the seabed, are fully covered, and can only be detected with specialized, bottom penetrating sonar systems, or other sophisticated detection systems like magnetic anomaly detection," said Lammers. "For buried mines it is even more difficult, as you have to look into the bottom to detect them. At the moment there are only very few sonar systems that are able to do so," Lammers said. "It's only possible to classify them, but you can't identify them."

"Penetration sonar systems are low-frequency systems and are for the moment quite large to deploy from a ship, or incorporate into a UUV," Lammers said.

Low-Frequency Broadband

The Naval Research Laboratory (NRL) in Washington, D.C. has developed Low-frequency broadband (LFBB), a technology area that exploits the structural acoustics involved with underwater sonar. According to Dr. Brian Houston, Acoustics Division Superintendent at NRL, LFBB can go beyond determining if something is there, it can also determine what it is.

"When you transmit sound, the acoustic return is very different depending on the physical object that is reflecting that acoustic energy. It might be a naturally occurring thing like a rock on the bottom, or something that's man-made, like a mine. In the water column, it might be a submarine versus a whale. What's in the acoustic return is very different for each of those targets.

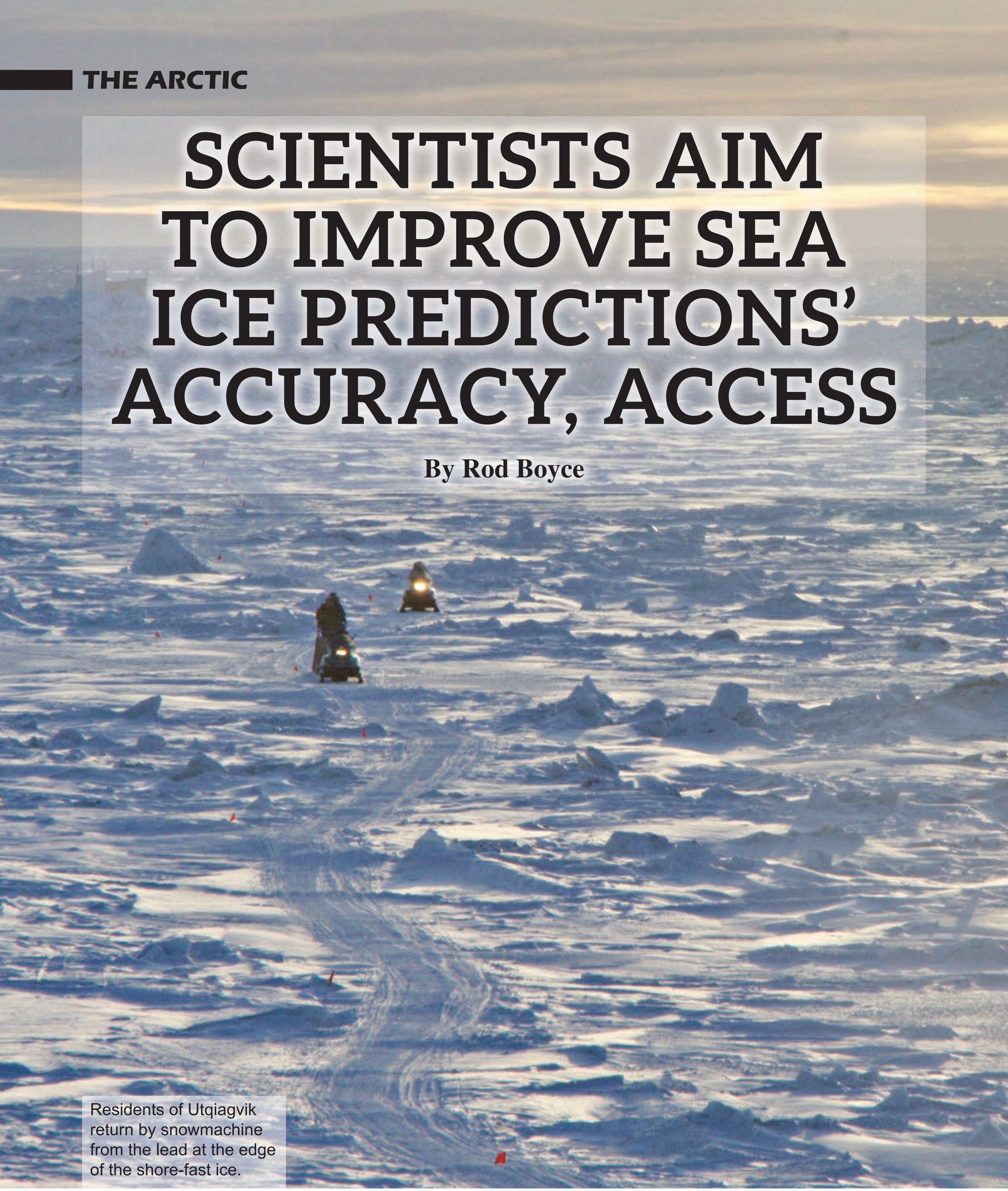
Sonar has traditionally helped us know where something is, how far a way it is, and sometime provides an image. But in addition to bearing and range, we can now determine what it is. That return has specific physics in it that we can exploit, and we can know something about the physical object and based on how it responds.

Houston said LFBB is both a sensor approach as well as the methodical analysis of data. "We are now doing a lot of onboard processing, so we can take the data and process it on board the vehicle to enable autonomy decision making," he said.

The General Dynamics Mission System Knifefish 21-inch UUV uses the LFBB technology and is the only system currently available that is capable of detecting, classifying and identifying buried mines in a high-clutter environment. Knifefish is a program of record and part of the Littoral Combat Ship (LCS) Mine Countermeasures (MCM) Mission Package. According to a Navy statement, The Navy plans to procure 30 Knifefish systems--24 in support of LCS Mine Countermeasure Mission Packages and an additional six systems for deployment from vessels of opportunity.

SCIENTISTS AIM TO IMPROVE SEA ICE PREDICTIONS' ACCURACY, ACCESS

By Rod Boyce



Residents of Utqiagvik return by snowmachine from the lead at the edge of the shore-fast ice.

Photo by Andy Mahoney, UAF Geophysical Institute

Sea ice predictions have improved markedly since the founding of an international forecasting and monitoring network 14 years ago.

"These forecasts are quite encouraging in their increasing accuracy," said Uma Bhatt, an atmospheric sciences professor at the University of Alaska Fairbanks Geophysical Institute. Bhatt spoke about the Sea Ice Prediction Network at the American Geophysical Union's annual meeting last month.

As the amount of sea ice in the Arctic declines, thins and becomes more mobile, accurate forecasts are becoming even more vital for things like fisheries and resource development, shipping, subsistence activities and wildlife management.

Bhatt said the SIPN team hopes to work with the Alaska maritime industry, especially the Bering Sea snow crab fishermen, to make ice forecasts even more accurate and useful to those who work in or live next to the world's polar waters and to scientists studying sea ice decline and the Arctic climate.

The SIPN team plans to enhance sea-ice predictions by including data for sea-ice thickness, surface roughness, melt ponds, and snow depth; involve the public in climate and sea-ice prediction; and evaluate the socioeconomic value of sea ice forecasts.

"The computer models are continually being improved," Bhatt said back in Fairbanks. "That is what researchers do: keep improving their models. The improvements are slow and steady, but you see it once you look at multiple years."

WHAT IS SIPN?

The Sea Ice Prediction Network formed shortly after the then-record Arctic sea ice minimum of 2007.

"That really shocked some scientists and garnered a lot of public attention," Bhatt said.

Sea ice outlook forecasts began the following year and continued through 2013 on minimal funding. The National Science

Foundation began providing financial support in 2014, allowing the eventual inclusion of forecasts for Alaska and Antarctica.

The network uses dozens of forecasts from a global community to provide September sea ice minimum forecasts in June, July, August and, finally, September, usually the month during which sea ice is at its lowest. The network also publishes the current extent for June, July and August.

A new phase, SIPN2, began in 2018 with National Science Foundation support for activities such as an analysis of sea ice maps, more analysis of forecasts and a socioeconomic component.

Bhatt is the project lead and principal investigator for the SIPN2 Project Team, which includes several members of the UAF International Arctic Research Center, including IARC Director Hajo Eicken.

"The sea ice outlook provides a unique opportunity for a diverse group to work together to seek common conclusions about seasonal sea ice forecasting, using multiple models and methods, and currently we're working on the next phase," Bhatt said.

GETTING BETTER

Forecasters have been learning more about sea ice behavior and improving their forecasting. Error percentage decreased notably from August to September in all forecast methods in 2021, the first year that September was included, and should continue to be low in the future, Bhatt said.

Improvement also has occurred in the geographic scope of the forecasts, which for five years have included the Bering, Chukchi and Beaufort seas around Alaska. The data record is short, but the accuracy rate is good.

Sea ice forecasters from around the world don't all use the same prediction model, a fact that has allowed for a comparison of results and methods — and, ultimately, a better forecast.

"Having been part of this effort since the start, it's great to see an international community grow around forecasting," Eicken said. "The work of this team has increasingly focused on how to improve predictions that benefit Alaskans and other local groups in the Arctic."

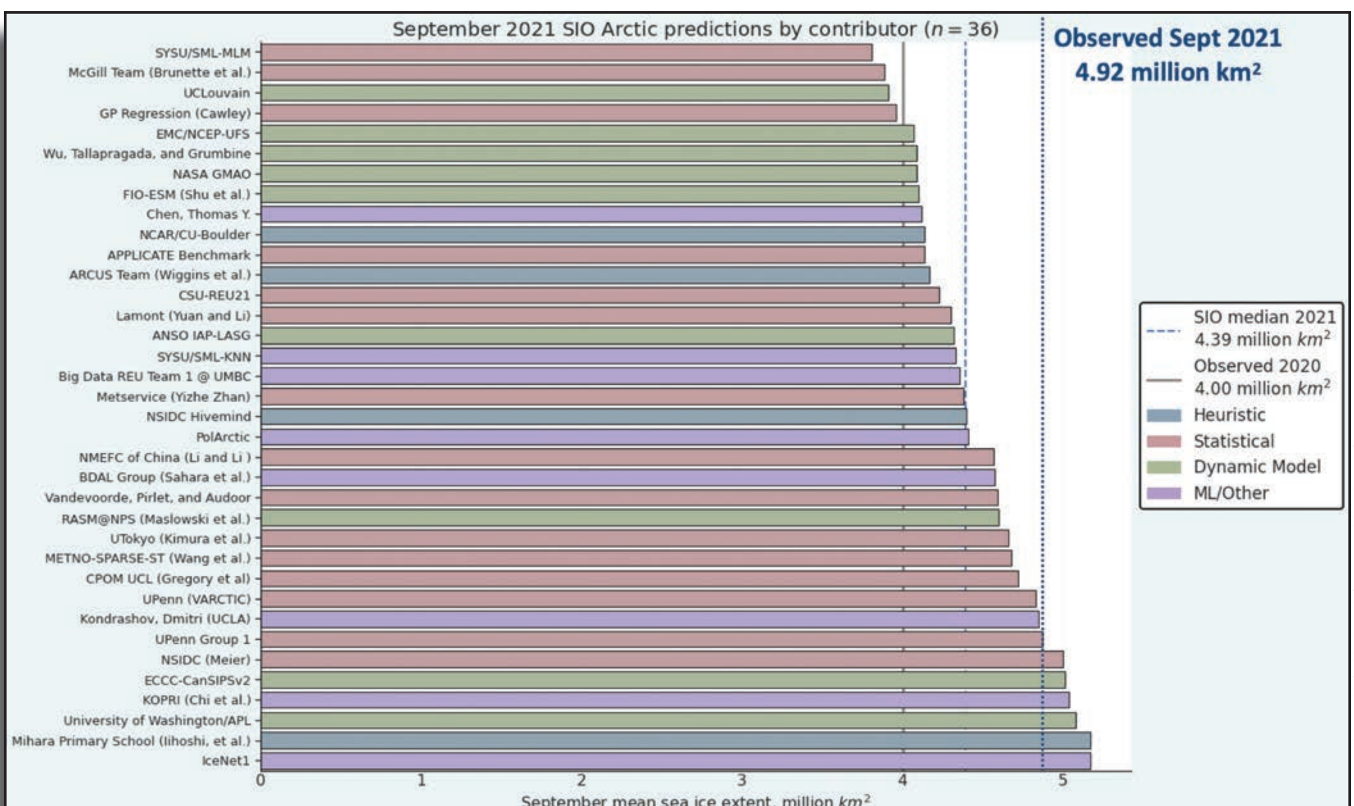
Some puzzles have popped up over the 14 years of the network's existence. For example, the median June forecasts for the coming season correlate best with observations of the previous September. Researchers want to know why.

"So we are very good at forecasting the prior year," Bhatt said, tongue in cheek.

WHAT'S NEXT?

The team may expand its forecasting into the winter months to address the needs of Bering Sea crabbers, a key part of Alaska's multimillion-dollar seafood industry.

Joseph Little, a former economics professor in the UAF College of Business and Security Management and now an



Matthew Fisher, U.S. National Snow and Ice Data Center.


Deformed sea ice tops the coastal waters of the Bering Sea near Toksook Bay on April 20, 2013. Rapid ice drift in the Bering Sea is a hazard for fishing vessels.

Photo by Hajo Eicken, UAF International Arctic Research Center

affiliate research professor at IARC, and others surveyed crabbers. They want information on sea ice location, extent, direction and concentration in winter and spring.

Bhatt said such forecasts would aid safety, route planning, navigation, resupply and fuel purchases.

Forecasters also continue to work with models to improve sea ice outlooks by understanding the influences, for example, of snow on ice and of melt ponds. They will also use a new data portal to look at potential bias such as a prediction being influenced by the observation of the prior year.

"Over the course of 14 years, the Sea Ice Prediction Network has strengthened and developed to highlight common features in seasonal sea ice forecasting," Bhatt said. "SIPN is committed to fostering a network that synthesizes diverse thinking and continues to reduce the gap between sea ice forecasting and stakeholder needs."

Follow this link to Bhatt's AGU presentation: **bit.ly/3G0JeZN**

Diving into the

Autosub 1 on its first ever official mission in Portland Harbour in 1996.

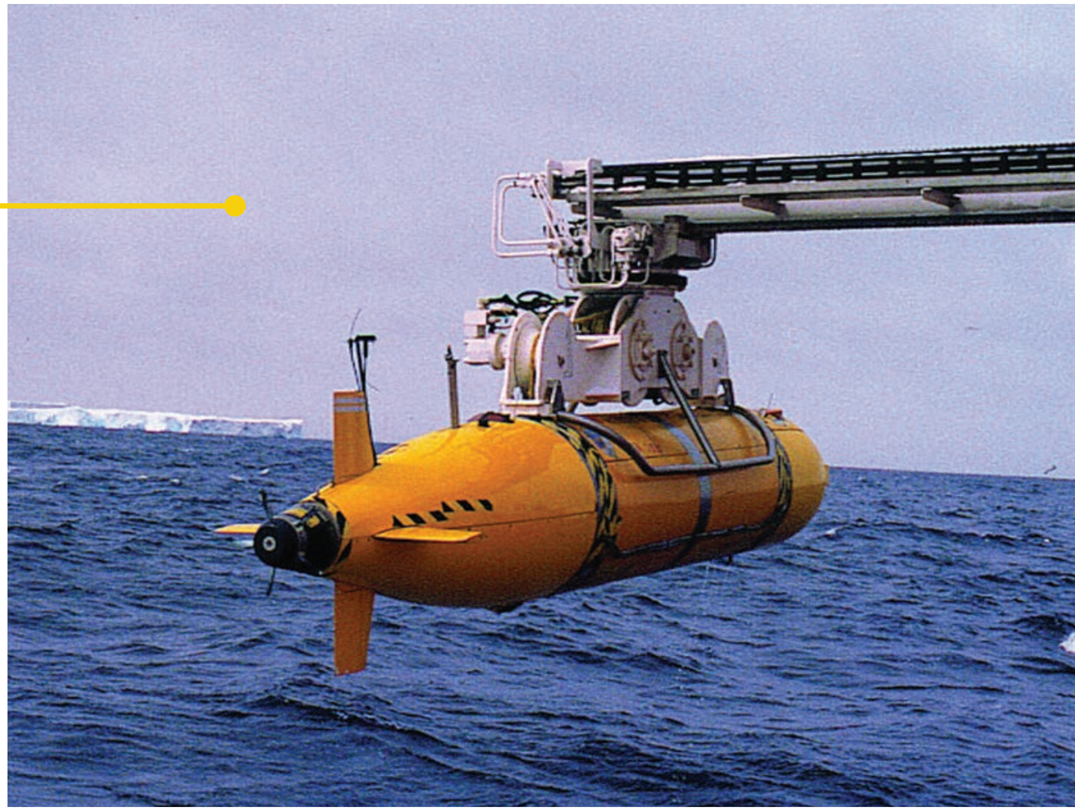
All images from the National Oceanography Center

Autosub Program

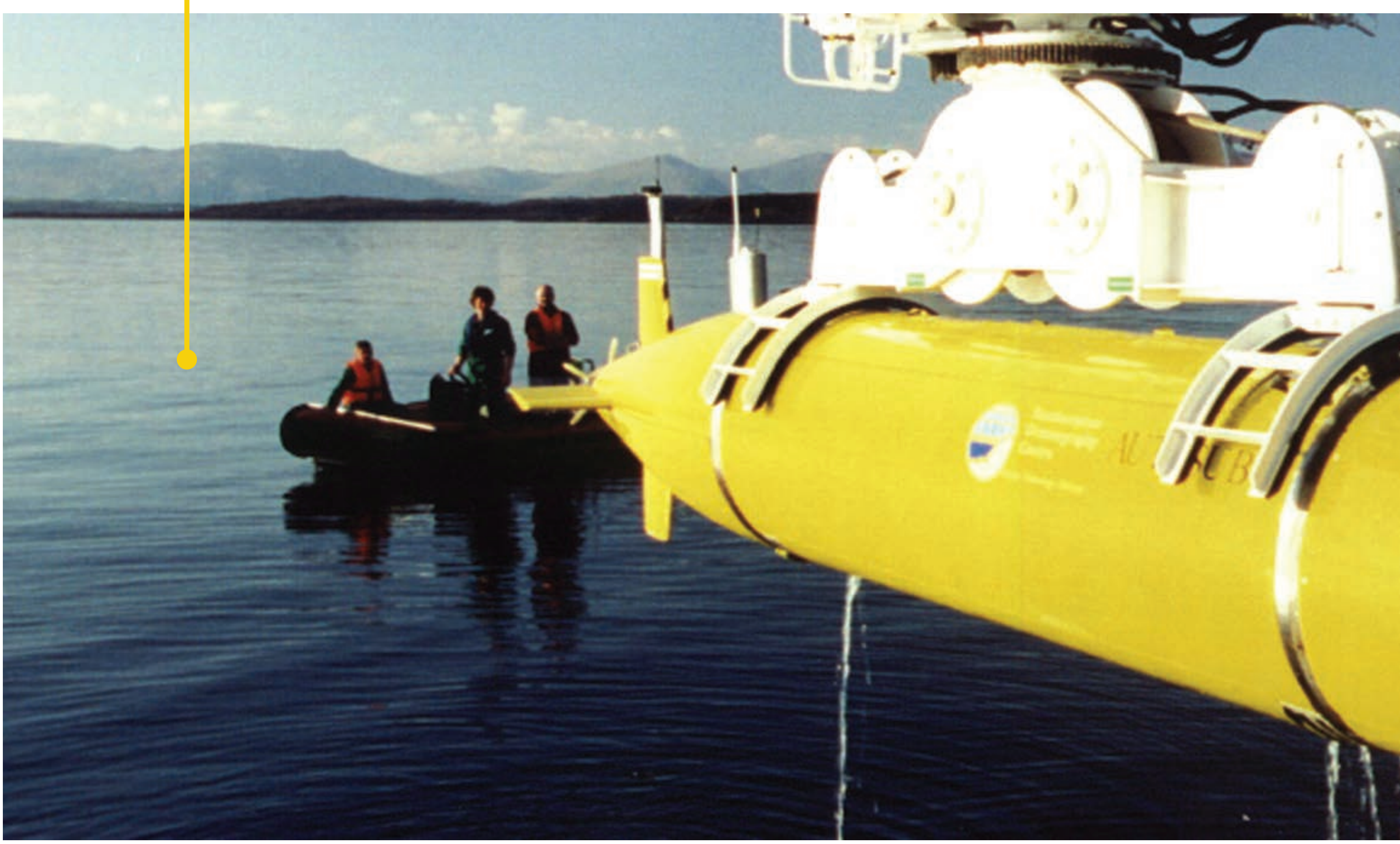
*In our last **MTR**, to mark 25 years of the UK's National Oceanography Centre (NOC) working with AUVs, we talked with Dr. Maaten Furlong, Head of the Marine Autonomous & Robotic Systems Group at NOC, about the organization's history and future plans. Now we take a deep dive into the Autosub program.*

By Elaine Maslin

Operations in 1999, with Autosub 2 in Antarctica.



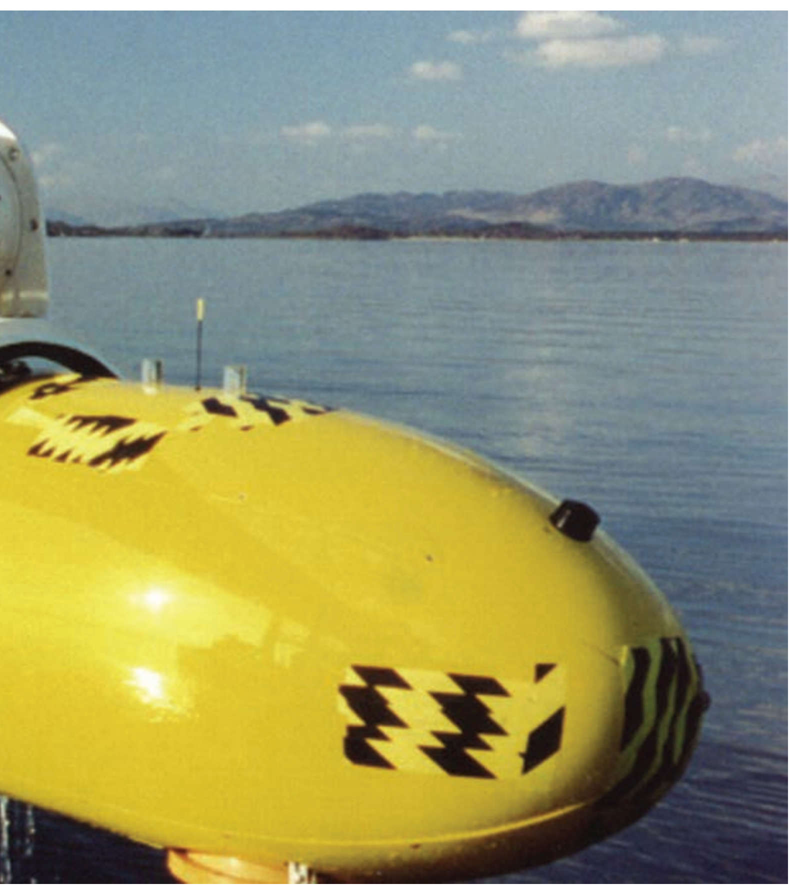
Autosub 1 during trials off Oban, Scotland, in 1999.



The UK's National Oceanography Center (NOC) has a long history, going back to the National Institute of Oceanography, formed in 1949, becoming the Institute of Oceanographic Sciences (IOS), incorporating two other bodies, in 1973, based in a village called Wormley, west of London, before becoming part of the NOC at a new dedicated waterfront premises in 1995.

Similarly, in 1996, while the first Autosub splashed into the water, just outside the NOC's then new Southampton facilities, work on it had been underway for some time already. In fact, the idea for this vehicle had dates back to the IOS at Wormley. Two staff there had recommended, in a European Commission review paper, the need for an "untethered remotely operated vehicle (UROV)", capable of diving down to 6,000m, able to navigate, operate for 24 hours and gather and store large amounts of data. At the time, that was a tall order. But others at Wormley had similar ideas with support from the UK's Natural Environment Research Council (NERC), the Autosub program was launched.

Initially, in 1987, there were two vehicle concepts. Dr. Maaten Furlong, Head of the Marine Autonomous & Robotic Systems Group at NOC, takes up the story: "The first was the Dolphin vehicle, it was a very long-range system which was focused on physical oceanography. Like a modern glider, it would go up and down in the water column sending back data on the physical properties of the ocean. The second was the DOGGIE concept. This was a deep ocean vehicle which would look at geology and geophysics (using sonar). These were the primary ideas that sat behind the Autosub program and a huge amount of work happened at IOS in developing these concepts."



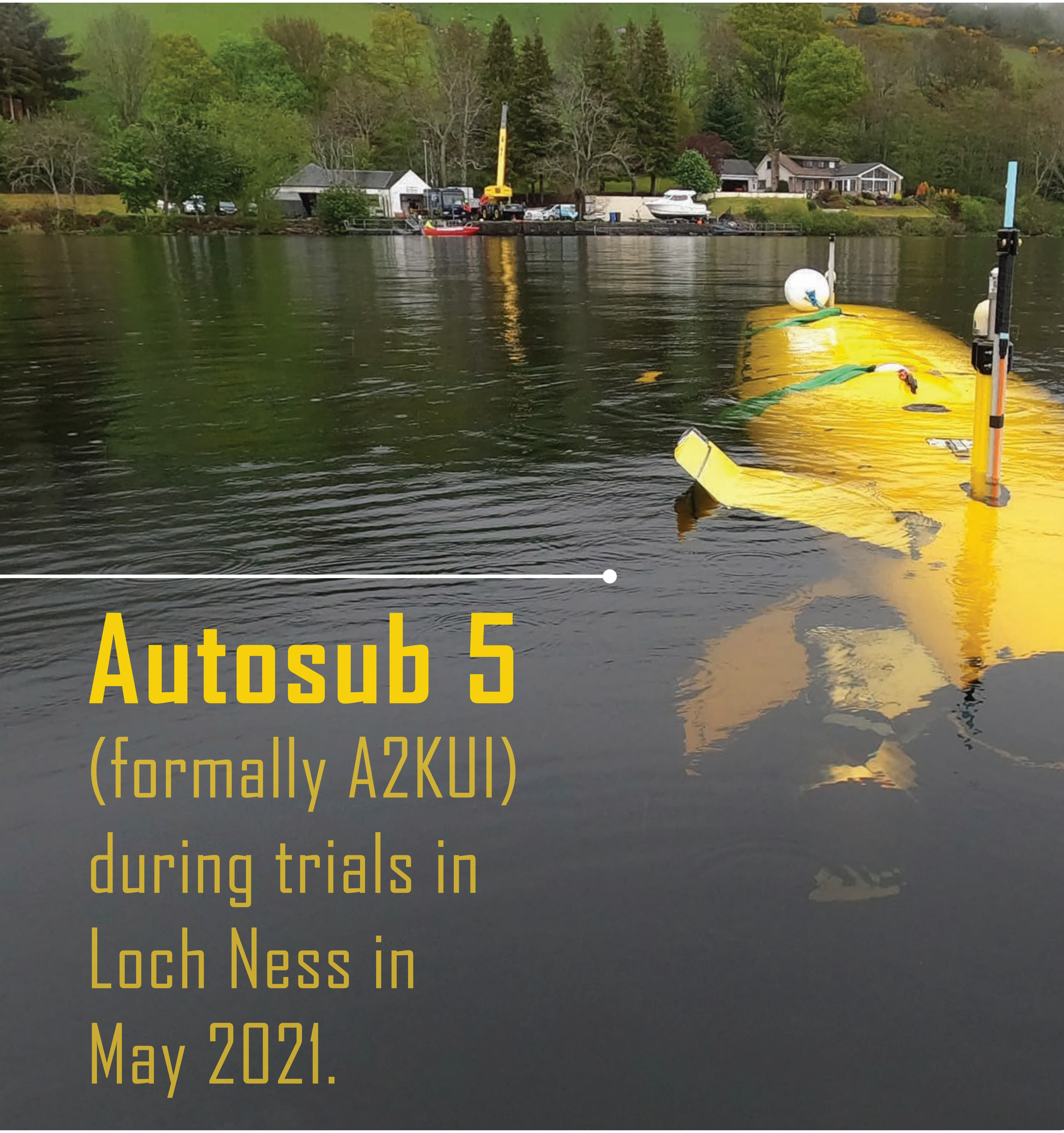
The IOS scoped out what was needed to build these types of systems – where new developments were needed – and then set about tackling them. It was an ambitious goal and, perhaps unsurprisingly, the program slipped. A 1992 target date for sea trials was shifted to 1996 and less ambitious specifications (500m depth and 70km range) were drawn up – largely due to challenges around power supply for longer missions in a pressure housing suitable for 6000m. Something of a compromise was also agreed; to try and create a base platform to meet the needs for potential users of Dolphin and DOGGIE.

"It was amazing what was achieved," reflects Furlong, "especially when you consider the technology they had then – poor batteries, slow processors and no roadmap," he says. "The team had to build a complete vehicle, pretty much from scratch, without any guidance." It was a new arena. When the Autosub 1 was first presented, there were just 36 other AUVs known at that time. "They designed all the pressure vessels, they did all the testing, they built all the control architecture," says Furlong. Part of the latter was in collaboration with Florida Atlantic University using Lonworks modules, enabling a distributed control architecture, which remained with the vehicles right through to Autosub6000. "The distributed architecture of the system was really ground breaking," he says.

1996 had been a big year for AUVs. MIT's Odyssey II had completed a survey off British Colombia and International Submarine Engineering's Theseus laid a 175km fiber optic cable under sea-ice in the Canadian Arctic. Woods Hole Oceanographic Institution's Autonomous Benthic Explorer had also been making observations around the Juan de Fuca ridge. This wasn't inexpensive work. Up to that point, NOC had spent some £5.3 million on Autosub-1 development (in 1989 terms).

Following demonstration missions off Dunstaffnage Marine Laboratory (now the Scottish Association of Marine Science), Autosub-1 started doing the science missions it was built for, including herring stock assessments in the North Sea using a fish finding echo sounder, leading to krill assessment work in Antarctica, and a project in the Strait of Sicily, where Autosub-1 got stuck under a ledge and required the help of an ROV to be dislodged.

Autosub-2 – a major rebuild of Autosub-1 was launched in 2000. It saw the initial vehicle's lead-acid car batteries changed out for 5000 D-cells in carbon fiber tubes, helping to extend Autosub-2's range to 400km. Autosub-2's focus was on under-ice missions, including work in the Fimbal Ice



Autosub 5

(formally A2KUI) during trials in Loch Ness in May 2021.

Shelf. This was risky work. Having made one journey under the Fimbal Ice Shelf, in 2005 Autosub-2 made a second journey – never to return. Luckily, aware of the risks of under-ice deployment, Autosub 3 was already being built and quickly replaced Autosub 2, says Furlong. Its crowning glory was work under the Pine Island Glacier in 2009. A total track of 887 km was covered over 167 hours, of which 510 km was beneath the glacier, mapping the underside of the ice with an upwards looking multibeam system.

However, one of the problems with Autosub-3 was that it was quite shallow rated, at 1600 m, and it still used primary batteries, says Furlong. So work started on Autosub6000 – a 6000 m-rated system. It used a lot of the technologies in Autosub 3, but moved over to rechargeable pressure tolerant lithium batteries, enabling the depths targeted. “Initially there were real concerns over the compressibility of the syntactic foam used,” says Furlong. “These vehicles are ballasted, so they are pretty close to just slightly positively buoyant. The worry was that the foam would compress faster than the seawater which could result in the vehicle becoming negatively buoyant and potentially sinking if it stopped moving. The other concern was how to accurately locate yourself at the seabed. You start at the surface with a GPS fix, then dive through 6km of water drifting with the current, and finally about 150m from the bed you can navigate using a Doppler Velocity Log and compass. So there was some early work done on to address this navigation offset problem, using a Linkquest USBL system to locate and send navigation offsets to the sub.

Autosub6000’s first science mission was bathymetric surveys of scours in the Agadir Canyon, in 4000 m water depth northwest of Morocco in 2008. It also went hydrothermal vent hunting in the mid-Cayman rise in 5000 m water depth and discovered world’s deepest hydrothermal vent at the time. Autosub6000 has also worked on the Darwin mounds in Rockall Trough area, undertaking high frequency side scan and photography surveys, looking at cold water coral, and also work in marine protected areas, says Furlong. “It’s also done work mapping the walls of Whittard Canyon, which involved rotation the multibeam sonar and angling it so it would image the canyon sides.”

However, there were still challenges with Autsub6000. “It’s a great vehicle, and has been really successful, but it is still limited to deployment from Research Vessels. We wanted to go further, as there are many missions which you just couldn’t do with Autosub6000. One example is a full Arctic crossing from Svalbad (Norway) to Barrow (Alaska) monitoring under the ice as you go, a second is surveying ocean choke points, such as Drakes Passage, which are currently difficult to routinely monitor.” The result was the Autosub Long Range (ALR) development in 2010-11. “It was quite different to the existing subs,” says Furlong. “A lot of new developments were required to enable the increased endurance with a lot of focus

ALR2, also known as Boaty McBoatface, as are the ALR vehicles.

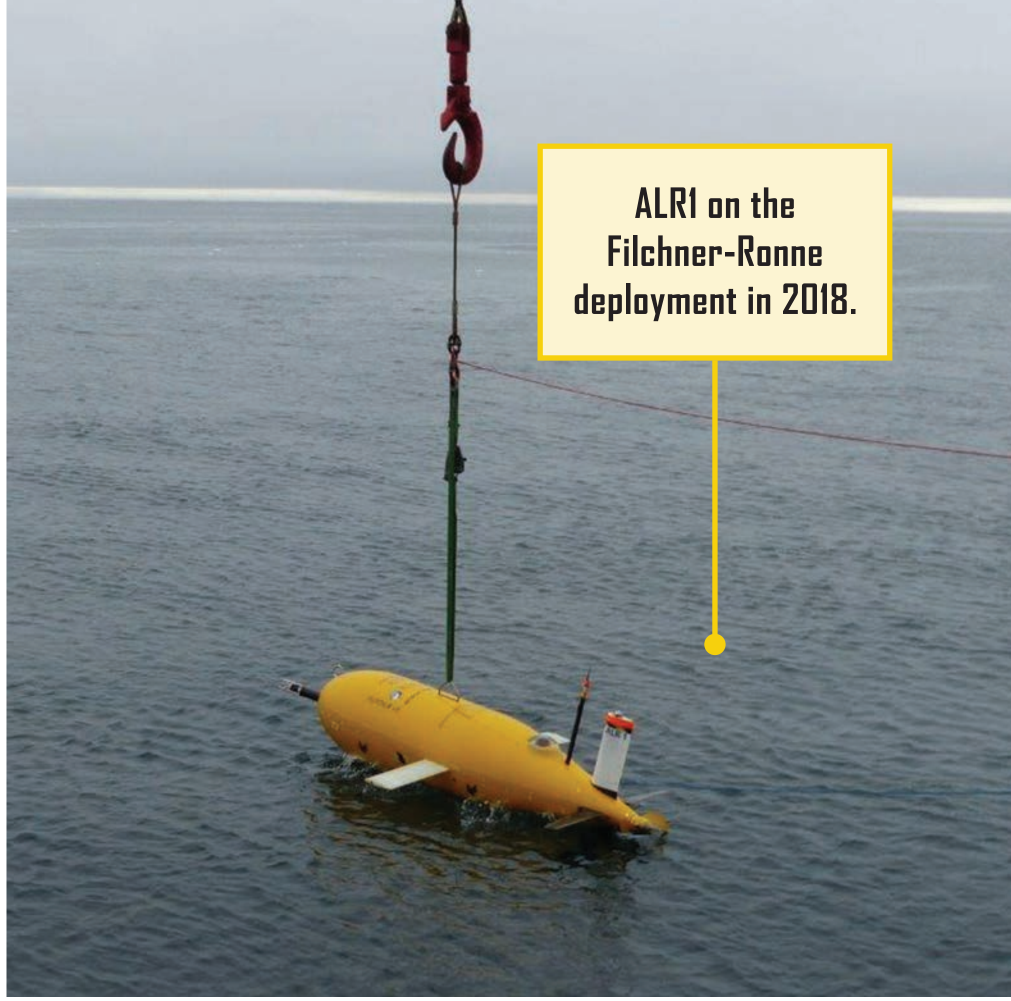
on very low power electronics. So we moved from Lonworks to a new system running on Windows CE on what was effectively, mobile-phone based processors." Not everything was new; the pressure spheres for ALR 6000 were repurposed 1970s forgings that had been manufactured for pop up seismometer spheres. Some of the ALR's early work included missions under the Filchner-Ronne Ice Shelf, west Antarctica. It went on two missions, going 108 km in, under fast sea-ice. The AUV was 994 m deep, under ice that was 550m deep.

Up until and including ALR 6000, each Autosub development had a focus, whether that was science, under-ice work or long-range operations. Under NOC's latest program, Oceanids, that focus has subtly shifted. "Whereas we've been working very much on single vehicles being used for single focus science or process studies, Oceanids is about building the next generation of vehicles using reusable modular technology. As the fleet increases and diversifies, we want to be able to reuse as much of these building blocks as possible."

Under Oceanids, an upgrade to the ALR, the ALR 1500, has been built. "We're (now) in the process of upgrading the ALR 1500 and also wanted to retrofit those developments into the ALR 6000," says Furlong. NOC is also building A2KUI (AutoSub 2,000 m under ice), now renamed Autosub 5. "This will replace the Autosub6000 and is also a replacement for the under-ice capability of the Autosub 3." And then there is Autosub Hover 1 (AH1), which has re-package the modular technologies of Autosub 5, into a hover capable vehicle, says Furlong.

For all these new vehicles, NOC has moved over to using the robot operating system (ROS) in its control architecture. "We're also running our own web-based command and control system," says Furlong. "It doesn't just control these vehicles, it also controls our glider fleet, so it's the one control system to rule them all. The goal is to build an extensible common interface to co-ordinate and control large diverse vehicle fleets."

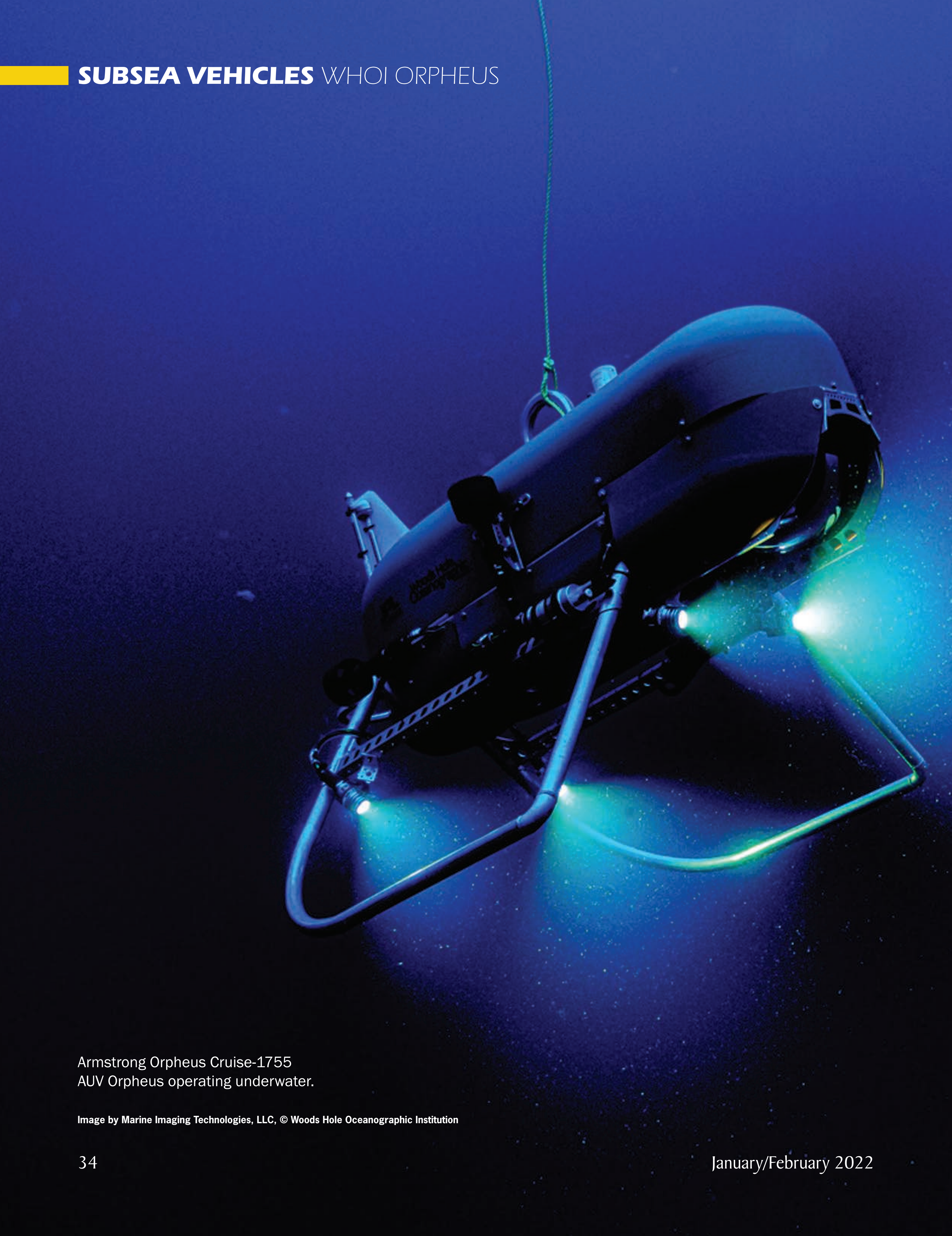
The campaigns also continue. Early January, a crew set out on the TARSAN campaign (Thwaites-Amundsen Regional Survey and Network Integrating Atmosphere-Ice-Ocean Processes). TARSAN will involve multi-day deployments of ALR1 under the Thwaites Glacier in Antarctica from the Nathanial B Palmer research vessel. "As with most campaigns this has involved adaptations of vehicle (ALR1) for the specific science



ALR1 on the Filchner-Ronne deployment in 2018.

and operational requirements. In this case with a focus on the under-ice deployment," says Furlong. Ahead of the mission, ALR5 was used to test some of the processes and procedures during trials in Loch Ness, Scotland. "It is an ambitious set of deployments," says Furlong. "Within the TARSAN campaign, we will be working with a number of other partners and their AUVs and gliders. However, the ALR will be undertaking some of the more ambitious and risky deployments, but the testing we have done has minimized this risk and should hold us in good stead."

**Versatile Autonomous Submersibles—the realizing and testing of a practical vehicle. Underwater Technology, Volume 23, Number 1, January 1998, pp. 7-17.*



Armstrong Orpheus Cruise-1755
AUV Orpheus operating underwater.

Image by Marine Imaging Technologies, LLC, © Woods Hole Oceanographic Institution

A JOURNEY TO THE UNDER — *AND OUTER* — WORLDS

IT'S OFTEN REMARKED UPON THAT WE KNOW MORE ABOUT THE SURFACE OF THE MOON THAN WE DO THE DEPTHS OF OUR OCEAN. SCIENTISTS ARE NOW SHOOTING FOR BOTH – AND BEYOND.

ELAINE MASLIN REPORTS.

Work by NASA's Jet Propulsion Laboratory (JPL), developed for exploring Mars, is now being leveraged by Woods Hole Oceanographic Institution (WHOI) to help tap Earth's deepest water secrets. In turn, WHOI's work will help NASA explore oceans on other worlds in our solar system.

Central to the two missions is the deployment of underwater technology, low power miniaturized sensors and terrain-based navigation. For WHOI's part, it's developing a low-cost, full ocean depth autonomous underwater vehicle platform (AUV), Orpheus, and a miniaturized chemical sensing, while JPL is giving Orpheus the ability to navigate, using image-based terrain relative navigation (TRN) – technology developed for use by the Mars rover and Ingenuity, its robot helicopter colleague. It may sound like science fiction, but it's fast becoming science fact and the potential impact of successful exploration in both areas could also have huge ripple effects, says Tim Shank, Associate Scientist and deep-sea biologist at WHOI.

ORPHEUS – AN AUV FOR THE UNDERWORLD

Spearheading WHOI's Orpheus development over the last five years has been Shank and Casey Machado, operations manager at WHOI's Autonomous Vehicle and Sensor Technology (AVAST) facility (a kind of technology acceleration hub at WHOI where anyone with ideas can get help to test them out). Key to Orpheus' design is for it to be compact and cost

effective, says Machado. At $270,000 a pop, it's certainly the latter. That's meant taking a NASA approach – also known as "the rocket equation", she says. That means really questioning everything that goes on the vehicle and using single sensors for multiple uses, where possible. "We want them to be small and accessible so we can hopefully expand our fleet in the future," says Machado.

The vehicle's batteries and electronics are stored in a glass sphere at its nose, along with its 4k HD camera, that's used for gathering data but also the TRN. It also has a set of LED lights on the under carriage, to illuminate the seafloor, and an open bay for mission-specific scientific payloads. It has four thrusters, fore, aft and vertical, and while it's fairly slow, it's also power efficient, maximizing exploration capability, says Machado. Critically, it's designed not just to move around above the seafloor, but also to be able to land to take samples – having identified a feature of interest.

Two vehicles have been built to date, named Orpheus and Eurydice, after the lovers of Greek myth legend. Both were taken on some of their first real salt-water dives on a mission off Florida from the Okeanos Explorer last year. The technology demonstration mission, funded by the Ocean Exploration Cooperative Institute (OECI), saw the vehicles undertake dives down to 866 m. Over 10 days, Orpheus did seven dives and Eurydice, the newer vehicle, one. Prior to this mission,

WHOI's **Tim Shank** and **Molly Curran** position AUV Orpheus on deck for deployment operations.

Image from Woods Hole Oceanographic Institution

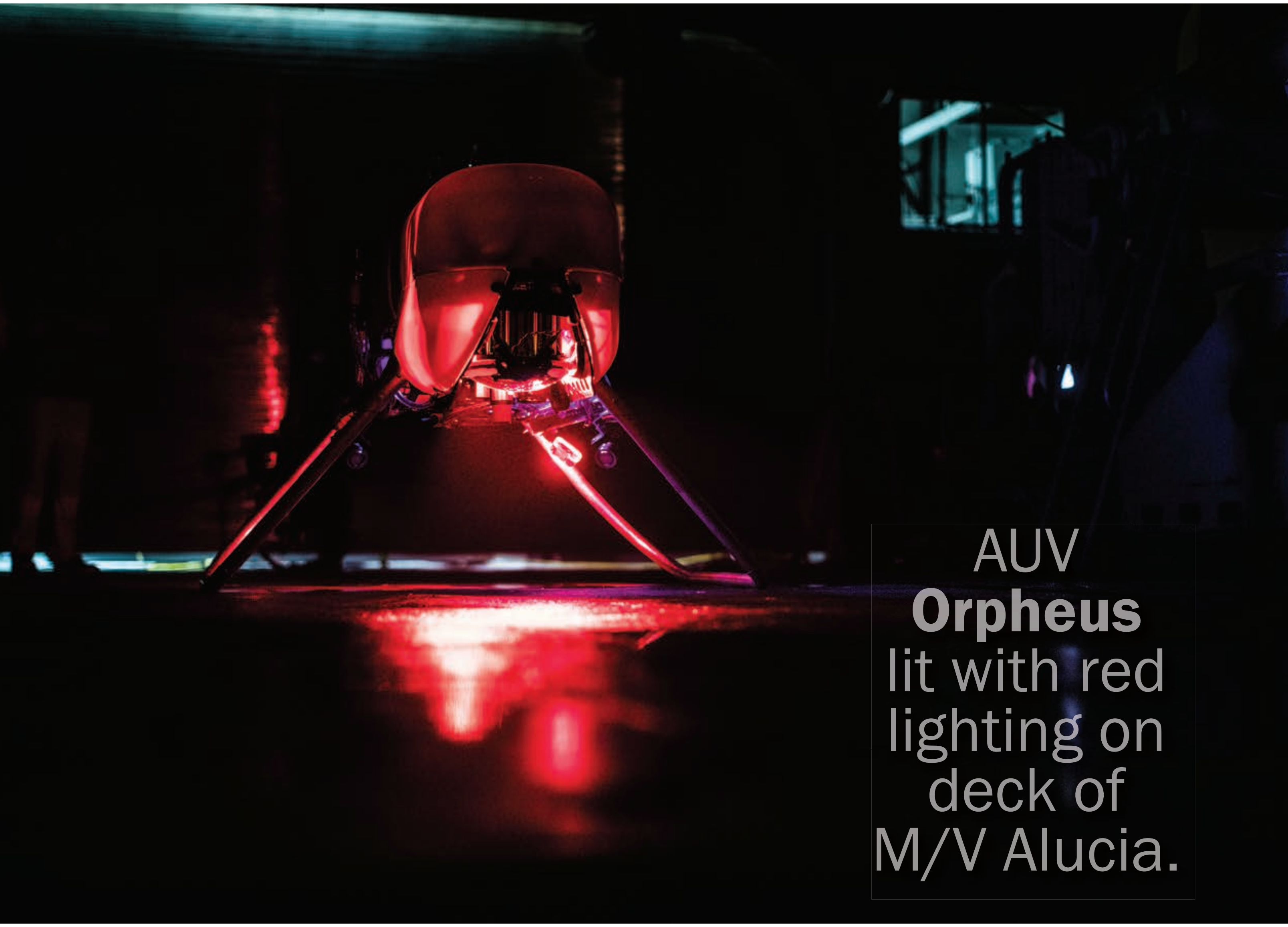
Orpheus had only done three dives. It was Eurydice's first saltwater outing.

The surveys covered coral mounds on the Blake Plateau, investigated coral distribution that hadn't been investigated before and brought back 700GB of high-resolution video. "But what's important for us is that we demonstrated really reliable autonomous control near and on the bottom," says Shank. "It was a first chance we really got to test heading and altitude and the ability to land the vehicle. AUVs don't really want to touch bottom, but this one does, so it can survey an area and then land on the bottom and do additional work. We demonstrated that control in a fantastic way."

Image-based terrain relative navigation

The mission also helped to demonstrate and advance the TRN capability, on which WHOI has been working with engineers Andy Klesh and Russel Smith from JPL. TRN works by using software to pick up unique features in what the camera sees and then uses them as navigation aids, tracking and following them. "It constructs a network of features on the seafloor (even just sand ripples)," says Shank, "and as we roll along the seafloor with the vehicle, it connects all these dots and basically makes a feature map for us, which is simply amazing, because at 10,000 m full ocean depth there's little we can do with traditional way of acoustic navigation. What we plan to do is combine this with the visual camera data we have to make 3D seafloor maps to centimeter or even millimeter scale. So we're super excited about this."

TRN can be done with a small cheap camera – machine vision cameras are in the order of $1700, says Machado. While it's not a complete navigation solution – some acoustics will



AUV **Orpheus** lit with red lighting on deck of M/V Alucia.

Image by Luis Lamar, courtesy of OceanX Media

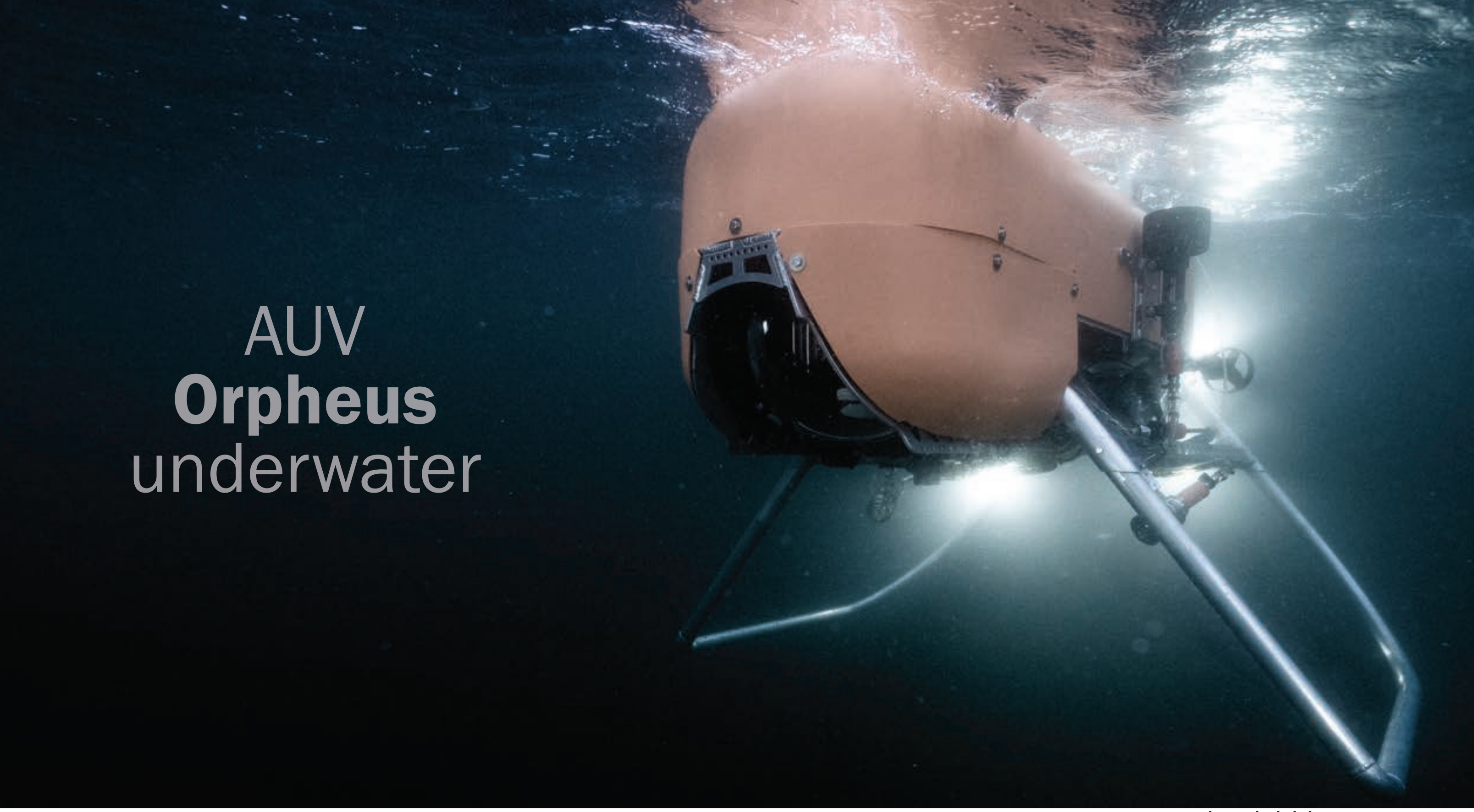


Image by Luis Lamar

be needed to give the vehicles an initial geodetic coordinate, to locate it within a global reference system – "once it is well calibrated to give us quantitative results, we can operate just by seeing the seafloor with a camera we already have onboard." That's instead of having to develop acoustics for that depth at cost and risk, she says.

The TRN software WHOI is using is the same sort of software that the Mars Rover used to find a relatively flat and a safe space to land on the moon. But there's more to the link with NASA and JPL than that. There are six ocean worlds in our solar system, explains Shank. These are ice-covered oceans on various moons. "You're looking at kilometers and kilometers of ice to get through, but once you get through the ice, we believe that there are salty oceans there, on Enceladus and Europa." Europa is of specific interest and the central aim is to see if there's life there. "That's the goal and they're teaming up with us because together we can advance getting to that moon and getting in the ocean and exploring it."

IS THERE LIFE ON THE MOON EUROPA?

It's believed that there could be life there because Europa, one of Jupiter's 80 moons, and other moons have similar properties to Earth – a saltwater ocean and a hard core in the center. "Through gravity, with Jupiter, that core is squeezed, it's pushed and pulled, to the point where it creates heat and that heat fractures that rock core, allowing seawater to go down and be superheated by that heat and then back rush up through the seafloor, much as the way that it happens on earth in hydrothermal vents. We're working with JPL to work out how we would communicate, even (underwater) vehicle to vehicle, back up to the surface lander, back to Earth," says Shank. Near-term, NASA's Europa Clipper mission will send an orbiter to study the moon during a series of flybys, while in orbit around Jupiter. Planned launch is 2024.

Of course, that's not the sole goal. There's just as much to discover on Earth in the underexplored Hadal Zone (6,000-11,000 m deep), says Shank. "Right now we have no systematic way of doing exploration or research in the Hadal Zone. It's 47% of the depth of our ocean, with animals that have novel adaptations, animals that have produced novel genes, so it has a high capacity for discovering natural products, antibiotics, treatments for diseases and those kinds of things and these vehicles are going to allow us to do that.

Why is Hadal Zone so interesting?

"From the few samples we have, we know the hadal zone is unlike the rest of the ocean. It almost can't be considered as part of the rest of the ocean," says Tim Shank, Associate Scientist and deep-sea biologist at WHOI. "There's activity down there and microbes on the order of shallow water coral reefs. There's a whole different ecosystem landscape there and then there are novel adaptations."

The deepest living fish caught and tested, for example, had 12 genes that are the code for the integrity of its cell membranes, for example, compared with 4-5 in a normal fish. It also produced biomolecules that hold water in the individual cells, so that the proteins can function under the immense pressure in the Hadal Zone.

"We've got human problems, human diseases like Alzheimer's, where the proteins don't operate correctly and it's analogous to what we would see with fish in the hadal zone," says Shank. "If we can learn how to do that, we can apply that to human diseases. That's not to mention just understanding academically how life has evolved in our deep sea. We're seeing now that individual trenches have their own signature of life in there. Their own set of species. They're closely related to other trenches often, but we see that they're maybe evolving in-situ, in isolation in these trenches. Those are key places for us to go to understand how evolution works on earth so we might understand how it works on other ocean worlds. The impact of the study of the hadal zone reverberates and ripples out into so many different disciplines. It's a truly exciting place to go."

MINIATURIZED IN-SITU CHEMICAL SENSING

This is where another technology capability demonstrated on the Florida mission comes in; WHOI's ISEA-X in-situ chemical sensor. ISEA-X is able to detect a variety of chemical species, including hydrogen sulphide, bisulfide, iron sulfides, all kinds of reduced chemical species, but also oxygen, peroxide, manganese and organics. It's a technology Shank has been working on for almost 20 years, in which time it's gone from weighing 60-70lb to less than 10lb today, with an eight-day endurance capability.

"What was really fantastic was that, after the dive, we were able to download the data and send it right to the lab in New Jersey. They analyzed that data and showed us where we had spikes of different temperatures and chemical species. We took the times that they told us there were these spikes and we mapped them on to our 3D seafloor reconstructions; the mosaics we made from the Orpheus downlooking video. That's a real thrill," he says. "Scientists believe there are fluids coming out of the seafloor at 8,000-10,000 m and this is the instrument that will allow us to discover those, explore those and conduct more research, so we are super excited about that."

STEPS TOWARDS AUTONOMOUS HADAL ZONE EXPLORATION

Following last year's OECI demonstration mission, WHOI will be working on making Orpheus and Eurydice full ocean depth capable, but also to integrate the vehicle TRN odometry data into the vehicle control system. "Right now, it's independent," says Shank. "If we could integrate it, for closed loop control, we can come to the point of developing algorithms that we can use. As the vehicle runs over the seafloor, if it detects a certain chemical it knows that it can turn around and come back and return to that same point and sit down on the seafloor to take a sample. That's the real goal; to go over a hydrothermal vent, to go over a hydrocarbon seep, to go over a giant clam, stop and turn-around, or communicate to another Orpheus vehicle that there's a clam over at a certain coordinate, to go, sit down, and do some more work." Work to integrate environmental eDNA and other sensors will also be carried out, working with JPL NASA to miniaturize them to get them on the vehicles.

The grand vision – investigating the world's Hadal Zone trenches

"The idea is to have 10-12 of these being able to operate simultaneously, below 6,000 m, in a given trench, communicating with each other and reporting back up to the surface," says Shank. "Once we have that group, we're ready to go for the real grand challenge in our vision. That's to go around and do a global tour of exploration of the different trenches. We have reason to believe the trenches are vastly different, depending on where they are in the world, and the diversity is really different and there are hubs of biodiversity and evolutionary novelty and it's really important for us to compare them."

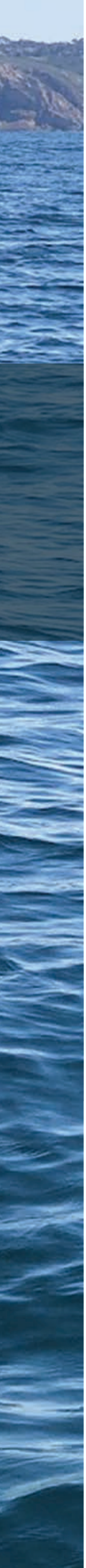
Two vehicles have been built to date, named **Orpheus** and **Eurydice**, after the lovers of Greek myth legend.

LANDER LAB:
TECHNOLOGIES, STRATEGIES AND USE OF OCEAN LANDERS

By Kevin Hardy, Global Ocean Design, MTR Columnist

Figure 1.
Ocean Lander DOV BEEBE surfaces off the coast of La Jolla, California.

Photo by Ashley Nicoll, Scripps Institution of Oceanography/UCSD



Moon landers held my attention in the 1960's as a teenager. Unmanned robotic vehicles like Surveyor, descend out of a dark sky onto an alien world, and took the first look around.

The deep and dark ocean seemed as distant and alien. SEALAB II, bathyscaphe Trieste, and the Scripps Institution of Oceanography in my hometown of San Diego had immense gravitational pull on my curiosity.

Ocean Landers, unmanned robotic vehicles, like Scripps Professor John Issacs' Monster Camera, descend out of a dark sea onto an alien world, and took the first look around. Our first glimpse of The Other Earth.

WHY LANDERS?

There are multiple classes of unmanned undersea vehicles (UUVs): Remotely Operated Vehicles (ROVs), Autonomous Undersea Vehicles (AUVS), Gliders, midwater SOLO drifter floats, towed platforms, and Ocean Landers, also called "free vehicles". Each unmanned vehicle has a unique set of strengths and weaknesses, often complementary to another class. Ocean Landers are the oldest, but an overlooked platform for many seagoing projects.

Ocean Lander construction is straightforward: Buoyancy high, weight low for stability. The vehicle is self-buoyant, weighed down by an expendable anchor, usually iron. Proper design minimizes cross-section perpendicular to the direction of vertical travel, known as the vehicle's frontal projected area. Water drag provides a terminal velocity. A positively buoyant lander floats above its anchor, making it independent of the seafloor rocks, mud and slope. No legs required for many missions. A dual or triple redundant release system gives multiple chances for return. Designers can choose from a suite of release mechanisms to suit the mission profile. On return to the surface, the vehicle becomes a spar buoy. It's top most structure is raised out of the water, providing a line-of-sight to the ship for a radio and strobe light, or to the sky for a satellite tracking system. A flag is always a good thing, and reflective tape can help with a searchlight at night. We always add a tag for someone to contact the lander's owner should it go AWOL. Davy Jones can be such a prankster.

Ocean Landers can carry every imaginable sensor and sampler. They can even recover sediment cores by using a clever sword-in-a-sheath design by a chap named David Moore of the USN NEL-San Diego. He had to solve the "core extraction problem" caused by gloppy mud. Sam Raymond and Benthos turned this idea into a product it sold for years called the Pogo Corer.

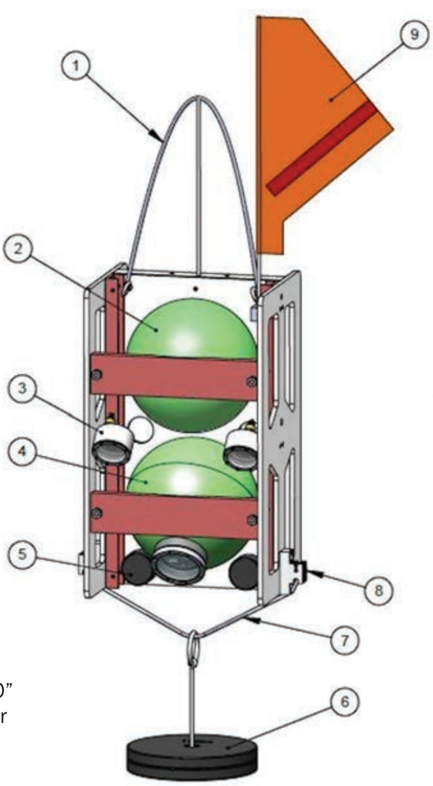


Figure 2.

Typical elements of a small Ocean Lander: (1) Spectra lifting bale, (2) 10" Command/Control/ buoyancy sphere, (3) LED lights, (4) 10" Camera/instrument/ buoyancy sphere, (5) counterweights, (6) expendable anchor, (7) drop chain, (8) release burnwires and mounts, and (9) recovery flag. Small but mighty: with 10" glass spheres, this lander can travel to 10km.

Illustration of Picolander®, used with permission, Global Ocean Design

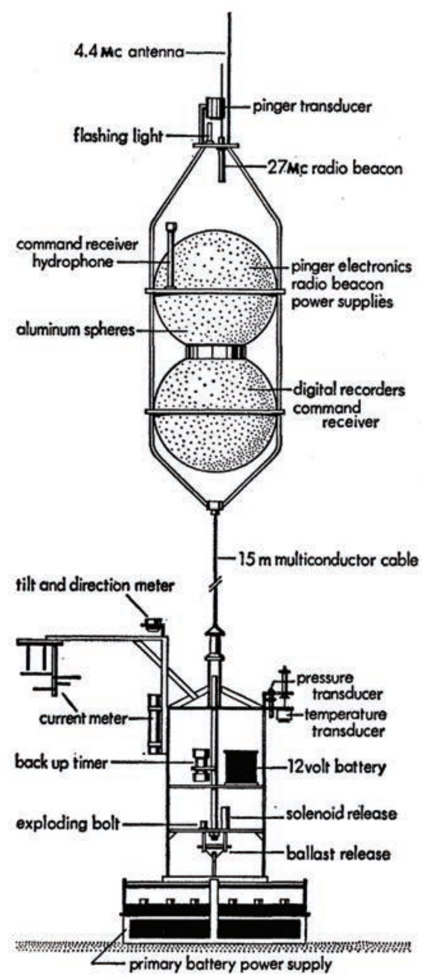
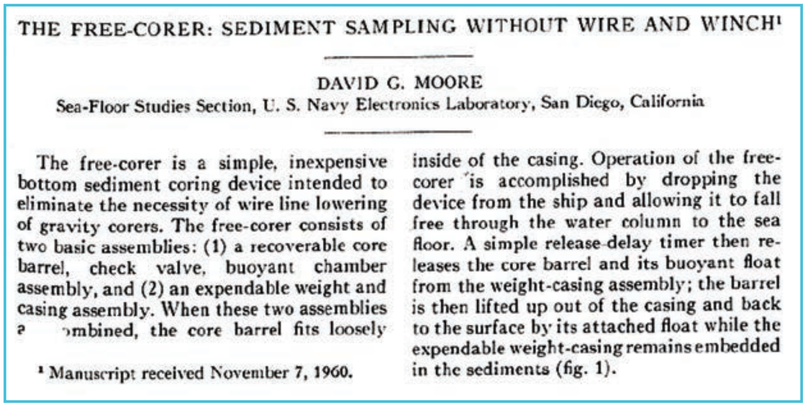


Figure 3.

Then-and-Now. Munk/ Snodgrass Deepsea Tide capsule (1968). Twin 24" diameter, 1" wall, spun 7075-T6 aluminum spheres provide buoyancy and house electronics. A 15m EM cable tethers the spheres to the sensor frame. Modified automotive wet cell batteries provide system power and negative ballast. The battery ballast remains on the seafloor when the capsule is recovered.

Photo Credit: Deep Sea Instrument Capsule, Frank E. Snodgrass, Science, Vol. 162, No. 3849 (Oct. 4, 1968), pp. 78-87.

Figure 4.
The Moore Corer



THE FREE-CORER: SEDIMENT SAMPLING WITHOUT WIRE AND WINCH[1]

DAVID G. MOORE
Sea-Floor Studies Section, U. S. Navy Electronics Laboratory, San Diego, California

The free-corer is a simple, inexpensive bottom sediment coring device intended to eliminate the necessity of wire line lowering of gravity corers. The free-corer consists of two basic assemblies: (1) a recoverable core barrel, check valve, buoyant chamber assembly, and (2) an expendable weight and casing assembly. When these two assemblies a ombined, the core barrel fits loosely inside of the casing. Operation of the free-corer is accomplished by dropping the device from the ship and allowing it to fall free through the water column to the sea floor. A simple release-delay timer then releases the core barrel and its buoyant float from the weight-casing assembly; the barrel is then lifted up out of the casing and back to the surface by its attached float while the expendable weight-casing remains embedded in the sediments (fig. 1).

[1] Manuscript received November 7, 1960.

Photo credit: "The Free-Corer: Sediment Sampling Without Winch and Wire," David G. Moore, Journal of Sedimentary Petrology, Vol 31 (4):627-630, 1961.

Materials have to handle the pressure. A lunar lander travels 400,000 km to the moon and the ambient pressure changes 1 bar. Ocean vehicles experience that every 10m of depth. Some buoyancy materials overcome the pressure by specific gravity and bulk modulus, other buoyancy materials do it by displacement and the compressive strength of the material.

We'll discuss all of these elements in the course of this column. Like Edison's ratio of inspiration-to-perspiration, our profession calls it R&D, with emphasis on the D.

The concept of ocean landers/free vehicles for geophysical research was first proposed in 1938 in a brilliant paper by Maurice Ewing (Lamont) and Allyn Vine (WHOI), titled "Deep-Sea Measurements Without Wires or Cables," published in Transactions of the American Geophysical Union. Many of its insights are still valid today. The authors cited operational benefits of ocean landers/free vehicles including:

1. *Much less specialized and expensive equipment required on the ship;*
2. *Long, undisturbed placement of recording instruments on the bottom;*
3. *Recall by time-clock or signal from the surface;*
4. *Once a free vehicle is released, the ship is free to move to another position to deploy another free vehicle, meaning large survey areas are possible;*
5. *Stations at specified distances or heights off the bottom;*
6. *Unlimited depth;*
7. *Ballast release by contact with the bottom is possible if no bottom dwell time is required;*
8. *Operators can follow progress down and up by sound-ranging;*
9. *Initial lifting force when leaving the seafloor may be multiplied by a pulley-system;*
10. *The ballast is on the bottom and left behind, minimizing the danger of being stuck in the mud.*

Other benefits not mentioned in the Ewing-Vine article include:

1. Flexible Configuration: A lander can be configured to whatever ship-of-opportunity presents itself. Small vessel, small lander; Large vessel with an A-frame, larger lander. Lander frames can be bolted together like building blocks. Side pods provide additional buoyancy or instrument bays;

2. Interchangeable payloads: Like a pick-up truck to the deep sea, if a payload fits within physical, weight, electrical, and control parameters, it can be delivered to any place in the ocean, and recovered on command;

3. Profiler: The zone of interest maybe the water column between the surface and seafloor;

4. Ships-of-opportunity: A less specialized but appropriately sized seaworthy vessel may be found in a smaller harbor closer to a point of interest, during a more advantageous time, at a more modest cost;

5. Test bed: Ocean landers make excellent test beds for systems destined for more advanced vehicle types or more advanced Lander missions. Materials, sensors, cameras, lights, batteries, thrusters (without props), solenoid releases, recovery beacons, acoustic comms, and a lot more can be tested using small landers, from small vessels, with smaller budgets, and less worry. It doesn't bet the farm to test a hunch;

6. Training: An ocean lander provides operational training on launch-and-recovery techniques for larger systems, giving engineers and scientists the field experience and confidence that comes from a successful deployment and recovery;

7. Collaboration: Researchers can combine a variety of instruments to measure and sample the ocean from distinctly separate, but interacting points of view. With similar landers at dispersed universities, researchers need only plan on bringing their instrument as their colleagues have a similar lander, so they know their instrument fits;

8. Persistence: Expanding on Ewing & Vine, a lander can remain on the seafloor for an entire year or longer if needed. Using glass, plastic and titanium, landers are capable of long duration deployments of even multiple years. One application may be to surround the base of an offshore oil platform where they can continuously monitor for a hydrocarbon leak, communicating with each other and back to the platform;

9. Baited lure: The lander can be used to lure animals towards its position by the use of bait. Low-light cameras using red LEDs can image animal behavior without disturbance, or await the arrival of an ROV or manned submersible;

10. Scout: Landers can precede a manned submersible or ROV operation to determine a specific area of interest. They can also stand-by as a rescue vehicle, using their full buoyancy to help bring another vehicle back to the surface;

11. Pack horse: Working with manned or unmanned vehicles with mobility but limited VB to carry samples, a lander can act like a chest-of-drawers to hold the samples collected by the mobile craft. The mobile craft is recovered first, and the lander is recalled with its payload to the surface afterwards;

12. Cheap anchors: Only scrap iron is needed for anchors, so the ballast weight may be purchased in the port of operation, saving the cost of shipment of a heavy drop weight;

During COVID, when barbell weights became very expensive and hard to find, the idea came to make ferrocement anchors, replacing the gravel with readily available scrap steel stampings. The scrap stamped steel was valued at 4 cents/pound. The anchor worked great, and would later corrode and dissolve into ocean friendly materials. Non-magnetic SS stampings are likewise available, if magnetic signature is an issue.

Kevin Hardy

Figure 5.

Ferrocement expendable anchors, where steel stampings replace coarse gravel in the mix. Cheap, heavy, and biodegradable.

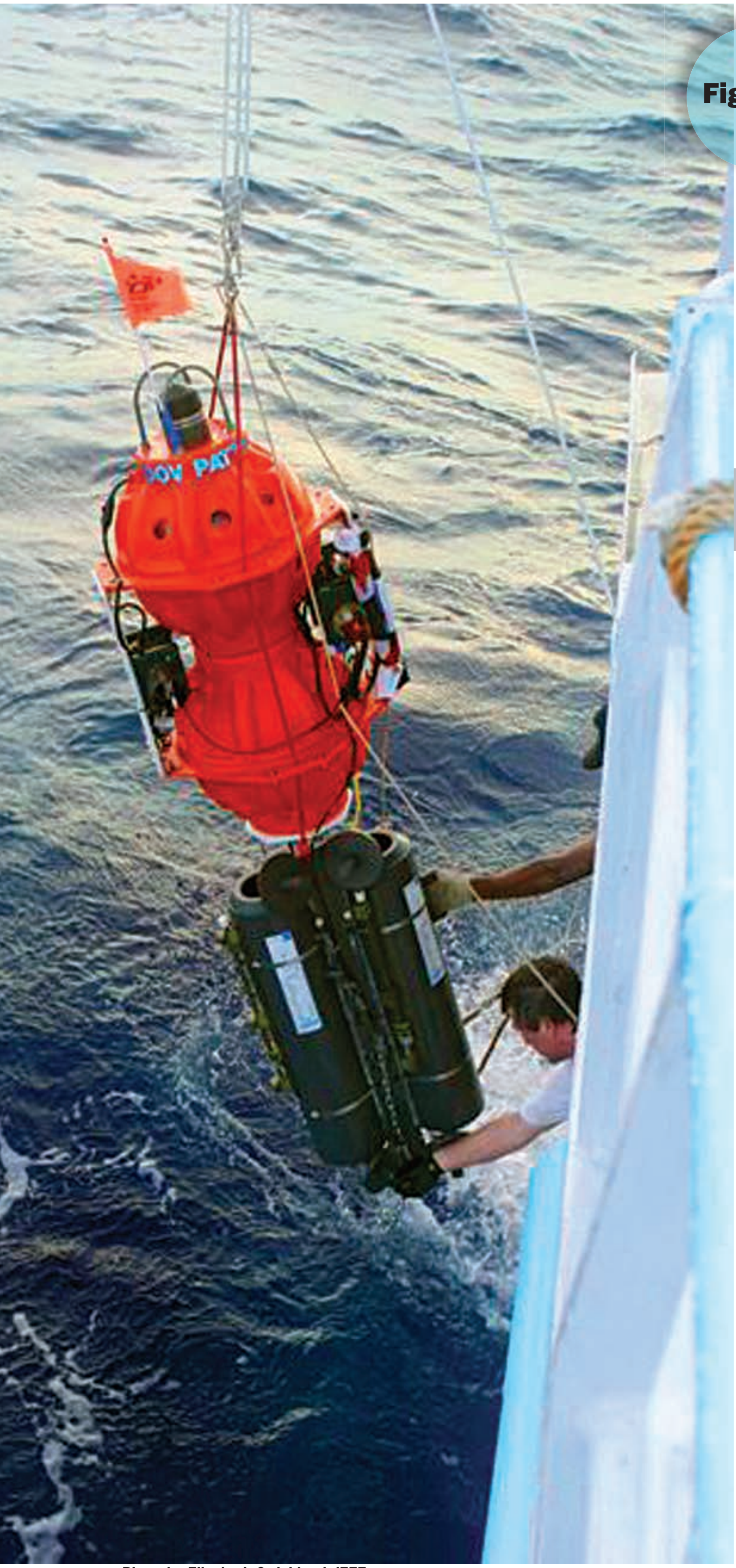


Photo by Elizabeth Strickland, IEEE

Figure 6.

Without winch and wire, or the big boat. The author, Kevin Hardy, then with Scripps, deploys Ocean Lander DOV Patty into the 10,700m Sirena Deep off Guam in 2011. The Munk/Snodgrass design influence is easily seen. Our ship-of-opportunity is the 62-ft Super Emerald out of Saipan.

13. Shipping: A lander and its surface support gear can be shipped by overnight air freight from point-of-origin to point-of-operation, allowing rapid deployment to an active site of interest. One research group brought a small lander as check-on luggage to Fiji, where they used it to gather samples at a maximum depth of 2km.

14. Disruptive technology: Landers are simple enough to be used by any size institution anywhere in the world. I've mentored high school through graduate students in lander design and construction, and had them build and deploy their own. Their use in the ocean at any depth for any length of time provides unique observational and sampling capability. Ocean Landers are a UUV technology that empowers and enables all nations during the UN Decade of Ocean Science for Sustainable Development (2021-2030).

It was noted by Ewing and Vine that locating the free vehicle after it had returned to the surface was a serious problem. Today, Ocean Landers have the advantage of RDF and satellite trackers. They sink and rise pretty fast. Currents are relatively thin layers, and the vehicle passes through them fairly quickly, minimizing offset. The surface location problem has become more manageable.

Landers have been my muse to develop new undersea vehicle component technologies. Looking to send landers to the deepest trenches on a limited budget, I was looking for both buoyancy and housings. In 2001, I approached Gerald Albich, then General Manager of the German company Nautilus Marine Service (NMS), manufacturers of the impressive Vitrovex line of hollow glass spheres for ocean science. My suggestion

Figure 7.

The author, Kevin Hardy, lifts the single sphere hadal lander, DOV Mary Carol, with one hand onto the ship after a test dive off San Diego in 2002. DOV Mary Carol later dove both the Puerto Rico Trench and Aleutian Trench.

Photo by Dr. Art Yayanos, Scripps Institution of Oceanography/UCS

was to leave the 17” OD the same, but make the ID smaller, creating a thicker wall. We discussed modifications to the tooling. The thick-wall glass spheres, serving as both flotation and as a housing, would be capable of reaching the floor of the deepest ocean trench. With funding from Japan, whose researchers wanted to study the deeper waters of the western Pacific, NMS completed the development. Exploration of the ultra-deep sea changed dramatically after that.

Ocean Landers inspire such invention. Come along on the journey.

References: Copies of the Ewing & Vine (1938), Snodgrass (1968), and other papers are available for download at **https://www.globaloceandesign.com/other-lander-reference-papers.html**.

Post-**script**: I am grateful to MTR Editor **Greg Trauthwein** for his invitation to write this column. I am, in perhaps my favorite self-image, an educator. There is enough material to continue the column for some time, and perhaps, in the end, bind the articles into a Handbook of Ocean Lander Design. We imagine supplementing the articles with video “How to’s”, and share some drawings of useful lander lab gear. We’ll share experiences and designs from other Landerians from around the world, and suggest Yet-To-Be-Done ideas waiting their turn.

I look forward to receiving your comments, suggestions, and most importantly, your contributions to future articles. Please send your thoughts and photos to me at: Kevin Hardy **subdude23@mac.com**.

Advanced Navigation's Next-Gen Satellite Compass

Advanced Navigation, a leader in AI-based navigation solutions, has released the second generation of its satellite compass. GNSS Compass is a plug and play solution that provides accurate position, heading and time in a self-contained unit. The new system provides significantly higher heading performance, combined with a reduction in price to under $2,000, opening up the advanced technology to cost sensitive applications previously dependent on magnetic heading.

The new system significantly improves the availability and accuracy of heading under difficult conditions, such as under bridges, when there is limited visibility of the sky and in the presence of RF interference. This is achieved through a new multi-frequency GNSS receiver, cutting edge antenna design and algorithm improvements.

The updated GNSS Compass supports L1/L2 RTK positioning and heading using all satellite constellations including GPS, GLONASS, Galileo and BeiDou. Two interface variants are available to cater to all applications. The serial variant supports plug and play operation with existing NMEA 0183 and NMEA 2000 applications. The Power over Ethernet variant allows simplified power and network cabling for all new applications. Used in Nortek's Signature VM survey package, this system is ideal for marine applications requiring accurate heading and positioning in the most demanding conditions. The second generation delivers the same ultra high reliability, with higher performance, at a more affordable price point. GNSS Compass v2 is shipping now.

Photo courtesy Advanced Navigation

bit.ly/33YtGYQ

VectorNav Technologies

VectorNav Technologies, a leader in inertial navigation solutions, continues its development of advanced capabilities for its line of RTK/PPK-enabled GNSS-Aided Inertial Navigation Systems (GNSS/INS). VectorNav's Tactical Series VN-210 and VN-310 GNSS/INS products now support external integration with several Quartz and Fiber Optic Gyroscope (FOG) based IMUs and Gyrocompass. The FOG IMUs enable the Tactical Series to provide a gyrocompassing solution, as well as extend navigation capabilities for operation in GPS-contested and GPS-denied environments. Connection to the external IMU is made via a single interfacing cable from the VN-210 or VN-310 auxiliary port directly to the external IMU. This integration enables users to utilize a single system for position, velocity, and heading/pitch/roll data, simplifying integration and accelerating time to market.

VectorNav has also furthered its support of the hydrography and bathymetry markets: HYPACK's 2021 Q3 update provides support for VectorNav's Tactical Series. HYPACK's support includes HYPACK Survey and HYSWEEP Survey drivers for VectorNav sensors. When surveying with the Tactical Series, users can now record their raw output to use in other position processing software, such as Inertial Explorer. VectorNav's Tactical Series includes the VN-110 Inertial Measurement Unit (IMU), VN-210 GNSS/INS and VN-310 Dual Antenna GNSS/INS, which includes an onboard GPS-Compass. Each product in the Tactical Series is available in a Ruggedized, IP68 rated enclosure tested to numerous MIL-STD and DO-160G standards, or a miniaturized, board-mount package weighing only 15 grams.

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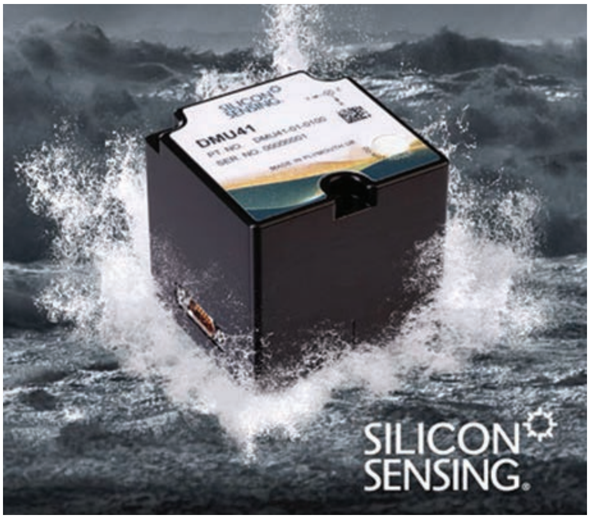
Photo courtesy VectorNav

Silicon Sensing MEMS IMU



Recently launched by Silicon Sensing is the new DMU41, a non-ITAR, tactical grade, 9 degrees of freedom (DoF) inertial measurement unit (IMU) - ideal for use in ASV/AUV applications.

This is a high performing all silicon micro electro-mechanical systems (MEMS) IMU, able to compete directly with FOG-based IMU's, yet its volume and weight are both 50% lower than its predecessor and it consumes significantly less power.

"For manufacturers and operators of the latest generation of autonomous vehicles, DMU41 offers the opportunity to enhance control and prolong navigation performance over time in tasks such as surveying and mapping, while ensuring valuable payload space on the platform is preserved," said Steve Capers, General Manager, Silicon Sensing Systems Ltd.

Measuring 50 x 50 x 50 mm and weighing 200g, DMU41 delivers inertial performance that combines excellent angle random walk and bias stability with exceptional low noise characteristics. It contains three inductive and three piezoelectric resonating ring gyroscopes with six capacitive accelerometers, all designed and manufactured by Silicon Sensing, along with three magnetometers. All inertial sensor data is blended to give optimal motion sensing information, with DMU41 able to provide data at variable output rates up to 2kHz. Outputs can combine angular rate, acceleration, delta angle and delta velocity, temperature and built-in test results - and every DMU41 is calibrated over the full operational temperature range to guarantee sustained, reliable performance.

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Twin Triggers of Triassic era extinction event - *Study*

Curtin-led research has revealed an increase in levels of both acid and hydrogen sulfide in the ocean was the double whammy that wiped out marine life during a mass extinction event 201 million years ago. Lead author, Curtin PhD graduate Dr Calum Peter Fox, from the WA-Organic and Isotope Geochemistry Centre (WA-OIGC) in Curtin's School of Earth and Planetary Sciences, said the research revealed the twin processes that combined to the end the Triassic era, paving the way for the emergence of dinosaurs in the Jurassic period.

"The end-Triassic event saw rapid increases in CO2 due to a surge in volcanic activity, which is understood to have caused unfavorable conditions for life resulting in mass extinction, however the multiple drivers for loss of life during this period were not previously known," Dr Fox said.

"By studying microscopic fossils preserved in rock in the Bristol Channel Basin, in the southwestern United Kingdom, we identified the twin mechanisms responsible for the mass extinction. "These were a deadly combination of ocean acidification, which inhibited growth of all marine life using calcium carbonate to create shells or body parts such as mussels, oysters, and corals, and rising levels of hydrogen sulfide in the ocean, which was extremely toxic for all marine life."

Co-author John Curtin Distinguished Professor Kliti Grice, also from WA-OIGC in Curtin's School of Earth and Planetary Sciences, said the research provided intricate and important details of the history of our ever-evolving planet.

"The revelations about the cause of past marine extinctions will help us understand the current global warming crisis and how we can protect our deteriorating ecosystems and environment," Professor Grice said.

"In order to help understand how our environment and ecosystems may change during this event, we must investigate those in the past.

"There is still much to learn about mass extinction events and studying these disruptive time intervals further will inform us more about the history of our Earth, but also what climatic changes we can expect moving forward as CO2 levels continue to increase."

This research, led by Curtin University and funded by the ARC, was conducted in collaboration with researchers at the University of Southampton, Lahmont-Doherty Earth Observatory, MIT, and Oxford University. Dr Fox did the research as part of his PhD studies at Curtin and is now at Khalifa University.

The full research paper can be found online here.

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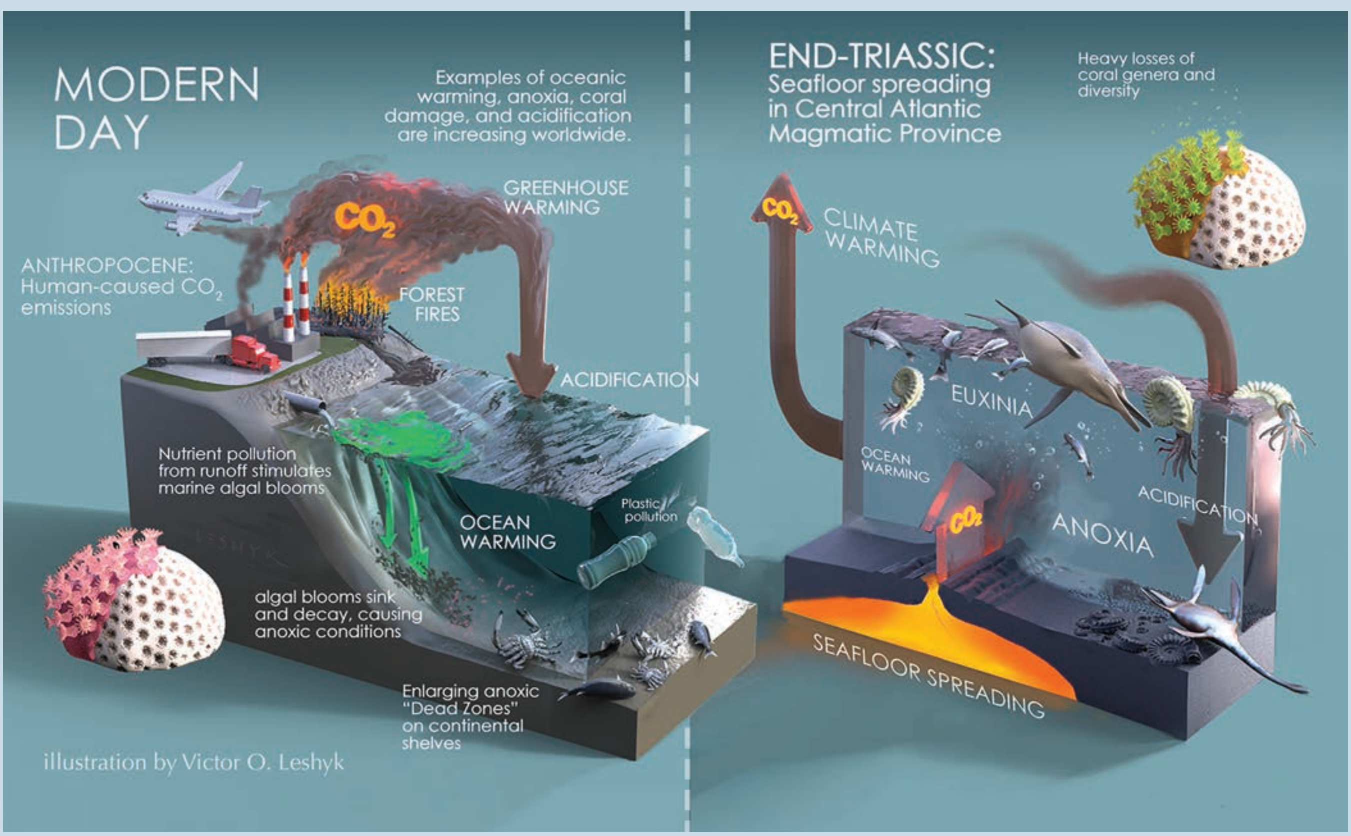
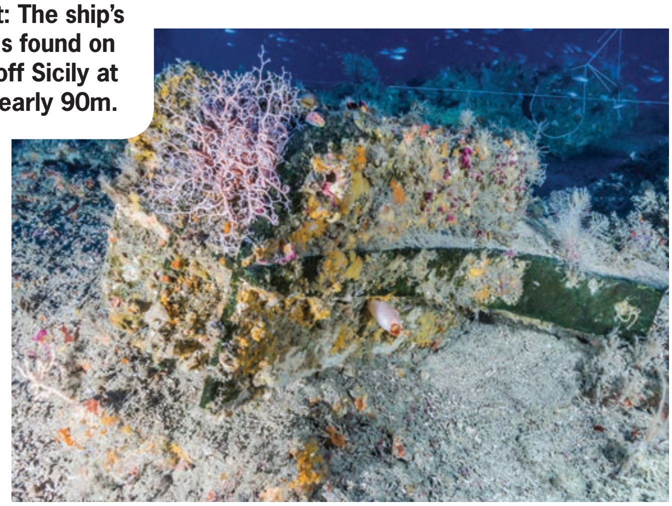


Illustration by Victor O. Leshyk



The ram being investigated in the laboratory.

Bottom right: The ship's ram as it was found on the seabed off Sicily at a depth of nearly 90m.

Top two and left image credits: Istituto Centrale per il Restauro (ICR) - Laboratory of Biological Investigation

Bottom right photo Image credit: K. Egorov / Società per la Documentazione dei Siti Sommersi – Global Underwater Explorers (SDSS-GUE)

Home Sweet Home

100+ underwater animal species found living on 2,200-year-old Med shipwreck

On March 10, 241 BCE, a sea battle took place near the Aegadian Islands off northwestern Sicily. A fleet equipped by the Roman Republic destroyed a fleet from Carthage, ending the First Punic War in Rome's favor. But scientists have now shown that this destruction and carnage utimately made a a rich flowering of marine life possible. In a recent study in Frontiers in Marine Science, they reported finding no fewer than 114 species of animals, co-existing in a complex community, on a ship's ram from a Carthaginian ship sunk in the battle. This is the first study of marine life on a very ancient wreck. The ram is not only a priceless archeological find, but also a unique window into the processes by which marine animals colonize empty sites and gradually form mature, stable, diverse communities.

"Shipwrecks are often studied to follow colonization by marine organisms, but few studies have focused on ships that sank more than a century ago," said last author Dr Sandra Ricci, a senior researcher at Rome's Istituto Centrale per il Restauro (ICR). Here we study for the first time colonization of a wreck over a period of more than 2,000 years. We show that the ram has ended up hosting a community very similar to the surrounding habitat, due to 'ecological connectivity' – free movement by species – between it and the surroundings."

The ram, nicknamed 'Egadi 13', was recovered in 2017 from the seabed around 90 meters deep by marine archeologists from the Soprintendenza del Mare della Regione Sicilia, directed by Dr Sebastiano Tusa, in collaboration with divers from the organization Global Underwater Explorers.

Read the full story on *MarineTechnologyNews.com:*
bit.ly/3rN8b5z

Sonardyne Hybrid Positioning

Acoustic and inertial position reference systems from Sonardyne have been chosen to underpin the station keeping activities of multiple deepwater vessels operating in the energy and ocean research sectors. Through a combination of upgrades to existing installations and the purchase of new systems, four deepwater drillships, a marine construction vessel and a floating production system working in North and South America will be using Sonardyne's 6G (sixth generation) Marksman DP-INS technology. In addition, an ultra-deepwater scientific drilling vessel has now also upgraded its Marksman DP-INS system to the latest (sixth generation) equipment configuration. Marksman DP-INS improves vessel positioning performance by exploiting the long-term accuracy of Sonardyne's Wideband acoustic signal technology with high integrity, high update rate inertial measurements. The resulting navigation output is capable of riding-through short-term acoustic disruptions associated with deep water drilling and is completely independent from GNSS so can be considered as a third, independent reference for DP Class 3 vessels.

The system uses a combination of single or dual redundant surface transceivers, Sonardyne's own vessel-based INS sensor and Long Baseline (LBL) seafloor transponders. However, unlike conventional LBL operations, Marksman DP-INS does not need a full seabed array of transponders to be installed and calibrated before subsea operations can commence. For most subsea tasks, positioning specifications can be met with only one or two transponders deployed on the seabed. Additionally, as the system needs only occasional aiding from the acoustics, transponder battery life is substantially increased so the need to task an ROV to deploy and recover transponders for servicing is reduced. Read the full story here: **bit.ly/33NDghJ**

Image courtesy Helix Energy Solutions, by Robert Almeida

First North Brazil Current Ring of '22

Woods Hole Group's (WHG) EddyWatch team monitors and reports on Ring Sylvia, *[named for Sylvia Alice Earle, Ph.D.],* the first North Brazil Current (NBC) ring to form this year. Ring Sylvia shed from the NBC on 18 January 2022 near 08°30'W, 53°00'W, offshore eastern Suriname (Figure 1). The ring is oriented northwest to southeast, is 520 km across, and spans water depths from 50 m to 5,000 m. Following separation, the NBC Retroflection reformed 100 km southeast of Sylvia.

WHG's EddyWatch team uses satellite imagery, drifting buoys, and rig-mounted current meters to monitor the location and current intensity of NBC rings. Over the next couple months, Ring Sylvia will migrate westward to west-northwestward along the coastline of Suriname and Guyana and impact active oil and gas facilities in the area. WHG has begun to issue daily forecasts to assist operators with planning safe and efficient operations in and around strong currents.

Read the full story and more images click here: **bit.ly/3nU0I3Q**

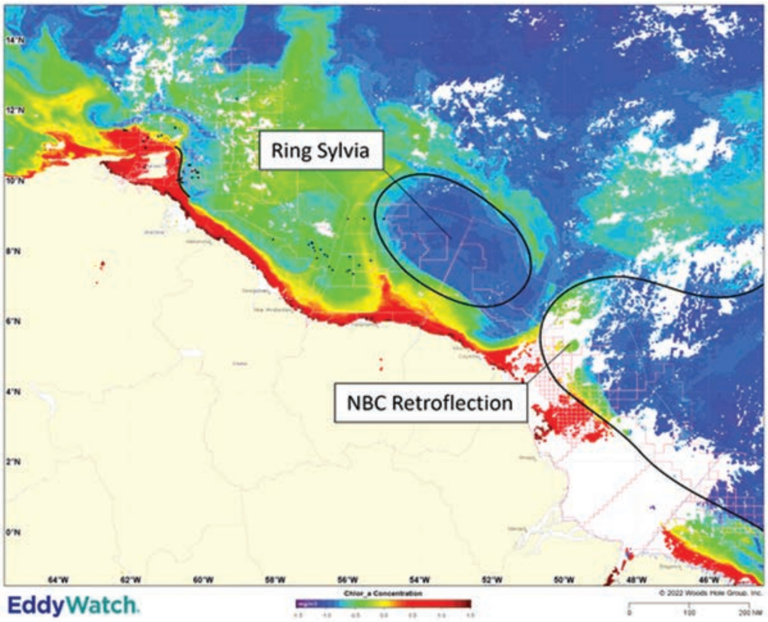


Image courtesy Woods Hole Group

Figure 1: Satellite ocean color image of Ring Sylvia and the NBC Retroflection on 18 January 2022.

DLM Custom Data Logger

Dynamic Load Monitoring (DLM), of Southampton, UK, has provided a custom data logger and subsea measuring technology for use in a new tank where cable protection systems are tested.

Darlington, UK-based Subsea Innovation Limited, a designer of subsea and offshore equipment, will primarily use the equipment for testing and verifying its in-house designed subsea equipment such as pipeline repair systems (clamps and connectors), hang-off systems, and other bespoke subsea and offshore equipment.

It will also be used for internal testing for Subsea Innovation's purpose-designed and built submerged wear test rig. The company also maintains and manufactures deck equipment for cable lay vessels.

This is the second major order that DLM has delivered to the company recently, having provided two custom monitoring systems that were installed on subsea bend stiffeners at an offshore wind farm. However, DLM is increasingly responding to demand for custom and standard solutions from similar maritime technology and marine electronics companies.

In this instance, a custom data logger takes inputs from several sensors, initially feeding back information on load, rotation, and temperature. More sensors can be added to an expandable system should the need arise in the future. A stainless steel enclosure is mounted in Subsea Innovation's workshop next to the test tank, which remains in construction. Within the enclosure, the logged data is collated and logged again as a package in a Programmable Logic Controller (PLC) on a memory card.

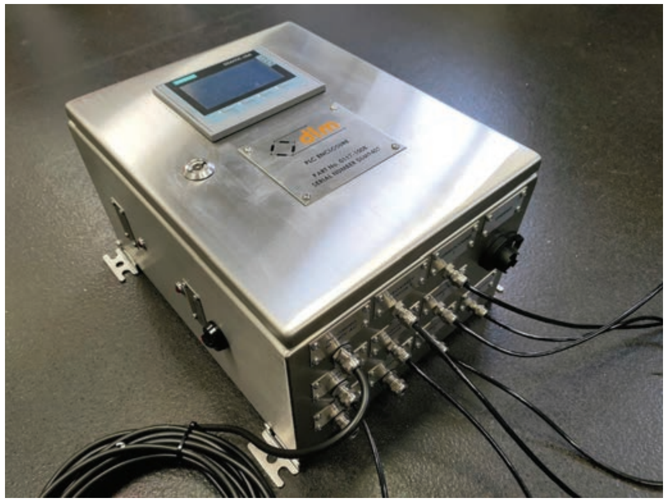


Image courtesy DLM

Eco Wave Announces Key Milestone

Photo courtesy EcoWave

Eco Wave Power Global AB announced the first set of floaters and supporting structures for Eco Wave Power's grid-connected EWP-EDF One project have been delivered to the Jaffa Port project site in Israel, marking a key milestone in the development of this innovative wave energy array.

The floaters were delivered in accordance with the collaboration agreement entered between EWP-EDF One Ltd. and Lesico Ltd.

The project's next step is the upcoming installation of the first floaters on the Jaffa Port breakwater.

JW Fishers Helps to Locate Missing Persons

In 2020, Berkshire County purchased a JW Fishers Side Scan Sonar system. In May 2021 the Berkshire County Sheriff's Office was called to assist local and state authorities in searching for a man thought to have gone missing in Pontoosuc Lake in Pittsfield, Massachusetts. The search began a day after police received reports of a suspicious vehicle in the parking area of Blue Anchor Park. Items located in the missing man's vehicle prompted police to launch the search. Investigators believed it was unlikely that the missing person left the area by any other means and launched a search of the lake with the Berkshire County Sheriff's Office, Massachusetts Environmental Police, and Massachusetts State Police. The first day of searching lasted over 7 hours before it was determined that more resources needed if the search was to be successful.

In the end, the Pittsfield Police, Pittsfield Fire, Massachusetts State Police, Massachusetts Environmental Police, and the Berkshire County Sheriff's Office found the missing New York man's body with the assistance of its JW Fishers Side Scan Sonar.

The side scan has been a valuable additional resource for our team." To read more click here:

bit.ly/3fVjWRW

Photo courtesy JW Fishers

$34.4m for Sustainable Seabed-harvesting Tech

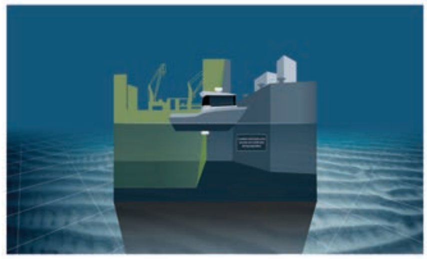
Photo by Morten Hjertø/Tau Tech; Copyright: Tau Tech

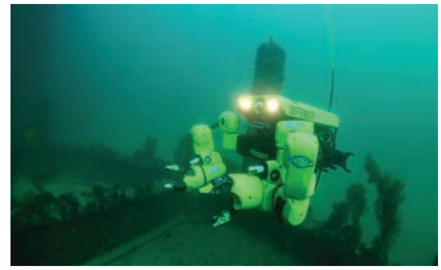
From left: Bernt Rogne, Sverre Olav Farstad and Øystein Tvedt.

Through a five-year research project, Norway's Tau Tech has developed a technology that reportedly enables sustainable seafood harvesting from the seabed, as the practice of dredging the seabed for bottom-dwelling species is controversial globally and banned in Norway. Tau Tech raised $34.4m from impact investor Norselab, Hofseth International and industrial profiles in Western Norway to start harvesting Arctic scallops on a commercial scale, using the new technology. The most widespread catching method for shellfish globally, dredging, is controversial for the potential damages if can cause to the ocean ecosystem, including the release of large amounts of naturally stored carbon from the seafloor. Norway is one of the few countries that prohibits this method to protect seabed fauna. As a result, valuable seafood resources along the Norwegian coast have remained inaccessible for 30 years. Together with Norwegian independent research institute SINTEF, Tau Tech has developed a seabed-friendly harvesting method. In cooperation with the Institute of Marine Research, the Directorate of Fisheries and other leading marine experts, the company has proven over the past five years that its technology makes it possible to identify, select and sort shells without destroying surrounding vegetation and life. This opens up new, sustainable opportunities for fisheries nationally and internationally by providing access to untapped seafood resources, while also protecting fragile marine ecosystems and preserving invaluable carbon sinks. To read more click here:

bit.ly/3tRNkkt

New Products





EdgeTech 6205s2

EdgeTech introduced the 6205s2 Combined Swath Bathymetry & Side Scan Sonar System. Building on the 6205 and 6205s systems, EdgeTech redesigned the 6205s2 and delivers a more compact and lighter package with additional features and benefits including the options for an integrated INS, the higher res frequency pair of 850/1600 kHz, and EdgeTech's gap-fill side scan output.

bit.ly/3GWpdVi

EIVA Software

EIVA's new software variant NaviSuite Kuda Core provides advanced hydrographic survey software capabilities at an entry-level price. Tailored to support hydrographic surveys with a single USV or small survey vessel using multi-beam echosounder (including backscatter), LiDAR and/or camera, this software solution is priced at $2200 annually, designed to be simple to configure and run.

bit.ly/3qTjR7N

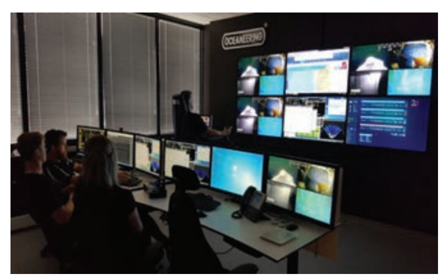
RE2 Robotics

RE2 Robotics received Phase I SBIR funding from the U.S. Navy to develop a system that enables "coupled control" of a ROV and robotic manipulator through a single control system. Coupled Locomotion And Manipulation System (CLAMS), will combine the robotic arms' control system and the ROV control system into one unit, improving coordination of the underwater movements.

bit.ly/3AsXOrx

Blueprint Lab Blueprint Lab creates advanced manipulator systems for harsh environments, predominantly subsea but also land and nuclear environments. It is also known for its flagship manipulators, the Reach Alpha 5 and the Reach Bravo 7, each providing a stronger, faster, lighter and more dexterous robotic arm capability for their class of vehicle. It manufactures rotators, rotating grabbers, and other high-performance subsea electric actuators, too. Two notable upgrades in 2021 were the release of the High-Force Electric Cutter designed to cut 1-in. conduit cable, and a new depth rating of 450m for the entire Bravo range. To improve suitability for offshore clients, the Reach Bravo Spares Package and Operator Tool Kit have also been released. The Reach Bravo, making use of these improvements, continues to be a significant subsea tool for offshore energy and military operators. The Bravo 7, flagship of the range, is a robust, electric 7-function manipulator designed for Inspection-Class ROVs.

bit.ly/3GOwtyO



Tiger "Goes Nuclear"

Built to survive in nuclear storage ponds, a sixth Saab Seaeye Tiger-N robot has been ordered for the Sellafield nuclear site. The sixth Seaeye Tiger-N joins a fleet of nuclear-environment enabled Seaeye Tiger-Ns, deployed to gather and sort, metre-long, 15kg radioactive fuel bars, for removal to long-term storage, among other roles.

bit.ly/3IBWvcX

OceanAlpha

Malaysia geo-solutions provider HGIS has used their first uncrewed surface vehicle (USV), the 5.5 m M40P developed by OceanAlpha, to complete an entirely remote nearshore inspection of a subsea pipeline in TALI Field for their project with Brunei Shell Petroleum (BSP). The USV was remotely controlled and monitored using OceanAlpha's independently developed control system.

bit.ly/343ABA2

Oceaneering

Oceaneering conducted the first onshore remote piloting of a remotely operated vehicle (ROV) in the U.K. sector for bp, conducted from Oceaneering's Onshore Remote Operations Center (OROC) in Stavanger, Norway. This project was the first implementation of ROV remote piloting in the U.K., the first cross-border implementation, and the first operational implementation for bp.

bit.ly/3FQ3FII

Who’s News?

Latest People & Company News

Photo Courtesy NOC

Professor Ed Hill receiving CBE insignia from HRH The Duke of Cambridge.

Photo Courtesy NOC

Obituary: Raymond Pollard

Professor Ed Hill Honored

The National Oceanography Center’s (NOC) Chief Executive, Professor Ed Hill, received the insignia of a CBE at an investiture at Windsor Castle held by HRH the Duke of Cambridge. Professor Hill was awarded the CBE in the Queen’s Birthday Honors 2020 list, in recognition of his services to ocean and environmental sciences. Professor Hill has been committed to ocean exploration and observation throughout his 35-year career, and recently led NOC to becoming an independent charity. Under his guidance, hundreds of scientists, engineers, and technicians have continued to advance ocean science and technology to guide solutions and changes that impact human society, as well as supporting global efforts in addressing the challenges the world is facing, including climate change. His career has seen him as a leading researcher and chief scientist, undertaking over 20 expeditions at sea studying water circulation on continental shelves. He has served on numerous national and international advisory bodies and is a key source of expertise to the UK government. He was appointed OBE in 2010 for services to environmental sciences.

Obituary: Raymond Pollard

The National Oceanography Center (NOC) was saddened by the passing of Raymond Pollard, a major contributor to the subject of oceanography. Pollard inspired and mentored many young scientists and played a critical role in forming and developing science teams at the NOC. He was known for giving ‘straight off the ship’ presentations, bringing the immediacy, insight, and excitement of new results to audiences in such an inspiring way. The oceanographer led the formation of the James Rennell Center for Ocean Circulation in 1989 to deliver the World Ocean Circulation Experiment (WOCE), which integrated observations and ocean modelling. This ultimately led to the Institute of Oceanographic Sciences (IOS) moving to Southampton.

Pollard began his career by completing an honors degree in mathematics at the University of Cape Town before studying at Cambridge University for his doctorate. His thesis on the theory of near surface inertial oscillations led him to the Woods Hole Buoy Group, where he made the first high quality observations of the structure of inertial oscillations and their propagation of wind energy into the upper ocean. He led numerous major seagoing expeditions, some of which include the Crozet Islands and in the Southern Ocean and Southwest Indian Ocean. Raymond was also an innovator, creating new measurement techniques and playing a crucial role in the development and use of towed undulating CTDs. He was also an early user of Acoustic Doppler Current Profilers (ADCPs) and he played a critical role in bringing scientific computing onboard ships – most notably on the RRS Discovery.

A Legend Leaves OceanWise

In December OceanWise said farewell to a legend of the industry: John Pepper who took the final leap to retirement and stepped down from his post as OceanWise Chairman.

Pepper has 50 years’ experience working in the Geospatial Information industry, joining Ordnance Survey from school where he first trained as a land surveyor, and then transferring to the UK Hydrographic Office, before joining Mark, Caroline and Mike at OceanWise just after the company was founded almost 12 years ago. Pepper has been a key figure in promoting the need for the OceanWise

Who's News?

Latest People & Company News

Photo Courtesy PMI

Centa tapped to lead PMI

Photo Courtesy OceanWise

John Pepper, OceanWise, Retires

Photo Courtesy GUH

The Global Underwater Hub appoints Kirstin Gove, Trish Banks and Jacqui Taylor.

marine mapping products, having helped establish, and then chairing the IHO's Marine Spatial Data Infrastructure working group from 2008 – 2014. In parallel, he drove forth the OceanWise business development and marketing portfolio and helped create and deliver the Marine Data Management training courses and free annual workshops. He leaves OceanWise to pursue his passions in travel, sports and food and wine and spend more time with his family.

Centa Named President of PMI

PMI Industries, Inc., an engineering, manufacturing, and testing company appointed Robert (Bob) J. Centa, MBA to president. Centa succeeds Bob Schauer who is retiring after 17 years of service to PMI. Centa was most recently the Chief Financial Officer of The Great Lakes Brewing Co. in Cleveland, Ohio.

Centa brings a broad business acumen and over 25 years of experience in leadership, strategy, operations, and finance in manufacturing and distribution, as well as a wide range of industries and companies as diverse as start-ups, family-owned, private equity, and large publicly traded.

Senior Appointments @ GUH

The Global Underwater Hub (GUH) announced a series of senior appointments to deliver its ambition of transforming the underwater industry in the UK, appointing a finance director and head of communications. Kirstin Gove has joined as head of communications. A former STV news anchor and broadcast journalist, Gove has nearly three decades of experience working across various sectors of the energy industry including oil and gas, drilling and decommissioning.

Jacqui Taylor has been appointed as a finance director, a position in which she will be responsible for driving commercial strategy design, development and delivery of board reporting and oversight of governance for the GUH. Taylor is a qualified chartered accountant with more than 20 years of experience. To support the GUH's continued expansion, Trish Banks has been promoted to the role of operations director, having previously played a key strategic role in the growth of Subsea UK and its transformation into the GUH.

CGG Confirms Multi-Client Survey

CGG announced phase three of its dual-azimuth multi-client 3D survey in the Northern North Sea. Starting in early May 2022 and continuing throughout the North Sea season, phase three will expand on phases one and two of the program conducted in 2020 and 2021.

Initial data from the phase three acquisition are expected to be available in early 2023, and final processed data in early 2024. The multi-year survey adds a second azimuth over CGG's existing Northern Viking Graben (NVG) multi-client 3D survey and extends coverage into the UKCS. The survey is supported by industry pre-funding.

In Memoriam: Chris Welsh

Businessman, aircraft pilot, competitive sailor, and explorer-submariner Chris Aiden Welsh passed away suddenly of natural causes at his home in Point Richmond, CA, on March 15, 2021, at age 58.

Chris lived many lives at once, all of them at full throttle. His gregarious nature was a superpower. He understood that a good team, empowered by a clear goal, a defined timeline, and heartfelt passion, can achieve remarkable things.

Born and raised in Newport Harbor in Southern California, he was introduced to sailing by his mother, Sally Welsh, at age 3. He studied finance and real estate at UC Berkeley. The profits from his real estate investments financed his passion for competitive sailing. In 2004 he purchased Ragtime, a Spencer 65 at auction. Built in 1963 in New Zealand by John Spencer, and originally named Infidel, Welsh and friend Alan Andrews restored Ragtime for the 2008 Los Angeles-to-Tahiti race. Overcoming numerous technical difficulties, they finished first. Ragtime's reputation spans numerous ocean regattas, including 17 Los Angeles-to-Honolulu Transpac crossings.

Chris purchased Richard Branson and Steve Fossett's record-breaking trans-Atlantic 125-ft catamaran PlayStation, built by Morrelli & Melvin (Newport Beach, CA), after Fossett was killed in a plane crash near Mammoth Mountain in 2007. Chris recounted arriving to examine the boat, when the broker asked, "When do you want to see the submarine." Chris said he replied with bewildered amusement, "What submarine?" It was DSV Deepflight designed by futurist engineer Graham Hawkes. PlayStation was being modified to serve as a mothership for an expedition to dive the deepest ocean trenches. A whirlwind of fascination with submarines began for Chris. He and Richard Branson created a cooperative venture, Virgin Oceanic, in 2009. The venture was paused in 2014 awaiting further technology development.

Chris renamed PlayStation to Cheyenne. While Chris continued the 'mothership' concept, he hedged his bet and made certain he got the PlayStation's main mast. Over time, the goal of diving the trenches evolved into diving the seven seas with researchers aboard Cheyenne, using a new submarine Pentarius (https://pentarius.com). His goal was to enable scientific observations of the human-influenced effects on the oceans by overfishing, climate change, and pollution. Chris was particularly drawn to the well-being of giant squid and the impact of plastics on the ocean's health. He also participated in IDUM, International Dialog on Underwater Munitions, who advocate for the global eradication of all classes of underwater munitions from the seas. In July 2011, Chris joined a multi-institution oceanographic expedition out of Guam to the Sirena Deep, 8-hours south, onboard the Super Emerald, a 62-ft interisland vessel chartered out of Saipan. Four ocean landers were deployed. To the east, an area of low pressure coalesced into a tropical storm, heading west. Using his Transpac experience, Chris advised the captain. The vessel moved north into the lee of Guam, as the storm developed into Typhoon Muifa, passing on the other side of the island. Muifa grew to a Cat 5 hurricane with sustained wind speeds of 161 mph.

A licensed submarine pilot, Chris acquired DeepFlight, LLC, a manufacturer of personal submarines founded by Graham Hawkes (www.deepflight.com). Chris was expanding the market for tourist submarine operations at island destination hotels around the world. That work continues.

Chris is survived by his wife, Tina, his parents Sally and Terri, his younger brother Doug, sister-in-law Mary, nieces and nephew Britt, Becca and Charlie, and his beloved dog, Cooper. "And, as we like to say," adds Tina, "a thousand sailors around the world."

(Remembrance by Kevin Hardy, friend and Super Emerald shipmate.)

MARINE TECHNOLOGY REPORTER

2022 Editorial Calendar

January/February 2022

Underwater Vehicle Annual

- Underwater Defense
- Manipulator Arms and Tools
- Autonomous Navigation GNSS MEMS
- Unmanned Vehicle Propulsion
- IMR: Offshore Inspection, Maintenance & Repair

Event Distribution:
Subsea Expo
February 22-24 Aberdeen, Scotland

Digital Edition

MTR E-Magazine Edition: Oceanographic

Special Report on
Coastal Zone Management

March/April 2022

Oceanographic Instrumentation & Sensors

- Fiber Optic Cables, Connectors & Slip Rings
- Buoyancy Technology
- Environmental Testing Equipment
- Underwater Communications
- Underwater Battery Technology

Event Distribution:
Oceanology International:
March 15-17, London, UK
IPF:
April 26-28, Atlantic City, NJ

May/June 2022

Offshore Energy: O&G & Renewables

- Hydrographic Survey Sonar
- Sonar, Telemetry & Data Processing Software
- USV, ROV & AUV Platforms
- GPS, Gyro Compasses & MEMS Motion Tracking
- Interconnect: Underwater Cables & Connectors

Event Distribution:
OTC:
May 2-5, Houston, TX

July/August 2022

Autonomous Vehicle Operations

- ROV Technology: Work Class to Micro Systems
- Thruster Tech: Underwater Propulsion
- Underwater Tools & Manipulators
- Scientific Deck Machinery

Event Distribution:
MATE ROV Competition:
July 2022

Digital Edition

MTR E-Magazine Edition: Hydrographic

Special Report on
Offshore Wind Field Surveys

September/October 2022

MTR100: Focus on 100 Leading Companies, People and Innovations in the Subsea Space

Event Distribution:
Oceans 2022:
October 17-21, Hampton Roads, VA

November 2022

Ocean Observation: Gliders, Buoys & Sub-Surface Networks

- Acoustic Doppler Sonar Technologies ADCPs and DVLs
- Instrumentation: Profilers, Samplers & Sediment Corers
- Fresh Water Monitoring & Sensors
- Seafloor Mapping
- Geospatial Software Systems for Hydrography
- Underwater Imaging: Lights, Cameras, Lasers & Multibeam Sonars

Digital Edition

MTR E-Magazine Edition: Subsea Vehicles

Special Report on
Autonomous Defense Vehicles

OI '22 is a 'Go'
for in-person Event in London

Photo courtesy Oceanology International

*The **Oceanology International** exhibition and conference returns to ExCel London in March 2022*

Oceanology International (Oi) exhibition and conference is back on the calendar as an in-person event. The premier subsea technology event in the world, Oceanology International 2022 is scheduled to take place in ExCel London on March 15-17, 2022.

With the welfare of attendees a paramount concern, organizer RX Global has designed an exhibition and conference space which leaves no stone unturned in creating a COVID-safe environment.

In addition to the welcome return of long-term Oi exhibitors such as iXblue, Kongsberg Maritime, Fugro and Teledyne Marine, the Oi22 show floor will be accommodating 83 new stands hosting companies which are exhibiting at an Oi event for the first time. These include GeoAcoustics Ltd, which supplies sonar equipment for bathymetry, side scan and sub-bottom profiling; and Blueprint Lab, which manufactures robotic arms for use in challenging subsea environments.

At the center of ocean innovation and technology, Oi will showcase world first product introductions including the culmination of a four-year EU supported project called AIRCOAT, a hull coating which reduces friction, fouling and emissions while increasing vessel performance. From Sweden, Amo Kabel launch the first DNV approved aluminum power cables replacing traditional copper. A record-breaking underwater AUV thruster will be launched by Tianjin Haoye Technology of China and Canada's Seamor Marine will introduce the new Mako ROV built to carry a variety of accessories with a power capacity to run them all simultaneously.

Another attraction on the exhibition floor is the Ocean ICT area showcasing over 20 companies, dedicated to the latest developments in ocean IT, communications, satellite and data solutions. These include BeamworX, which specializes in the acquisition, processing and integration of single/multibeam echosounder and laser data; Hydromea, an emerging supplier in high-speed wireless underwater communication and

credit

Photo courtesy Oceanology International

portable robotics; and WSENSE, which manufactures monitoring and comms systems that harness a unique patented solution in the Internet of Underwater Things (IoUT).

Always popular at Oi events are the multiple on-water product demonstrations, this year on an even bigger scale and scope, unique to Oi and staged in the adjacent Royal Victoria Dock. This year Fugro will be demonstrating its Blue Essence 12 m uncrewed surface vessel (USV), the first in the industry with an electric remote operated vehicle (eROV) controlled from an onshore remote operations center. USV's will play an important role in the maritime sector offering a safer, more sustainable solution in support of the energy transition. The dockside will manage operations from multiple all-weather locations and includes demos from the likes of USV manufacturer OceanAlpha; ROV designer Blueye; and the hydrographic survey solutions provider Seafloor Systems. Visitors can also examine moored vessels on display such as the Kommandor Stuart from Hays Ships, and vessels hosted by Magellan, Briggs and NORBIT Subsea. The latter's 14.25m catamaran, SV Thame, is fully equipped for high-resolution bathymetric and terrestrial surveys.

Meanwhile, the all-new Ocean Futures Theater will be the flagship venue for the Oi 22 industry leading conference program. Headline presentations on The New Blue Economy, Energy Transition and Technology in Support of Science will feature distinguished guest panellists including Dr. Rick Spinrad, US Under Secretary of Commerce for Oceans and Atmosphere & NOAA Administrator, Vladimir Ryabinin, Executive Secretary IOC-UNESCO and Dr Ralph Raynor Professorial Research Fellow at the LSE. Associated technical presentations by a prominent array of academics, technicians, engineers, CEOs and scientists will be held during the show covering important areas such as Ocean Observation, Energy Transition, Pollution & Low Carbon, Hydrography & Survey and Uncrewed Vehicles.

www.oceanologyyinternational.com

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