MARINE TECHNOLOGY REPORTER

January/February 2024
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On the Cover

The Orca XLUUV delivered by Boeing to U.S. Navy
Image courtesy Boeing


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NEW YORK
118 E. 25th St., New York, NY 10010
Tel: (212) 477-6700; Fax: (212) 254-6271

CEO
John C. O'Malley
jomalley@marinelink.com

President & COO
Gregory R. Trauthwein
trauthwein@marinelink.com

Contributing Writers
Kevin Hardy
Celia Konowe
Edward Lundquist
David Strachan

Production Manager
Irina Vasilets
vasilets@marinelink.com

Production & Graphic Design
Nicole Ventimiglia
nicole@marinelink.com

Corporate Staff

Manager, Marketing
Mark O'Malley
momalley@marinelink.com

Accounting
Esther Rothenberger
rothenberger@marinelink.com

Manager, IT Services
Vladimir Bibik

Circulation
Kathleen Hickey
mtrcirc@marinelink.com

Advertising
Vice President, Sales and Marketing
Terry Breese
breese@marinelink.com
Tel: (561) 732-1185

Advertising Sales Manager
Frank Covella
covella@marinelink.com
Tel: (561) 732-1659

John Cagni
cagni@marinelink.com
Tel: +1 (631) 472- 2715

Mike Kozlowski
kozlowski@marinelink.com
Tel: (561) 733-2477

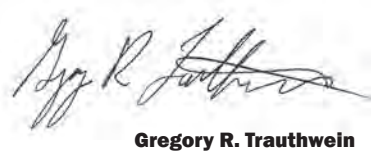
Editorial

Justin Zuure

About 12 years ago I was invited to the home of then Chief of Naval Operations, **Admiral Gary Roughead**, for "a discussion on unmanned underwater systems." When I first received the invite, my first thought was *"how did I get on this list."* But that dinner was truly transcendent in multiple ways. Personally, it gave to me a clear and unfettered view (though not for attribution or reporting) on the path, direction and importance of the subsea vehicle market. Sitting at that table that night were several U.S. Navy Admirals as well as the CEOs from about a dozen autonomous underwater vehicle companies, and the discussion was of considerable depth and scope regarding the navy and its need for subsea robotics to perform as well, as long as their cousins on the land and in the air.

Fast track to 2024, and many of the topics discussed that evening are coming to fruition now. Last month Boeing delivered the first Orca XLUUV, essentially a small, uncrewed military submarine that is designed to stay at sea for up to six months at time to complete as many missions that can be loaded into its considerable payload bay. In fact, *"The sky's the limit in terms of payloads that can be brought into the vehicle"* is how **Ann Stevens**, Vice President, Boeing Maritime & Intelligence Systems, said it in our recent interview which starts on page 22.

But bigger is not always better, and there has been a continued evolution of vehicles and systems across the size and capability scale, from the micro to extra-large. That, in turn, has spurred a fast evolution of associated technologies – from sensors to batteries to materials – all working in unison to maximize capability and endurance while minimizing power draw and the need for maintenance. As we all know, the military is a big and primary driver for these technologies, and we're pleased to present a pair of topical articles in this edition: first, **David Strachan's** look at the rise drone wars and of Combat UUVs, starting on page 8; second, an inside out look at the U.S. Navy and its subsea vehicles from our resident Navy insider **Edward Lundquist**.



Gregory R. Trauthwein
Publisher & Editor

MARINE TECHNOLOGY REPORTER

www.marinetechnologynews.com
Vol. 67 *No. 1*
ISSN 1553-276

118 East 25th Street,
New York, NY 10010
tel: (212) 477-6700
fax: (212) 254-6271

Marine Technology Reporter (ISSN 1559-7415) is published monthly except for February, August, and December by New Wave Media, 118 E. 25th St., New York, NY 10010-1062. Periodicals Postage Paid at New York, NY and additional mailing offices.

POSTMASTER: Send all UAA to CFS. NON-POSTAL AND MILITARY FACILITIES send address corrections to Marine Technology Reporter, 850 Montauk Hwy., #867, Bayport, NY 11705.

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MTR Editorial Advisors

Gallaudet

The Honorable Tim Gallaudet, PhD, Rear Admiral, U.S. Navy (ret) is the CEO of Ocean STL Consulting and host of *The American Blue Economy Podcast*. He serves on several boards, is a fellow at The Explorer's Club, and is a strategic advisor for a few dozen startups, research institutions, and nonprofits in the ocean, weather, climate, and space sectors. Gallaudet is a former acting Undersecretary and Assistant Secretary of Commerce, acting and Deputy Administrator of the National Oceanic and Atmospheric Administration (NOAA), and Oceanographer of the Navy. He has a bachelor's degree from the U.S. Naval Academy, and master and doctoral degrees from Scripps Institution of Oceanography.

Hardy

Kevin Hardy is President of Global Ocean Design, creating components and subsystems for unmanned vehicles, following a career at Scripps Institution of Oceanography/UCSD. He holds patents in the field of ocean landers. He is on the academic advisory board of Instituto Milenio de Oceanografía at the Universidad de Concepción, Chile. Hardy received an honorary Doctor of Science degree from Shanghai Ocean University in 2018. He proposed making thick wall glass spheres to Nautilus Marine Service/Vitrovex (Germany) that opened the hadal depths to routine exploration. He writes for the *Journal of Diving History* and the *MTR*.

Authors & Contributors

Darling

Konowe

Lundquist

Darling
As Head of Marine Facilities Programs at the National Oceanography Center, Eleanor Darlington is responsible for the delivery of scientific research expeditions on the global class research ships RRS James Cook and RRS Discovery and oversees the National Marine Equipment Pool.

Konowe
Celia Konowe is from Reston, Va., and has a bachelor's degree in environmental studies. She has study abroad experience in France and Ecuador. Currently, she is pursuing her master of environmental studies degree at Dalhousie University.

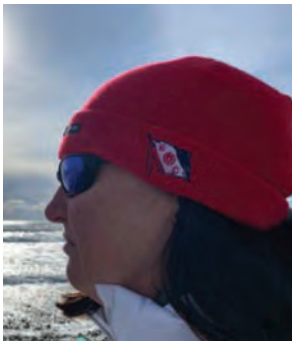
Lundquist
Edward Lundquist is a retired naval officer who writes on naval, maritime, defense and security issues.

Moniz
Rhonda J. Moniz is an underwater forensics expert specializing in diving technologies and subsea systems. She has more than 25 years of experience as a ROV pilot, master dive instructor, scientific diver, and dive safety officer. She is the president of the board of directors for the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS).

Strachan
David R. Strachan is a defense analyst and founder of Strikepod Systems, a research and strategic advisory focusing on autonomous undersea systems.

Sundin
Dr. David Sundin is Founder and Chief Scientist of Engineered Fluids, Inc., the leading provider of thermal management of batteries, EVs and data centers via Immersion Cooling. Dr, Sundin has over 30 years' experience developing and applying specialty electrical cooling fluids and has held leadership positions in a variety of IEEE and ASTM Committees.

Moniz



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SILENT, MOBILE, DEADLY: *THE RISE OF* COMBAT AUVS

By David Strachan, Senior Analyst, Strikepod Systems

Drone warfare has come into its own. The war in Ukraine, what many analysts are calling the first true drone war, continues to showcase and validate the combat effectiveness of small, lethal, expendable vehicles, particularly when employed by a resource-poor actor facing a heavily armed adversary. This has played out not only in the air and on the battlefield, where Ukrainian and Russian troops have successfully employed one-way attack (OWA) aerial drones, but also at sea, where flotillas of Ukrainian weaponized unmanned surface vehicles (USVs) have wreaked havoc on Russia's Black Sea Fleet, damaging several high-value warships, and driving others from Sevastopol to seek shelter in Novorossiysk. They have also been used to attack the Kerch bridge, a critical supply line to Russian operations on the Crimean peninsula. Given these highly asymmetric effects, naval planners and strategists around the world are taking careful note.

But despite their inherent advantages – low profile, high speed, real-time operator control – surface drones are vulnerable to barrier defenses, such as the security booms and nets installed by Russia in the wake of Ukraine's initial USV attack, or more high-tech measures, such as electronic warfare to disrupt communication between drone and operator. They are also vulnerable to visual and radar detection, and can be targeted by warship point defense systems and helicopter gunships. With these countermeasures in mind, small actors are now turning to the challenging, opaque undersea domain.

In Ukraine, wartime development of weaponized, combat autonomous underwater vehicles (AUVs) is underway, with two combat-capable AUVs being unveiled in recent months – **Toloka**, a family of OWA AUVs developed by Brave1, a Ukrainian defense technology cluster, and **Marichka**, a large displacement AUV developed by AMMO Ukraine. Although the Black Sea has taken center stage as a kind of maritime drone proving ground, Ukraine is not the only small actor relying on underwater ingenuity and innovation. In May, 2021, a **Hamas medium displacement AUV** was destroyed by the Israeli Defense Forces (IDF) as it was being deployed from a beach in northern Gaza, reportedly to attack an offshore installation. And in December, 2023, images surfaced showing what appeared to be another homebuilt Hamas AUV, the Al-Asef, ostensibly for use against Israeli ports and coastal targets. Iran is also understood to have developed a combat AUV, an unguided, long-range hybrid torpedo/AUV designed to strike stationary targets, such as anchored vessels or coastal infrastructure. These designs lie in stark contrast to the dominant combat AUV design paradigm for larger navies - i.e. complex, modular, multi-mission vehicles endowed with

advanced sensors and effectors, powerful onboard processing, high endurance, and large payload capacity. Several state actors are known to have such combat AUVs under development, including Russia, China, North and South Korea, India, Taiwan, Israel, France, the UK, Australia, and the United States. In general, they are large or extra-large vehicles that will be capable of detecting, classifying, localizing, tracking, and engaging enemy targets located on the ocean surface, in the water column, on the seabed, or even on land or in the air. They will be capable of deploying a range of weapons via launch tubes (vertical or horizontal), an internal weapons bay, or external stores. These weapons could take many forms - lightweight or heavyweight torpedoes, advanced sea mines, anti-ship cruise missiles (ASCMs), small unmanned aircraft systems (SUAS), or small AUVs that could be used as non-kinetic effectors, such as decoys or jammers.

To be sure, these larger vehicles are poised to have a significant impact on the conduct of undersea warfare. But it is smaller powers and non-state actors who, driven by wartime necessity, are rapidly developing the vehicles, tactics, and operations that could have a more immediate and profound effect. Whereas large and extra-large combat AUVs are designed to transit to an operational area and deploy combat payloads, the vehicles being deployed by actors like Ukraine, Iran, and Hamas are the combat payloads. In many ways, we are witnessing the real-time evolution of offensive mine warfare via the deployment of hybrid weapons leveraging the stealth and lethality of sea mines, the mobility of torpedoes, and the endurance and maneuverability of AUVs. For decades, sea mines and waterborne improvized explosive devices (WBIEDs) have provided terrorist, rogue, and nonstate actors with a cheap but effective sea denial capability. With the introduction of what are essentially mobile, guided mines, these actors have the potential to greatly enhance this capability, and to alter the nature of littoral maritime operations.

Through indigenous engineering, access to commercial off-the-shelf technologies, or the skilled re-purposing of COTS tech, such as Ukraine's integration of jet ski technology into its first generation OWA USVs, small actors with modest budgets and industrial capacities can gradually level the undersea playing field, gaining access to a domain where operations were once too complex or costly. And as we've witnessed with aerial drones, the potential for smaller powers to exert influence by amassing a "poor man's air force" of missiles and aerial drones is quite real. Could this extend to the undersea domain as well? For now, the barriers to entry remain higher

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than the surface or air domains, but they will continue to fall, and it is certainly possible that a determined actor could construct its own poor man's submarine force. Even a handful of crudely weaponized AUVs, strategically employed, could destabilize commercial shipping, delay or disrupt naval operations, or deny a more powerful adversary's access to the sea.

The question then becomes – how might these weaponized AUVs be countered? The current approach to mine countermeasures (MCM) – "find, fix, finish" – will need to quickly evolve. For warships operating in contested littoral areas, advanced hull-mounted sonars, such as the AN/SQQ-89A installed aboard Arleigh Burke-class destroyers which can detect and track a wide range of underwater contacts, would be key to warning of inbound AUVs. Intruder detection systems (IDS) would be critical for ports, coastal facilities, and anchored commercial vessels as these would be most vulnerable to weaponized AUVs. But once a threat is identified, innovative solutions will be needed to neutralize them, such as rapidly deployable nets or fencing. Underwater kinetic effectors might disable incoming vehicles, and anti-torpedo torpedoes may be effective against larger, slower moving AUVs.

The employment of overwhelming combat power against an enemy is the key to success in war, but how effectively that power is delivered can mean the difference between victory and defeat. Armed AUVs are a natural evolution of undersea warfare and they will continue to evolve, incorporating greater endurance, mobility, and lethality, and influencing the operations and tactics of small and large navies alike. While high-value, long-range AUVs bristling with sensors and weapons may provide larger navies with combat overmatch against peer or near-peer adversaries, large numbers of mobile, weaponized underwater vehicles could be an asymmetric gamechanger for smaller actors seeking to strengthen their maritime power.

About the Author
David R. Strachan is a defense analyst and founder of Strikepod Systems, a research and strategic advisory focusing on autonomous undersea systems.

UNMANNED AERIAL SYSTEM HAS EARNED ITS SEA-LEGS

By Edward Lundquist

The Swiss-Swedish joint-venture UMS Skeldar V-200 vertical take-off unmanned arial system (VTUAV) has earned its sea-legs. The V-200 has been selected for the German Navy's Braunschweig-class K130 corvette program, as well as the Belgian-Dutch replacement mine-countermeasures ship (rMCM) program.

The aircraft has conducted aerial inspections of merchant ships for emissions for the European Maritime Safety Agency (EMSA). "We provided a VTUAV that could land and take off from EMSA's ships," said UMS Skeldar CEO Axel Cavalli-Bjorkman.

The Finnish Coast Guard has also successfully demonstrated Skeldar V-200 operations to support day and night search and rescue missions from the Patrol Vessel Turva as part of the Valvonta2 project led by the Finnish Border Guard and funded by the European Maritime and Fisheries Fund.

The Germany Navy's corvette program calls for two V-200aircraft for each of their K130s.

ESG Elektroniksystem- und Logistik-GmbH (ESG) is the prime contractor for the German Navy's Sea Falcon program, which implements the requirement for a "Reconnaissance and Identification in the Maritime Operational Area (AImEG)" capability on the corvettes. According to a statement from ESG, the Skeldar V-200 can "operate for up to 5 hours with a maximum take-off weight of 235kg, a maximum speed of 75 knots and a payload of up to 40kg. It can take off and land automatically on the deck of the corvette in up to 20 knots of wind speed and sea state 3. An integrated sensor transmits real time optical and infrared images to the ground control station. The corvettes' capabilities for imaging reconnaissance will be significantly expanded in the future--objects can be detected and identified with the Sea Falcon far beyond the on-board sensor system."

The mine countermeasure vessels of the Belgian-Dutch rMCM program will feature the UMS Skeldar V200 aircraft.

Naval Group image

The Belgian and Dutch navies have a shared requirement for mine warfare vessels to operate in the high-traffic environment protecting the approaches to some of the busiest ports and waterways in the world. Together they are procuring 12 mine countermeasures vessels-- six for each navy -- which will carry a "toolkit" of unmanned and offboard systems. That toolkit suite, provided by Exail, includes two Skeldar V-200 aircraft. The ships will also have unmanned surface and unmanned underwater vehicles and towed sonars for mine detection. The toolkit includes the MIDS system (Mine Identification and Disposal System) for mine identification and neutralization; SEASCAN remotely operated vehicles (ROV); and K-STER expendable mine disposal vehicles (EMDS).

"Exail selected us as the result of an open procurement, which shows we have a strong product and we can be very competitive," said Cavalli-Bjorkman.

Flexible Payloads

The V200 can conduct Search and Rescue (SAR) missions, provide initial sensor information to queue follow-on investigations, and serve as a communications and data relay between dispersed nodes in a network, as well as act as a gateway to transmit data received from underwater systems. The company is also offering its autonomous V-200 Skeldar with new capabilities. UMS Skeldar has demonstrated the capability to deliver payloads such as a small unmanned surface vessel (USV) and carry sonobuoys to prosecute anti-submarine warfare.

The Skeldar V200's ASW sonobuoy dispensing capability was developed as part of the Canadian Department of National Defence's (DND) Innovation for Defence Excellence and Security (IDEaS) program.

While manned aircraft have been used to carry sonobuoys, there haven't been rapid-launch ship-based unmanned systems that can deploy passive sonobuoys for ASW operations.

According to Clifton Flint, who manages for global business development for sonobuoy systems at Ultra Maritime, said the partnership with UMS Skeldar has helped close that gap.

"This program has proven that deploying sonobuoys from Rotary Wing UAS with a compact logistical footprint is a practical and effective solution, adding another resource to the ASW toolbox for the benefit of the warfighter," said Flint.

UMS Skeldar is also collaborating with partners to introduce a signals and communications intelligence (SIGINT and COMINT) capability into the V-200.

Green Valley, Ariz., based Hydronalix is working with UMS Skeldar to carry and deploy its compact unmanned surface vessels (USVs) from the V-200. The autonomous Hydronalix USVs can carry sensor packages, serve as communications links, and deliver supplies.

"The USVs offered by Hydronalix are such versatile pieces of technology, which we saw a great many uses for including supporting covert surveillance missions and acting as a critical communications link" said Ted Ackerstierna, UMS Skeldar's vice president for the USA market. "Attached to our Skeldar V-200, which has an endurance of over six hours with significant payload weight, the complete system will be able to provide a wide range of enhanced capabilities for Marine Corps and Navy war fighters across their operational domains."

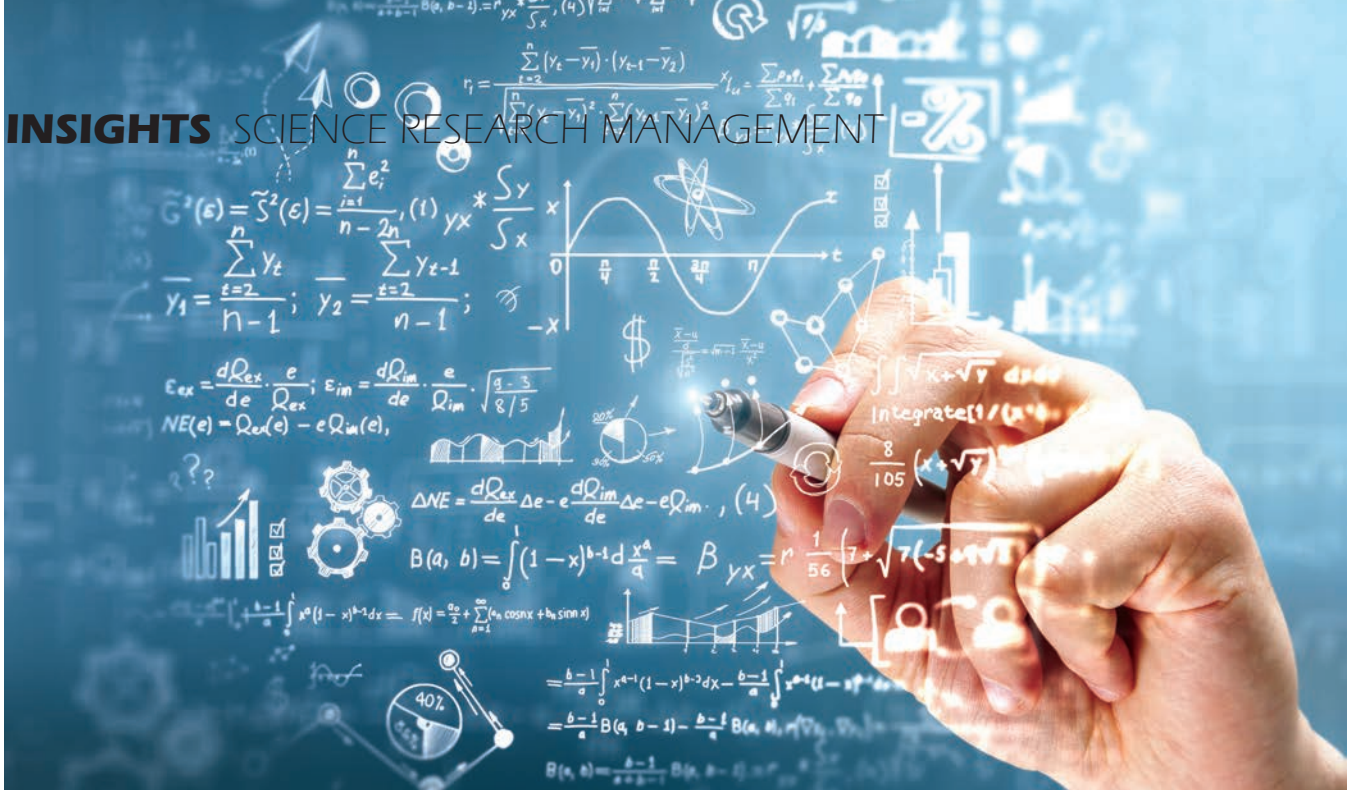
Hydronalix CEO Anthony Mulligan called the combination a "gamechanger." "The future distributed force concepts require innovative solutions that can provide the domain awareness for effective decision making. From rescue to ISR assignments, the UMS Skeldar UAV / Hydronalix USV platform combination with advanced mesh networking promises to serve Expeditionary and Special Forces under new distributed force designs."

Heavy Fuel

The Skeldar aircraft are powered by a Hirth heavy fuel engine, which uses safer heavy fuels, instead of the more dangerous gasoline fuels that powers most UAVs and are usually prohibited on ships.

Cavalli-Bjorkman recalled German Navy's a fly-off between the V-200 and another drone company "The flight test was conducted on a very cold day in February, and we had to show we could use F-44 heavy fuel, which is required for safety reasons on ships. We did it, with all the senior leaders—admirals and generals--watching. Our competitor did not show up, because their system could not operate with heavy fuel."

UMS Skeldar sees a large market for navies and coast guards that don't necessarily have the aircraft, deck space and facilities for manned helicopter operations from their ships but could benefit from the surveillance, data relay and payload delivery capabilities of VTUAVs. Likewise, larger navies could use an aircraft like the V200 for many missions that don't require a larger crewed aircraft.



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PAVING THE WAY IN INTERNATIONAL SCIENCE RESEARCH MANAGEMENT

Dr. Eleanor Darlington, *Head of Marine Facilities Programs at the National Oceanography Centre (NOC), discusses how NOC is paving the way in international science research management through its team of industry leading experts.*

The National Oceanography Centre (NOC) is at the heart of cutting-edge marine research, from coasts to deep ocean, and extending from tropical seas to the polar ice edges. As operators of two global class research vessels (RRS Discovery and RRS James Cook) alongside the National Marine Equipment Pool (NMEP), NOC is a leading provider of world class facilities to enable a diverse range of scientific research. National Marine Facilities (NMF) is the largest department in NOC, with 190 employees; the workforce is diverse and employment opportunities span from chefs to robotics engineers. Everyone is tasked with the same mission: to deliver world class facilities to enable world class science. With decades of experience, NOC works with international partners to share experience and expertise, leading the way on new developments and technological advancements.

Each research expedition and autonomous mission is unique. Every year, NOC delivers a diverse, multidisciplinary programme of work, facilitating marine researchers from across the UK and internationally, to undertake their novel work, all over the world. To achieve this level of operational complexity with such high success, NMF focuses on two key areas; highly skilled personnel who are industry leading experts, and a comprehensive project management process.

Effective Communication

Effective communication to all stakeholders is essential for successful delivery. This covers everything from calibration expiration of instruments, personnel capabilities, and budget management. NOC developed the Marine Facilities Planning (MFP) tool in collaboration with colleagues at Royal Netherlands Institute for Sea Research (NIOZ) and MAAS software engineering. This central web-based portal captures each request for ship time, equipment and handles all the contributing planning for each expedition. It is the one-stop-shop to understand deliverables. It is also a collaboration enabler for global research expeditions.

The MFP has been adopted globally by other ocean research institutions. This has created a shared language between operators, and common project management practise for marine research expeditions. As a result, the user experience from the perspective of the scientist, is more uniform across the world. With academics moving institutions internationally, this can ease transition into requesting facilities from their new country. But most importantly, it is prompting greater international collaboration between research ship operators. The structured management provided by the MFP software enables a streamlined approach to the daily management, enabling our people to think about the longer-term strategic goals of reducing car-

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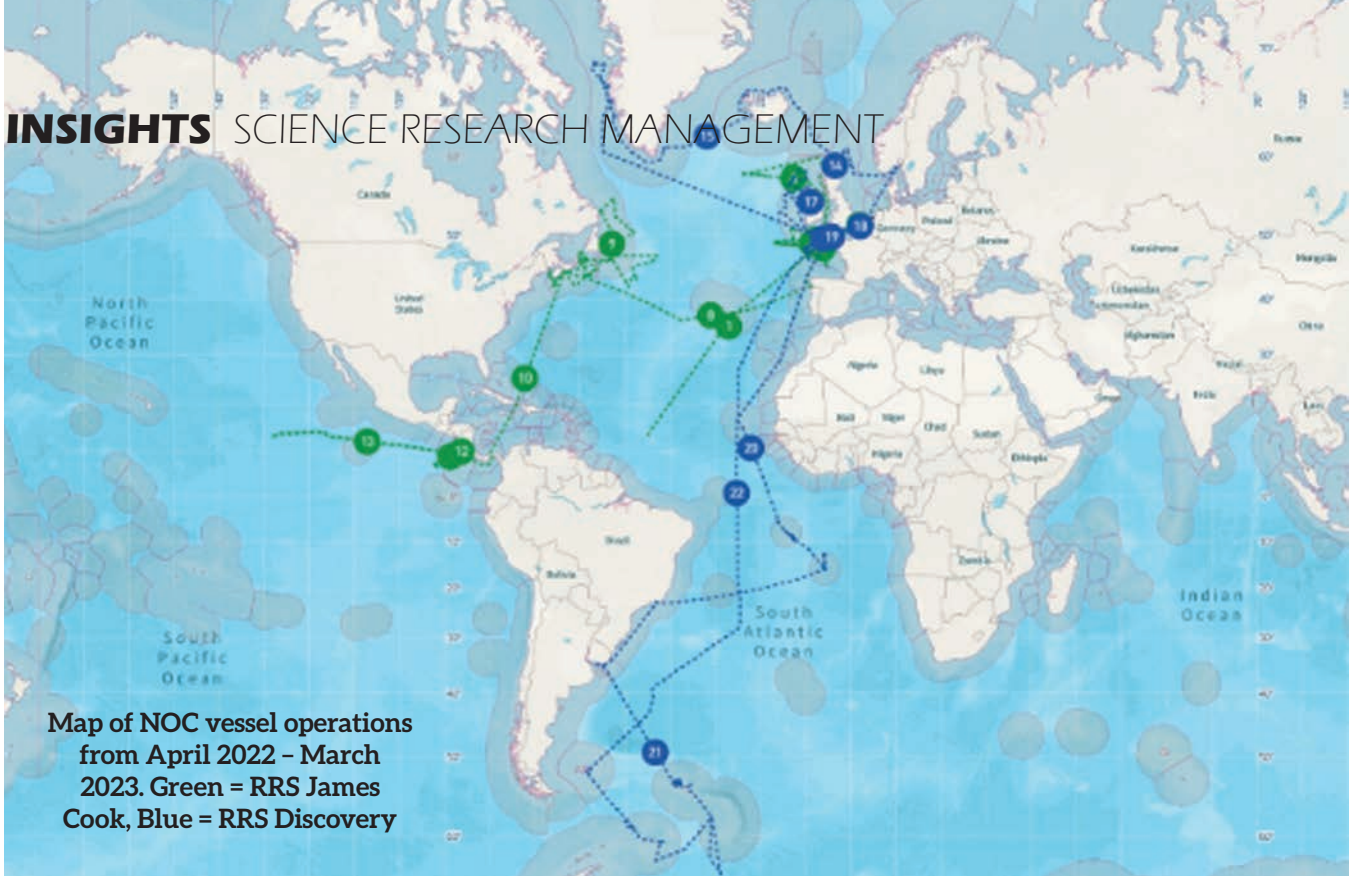


Map of NOC vessel operations from April 2022 – March 2023. Green = RRS James Cook, Blue = RRS Discovery

Credit: NOC

bon output, with an ambition of reaching net zero by 2040.

International Collaboration

One element of providing global coverage of world class marine science is to work with international partners, such as Spain, Germany, and the USA, and utilise their assets and marine programmes. The UK would then in return undertake expeditions on their behalf. In December 2022 NOC delivered a complex expedition on behalf of Germany. This utilised specialist seismic survey equipment from a Spanish institute and took place on the NOC operated vessel, RRS James Cook, off the coast of Costa Rica. By taking this collaborative approach it meant that assets and resources were shared across the nations. It was cost effective, time effective, and optimised the amount of carbon spent to deliver a specific project.

As well as increasing international collaboration, NOC are also seeking ways to reduce emissions from their vessels through initiatives to upgrade the fabric of the vessels themselves. In autumn 2023 NOC will trial Hydrotreated Vegetable Oil (HVO) in their vessels. This will play an interim role in reducing CO2 emissions, while industry determines what alternative fuel source is viable for vessels engaged in global operations.

Changes Cause by Net Zero

As we progress on our mission to operate world leading marine research facilities in a net zero world, we are moving from a model of ships plus autonomous systems, to one where autonomy is central. With the scaling up of autonomy, the project management is a key part in facilitating slick operations. Moving from a handful of vessels, to having hundreds of autonomous vehicles in the water, is a significant shift in operating mode. We are utilising the MFP to be able to undertake the same project management and international collaboration. This incorporates everything from asset management, freight requirements, customs and export licenses, and personnel scheduling. The final piece of the puzzle is deployment and recovery options. To make this as efficient and carbon neutral as possible, we are going to need to rely upon other research vessels. With the integration of autonomy into the MFP, international facilitation of shared assets is closer than ever.

Impacts of Software

Software plays a significant role in our everyday lives. Ensuring that the systems we use are fit for the future is vital to maintain a competitive and collaborative edge on our marine research operations. It is often the unseen backbone of operations; easy to overlook, but vital to ensure smooth running. NOC is leading the way in carbon accounting for operations and utilising tools in the MFP to aide decision making, putting the carbon cost of operations alongside the financial costs. It is only with continual innovation of such tools that we can enable marine research scientists to undertake novel research, while minimising the environmental impact of undertaking such studies.

We are on the cusp of a great revolution in oceanographic observing. The requirement to make measurements is still required more than ever, but we need to be more mindful of the way in which we do this. All these technological developments and improvements are brought to life in the operational world by the MFP. Software which is designed to deliver complex projects from start to finish, all encompassed under the principle of information sharing and optimisation. NOC continue to support other research vessel operators in utilising the MFP and encouraging wider international collaboration.

Credit: Rachel Marlow (NOC)

Trials of new autonomous technology, Autosub Long Range (ALR) in Oban, May 2023.

About the Author

As Head of Marine Facilities Programmes at the National Oceanography Centre, Eleanor Darlington is responsible for the delivery of scientific research expeditions on the global class research ships RRS James Cook and RRS Discovery and oversees the National Marine Equipment Pool.

All images courtesy Mocean Energy

MOCEAN ENERGY AIMS TO CREATE AN OFFSHORE RENEWABLE MICROGRID

*Garnering power from ocean waves is a generation behind the progress of offshore wind, but Mocean Energy, led by founder and managing director **Cameron McNatt**, is aiming to help offshore companies power up it's offshore and seafloor assets with its Blue Star system. A 10kW Blue Star prototype now has more than 14 months of operational experience under its belt, and the goal for 2024 is completion of that trial and continuing the path toward commercialization.*

By Greg Trauthwein

To start us off, can you give us a by the numbers look at Mocean Energy today?

Mocean Energy has been operating since 2016, today we have 23 people. We have built a 10-kW prototype that's been tested at sea for more than 14 months. Our first product, Blue Star, will be 20 kW of wave energy and five kW of solar and that will be about saving money and CO2 in offshore operations.

What attracted you to this business and when did you know that yours would be a career in ocean technology?

Like most careers, it's a bit of a winding journey. I grew up in Maryland going out on the water and sailing. My first job was with a company that developed software for naval architecture applications, and I ran with that and earned a Master's in Ocean Engineering at Oregon State University, which is where I first started working on Wave Energy. Next I went to the University of Edinburgh to do my PhD in Hydrodynamics and Wave Energy. And then the funding opportunity came up and my co-founder Chris Retzler and I started Mocean.

Before we dig into BlueStar and its application in helping to electrify the sea floor, can you give us the overview of the Mocean wave energy converter technology?

Conceptually, our wave energy devices is very simple mechanically: we have a big hinge and waves cause a flexing about that hinge that drives a generator. But what we've brought to the table is innovations around the shape of the machine. Our prototype has these big scoops on the front and

the back that we call wave channels. They do a number of somewhat nuanced and complex hydrodynamic things, but basically they cause the machine to move a lot more in waves. And if you move more in waves, you generate more power. (To develop the machine) we developed a software optimization program that created tens of thousands of different shape concepts, we ran them through a simulation and competed them against one another to find the best.

What are the biggest maintenance considerations of the unit?

Mechanically it's very simple, it's a hinge that moves back and forth and drives a generator. I think some of the more challenging aspects of that are converting that low speed, high torque mechanical power into electrical power. Generators typically want to run fast, whereas what we have is a very slow speed power and we're using a gearbox to convert that into electricity. So that's something that needs special consideration, but we are generating more and more data around that.

Is there a 'fail safe' mode for when the waves get too big?

We designed the system to be fail safe; it doesn't need to enter any survival mode. That's intentional because if something breaks and you can't enter (or exit) that survival mode of operation, you're in trouble. We've seen some big storms this past year, we have some great videos on YouTube from cameras on the machine. The front of the machine has this big slope plate that ensures that the bow always stays submerged. Waves are over topping (the unit) and that's a natural load shedding mechanism. On the hinge side, what would be a concern is what's called an end stop.

If you have the hinge rotate so far around that you get a metal on metal impact, that's a bad thing. But we've designed the hinge to be able to accommodate greater than plus or minus 90 degrees of rotation. In all of the testing we've done offshore and in wave tanks, we've never seen that happen.

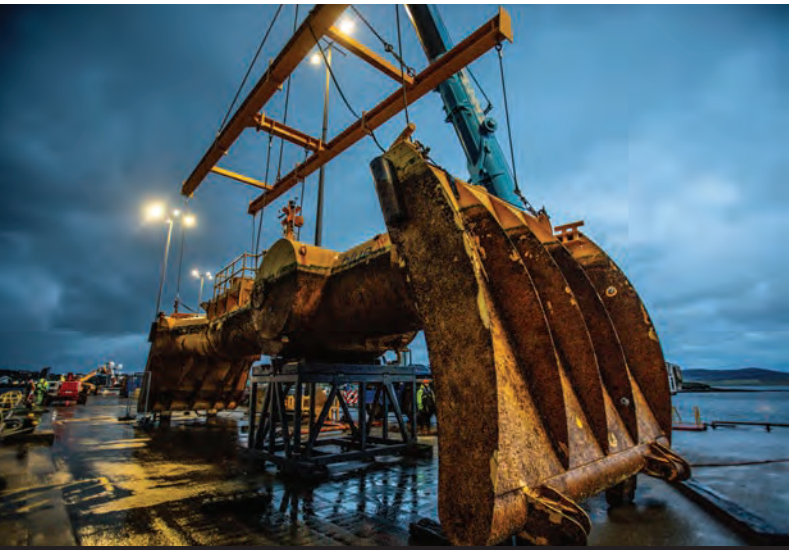
What do you see as the primary challenges or hurdles to bring WEC technology from the fringe to the mainstream?

We found an interesting market and application where we're deploying the technology: decarbonizing oil and gas. I'm talking about powering sub-sea equipment in the oil and gas sector where the traditional way that the equipment gets power is by running a cable along the seabed, either from a platform or from shore, and installing that cable is expensive. So I liken it to a traditional electrical grid model. You have a central power station, you distribute that power by cables, and what we're

All images courtesy Mocean Energy

proposing is the distributed renewable model. So instead of running a cable, we provide renewable energy where it's needed. We're trying to change the narrative and say, yes, we use wave energy, but our product is also going to have solar panels and battery storage is a really important part of it.

We're providing an offshore renewable microgrid solution, power and communication. So we can link up to various wireless communications including the growing low orbit satellite network, Starlink and others. Within that we can offer a cost savings CO2 savings and it's really low hanging fruit in this decarbonization challenge. It's much faster and less expensive to install these kinds of systems than, say, powering an entire offshore platform with a wind farm. And there is a substantial CO2 savings. So with one of our small machines, we estimate that we can save as much CO2 as a machine that generates 10 times as much power in a traditional renewables market.



The front of the machine has this big slope plate that ensures that the bow always stays submerged. Waves are over topping (the unit) and that's a natural load shedding mechanism.

You talked about decarbonizing oil and gas, but where else do you see potential for this Blue Star technology?

Besides pulling hydrocarbons out of the ground, the industry is very keen to sequester CO2 into the ground. There are projects that are being developed where you're going to put very similar technology offshore to put CO2 into the ground. You have [the push for residency for] autonomous subsea vehicles, [a subsea docking station that needs power]. There's emerging things like subsea data centers, direct water CO2 capture from the oceans, rather than pulling it out of the air, people are talking about pulling it out of the ocean, and that kind of technology needs power.

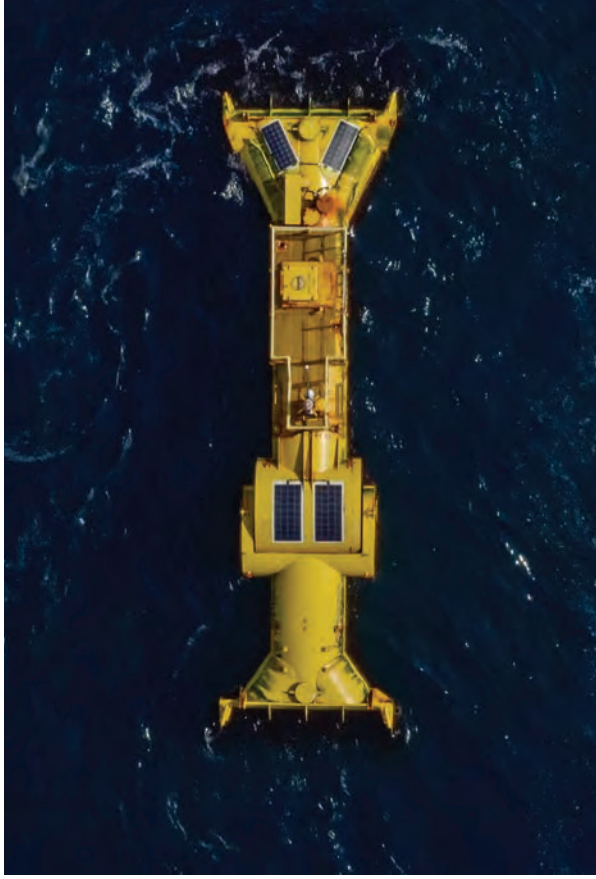
Let's look at the Blue Star technology today. Can you discuss where it's at in its development cycle and what's your timeline for its commercialization?

2024 is all about commercializing Blue Star. We have had our prototype out at sea for 14 months, cumulatively it'll be tested through next spring. And we feel that that gives us enough confidence in the performance of the technology that we can roll it out as a product. Certainly things have not gone perfectly, but if they went perfectly, we wouldn't learn anything. We're taking all of those learnings and we're applying them along with the kind of commercial design into the product. So that product is being designed and we're doing studies for customers right now, front-end engineering, design studies, feasibility studies, things like that towards getting the first Blue Star orders in 2024 and 2025.

When you look at 2024, what are the key milestones you hope to achieve?

It's completing that trial next spring and demonstrating this as success of the technology. It's getting that substantial commercial traction from a customer, really towards getting a system offshore. And then we're also working on scaling up, so we're working on the larger scale technology, the Blue Horizon. So we have a project to get that in the water in a couple of years.

Mocean Energy developed a software optimization program that created tens of thousands of different shape concepts.



All images courtesy Mocean Energy

Image courtesy HII

Making the REMUS 620

Last month we visited with ***Duane Fotheringham****, President, Unmanned Systems, HII Mission Technologies division, for insights on the new REMUS 620.*

Can you summarize the key technical highlights that you believe define the REMUS 620.

The REMUS 620 is a completely modular and open architecture platform designed to be easily reconfigurable and to carry a wide range of payloads. A great example of the modularity is the energy system. It can carry 1 to 3 energy modules that when using a Li-Ion batteries provides up to 110 hrs/275nm of range. The open architecture interfaces allow the integration of 3rd party software and compatibility with open architecture standards such as the U.S. Navy's Unmanned Maritime Autonomy Architecture (UMAA).

Duane Fotheringham, President, Unmanned Systems, HII Mission Technologies division

How about a 'By the Numbers' look at the REMUS 620 that give size and scope to its development and delivery later this year?

We have been developing the concept for a new medium class vehicle for some time, based upon everything we learned on the REMUS 300. [In October 2023, HII was awarded the contract to build small unmanned undersea vehicles (SUUV) for the U.S. Navy's Lionfish System program. The Lionfish System is based on HII's REMUS 300. The contract has the potential to grow to as many as 200 vehicles over the next five years with a total value of more than $347m.] We started detailed design of the vehicle in October 2022 with the goal of having an operational vehicle in the water within 12 months. We did precisely that with the completed vehicle going into the test pool in October 2023. The new REMUS 620 completed its first sea trials in December 2023. We will continue testing this development vehicle in 2024 and start construction of the first two production vehicles for delivery to NOAA in mid-2024. We went from concept to in the water in 12 months and we will deliver a production vehicle to the customer in under 24 months. The REMUS 620 was developed completely on internal development funding and was completed on time and on budget. While we don't divulge actual numbers, I can say that it was a significant investment by HII. We believe this is the most capable medium sized UUV in the

market and because of the internal investment it is available now without development risk.

How the U.S. Navy demands for autonomous systems are changing, and how in turn that it is impacting your organizations investment and R&D?

The Navy has clearly articulated the need for autonomous systems for distributed operations and to extend the reach of manned platforms. A great example of this is the tremendous capability that torpedo tube launch and recovery (TTLR) of unmanned systems can bring to the submarine force. The recent success of Yellow Moray TTLR by the U.S. Navy and our academic partner, Woods Hole Oceanographic Institution (WHOI) makes this a reality. In 2024 we will invest in integrating the Yellow Moray TTLR solution into the REMUS 620. In addition to the hardware platform, we have also been making significant investments in our autonomy platform, Odyssey. This is a cross domain, autonomy architecture and the REMUS 620 will be the first REMUS delivered with the new Odyssey Mission user interface as the standard interface. This is the same mission software we are delivering on USV systems.

Using your career start to now as bookend, what technology do you see has had the greatest impact on the efficiency and effectiveness of AUVs?

It is difficult to narrow it down to a single piece of technology, there have been several waves of technology that have had a significant impact on the efficiency and effectiveness of AUVs. When we first started delivering vehicles in the early 2000s the vehicles depended upon dead reckoning navigation or placement of acoustic transponders for positioning. As the size, weight, power and cost (SWAP-C) of inertial navigation systems (INS) improved they became a standard offering which allowed the vehicles to stay submerged for longer and travel unattended for much greater ranges. Over the last 10 years payloads have increased in capability, for example synthetic aperture sidescan sonars (SAS) have improved so much in SWAP-C that we are delivering almost as many SAS equipped AUVs as traditional real aperture sonars equipped AUVs. The next big wave in technology is autonomy. Our newest Odyssey autonomy is taking advantage of AI/ML algorithms for everything from perception to prognostic health monitoring, allowing the vehicles to perform longer, more complex missions without operator input. Throughout this time battery technology has gotten incrementally better and electronic systems more efficient, allowing us to field AUVs with longer and longer endurance. The combination of all of these technologies have dramatically increased the range and complexity of missions that can be undertaken with AUVs.

Image courtesy Boeing

ORCA XLUUV

Boeing delivered the first Orca Extra Large Uncrewed Undersea Vehicle (XLUUV) to the U.S Navy following acceptance testing, the first of six Orca XLUUVs to be delivered to the U.S. Navy over the next 18 months. The first unit is to be used as a test asset for the Navy, so it doesn't have a payload section, said Ann Stevens, VP, Boeing Maritime and Intelligence Systems.

The XLUUV, designated by the Navy as "Orca," is a new class of autonomous submarine designed for long duration critical missions to achieve undersea maritime dominance. "This is the culmination of more than a decade of work, developing a long-range, fully autonomous undersea vehicle with a large payload capacity that can operate independently of a host vehicle," said Stevens. Back around 2010/11, then Chief of Naval Operations (CNO) Admiral Gary Roughead and the U.S. Navy signaled strong interest in uncrewed

"The sky's the limit in terms of payloads that can be brought into the vehicle."

Ann Stevens, Vice President,
Boeing Maritime & Intelligence Systems

subsea vehicles, specifically vehicles with increased endurance to allow them to be deployed and held in position until needed. "We listened to that and we put ourselves into that customer space to invent something that has persistence, that doesn't require a host vessel to deploy, recover, or sustain for long periods of time, and that has big payload capacity," said Stevens.

So Boeing started developing what it called Echo Voyager, the first XLUUV class of vehicle, back in 2012-2013, putting it to sea in 2016-2017. "It spent 10,000 hours at sea, and continued on through the Navy's acquisition of the Orca vehicle," said Stevens. When asked to define the outstanding characteristics of Orca, Stevens starts with the payload section. "You've got 34 by 8.5 by 8.5 feet; you could actually fit four LDUUVs in the payload section of an XLUUV. So that's really a big differentiator right there." The other differentiator is range. The diesel-electric powered Orca has a total endurance of around 6500 nautical miles. "You can go for months at a time without requiring a host ship or any sort of sustaining operation at sea," said Stevens. Designing, building and delivering advanced UUVs is one thing; ensuring that the platform is resilient from technology obsolescence is another. In this regard, Stevens said "this platform is particularly open in that you can deliver it with a payload or not. If we just take payload capability alone, there's an ICD (Interface Control Document) that anyone can develop to, both software and hardware. What we provide is the vehicle and some hardware dimensions to interface into. Anybody can bring a payload carriage, it doesn't have to be developed or vendor locked in, and then software as well. So we just say the payload design itself has to provide some neutral buoyancy and it has to fit within a certain power requirement. Otherwise the sky's the limit in terms of payloads that can be brought into the vehicle."

Source: Boeing

The Navy's top officer wants more players on the field

Unmanned Underwater Systems = Force Multiplier

By Edward Lundquist

Speaking at the Surface Navy Association's annual symposium in Crystal City, Virginia, on Jan. 9, the new **Chief of Naval Operations Adm. Lisa Franchetti** released her priorities for "America's Warfighting Navy," and talked about putting "more players on the field."

"We must think, act, and operate differently, leveraging wargaming and experimentation to integrate conventional capability with hybrid, unmanned, and disruptive technologies," she said. "Tomorrow's battlefield will be incredibly challenging and complex. To win decisively in that environment, our Sailors must be the best warfighters in the world with the best systems, weapons, and platforms to ensure we can defeat our adversaries. We will put more players on the field—platforms that are ready with the right capabilities, weapons and sustainment, and people who are ready with the right skills, tools, training, and mindset."

Getting more players onto the field calls for a "distributed fleet architecture" of both manned vessels and unmanned systems to spread the Navy's capabilities over an increased number of platforms. They are a force multiplier.

According to a report issued Dec. 20, 2023, by the Congressional Research Service, the Navy is moving to a more distributed fleet architecture, "meaning a mix of ships that spreads the Navy's capabilities over an increased number of platforms and avoids concentrating a large portion of the fleet's overall capability into a relatively small number of high-value ships (i.e., a mix of ships that avoids 'putting too many eggs into one basket')."

To meet that goal, the U.S. has a lot going on in the undersea domain, including unmanned underwater vehicles (UUV), manned submarines, and torpedoes and other weapons.

Maritime drones come in a variety of shapes and sizes to meet a broad spectrum of requirements, such as surveillance and environmental sensing; laying mines or finding mines; to neutralizing enemy swimmers and blowing up targets. The U.S. Navy's efforts to develop, test and field new autonomous unmanned platforms and capabilities at sea spans a spectrum from small, hand-carried unmanned UUVs, to surface ship and submarine launched torpedoes, to the extra-large UUVs, all the way to the manned submarine fleet.

Large UUVs

The largest UUVs are the Boeing XLUUV and Snakehead LDUUV.

The Navy accepted delivery its first Extra Large Unmanned Undersea Vehicle (XLUUV) Test Asset System in December. The Boeing Orca XLUUV, designated XLE0, from the manufacturer Boeing.

In addition to the test vehicle, five more Orcas are being built. A December 2023 news release from By Program Executive Office Unmanned and Small Combatants, stated that XLE0 began in-water testing in Spring 2023 in Huntington Beach, California. "Lessons learned from XLE0's testing will

Photo by Richard Allen, Naval Undersea Warfare Center Division Newport

U.S. Navy photo by Mass Communication Specialist 1st Class Brian M. Brooks/RELEASED

be applied to Orca XLUUV 1 through 5, which will be built and delivered to the Navy in the future," the release said.

A Boeing press release said the Orca is "a new class of autonomous submarine that can perform long duration critical missions to achieve undersea maritime dominance in changing environments and contested waters."

The Orca XLUUV is a cutting-edge, autonomous, unmanned diesel-electric submarine with a modular payload section to execute a variety of missions critical to enhancing the Navy's undersea prowess. Configured to accommodate various payloads, the Orca XLUUV allows for the seamless integration of sensors, communication systems, and other mission-specific components, adapting to the evolving requirements of naval operations.

With its long-endurance capability, the Orca XLUUV can operate autonomously for extended periods. This allows for sustained operational presence and increased mission effectiveness in challenging undersea environments.

Orca is based on the Boeing Echo Voyager XLUUV. Like Echo Voyageur, Orca is 51-feet long, but features modular construction to allow for the insertion of an additional 34-foot payload module.

According to the Congressional Research Service "Navy Large Unmanned Surface and Undersea Vehicles: Background and Issues for Congress" report issued on Dec. 20, 2023, "the Navy wants to use XLUUVs to, among other things, covertly deploy the Hammerhead mine, a planned mine that would be tethered to the seabed and armed with an antisubmarine torpedo, broadly similar to the Navy's Cold War-era CAPTOR (encapsulated torpedo) mine."

Also in the large category, the Snakehead is a tube-shaped UUV, about four feet in diameter and eight feet long. The Navy refers to it as a "modular, reconfigurable, multi-mission underwater vehicle deployed from submarine large ocean interfaces, with a government-owned architecture, mission autonomy and vehicle software." The preliminary design was done by Naval Undersea Warfare Center at Newport, and the plan was to hand off construction to a competitively-awarded prime contractor. The first Snakehead was "christened" at NUWC Newport in September 2022, but the program is on hold for the time being.

Medium UUVs

Leidos and L3Harris are working on a medium-sized unmanned undersea vessel (UUV) for intelligence, surveillance and reconnaissance (ISR) for the submarine force and the explosive ordnance disposal community.

The Razorback UUVs were designed to operate from a dry deck shelter or from a craft of opportunity. Razorback is based on the HII REMUS 600 platform. The newest version will be deployed from a submarine torpedo tube and be fully integrated into the submarine's combat system. This new capability basically means any submarine can become a host platform for UUVs.

The Knifefish medium-class UUV is designed as part of the littoral combat ship mine countermeasures mission package. It can search a large area and can detect, classifying and identi-

fying mines, especially the hard-to-find bottom and buried mines in high clutter environments. Knifefish uses the low-frequency broadband capability developed by the Physical Acoustics Branch of the Naval Research Laboratory. The 2,000-lb., 22-foot long Knifefish is based on the Bluefin 21 UUV. It's sized for a 21-inch submarine torpedo tube, Knifefish is intended to be launched by a surface craft. According to the manufacturer, Knifefish will reduce risk to personnel by operating within minefields as an off-board sensor while the host ship stays outside the minefield boundaries.

Although it has passed its milestones, the MCM mission package being delivered to the Independence variant LCS does not yet have the Knifefish system.

Small UUVs

The Navy's expeditionary forces can deploy with small UUVs for underwater survey or mine countermeasures, and can operate from land or various craft of opportunity. Man-portable UUV s are available on the market, including the General Dynamics Mission Systems Bluefin Robotics Bluefin-9 and HII Remus 100 and 300.

Offensive Mines

The U.S. inventory of sea mines is either dropped by aircraft, such as the Quick Strike family of mines, or covertly deployed by submarines like SLMM and Hammerhead. Quick Strike are basically air dropped bombs with special fusing mechanisms that can wait to be detonated under the right circumstance. Submarines can carry the MK 67 submarine launched mobile mine (SLMM) is based on the MK 37 torpedo. It can clandestinely swim to a pre-determined location where it waits until target criteria are met, at which time it detonates.

The Hammerhead undersea mine is also submarine launched and can be delivered to a location where it sits and wait until a target is detected. It is based on the Cold War-era CAPTOR mine, which stood for "enCAPsulated TORpedo," which was armed with a MK 46 lightweight torpedo, and could operate

U.S. Navy photo by Mass Communication Specialist 2nd Class Gregory A. Pickett II

Members from Explosive Ordnance Disposal Mobile Unit (EODMU) 5 and expeditionary sea base ship USS Miguel Keith (ESB 5) prepare the MK 18 MOD 2 Swordfish to be deployed from the Open Water Transportation System (OWTS) during Exercise Noble Vanguard.

A collaborative research and development effort led by a U.S. Navy team recently demonstrated a new launch and recovery concept for large unmanned undersea vehicles (UUVs), with staff from the Naval Undersea Warfare Center (NUWC) Division Newport and Huntington Ingalls Industries (HII).

Photo By David Stoehr

at depths up to 1,000 feet.

Hammerhead consists of a mooring module that plants itself on the bottom; the power and sensing modules; and the business end, which is a Mark 54 Lightweight homing torpedo. This is a 600-pound weapon with a range of at least six miles widely used by the U.S. Navy and others for anti-submarine operations. (Anti-ship torpedoes are several times larger).

General Dynamics Mission Systems was issued a $93 million contract in 2021 to design, test and deliver the "Hammerhead Prototype encapsulated anti-submarine warfare mine system."

The new Hammerhead differs from CAPTOR in two important ways. One is that remote control capability, which means it can legally be positioned in peacetime.

The location of air-dropped Quick Strike mines can be observed, while Hammerhead can be surreptitiously and strategically placed at choke points, sea lanes, or near enemy submarine ports.

Another new submarine deployed mine is system is the Mining Expendable Delivery Unmanned Submarine Asset (MEDUSA).

The Navy's Unmanned Maritime Systems Program Office (PMS 406) is developing the system to "address the need for an advanced maritime mining system with long-range offensive mining capabilities."

The Navy has said that the Orca XLUUV could also deploy MEDUSA to conduct offensive mine warfare.

The Navy has an active tender out to industry to deliver the MEDUSA system.

Submarines

The current attack submarine fleet includes 26 of the 62 Los Angeles-class submarines built for the Navy and commissioned between 1976 and 1996. The lead ship in the class, USS Los Angeles (SSN 688) was commissioned Nov. 13, 1976. The newest, USS Cheyene (SSN 773), is now 27 years old.

USS La Jolla (SSN 701) was decommissioned in 2019, but continues to serve as a moored training ship (MTS 701) and the Nuclear Power School in Charleson, S.C. Likewise USS San Franscisco was decommissioned in 2022 and is now MTS 711 at Charleston. Some of the 688s were pulled from service at their mid-life point rather than incur the expense of the costly mid-life refueling. San Francisco was in commission for more than 41 years, while

USS Baltimore (SSN 704) served for just 15 and a half years of active service.

Los Angeles-class submarines carried MK-48 heavyweight torpedoes, submarine launched mines, and both Tomahawk and Harpoon missiles. Later ships in the class had vertical launch missile tubes located forward of the pressure hull to extend their weapons-carrying capacity.

Both Newport News Shipbuilding in Virginia and General Dynamics Electric Boat in Connecticut built the 688s. They are the only two shipyards that build nuclear powered ships in the U.S. Newport News was also building Nimitz-class nuclear powered aircraft carriers. while and EB was building the Ohio-class of ballistic missile submarines during this time.

The SSN-21 Seawolf class was intended to follow the 688s as the next generation of attack boats for the 21st century, and designed for the Soviet Navy threat.

Originally 29 were to be built, but only three were completed, with the third, USS Jimmy Carter (SSN 23) was built with facilities for carrying special operations vehicles and unmanned systems, as well as the ability to operate near the bottom to conduct special tasks.

As the Cold War ended, the need for the capability have way to the less capable and expensive USS Virginia class (SSN 774) class. The current program of record is for 66 boats, with 23 now active in the fleet. The lead ship was commissioned in 2004, and the newest, USS Hyman G. Rickover (SSN 795) joining the fleet in October of 2023. Newer versions will be fitted with the Virginia Payload Module (VPM) within a 70-foot hull section to carry Tomahawk cruise missiles and the Conventional Prompt Strike hypersonic missile.

Like the 688s, the Virginia-class boats are built in both Huntington Ingalls Industries Newport News Shipbuilding and General Dynamics Electric Boat shipyard.

Three additional Virginia-class boats will be built for Australia as part of the trilateral Australian-British-American security pact known as AUKUS. Eventually Australia will build the future SSN-AUKUS class submarines in Australia.

To test and refine the designs for the Seawolf and Virginia class submarines, the Navy built Large Scale Vehicles (LSVs), operated by the Naval Surface Warfare Center Carderock Division's Acoustic Research Detachment (ARD) on Lake Pend Oreille in Bayview, Idaho. Kokanee (LSV 1) is an unmanned, powered one-quarter scale model of the Seawolf (SSN-21). Cutthroat (LSV 2) is one-quarter-scale model of the Virginia-class boats, and is the world's largest underwater autonomous submarine vehicle. They are used as demonstrator vehicles for testing the hydrodynamic and acoustic properties of the hull design and other advanced technologies. Following the end of t he Cold War and the establishment of treaty limitations of submarine launched ballistic missile warheads, the Navy took

Submarines

four of its 18 Ohio-class SSBNs and converted them to conventional cruise missile carriers. The first four Ohio-class boats, 727 to 729, received the conversion between 2002 and 2008. Instead of 16 Trident missiles, they carry 154 conventional Tomahawk land attack missiles, and have the ability to covertly deploy special operations personnel and equipment. The remaining 14 Ohios had four of their 24 missile tubes deactivated to meet the treaty obligations.

The lead ship of the class, USS Ohio (SSBN 726), was commissioned in 1981. She underwent a conversion and reclassified as SSGN 726, rejoining the fleet in 2006. The newest, USS Louisiana (SSBN 743), was commissioned in 1997.

The Ohio Replacement Submarine (SSBN-X), now known as the Columbia-class, will begin to enter service in 2031. The lead ship, USS District of Columbia (SSBN 826), honors the nation's capital city. The Columbias are designed for a 41-year service life, with an expected completion of 124 strategic deterrent patrols. The new SSBNs share roughly similar dimensions (length and displacement) with the Ohios; much of its strategic weapon capabilities with the Royal Navy's Dreadnought class of SSBNs; and have similar sensors as the Virginia-class attack boats.

Torpedoes

Torpedoes come in two basic sizes—heavyweight and lightweight.

The Navy arms its submarines with heavy-weight 21-inch (diameter) MK48 torpedoes. Surface ships, maritime patrol aircraft and ASW helicopters use the lightweight 12.75-inch MK46, MK 50 or MK 54 torpedoes.

Many UUVs are designed to be deployed from submarines. To be carried about subs and launched while submerged, many UUVs resemble torpedoes.

Mk-48 and Mk-48 ADCAP (advanced capability) torpedoes are made by Lockheed Martin, and are wire-guided, which means they can get constant updates regarding the target and course to intercept. They can also operate without the wires, using their own active or passive sensors. They are programmed to detonate right below the target, breaking its keel.

Made by Raytheon, the MK 54 is the current lightweight torpedo, although Mk 46 and MK 50s can be found in use. These weapons are launched over the side of surface ships with the ubiquitous MK 32 surface vessel torpedo tube launcher, or dropped into the water by aircraft.

Both the lightweight and heavyweight torpedoes use OTTO II fuel and PBXN explosives in the warhead.

U.S. Navy photo by Mass Communication Specialist 1st Class Devin M. Langer/Released

JIM MCNEILL:

LEADING EARTH'S CITIZEN WARRIORS ACROSS THE SEA

By Celia Konowe

In the face of intensifying climate change and associated environmental unknowns, one world explorer has spent decades mobilizing individuals with the knowledge tools to better live, work and play harmoniously with nature. Many communities, particularly from the Industrial Revolution through modern society today, have an inherently discordant relationship with the earth, no longer seeing themselves and their actions as part of the global ecosystem. Enter Jim McNeill, founder of Ocean Warrior, and his accompanying ethos that to better understand the planet and how to maintain life on Earth, humans need to take the pulse of the planet.

"As I'm on deck here, I can't help but think about the stories that inspire me, of sailors getting in one of these wooden vessels and sailing as far north as they possibly could," says McNeill from the SV Linden, Ocean Warrior's three-masted schooner, while sailing north past Svalbard during September's Foundation Expedition. "It was all about endeavor… and reaching the North Pole, ultimately, that was the goal. I've never been motivated by glory," he chuckled, "but by finding out exactly what's happening to this ocean all over."

McNeill, former scientist and internationally renowned British explorer, has more than 36 years of experience travelling and working in polar regions. His aptitude for leading and the outdoors was sparked at a young age by participating in a winter course of Outward Bound, a UK-founded outdoor education organization, that led to lifelong interests in rock climbing and mountaineering. His career since has taken him across the harshest ecosystems, including roles in the environmental sector, military, emergency services and communications.

He's also served as consultant on extreme environments for numerous projects, from the BBC's Frozen Planet to Captain America.

The Foundation Expedition last September marked the start of a new realm in McNeill's journey to bridge discovery and citizen science: the ocean. While similar work has been conducted since 2001 as part of McNeill's first warrior program, Ice Warrior, "the oceans are a new domain for me and I like to do my homework thoroughly," he shared. The Foundation Expedition was exactly that: a chance to see how the Linden operated and to build the leadership dynamic with Captain Rasmus Jacobsen.

Map of Resolute Expeditions 2023 to 2034

Map courtesy Jim McNeill/Global Warrior

GETTING UNDERWAY

"A modern-day warrior is not about war. It's about the person—honesty, integrity, empathy, intelligence, courage, tenacity and resolve," shared McNeill. "It's about one's purpose and what better purpose is there besides the guardianship of the planet and the survival of humans among all species?"

With this mentality and inspired by stories of early explorers taking time off from their adventures to learn from nature, Ice Warrior was born. Ocean Warrior follows a similar structure, training volunteers in competence and safety on the seas. McNeill's goal though is to share the ability to explore, "inspiring people from all walks of life to become the new age of explorers, helping scientists discover change, and telling their own tales to inform and engage others."

For the first 10-day leg of the expedition, departing Svalbard on September 1, 2023, the 18-strong team of scientists, citizen scientists and crew members were tasked with "building an understanding of the vessel and her capabilities" to maximize the potential for scientific data capture. Ocean Warrior aims to install and test a variety of equipment to measure indicators like water quality, plankton, eDNA, salinity and ocean acidity, including weather stations, FerryBox, CTD, bathymetry, communications and safety. The instrumentation to be used on board by the team will be sorted by February 2024 through a consortium of ocean scientists, shared McNeill. Additionally, an online dashboard will convey findings and share stories.

Sailing to remote parts of the ocean between June and October, Ocean Warrior intends to cover 10,000 nautical miles a year during the next decade. While there's no typical day on board, tasks include scientific sampling and data logging, instrumentation maintenance, addressing crew necessities like food, and documenting personal experiences through images, videos and written logs. Additionally, the team will deliver and attend lectures about science on board and engage virtually with school groups. The scientists, citizen warriors and crew will be carried by the Linden, Europe's largest three-masted schooner of its kind, hand-built by shipwrights of the museum community of the Åland Islands in Finland and launched in 1993.

GROUNDSWELL

The Warrior programs, while training explorers, are also grounded in science—specifically in citizen science. "For over 60 years, we've known that polar regions are key to our survival," said McNeill of the work conducted through Ice Warrior. "They provide a cooling effect which allows us to live in what would otherwise be an uninhabitable environment. We know rapid and unprecedented changes are occurring in the Arctic that affect the rest of the world and yet, scientifically, it is still poorly understood."

the Views

the People

the Tech

High quality, precision data is fundamental to Ocean Warrior's success, and **Valeport's SWiFT CTDplus Chlorophyll profiler** was the choice due to its simplicity of use, internal rechargeable battery, and an integral GNSS module to geo-locate each profile. Using Valeport's world-leading high accuracy sensor technology to combine sensors for multiple profiles in a single drop, the SWiFT CTDplus Chlorophyll measured the physical parameters of the seawater including Conductivity, Temperature and Depth with Chlorophyll a observations.

All images copyright Jim McNeill/Global Warrior

Since Ice Warrior's founding 23 years ago, more than 450 people have been trained, helping scientists discover Arctic change and delivering this information to global audiences. Ocean Warrior will continue this theme, sampling in remote regions and rapidly communicating findings to scientists and the public sphere. "To give people real purpose and allow them to do something truly positive about the biggest crisis humanity has faced will hopefully inspire them to tell their own stories of their involvement, which reaches a much broader and deeper audience," explained McNeill. "The more we can engage the general public in science, the more they can be aware of the real image of what is happening to our world and cut through the sensationalism of the press and the lobbying of the commercial entities."

The expeditions further support the power of citizen science by combining the skills and passions of scientists, organizations, students, technologists and even those with no prior exposure to science. Sampling will also provide a platform for novel science, supporting new technologies and methods.

ALL HANDS ON DECK

"We need everyone—sponsors, technologists, scientists, grant-giving bodies, philanthropists and ordinary people to engage, help and support Ocean Warrior in the initial stages so that our part can be proven, improved and expanded upon," implored McNeill. By assessing the extent of anthropogenic impacts in extreme environments, which are the best regions for evaluating global change, it becomes easier to identify and counteract future problems earlier.

"Our remit is to discover indisputable evidence and to convey that in every way, shape and form we can in near real time," he added. In doing so, governments and industries can be better informed and held accountable for their actions—and just as crucially, their inactions.

Understanding the planet as climate warriors isn't limited to polar regions and the ocean. Global Warrior, which represents all of McNeill's extreme climate expeditions, will extend its reach into the desert sometime this year. Jungle and mountain programs will follow in 2025.

Ocean Warrior has a daunting, yet admirable task ahead of itself in scientific sampling, exploration and storytelling, engaging humanity everywhere and mobilizing interdisciplinary skills to understand the deep blue sea—a mystery to humans since time immemorial. The urgency, however, to crack the unknown and by extension mitigate and perhaps ameliorate anthropogenic harm is growing exponentially. Maybe now, with a pulse on the planet and McNeill's ocean warriors at the helm, humanity can do just that.

Image courtesy SAAB

ROVS

LARGE & SMALL ROVS NAVIGATE THE DEPTHS OF INDUSTRY INNOVATION

By Rhonda Moniz

The world beneath the ocean's surface remains one of the last frontiers of exploration, where the mysteries of the deep beckon to be uncovered. In this realm, Remotely Operated Vehicles (ROVs) are indispensable pioneers, venturing into the abyss to conduct critical tasks in industries ranging from offshore oil and gas to marine research and underwater construction. Work Class ROVs and other ROVs primarily in their capabilities, design, and intended applications. They are a class of remotely operated vehicles designed for heavy-duty tasks in demanding underwater environments. They are larger, more robust, and capable of performing complex operations at significant depths, making them essential tools in various industries. As technology advances, work class ROVs experience significant trends and innovations. The work class ROV market is dynamic, characterized by continuous innovation and adaptation to industry needs. Several notable trends are shaping the work class landscape.

- **Advancements in Automation and Autonomy:** Autonomous and semi-autonomous work class ROV technology has developed significantly in recent years. These systems have advanced computer vision, machine learning, and artificial intelligence (AI) capabilities, allowing them to perform tasks more autonomously. Automation reduces the workload on human operators and improves efficiency and safety.
- **Enhanced Maneuverability and Versatility:** Work class ROVs are becoming more agile and versatile. Innovations in thruster technology and control systems enable them to navigate complex underwater environments, making them well-suited for a wider range of tasks. Enhanced maneuverability is particularly valuable in confined spaces and subsea infrastructure inspections.
- **Data-Driven Insights:** Data is king in the modern world, and work class ROVs are no exception. These vehicles have advanced sensors, cameras, and imaging systems that capture real-time high-resolution data. This data is invaluable for immediate decision-making during operations and post-mission analysis, predictive maintenance, and trend analysis.
- **Compact and Portable Solutions:** While traditional work class ROVs are often large and require dedicated launch and recovery systems, there is a growing trend toward developing compact and portable work class ROVs. These systems are easier to transport, deploy, and operate, making them suitable for a broader range of applications and reducing overall costs.

THE FUTURE OF WORK CLASS ROVS: NAVIGATING UNCHARTED WATERS

As work class ROVs continue to evolve, several emerging trends offer a glimpse into the future of underwater operations:

- **Deep Sea Exploration:** Work class ROVs will continue to play a pivotal role in exploring the Earth's most remote and extreme environments, including the deepest parts of the ocean, venturing into uncharted territories, and discovering new species and geological phenomena.
- **Renewable Energy:** With the growth of offshore wind and tidal energy projects, work class ROVs will be instrumental in the installation, maintenance, and repair of renewable energy infrastructure.
- **Advanced Materials and Durability:** Future work class ROVs will likely incorporate innovative materials and construction techniques to enhance durability and longevity, enabling longer missions at greater depths.
- **Artificial Intelligence and Analytics:** AI-driven analytics will become more sophisticated, allowing ROVs to process and analyze vast amounts of data. Autonomous navigation and operation using AI algorithms will enable ROVs to navigate autonomously, while AI-driven navigation systems will help with obstacle avoidance, enabling the ROV to follow pre-defined transects and mission parameters while adapting to changing conditions.

AI will also improve imaging and data analysis using machine learning algorithms to process and analyze images and sensor data in real time, helping pilots and scientists make informed decisions during missions. Data transmissions from the ROV to the surface can be optimized by prioritizing and compressing the most relevant data for faster and more efficient communication. AI will also assist in predictive maintenance when ROV components may require maintenance or replacement based on historical performance, minimizing downtime and reducing maintenance costs. AI will revolutionize ROV technology by enhancing their autonomy, data processing capabilities, and efficiency. These advancements will enable ROVs to perform a wider range of tasks in underwater environments more effectively while reducing risks to human operators.

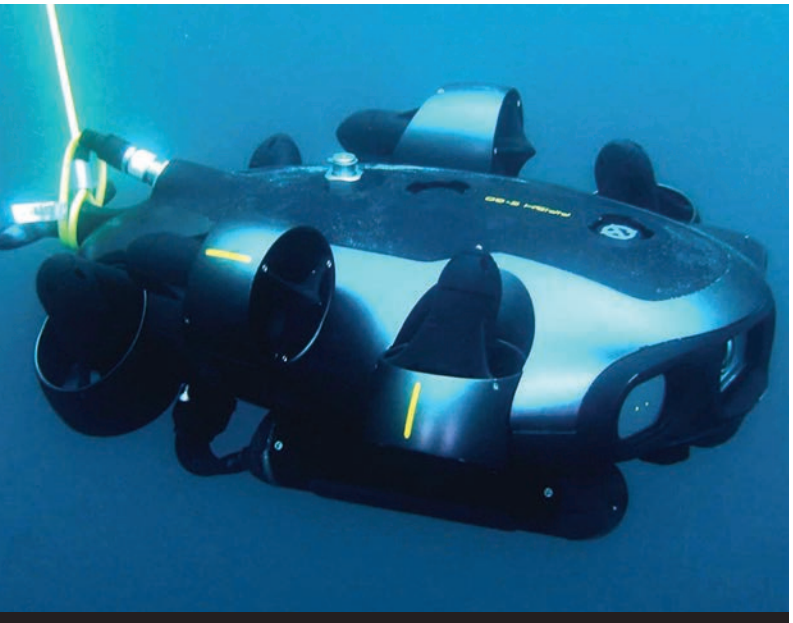
As AI advances, the potential for ROVs to contribute to scientific research, industry, and environmental monitoring in marine and aquatic ecosystems will only increase. Overall, the convergence of technological breakthroughs, scientific curiosity, environmental concerns, and economic opportunities is making this an incredibly exciting time in subsea technology. As we continue to push the boundaries of what is possible in underwater exploration and operations, the potential for new discoveries and innovations is virtually limitless, and the impact on various industries and our understanding of the underwater world is profound.

UPDATES ON THE LATEST VEHICLES AND CAPABILITIES

SEAMOR and **Voyis** have partnered together to combine the SEAMOR Mako ROV with Voyis' Discovery Stereo Camera, transforming the applications and abilities of both and reimagining what can be done in underwater inspection and exploration.

The portable Mako ROV is rated up to 600 meters and can be remotely operated on umbilical lengths of up to 950 meters. Its size and build make it ideal for pipe inspection, aquacul-

Image courtesy Seamor



The FIFISH E-Go seen from an angle, lying as it would be traveling horizontally through the water column.

Image courtesy QYSea Technology

ture, port security monitoring and various marine research operations. Likewise, the **Voyis** Discovery Stereo Camera is a widely applicable piece of technology offering high level clarity and precision in visual captures of underwater environments and immediate creation of real-time 3D models. The integration of both opens up unparalleled capacities in aquaculture management and hydroelectric applications, offering an efficient, cost-effective and reliable house for the stunning visual capturing capabilities of the Voyis Camera. Applications that look to be significantly improved in the ease and accuracy of data collection and monitoring include routine net inspections, equipment recovery, and surveying and sampling of the seabed.

Some companies have recognized the strong potential for autonomy optimization in the recent advancements in AI technology, and this includes underwater robotics company **QYSea Technology** and their newly modular, AI-powered advanced imaging and observational marine robot, the FIFISH E-GO. The E-GO offers a range of advanced capabilities not often seen in the subsea tech market. With a detachable motor, lighting, camera, and battery, module replacements can easily and quickly restore operability. This feature also allows for extensive expansion and customization of components. The E-GO has integrated AI into almost all operational aspects of their vehicle. With AI Vision Lock, it has high-level adaptive stabilization and can lock onto target objects with ease. Its plankton filtering algorithm is also AI bolstered, automatically optimizing visuals, monitoring tasks across aquaculture, search and rescue, hull check-ups and more, and even its laser scaling and measurement systems use AI automation for increased accuracy and the ability to identify damage in underwater structures. The FIFISH E-Go is QYSea's most powerful professional-class underwater robot and is now available across all QYSea platforms.

Latest innovation from **Copenhagen Subsea** is the enhanced Gorilla ROV, now equipped with an advanced 3D camera system. By integrating a 3D camera from Danish UVision, we have unlocked a new level of subsea exploration and inspection capabilities. With this cutting-edge technology, the Gorilla ROV now has the ability to capture highly accurate and detailed 3D scans of underwater environments. The 3D camera, mounted on the Gorilla, enables the creation of precise 3D models, providing invaluable insights for various applications. The 3D camera delivers exceptional image quality and resolution. Its advanced scanning capabilities allow for rapid data acquisition and precise measurements, ensuring accuracy in subsea mapping and inspection tasks. With the Gorilla ROV and its integrated 3D camera, subsea operators can now visualize underwater structures, assess damages, and plan interventions with greater precision than ever before.

Seatools completed Factory Acceptance Tests (FAT) for a Fall Pipe ROV developed for **DEME**, to be deployed on

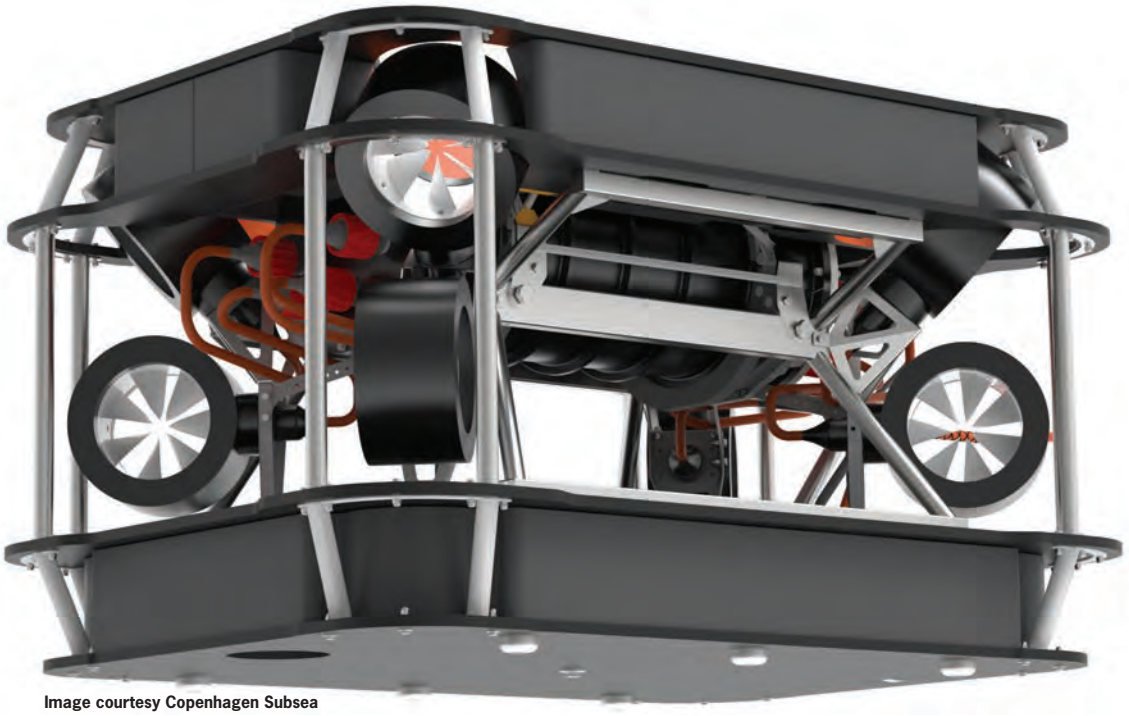


Image courtesy Copenhagen Subsea

Seatools completed Factory Acceptance Tests (FAT) for a Fall Pipe ROV developed for DEME, to be deployed on DEME's upcoming subsea rock installation vessel Yellowstone, scheduled to join the fleet in the first half of 2024.

Image courtesy Seatools

Image courtesy SMD

Omega Subsea Robotics ordered six complete ROV systems from Kystdesign.

DEME's upcoming subsea rock installation vessel Yellowstone, scheduled to join the fleet in the first half of 2024.

The new Fall Pipe ROV introduces several unique features, including the integrated rotator, allowing for the offsetting of the ROV's heading relative to the vessel heading. This helps to ensure an optimal vessel heading, enhancing the workability level of rock installation operations while saving significant power compared to conventional Fall Pipe ROVs.

Another feature of the ROV is its expansive on-board survey equipment suite, employed for precise ROV positioning, monitoring operations and the environment, as well as conducting comprehensive pre- and post-surveys. To handle the vast amounts of data and complex control algorithms related to dynamic positioning, the ROV is equipped with Seatools' in-house developed multicore processing technology. The **Yellowstone ROV PLC**, featuring a quad-core processor, efficiently distributes tasks among individual cores, resulting in improved control task execution, particularly beneficial in complex control loops like electro-hydraulically driven dynamic positioning (DP) systems

Kystdesign announced an expansion of its cooperation with **Omega Subsea Robotics**, signing its largest contract ever for the delivery of six complete ROV systems.

The contract award includes delivery of four standard Constructor ROV systems and two brand new compact Constructor ROV systems. The systems will be delivered to Omega Subsea Robotics in three deliveries of two systems each, and all are to be completed by the end of the year.

The ROV systems will be installed on selected vessels in the **Solstad** fleet. Omega Subsea will be responsible for the administration, crewing and operation of the ROV systems.

All ROV's included in this delivery are powered with 220 horsepower and designed to operate down to ocean depths of 3000m.

SMD has been developing work-class ROVs for more than three decades. In 2023, the company's latest products were the electric Quantum EV and Atom EV ROVs, which are more compact than previous generations, help reduce CO2 emissions, and can even operate autonomously when equipped properly. According to SMD, Quantum EV is a 270hp heavy construction vehicle with a high payload and powerful thrust output. Atom EV is a 130hp light construction vehicle suited to shallow-water, high-current work in offshore renewables. The ROVs feature a new DC power transmission system that is said to be far more efficient and environmentally friendly than previous generations. Further, the ROVs employ advanced flight control computers to help complete operations faster and maintain control in arduous conditions, such as high

Image courtesy Kystdesign

currents, SMD explains. The flight control system can also link to other SMART systems unlocking autonomous functionality. They use unique electric propulsion technology that offers extreme performance in fast-moving water, but not at the expense of fine control. “All this adds up to a range that can work where current generation vehicles can’t, that opens up the operating weather window and delivers higher quality results. All while being more environmentally friendly,” SMD says. Looking to the future of work class ROVs, SMD shared, “Work class ROVs are a multipurpose tool. And as with any tool there is always a focus on how well it does the job, its reliability, and its dependability. But the offshore energy mix is changing. And we are also seeing changes to the way people work (and go to sea) with much more emphasis on work-life balance and the environment. So, the robotic tools that construct and maintain energy infrastructure need to evolve.

In the future, the tools we today call work class ROVs will need to be suitable for uncrewed vessel and resident work; we may see less cabled connections to the surface and onboard power systems; we will probably see AI start performing tasks, with a move from person in loop to person on loop-command to control. It will be easier and faster to undertake tasks and see the results, with real-time information at the fingertips of stakeholders anywhere in the world.”

NBOSI SMALL CTD MAKER PACKS A POWERFUL PUNCH

Neil Brown Ocean Sensors Inc. (NBOSI) has a long history supplying research-quality Conductivity-Temperature-Depth (CTD) sensors in a compact, cost-effective and easy-to-integrate package for a range of subsea vehicles, including the fast-growing micro AUV market. ***Dave Fratantoni****, CEO, NBOSI, discussed the tech and the market potential.*

By Greg Trauthwein

What is NBOSI?

NBOSI builds conductivity temperature depth sensors (CTDs) for AUVs. Our CTDs are accurate, rugged, and reliable; custom-designed for integration with autonomous marine platforms of all types: AUVs, ASVs, gliders, ROVs, and everything in between. As an ocean scientist, I appreciate the value of measuring temperature and salinity because of their fundamental role in shaping ocean dynamics and influencing ecosystems. As an engineer and a vehicle operator too, I also understand that accurate temperature and salinity can yield important information about things like ocean density and sound speed, that have direct impact on performance. I would argue that measuring temperature and salinity from any platform is a really good idea, but autonomous mobile platforms in general are almost always power and size and space limited, and they're often designed from the beginning for challenging missions that emphasize robustness, reliability and hydrodynamic efficiency. Because of that, there's really no one off-the-shelf CTD solution that's going to fit this cornucopia of AUV and ASV designs out there.

The company was spun out of the Woods Hole Oceanographic Institution in 2003 and was founded by three people: **Neil Brown**, **Dr. Ray Schmitt** and **Bob Petitt**.

As a WHOI scientist myself 20 years ago, I was *'customer number one'* and applied early versions of the NBOSI sensor technology to my fleets of Webb Research, now Teledyne Slocum, gliders, L3Harris (OceanServer) Iver2 vehicles, and Liquid Robotics Wave Gliders.

Over those 20 years, NBOSI has maintained a strong relationship with both WHOI and another contemporary WHOI spinoff, Hydroid, which is now part of Huntington Ingalls Industries. We have been fortunate to equip many variants of the hugely successful REMUS line of AUVs with our sensors.

We expect to sell our 1000th sensor in the first half of 2024.

There are many CTDs on the market; what makes the NBOSI offering unique?

There are a lot of good sensors, and it's not our goal to compete with all of them. But there are some sensor technologies and their implementations that are simply better suited for certain purposes than others. For example, there are some highly refined sensors which enable extremely accurate measurement of salinity, and these types of measurements are crucial for understanding large-scale ocean dynamics and quantifying climate variability, especially in the deepest waters. But this accuracy comes at the cost of size and power, fragility of the sensor, potentially complex plumbing and the need for constant at-sea

"As a WHOI scientist myself 20 years ago, I was 'customer number one' and applied early versions of the NBOSI sensor technology to my fleets of Webb Research, now Teledyne Slocum, gliders, L3Harris (OceanServer) Iver2 vehicles, and Liquid Robotics Wave Gliders."

Dave Frantantoni, CEO

NBOSI ocean sensors

calibration. None of those are consistent with autonomous operations and on top of it all, those sensors can be quite expensive.

Fortunately, that sort of extreme accuracy really isn't required to capture operationally useful temperature, salinity, and sound speed measurements in the environments where most autonomous operations are conducted. So at NBOSI, we focus on developing low-power, low-cost, robust sensors that are specifically tuned for mobile platforms. Our goal is to provide a sensor that's reliably accurate at a level appropriate for the customer's mission. We design our sensors to be free flooding so that you don't need energy-intensive pumps to achieve high quality. We embed a fast response thermistor right in the middle of the conductivity cell to eliminate salinity spiking, and we build our sensors to be as compact and hydrodynamic and easy to integrate as possible. Importantly, our enclosed field electrode-based conductivity cells can be calibrated independently from the vehicle in which they're mounted. We've chosen a technology that allows us to optimize the measurement for vehicles that have tight constraints on both hydrodynamic efficiency and universal mounting. We never know where a sensor is going to need to be mounted on a vehicle, and we're able to adapt to that.

Where do you see opportunity for NBOSI?

We see tremendous growth globally in the small and micro AUV markets. Sensors for small vehicles are substantially constrained by power, size and cost. It doesn't do you any good to build a small vehicle if you can't equip it with sensors to perform a mission. So we're responding by further miniaturizing our sensor electronics and moving towards an even more compact and completely self-contained sensor design that will be easier to integrate, calibrate hot-swap in the field, and otherwise support these new small AUVs. We're on track to roll out this new sensor in early 2024.

Can you share insights on how one of your customers has used your technology to help meet and exceed its operational goals?

In the past year we've provided a number of custom sensors for a new class of mine hunting vehicles built in Japan by Mitsubishi Heavy Industries. It's a defense-related application for one of our allies, and it gives us great satisfaction to know that we are contributing in that way and that our technology is supportive of new vehicles organically built in Japan.

Recently, we supported Cornell University with a specially configured and calibrated sensor for remote study of a deep brine pool in the Gulf of Mexico. So this is an autonomous measurement made in an area where other CTDs may have been applicable, but they probably would've been destroyed because of the harsh environment. Finally, we're proud to be offered as standard equipment on the new Huntington Ingalls Remus 300, the cutting-edge vehicle on which the U.S. Navy's new and massive Lionfish small UUV program is based.

BATTERY THERMAL MANAGEMENT IN SUBMARINE APPLICATIONS

Dr. David Sundin, Chief Scientist, Engineered Fluids, Inc.

Developments in battery technology have yielded compact energy storage systems that output higher voltages than ever before. Manufacturers of submarine equipment have taken advantage of these new power sources, designing high power propulsion and electronics systems into the latest generation of their equipment. With higher voltage systems, thermal management of the entire electrical system becomes a more important design consideration. The batteries themselves should be maintained within a narrow band of optimal operating temperatures. Power electronics can generate temperatures that exceed the ability of traditional air cooling to dissipate. Making things even more difficult, compact submarine design usually doesn't allow enough room for traditional air cooling to be effective.

This article will show how these challenges can be solved with a cooling technology called Single-phase Liquid Immersion Cooling (SLIC). SLIC Technology cools 2000 times more efficiently than air, and in tight spaces where air cooling won't work.

What is Single-phase Liquid Immersion Cooling?

SLIC Technology refers to a cooling technique where a battery or electronics assembly is immersed directly in a bath of a non-conductive heat transfer fluid. The coolant fluid acts as an electrical insulator, with a dielectric strength of tens of thousands of volts, so high voltage electronics can be submerged without a problem. Any type of electronics can be immersed, without any protective covering. In a UAV, the entire battery and electrical connection system can be immersed. The dielectric fluid is then circulated via a small pump to a heat exchanger, where it is cooled, and then recirculates back to the hot components. There is no boiling, vapor or noise.

On land-based battery and electronics cooling, heat can be transferred into the air via a small radiator system. In marine and submarine applications, a heat exchanger is often built into the hull of the vessel, or heat can be transferred directly through the hull into water.

SLIC Technology is being used today in other industries to cool thousands of different electronic and electrical applications. Immersion cooling is embedded into electric automobiles and heavy vehicles, electric personal watercraft, stationary battery arrays, and data centers.

Immersion Cooling can pack a lot of cooling into a small space. Dielectric coolants are 1500-2000 times more efficient in moving heat than air is. A cooling system of only 20 liters of volume can cool more than a kilowatt of generated heat. Another advantage of immersion cooling is that it extends the life of batteries and electronics assemblies because they're protected from dust, pollution, water and vibration. In addition, hot air is not exhausted inside the submarine enclosure.

Thermal Management of Battery and Charging Systems

Charging and discharging batteries generates heat inside them, and the more rapid the charge/discharge cycle, the more heat is generated. Because batteries are only manufactured to work between certain temperature extremes, they will stop working if there is no thermal management system to maintain them within the working range. Battery Cooling Systems need to be able to keep the battery pack in the temperature range of about 20-40 degrees Celsius, as well as keep the temperature variation within each cell to a minimum.

The efficiency of Immersion Cooling to keep batteries at their optimal temperature was proven in a set of experiments performed at Engineered Fluids, Inc. In these experiments, an array of Samsung Model 286s prismatic 94 aH cells were subjected to a series of rapid charge/discharge cycles, once while being cooled with forced air and then again while immersed in an Engineered Fluids Dielectric Coolant. Through this data it is easy to see that Immersion Cooling showed huge advantages over air cooling:

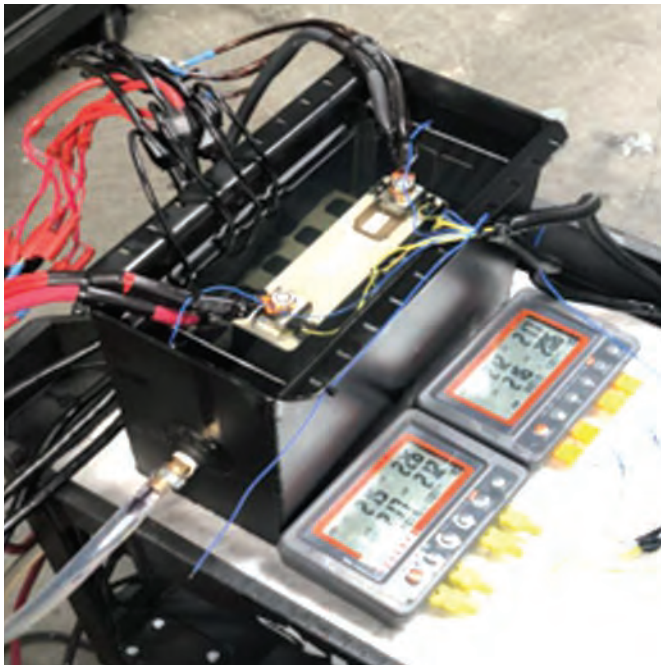


Image courtesy Engineered Fluids Inc.

With Immersion Cooling, the average battery temperature was five degrees C lower than for those cooled with air. Relating this to expected battery service life, this 5 C lower cell temperature translates to an approximate extension of battery life by a factor of 1.4

Test Results: Comparison of Battery Temperatures with Air Cooling and Immersion Cooling:

Parameter	Results for Air Cooling	Results for Immersion Cooling
Coolant Temp	23 +/- 5C	23 +/- 2C
Flowrate	1 liter/min	1 liter/min
Minimum Battery Temp	20.2 C	21.3 C
Maximum Battery Temp	36.7 C	23.1 C
Temperature "Swing" Range	16.5 C	2.2 C
Average Battery Temp	27.7 C	22.0 C
Relative Standard Deviation	0.103	0.023

Immersed in AmpCool Coolant, the battery was held at its optimum operating temperature for the duration of the test. The battery cell cooled with forced air experienced temperature swings from 20 to 37 C., with five times the standard variation around the average. Immersion Cooling also kept temperatures steady and even inside the test cell. Air-cooling allowed temperature stratification inside the cell, lessening the battery efficiency and service life.

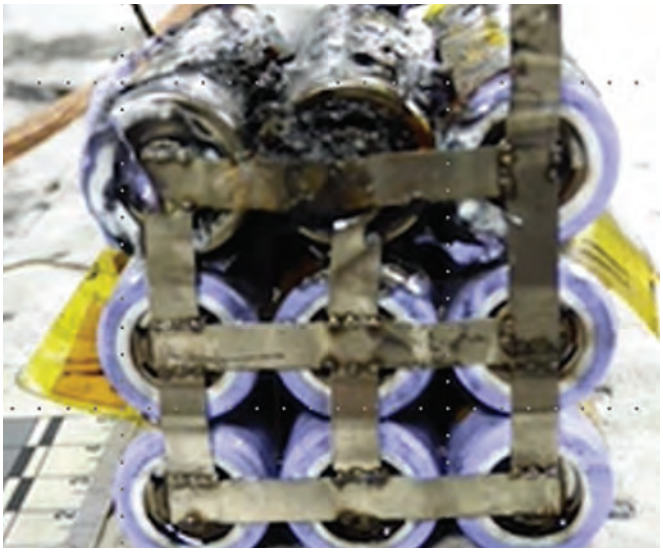
Another aspect of thermal management of battery systems is the case when temperatures are too low to allow efficient use of the battery system. Lithium-ion batteries lose efficiency and amp-hour capacity (which translates to vehicle range) quickly when battery temperatures approach 5 C., and are severely degraded at temperatures below that. SLIC Technology, unlike other cooling methods, can easily be used to warm the batteries to their optimum temperature range, ensuring efficient charging, full range capacity and maximum battery life.

Battery Safety

Another consideration of Battery Thermal Management is fire safety. When short-circuited or overheated, lithium-ion battery cells can enter into "thermal runaway", an intense exothermic reaction. Temperatures of a failed cell can reach 1200 C, and often will involve adjacent cells by overheating them, causing their failure. A set of experiments at Southwest Research Institute demonstrated the ability of Immersion Cooling to remove and absorb enough heat from a thermal runaway event to prevent damage to neighboring cells.

Battery packs of nine Li-ion cells were formed by binding cells with 0.5 mm spacing between them. One battery pack was cooled with air, the other by immersing it into Engineered Fluids' AmpCool™ Fluid. In each battery pack, a nail was driven through one of the cells in the middle of the pack, short-circuiting it and initiating a thermal runaway situation.

The pictures below show the results of the experiment. In the air-cooled pack on the left, the punctured cell began an intense fire which soon enveloped the other cells in the pack, destroying all of them. In the pack immersed in AmpCool Coolant, on the right, the punctured cell began an intense fire, but the energy was absorbed and contained by the coolant fluid. Ad-



Images courtesy Engineered Fluids Inc.

This experiment has since been replicated with other batteries and cell configurations, and demonstrates the inherent fire safety of SLIC Technology.

jacent cells were not affected, and continued to operate normally. Only the punctured cell failed.

This experiment has since been replicated with other batteries and cell configurations, and demonstrates the inherent fire safety of SLIC Technology. Images courtesy Engineered Fluids Inc.

Electronics Cooling

Electronics assemblies on board marine and submarine vehicles are now smaller, while having increased power capacity. Modern UAVs have several assemblies of power-dense electronics components that all require advanced thermal management:

- Motor driver and battery management electronics
- communications electronics
- energy recovery systems
- navigation electronics
- enhanced vision and object detection, RADAR, LIDAR

Cooling electronics by immersion through SLIC Technology has been shown to be the most efficient and lowest cost means of thermal management. Cooling electronics by direct immersion in a single-phase dielectric coolant has advantages over air or "cold plate" cooling, increasing the MTBF (Mean Time Between Failures) of electronic components and circuit board assemblies:

Elimination of fans. The fans that are used to force air through electronics chassis are a major source of failure in themselves, they also impart additional high-frequency vibration to the electronics chassis and circuit boards.

Elimination of component corrosion. Immersed in a dielectric fluid, corrosion cannot occur.

Moisture displacement. Condensation in humid environments cannot occur.

Elimination of temperature swings.

Summary

Marine and Submarine Electric Vehicles have several sets of electrical assemblies that need to be cooled, insulated and protected. Along with batteries, propulsion motors, charging assemblies, electronics, navigation and vision systems are all operating at higher temperatures and higher voltages. Immersion cooling can protect these assemblies from overheating, from corrosion and contamination, from temperature swings and from the threat of fire and explosion. Immersion cooling can lower total vehicle weight and raise its reliability. Immersion Cooling is a proven, safe, and clean technology.

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About the Author

Dr. David Sundin is Founder and Chief Scientist of Engineered Fluids, Inc., a provider of thermal management of batteries, EVs and data centers via Immersion Cooling. He has over 30 years' experience developing and applying specialty electrical cooling fluids and has held leadership positions in a variety of IEEE and ASTM Committees.

MARINE TECHNOLOGY REPORTER

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January/Februay 2024

Ad close Jan.31

Underwater Vehicle Annual

- Offshore Wind: A Floating Future
- Subsea Defense
- Manipulator Arms & Tools
- Autonomous Navigation
- Battery Technology

Event Distribution:

Oceanology International,
London, UK
Subsea Expo
Aberdeen, UK
Floating Wind Solutions
Houston, TX, USA
Europe Offshore Wind
Bilbao, Spain

February 2024

Ad close Feb. 4

Digital Edition

MTR E-Magazine Edition:

Oceanographic

March/April 2024

Ad close March 21

Offshore Energy

- Oceanographic Instrumentation & Sensors
- Subsea Defense: The Hunt for UXO
- Inspection, Repair & Maintenance
- Underwater Communications
- Cables & Connectors

Event Distribution:

Offshore Technology Conference (OTC),
Houston, TX, USA
UDT
London, UK
IPF Wind Conference
New Orleans, LA, USA
AUVSI Xponential
San Diego, CA, USA

May/June 2024

Ad close May 21

Dredging Technology

- Hydrographic Survey
- Scientific Deck Machinery
- Workclass ROVs
- Seismic & Geotechnical Surveys
- Sonar, Telemetry & Data Processing Software

Event Distribution:

WEDA Dredging Summit & Expo
Las Vega, NV ,USA

July/August 2024

Ad close July 21

Autonomous Vehicle Operations

- Underwater Tools & Manipulators
- GPS, Gyro Compasses & MEMS Motion Tracking
- Subsea Defense
- Deck Machinery & Cranes
- Battery Technology

Event Distribution:

Oceans 2024, Halifax
Halifax, NS, Canada

August 2024

Ad close Aug. 4

Digital Edition

MTR E-Magazine Edition:

Hydrographic

September/October 2024

Ad close Sept. 21

MTR100

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

November/December 2024

Ad close Nov. 21

Ocean Observation: Gliders, Buoys & Sub-Surface Networks

- Instrumentation: Profilers, Samplers & Sediment Corer
- ADCPs & DVLs
- Subsea Defense: The U.S. Navy
- Subsea: Electrification
- Underwater Imaging: Lights, Cameras & Multibeam Sonar

December 2024

Ad close Dec. 4

Digital Edition

MTR E-Magazine Edition:

Subsea Vehicles

GAZELLE

PREPARING FOR A FLOATING WIND FUTURE

All images courtesy Gazelle Offshore Wind

As offshore wind power spreads globally, it's widely acknowledged that the maturing of floating wind power platforms will exponentially increase the availability of resources, as the majority of wind power lies outside the installation zone of fixed systems. Enter Gazelle Wind Power, which offers a compelling, modular engineered solution and value proposition to the market. Newly minted Gazelle CFO Alvaro Ortega discusses the outlook for Gazelle in the offshore floating wind sector.

By Greg Trauthwein

Today, it's acknowledged that the vast potential for offshore wind extends beyond the reach of traditional fixed-bottom units, and conservative estimates call for 300 GW of floating offshore wind by 2050, according to Gazelle CFO Alvaro Ortega. "This is just floating, so that is the massive opportunity for Gazelle."

As the advent of fixed offshore wind is still in its adolescence, talk increasingly turns toward floating offshore wind, a technology and market that was, for the most part, only recently born.

"Waters more than 60 meters deep require [a floating wind solution], said Ortega, "it cannot be bottom-fixed [at that depth]."

When talk turns to floating wind, there are many long-established technologies and companies in the floating offshore oil and gas industry that will translate to floating wind. However, it's not an exact match, and the key will be to maximize efficiencies of the platform and its foundation, which account for 30 - 40% of the cost.

Gazelle is banking on its modular solution, which Ortega says should represent a 30% reduced platform cost versus the semi-submersibles on the market today. "We are targeting 75% less of mooring length compared. So less mooring length, less materials will be used."

Gazelle is banking on its modular solution, which Ortega says should represent **a 30% reduced platform cost.** *"We are targeting 75% less of mooring length compared. So less mooring length, less materials will be used."*

Alvaro Ortega, CFO, Gazelle Wind Power

All images courtesy Gazelle Offshore Wind

Gazelle Today

By Ortega's estimation, Gazelle is racing to bring its solution to bear, as it is currently in its fourth round of funding and just completing prototype, small-scale basin tests at the Imperial College in London, in Plymouth, England as well as in Northern Spain. "So far, the results at a very small scale have been successful. So our next steps is to develop and to deploy the pilot, and we are already working on that, aiming for deployment by the end of 2024 off the coast of Portugal, using private equity but also looking for public grants, too."

Gazelle is banking on its design as the key differentiator in the floating wind sector, a design that is modular – making it easier to build, transport and deploy – as well as a design that offers significant reductions in some critical cost and environmental impact areas.

Last year Gazelle unveiled its next generation technology, an enhanced design that further refined the company's solution to address the primary challenges facing the offshore wind industry – cost, supply chain bottlenecks and sustainability – by providing a lightweight, cheaper technology that minimizes the impact on fragile marine environments while using existing port infrastructure.

As a third-generation technology, the platform is designed to deliver enhanced mooring innovation that enables serial production. The platform makes first generation technology — which was primarily designed to float and survive harsh ocean conditions — obsolete and improves on second generation designs that are focused on industrialization.

Central to Gazelle's long-term play is 'reduction': reducing costs by 30% compared to conventional semi-submersible designs; reducing the time to assemble and install the units at project sites via a modular assembly process; reducing environmental impact by using less steel and materials, while also helping to eliminate seabed scouring and installation impact.

The Gazelle platform's unique geometry provides reduced draft in port, which means it floats higher in the water enabling the use of shallow ports with high stability in towing and wet storage. Pivoting arms allow the platform to move with the wind, waves, and tides that result in lower forces, enabling a lighter—and therefore cheaper—structure.

Further, the Gazelle platform uses a dynamic mooring system representing a paradigm shift from an active ballast to a natural, passive system that balances forces and motions through a counterweight, keeping the turbine pitch low and improving operational efficiency. Vertical mooring lines attached to the pivoting arms reduce the platform's environmental footprint by minimizing impact and allowing for a 75% reduction in mooring length when compared to semi-submersibles with catenary mooring in depths of 100 meters or more.

Proving the Concept

Small-scale model testing and computer simulation are all nice and necessary parts of the development process, but Ortega and the entire Gazelle team know that the future depends on developing and proving the system works in one of the world's harshest and unrelenting atmospheres.

"Developing the prototype is our main goal, and we are planning to have the prototype in the water by the end of 2026.

We're already working on the pre-FEED, and now we're going to be working on the engineering portion. Our main goal is to prove the concept," said Ortega. Apart from the technical, Gazelle is actively seeking partnerships – from developers to shipping companies to technology providers – as well as strategic investors that "come in not only to bring equity, but also to participate with us on the deployment."

The opportunities for Gazelle, and in fact all players in the floating wind sector are literally boundless as the market evolves. "80% of the wind resources are in places where only offshore floating wind can be deployed," said Ortega. "When we look at the map, the three main areas where we are planning include Europe, which represents 60GW of potential;. Asia Pacific and its 81GW of potential; and then North America, where we're talking about 31GW," Ortega said.

While envisioning market potential is the end game, Ortega and the Gazelle team are firmly planted in the here and now, focusing first on the pilot test, plus the most recent news where Gazelle were preselected for a project seeking to deploy 1GW of floating wind on the Italy's side of Adriatic Sea by the end of 2028. "The developer is Maverick, controlled by Green Bridge, and it released plans for this wind farm, that will include 70 turbines of 15MW each, and has preselected Gazelle as one of the providers for the offshore wind platform. So, we're not only talking about a pilot; we're also talking about some specific projects that we're planning to use our offshore wind platforms."

Armed with an innovative design that offers much promise, Ortega nonetheless sees many hurdles to clear.

"I think one of the main challenges is bringing this third generation of turbines to place. [Phase one was] to float, being able to deploy platforms to float and survive, but not to be industrialized. The second is where we are right now, looking to solve the main issues of fabrication, assembly, as well as the issues with very deep waters on the West Coast of the United States where we have one kilometer or more. [The third generation] is innovation in the supply chain, improving the assembly process to make it scalable and easy to attach. As in our case, manufacturing different modules that attach to each other rather than having to produce the whole platform in a manufacturing facility and then transferring that massive [structure]. And, being able to do this without having to make major infrastructure investments, which can be in the billions of dollars," Ortega concluded.

The secret sauce in the Gazelle Wind Power floating offshore wind design is in its modularly designed, manufactured and assembled base: less material used, reduced environmental impact, lower costs and lower draft needed to float it out.

MARINE TECHNOLOGY TV

Watch the full interview with Alvaro Ortega

All images courtesy Gazelle Offshore Wind

PODCAST

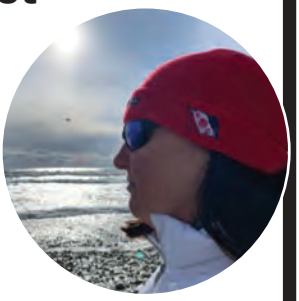
DEEP DIVE Podcast Debuts

In episode one of the **DEEP DIVE** podcast, host Rhonda Moniz hosts **Dan Shropshire**, Vice President Business Development and Program Execution at Teledyne Marine Vehicles & **Emily Shumchenia**, Director - Regional Wildlife Science Collaborative for Offshore Wind (RWSC) for a topical discuss on the progression of the nascent offshore wind industry off the east coast United States.

As the industry literally takes shape under our waters, there is increased focus on the entire design, installation and operation phase of offshore wind, with increased attention paid to what's going in the water; how it is being installed; and its cumulative impact on the environment and wildlife once it's up and running.

Subsea technology and technology companies will play a pivotal role in monitoring, measuring and gathering data for the sake of stakeholders in the relatively new but fast-growing corner of the Blue Economy.

Meet the Host



Rhonda J. Moniz is an accomplished underwater forensics expert specializing in diving technologies and subsea systems. With more than 25 years of experience as a remotely operated vehicle pilot, master dive instructor, scientific diver, and dive safety officer, she has demonstrated expertise in overseeing multiple investigations, diverse field projects, expeditions, and training programs. In addition to her work as an explorer and diver,

Ms. Moniz has made significant contributions to the media industry as a journalist and filmmaker. She was awarded the prestigious Woods Hole Oceanographic Institutions Fellowship for Scientific Journalism. She is an active member of the Explorers Club. She has served as a subject matter expert for renowned media outlets such as CBS, CNN, Discovery, the Oxygen Channel, and PBS productions, lending her expertise to various television shows. She served most recently as a subject matter expert for CNN in its coverage of the Titan submersible tragedy. She is the president of the board of directors for the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS). She is on the U. S. Integrated Ocean Observing System (IOOS) board of directors.

Listen to DEEP DIVE

DEEP DIVE is a new podcast from *Marine Technology Reporter*. In each edition, DEEP DIVE host Rhonda Moniz will explore different areas of Subsea Technology from science to offshore energy to defense.

To participate in a future podcast, contact:
Greg Trauthwein @ trauthwein@marinelink.com

To listen to the first DEEP DIVE podcast, visit www.MarineTechnologyNews.com or scan the QR Code

All images courtesy Oceanology International

Oi 2024

Oceanology International 2024 (Oi24), arguably the world's biggest and best marine science, ocean technology exhibition and conference, is scheduled to take place from March 12-14, 2024 at London's ExCeL. The event is expected to bring 7,500+ attendees and 450+ exhibitors from 80+ countries, with 100+ companies set to conduct product or service launch activity.

The event gathers personnel from ocean technology science, commerce and defense to London for three full days and nights chock full of a vibrant exhibition, on-water technology demonstrations on the Royal Victoria Dock just outside the exhibition hall, conferences and social gatherings – all events aimed to spark imagination and collaboration amongst leading companies and organizations in the sector.

The three-day marine science, ocean technology exhibition and conference once again promises to deliver an unparalleled global marketplace, a packed event schedule and targeted network opportunities for all those involved in exploring, protecting and sustainably operating in the world's oceans and waterways.

The 2024 edition of Oceanology International and its co-located event OceanICT will provide a platform 'where missions are made possible', according to the event organizers RX Global. It will feature an even stronger emphasis on future technology and transformational solutions, with a focus on a sustainable blue economy. The spotlight will be on new launches on the exhibitor floor and demonstrations at the live in-water dockside location, with hundreds of exhibitors preparing to introduce products and showcase developments across the fast-paced ocean technology, science and engineering sectors.

Featuring a compelling line-up of industry-leading speakers, the full strategic Oi Conference Program will encompass a diverse range of Technical Sessions and Ocean Futures-focused content across five different conference locations. World-class scientists, thought leaders and innovators in the vanguard of the global ocean tech community will bring insightful and original content.

Among the key contributors to the conference program are Rick Spinrad, Under Secretary of Commerce for Oceans and Atmosphere, and NOAA (National Oceanic and Atmospheric Administration) Administrator, who is the keynote speaker at the opening plenary of the Ocean Futures Theatre, where thought leaders will discuss meeting future ocean technology needs. Sir David King, Emeritus Professor of Chemistry, University of Cambridge, will speak at the Catch the Next Wave conference – returning for 2024 on the final day with a special edition focusing on the climate and biodiversity crisis.

David Ince, Oceanology International Portfolio Director, said: "At this pivotal and exciting time for the ocean technology industry, our focus is to provide an event where missions are made possible. Demand for new solutions in the blue tech and energy transition markets is exploding, so we are looking forward to delivering an inspirational Oi event in London with the power to propel the direction, progress and impact of the sector. The influence of Oceanology International is built on the scale, breadth, history and reputation of our event and I am confident that, once again, Oi will be a catalyst for ideas and innovation, with unprecedented access to comprehensive solutions, diverse content and expertise.

"As always, Oi24 provides the one occasion and one location where thousands of ocean professionals, international buyers and end users, suppliers and manufacturers can gather to do business face-to-face. For anyone looking for new solutions for their business or projects, Oi is the place to discover cutting-edge technology to ultimately drive revenues. We are committed to work hard to introduce new event services, partnerships, and collaborations to enhance the experience for all

All images courtesy Oceanology International

@OI - PRODUCT DEBUTS

participants and to deliver another packed three days of exhibition and conference activity, features, workshops and one-to-one meetings."

Oi is the one occasion connecting all global stakeholder groups in oceanology across blue-tech, energy and offshore sectors, delivering the sector's key forum and networking opportunity. Thousands of oceanology stakeholders, spanning industry, government and academia, from engineers, hydrographers and geotechnics to energy professionals, oceanographers, site investigators, marine surveyors and many more, will come together across a wide range of sectors, including offshore oil & gas, renewables, defense, maritime security, marine science, ports, aquaculture and subsea.

Oi's focus in 2024 will reflect the global challenges confronting the industry and influencing the trajectory of technology development across numerous ocean-based sectors. Key themes such energy transition, climate change and ocean health, offshore energy, geotechnics, hydrography and ocean science, improved sustainability in offshore operations and the development of ocean-tech investment and finance opportunities, plus new applications of autonomous systems and AI, and ocean connectivity will feature throughout the exhibition and the varied conference agenda. Visitors will discover the latest technology and innovations in acoustics, autonomous and unmanned vessels, bathymetry, cameras, robotics, navigation and more.

The industry's most influential associations returning to the show to support their members and hold their own events, include: the SUT (Society of Underwater Technology); MTS (Marine Technology Society); THS:UKI (The Hydrographic Society UK & Ireland); and SMI (Society of Maritime Industries). The international profile is underscored at Oi24, with 10+ International and Regional Pavilions, promoting more than 100+ SME's, start-ups, accelerators and innovation clusters. The Canada Pavilion will have strong representation with a 75-person strong delegation and 24 companies, with Rhode Island, Business France and the Dutch Pavilion also returning.

Oi24 Events and Features

Oceanology International is able to capitalize on the advantages of ExCeL's expansive 18,000m2 of indoor exhibition space to stage a number of unique features and events, with the Royal Victoria Dock enabling live outdoor, on-water demonstrations. Features at Oi24 include:

Exhibition: The show floor is expected to host 450+ exhibitors from 80+ countries, with 10+ International and Regional Pavilions. With exhibitor product development and R&D cycles aligned with Oi's return to London every two years, more than 100 companies are expected to conduct product or service launch activity. Exhibitors introducing new solutions at Oi24 include:

- **Cathx Ocean**, combining sensor data, machine vision and machine learning based automation to deliver information real-time to facilitate earlier decision-making with its brand CLARITY;
- **Deepinfar Ocean Technology**, a high-tech enterprise specializing in the research and development, manufacturing and sales of a full range of underwater robots and related underwater core components;
- **MacArtney Underwater Technology Group**, offering connectivity, data acquisition, and launch & recovery systems for marine and offshore, ocean science, and naval industries;
- **Neptune Sonar,** an underwater transducer technology specialist introducing Zeus Piezoceramics, a new ceramic manufacturing venture providing PZT components;
- **QYSEA Technology**, a high-tech enterprise focused on the R&D, production, and sales of underwater robotics, which will be showcasing the FIFISH ROVs in a large water tank.

Future Tech Hub

The Future Tech Hub will highlight the start-up and tech-accelerators who are building transformative new technological eco systems. Participating exhibitors include:

- **Abyssens**, an engineering office specializing in underwater acoustics;

@ OI - ON-WATER DEMOS

All images courtesy Oceanology International

- **ANB Sensors**, developers of revolutionary, calibration free pH sensors for ocean monitoring;
- **C-Kore Systems**, simplifying subsea testing with its new Optical TDR unit;
- **Ictineu Submarins**, designers of new generation submersibles;
- **Robosys Automation**, provider of AI powered maritime autonomy and smart shipping software;
- **Tidewise**, developer of robotic systems; and
- **uWare Robotics**.

Dockside Demonstrations

On the Royal Victoria Dock, the Dockside Demos feature gives visitors the opportunity to experience different vehicle, imaging, sonar and instrumentation technologies live and outdoors, in- and on- the water. Viewing platforms and micro theatres enable close scrutiny of the technology, while the operators are on hand to provide more information. On the dockside, attendees can join brands such as Teledyne Marine, Blueye Robotics, Ocean Power Technology and Maritime Robotics and see live demos of data streaming in from vehicles and vessels in the water.

Conference Program

The Oi24 Conference Program features three days of Technical Sessions and Ocean Futures-focused content across five different conference locations features topics including: Uncrewed Vehicles and Vessels; Ocean Observation and Measurement; Site Investigation; Data Interpretation, AI and Ocean ICT; Navigation and Positioning; Offshore Renewable Energy; Asset Integrity and Monitoring; Bathymetry. There are also a number of associated events which will encompass a range of keynote speeches, workshops and presentations from attending societies and companies.

Dan Hook, Oi24 committee member and CEO at RAD, said: "Oi has always been a solid date in the calendar for getting updates on information, meeting customers, meeting potential suppliers, hearing what's happening in the industry – you learn a lot, whether you are there for one day or the whole event. As a new committee member, I will get a lot of benefit from Oi. I get to hear about the latest innovations, the latest companies, the latest user cases, the latest pieces of technology and success stories coming to the industry."

Ocean Futures Theatre

The prominent keynote Ocean Futures Theatre within Oi brings together thought leaders from industry, academia and government to discuss meeting future ocean technology needs in line with market developments and new ocean enterprise strategies.

With exclusive content delivered by leading academics, technicians, engineers, CEOs and scientists, it is packed with three days of world beating technical conference, featuring panel discussions and strategic debates on topics including Transitioning the Ocean Economy, Sustainable Offshore Operations, BlueTech Investment and Future Talent/Careers. Rick Spinrad, Under Secretary of Commerce for Oceans and Atmosphere & NOAA Administrator, is confirmed as the keynote speaker at the opening plenary.

Catch the Next Wave

Returning in 2024 for its sixth edition, the Catch the Next Wave conference pairs speakers from within and outside of the ocean community, with the aim of sparking new thinking and ideas across disciplinary boundaries and between sectors. The special edition at Oi24 will focus on the climate and biodiversity crisis. It will take a futuristic look at how key areas of rapidly evolving technology might contribute to innovative solutions at the ocean-climate nexus, helping to achieve net zero and beyond, at the same time as supporting the restoration of the Earth's essential biodiversity and ecosystem services.

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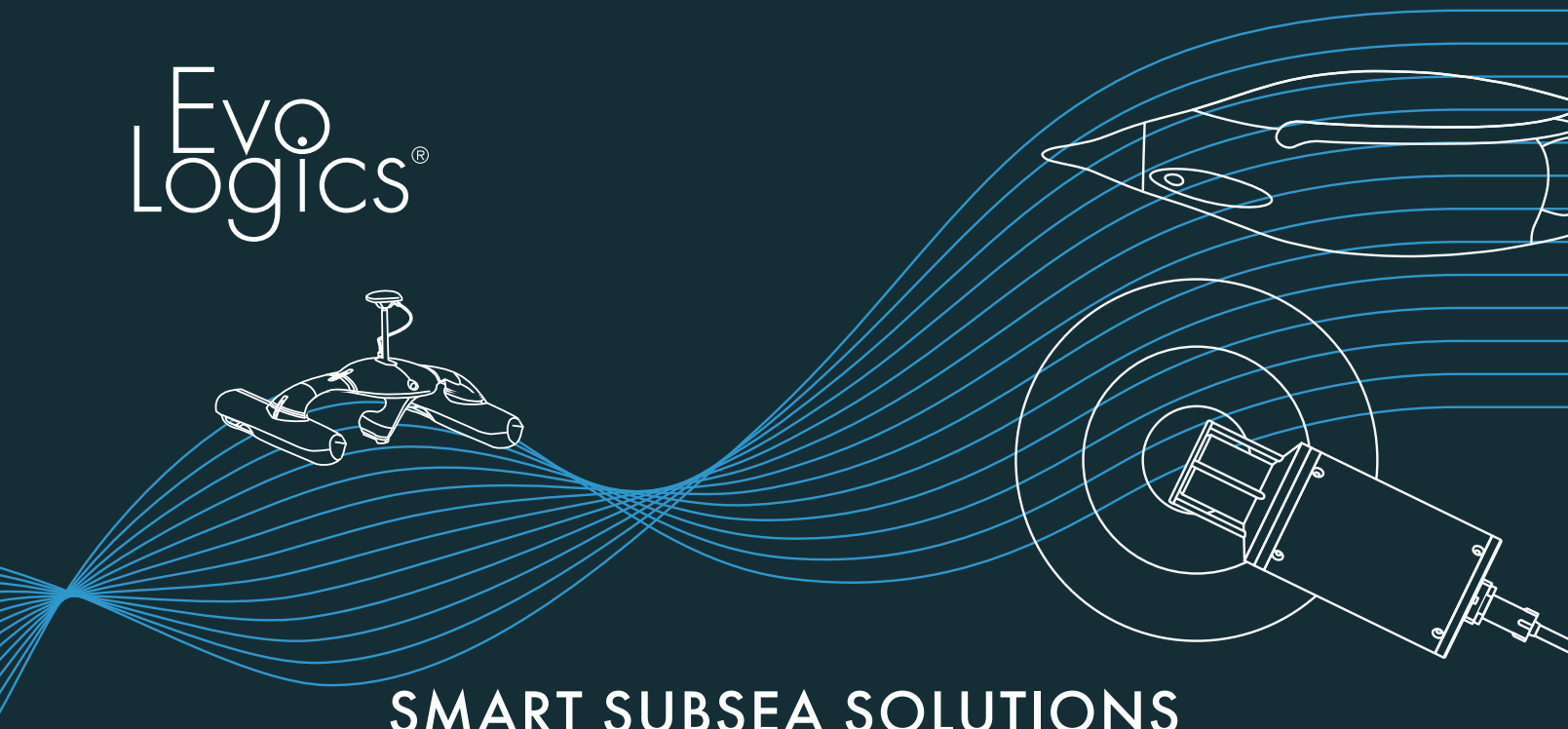

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