MARINE TECHNOLOGY REPORTER

March/April 2025
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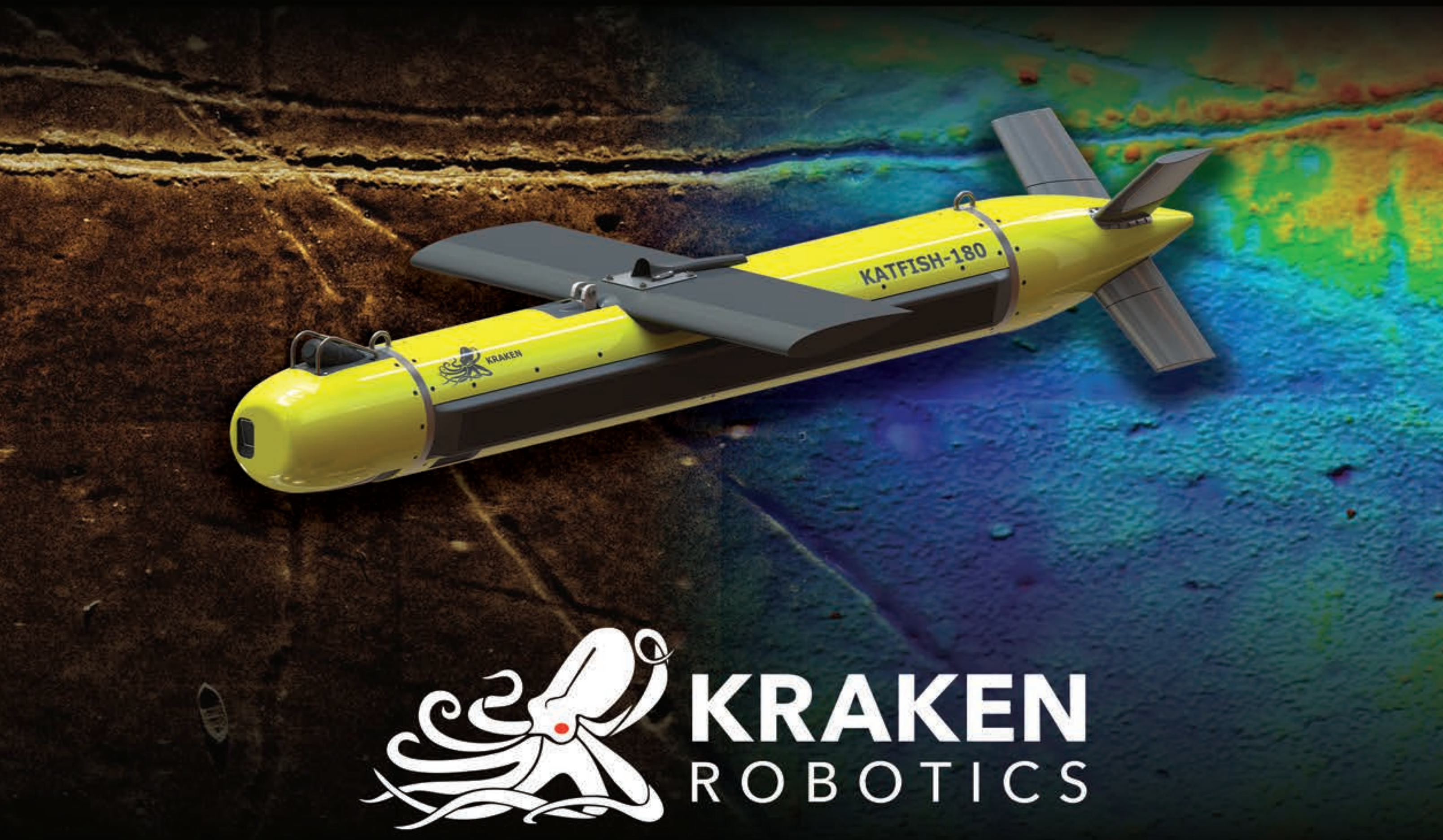
Research Vessels
Rebuilding the UNOLS Fleet

Lander Lab
Pull Tester Built on a Budget

Tech Talk
ROVs

Opinion: Rick Spinrad
The Future of NOAA

Volume 68 Number 3



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On the Cover

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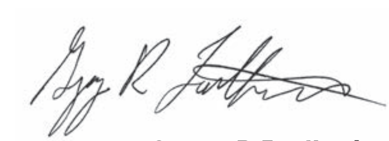
Editorial


Justin Zuure

This edition is packed with the latest developments in subsea technology as it applies to defense, offshore energy and academia, but it starts on page 8 with **Rick Spinrad's** observations on the scrum in Washington DC with the arrival of Trump 2.0, specifically the proposed (and since enacted) cuts to the National Oceanographic and Atmospheric Administration (NOAA) – *Save a Nickel, Kill a Thousand: The Pennies-Wise, Lives-Foolish Effort to Eliminate NOAA.* The cuts at NOAA are but a microcosm of changes, and the last several administration changes have come with increasing volatility in policy swings across the board. Big picture, how all of these changes will cumulatively impact your business, your research, is a chapter still to be written, but in the near term expect more volatility and uncertainty, but at the same time a renewed interest and investment in all matters maritime, subsea and defense.

Speaking of defense, we again welcome the insights of David Strachan, Strikepod Systems, for his Subsea Defense column. In this edition he focuses on modern mining of the world's waterways, eschewing the popular notion of a sea filled with 'spiky ball' configured mines and instead looking at modern mines and deployment systems, systems that allow covert delivery from non-descript commercial vessels. Another pair of features looks at the U.S. Research Vessel fleet, today and tomorrow as **Bruce Appelgate** spoke with Rhonda Moniz on the status and direction of the UNOLS fleet, while I had a one-on-one video interview with Appelgate specific to the new hybrid hydrogen vessel currently under design, aiming for delivery and operation before the clock turns to 2030.

As of this writing I and the *MTR* team are preparing for the biggest subsea event of the year on the commercial side, with the opening of yet another Ocean Business in Southampton, UK, on the premises of the National Oceanography Centre. If you will be in Southampton and are launching a new technology, drop me an email, as the first two days of the event we'll have the **"MTR TV" video team** on premises in Southampton, recording interviews with industry leadership.



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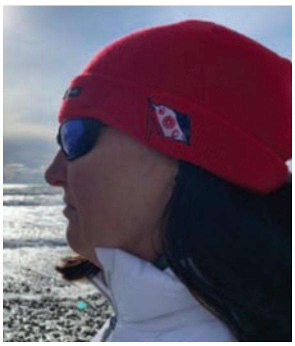

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Stenius

Spinrad

Torroba

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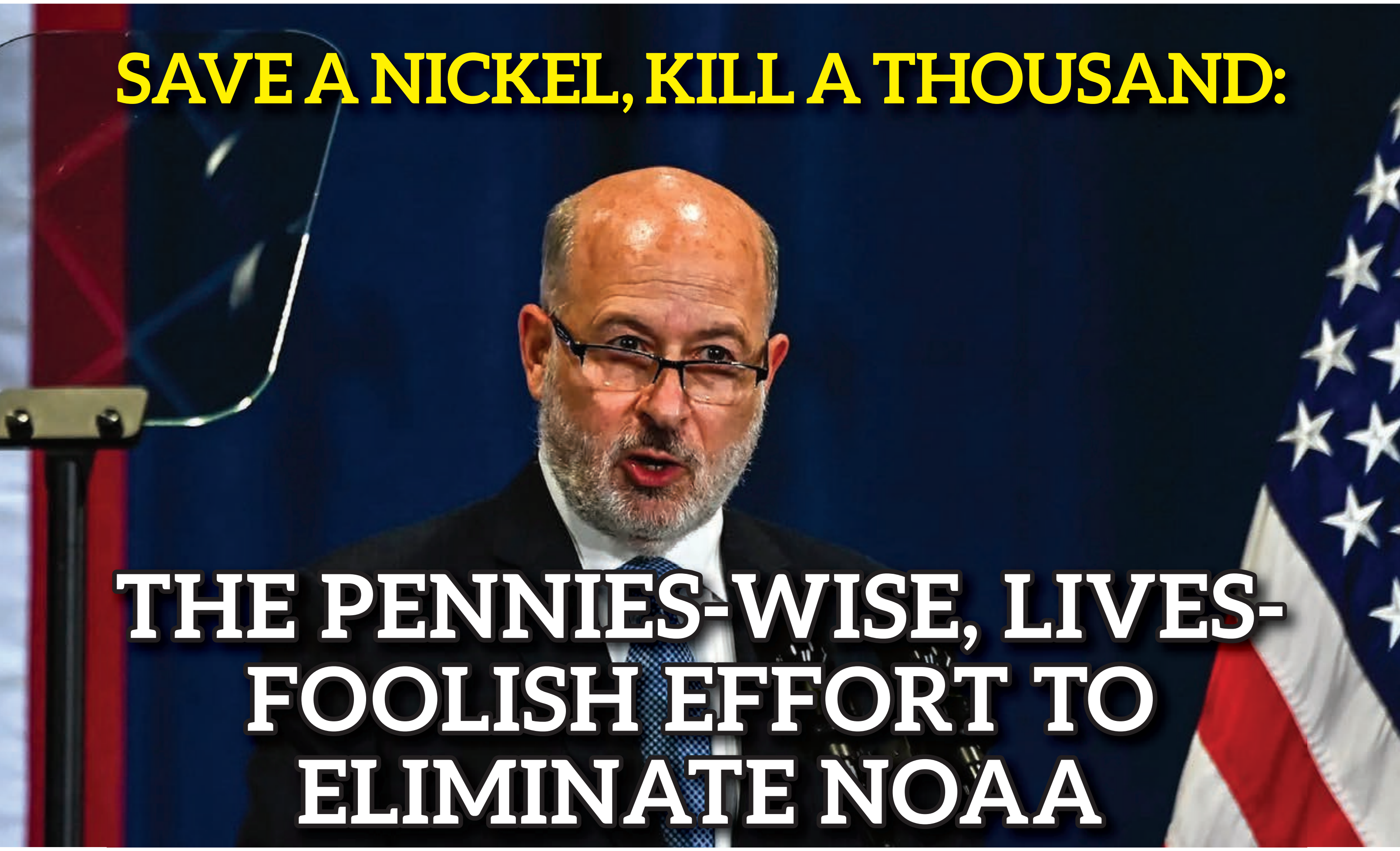
Gallaudet

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*.



SAVE A NICKEL, KILL A THOUSAND:

THE PENNIES-WISE, LIVES-FOOLISH EFFORT TO ELIMINATE NOAA

By Rick Spinrad, Ph.D., *NOAA Administrator from 2021-2025*

I know how to reduce the federal budget by $7B, if we are willing to kill a few thousand Americans every year, put our economy further into debt, and guarantee the loss of real property around the country. It can also be done without eliminating many services currently provided by the federal government, except you'll just have to pay hefty user fees (assuming you're actually allowed access) to a private company to get those services. And this all assumes that someone is also willing to absorb the capital expenses associated with operating their own air force, navy, and space force. The way you do this is by defunding the National Oceanic and Atmospheric Administration (NOAA), or just simply invoking a reduction in force by removing personnel and incapacitating the agency.

With the threat of eliminating NOAA, or even just splitting up its parts, or arbitrarily firing employees, and conducting what amounts to a fire sale, that is the outcome we will see. "Will", not "might". The predicted impact to lives, livelihoods, and property isn't hyperbolic. In fact, just look back to where we were before we had the benefit of many decades of investment in what NOAA does for America … at a cost, oh by the way, of 6¢ per American per day.

Before modern NOAA existed (established, incidentally by President Richard Nixon in 1970), an unforecasted hurricane hit Galveston in 1900 destroying the city and killing about 8,000 people. A devastating geomagnetic storm in 1989 (before NOAA developed its current capacity for space weather) wiped out large portions of North America's electrical grid, shutting down the Toronto stock exchange, causing widespread communications blackouts, and impacting military operations around the world, because there was insufficient warning to prepare for impacts. The great droughts of the 1930s in the mid-west were mostly unpredicted, and left millions of Americans destitute and starving, and millions of acres of farmland lost. NOAA now protects people and property from these (and countless other) disastrous weather, ocean, and climate events every hour of every day.

But, you may say, we didn't have Accuweather, and The Weather Channel, and the rest of the private weather enterprise back in those pre-NOAA days. That's true, and those companies have been extremely helpful and economically prosperous … due to their reliance on NOAA's data and forecasts. It's NOAA that operates 122 Doppler weather radars, 16 environmental satellites, 15 ships (that provide accurate nautical charts and sustainable seafood), and 10 airplanes (including the Hurricane Hunters, and the planes that monitor atmospheric rivers). Without NOAA, someone would have to pick up the bill for all of those assets, and their continuing operations and maintenance costs. And that someone will be the privileged few willing to pay the private sector the fees and subscriptions that would have to be charged, like one does for Netflix or Amazon Prime. Wanna know when that hurricane's going to make landfall, or where those tornadoes are going? Pay up.

NOAA has historically been grossly under-resourced to fully implement its stated mission: "To understand and predict changes in climate, weather, ocean and coasts; to share that knowledge and information with others, and; to conserve and manage coastal and marine ecosystems and resources." With just 12,000 federal employees the agency has always struggled to meet the mission (and done so heroically at times, as when Superstorm Sandy hit the northeast US in 2012), and if anything, needs at least an additional 5,000 employees to be most effective.

So go ahead, **Mr. Musk** and **Mr. Trump**, fire those NOAA employees and cut the agency's budget, but have the guts to stand up and take the hit for the deaths and destruction that result, while saving our wealthiest Americans a whole 6¢ per day.

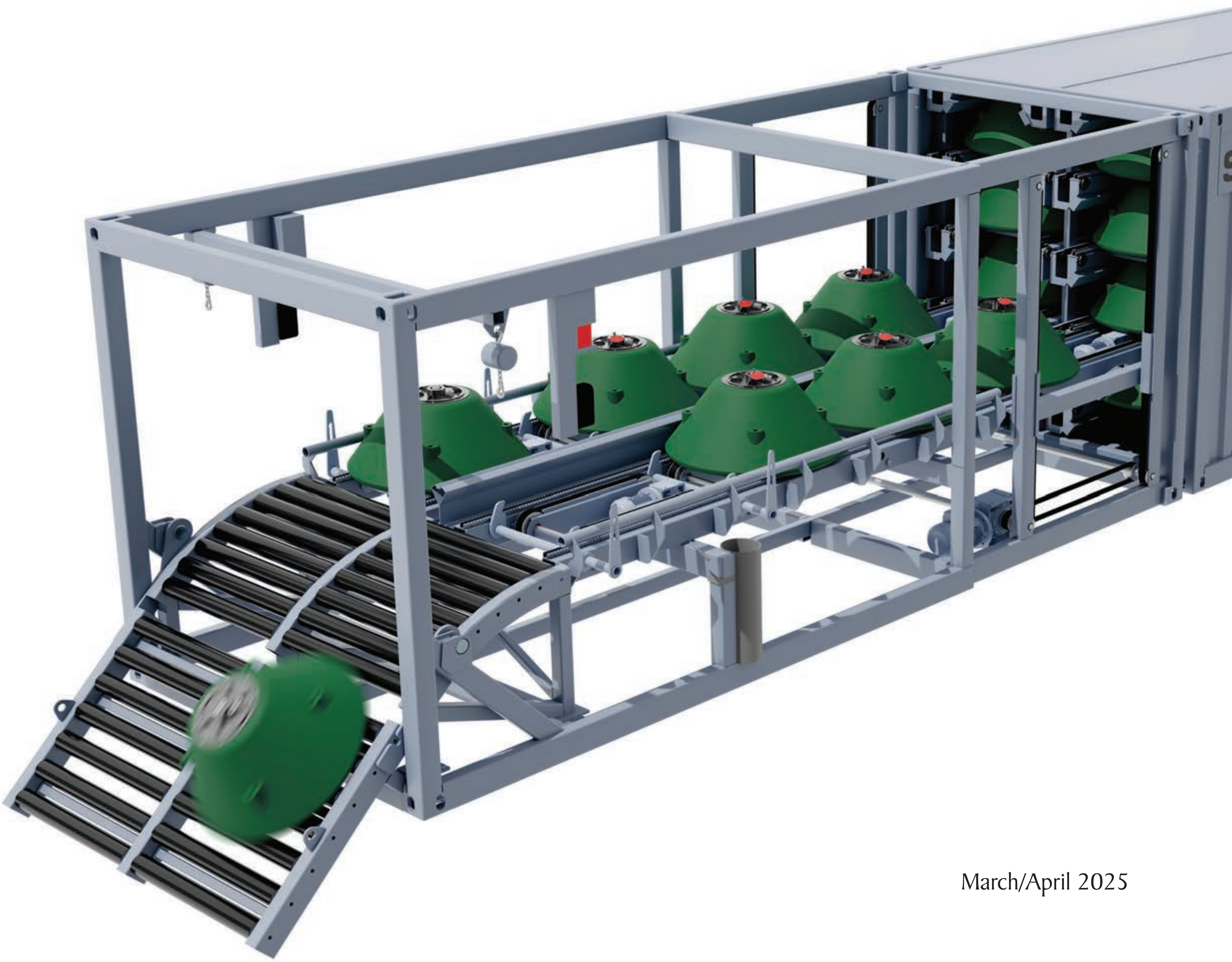
The preceding was authored by Rick Spinrad, Ph.D., who was NOAA Administrator from 2021-2025. The opinions expressed here are solely those of the author and do not necessarily reflect the opinions of the publisher.

UNCLEAR PRESENT DANGER

The Future of Mine Warfare Is Deception

"All warfare is based on deception," writes Sun Tzu in his seminal work, The Art of War. *"When using our forces, we must appear inactive; when we are near, we must make the enemy believe we are far away."*

By David Strachan, *Strikepod Systems*



These words ring particularly true when considering the future of minelaying, a largely overlooked but potentially decisive element of naval warfare. As global attention focuses on hypersonic missiles, armed quadcopters, loitering munitions, and attack USVs, it could be mines, minelaying, and mine countermeasures (MCM) that ultimately shape the course of future wars.

The popular depiction of sea mines often involves dense underwater forests of classic "spiky balls" and chains - moored contact mines deployed in structured minefields to achieve strategic or operational objectives. While this impression isn't mistaken (cheap and effective contact mines can still be found in the inventories of navies worldwide, and have been deployed as recently as the Russo-Ukraine War), it fails to capture the gravity of the modern sea mine threat, now characterized by multi-influence sensors, sophisticated activation algorithms, and counter-countermeasure capabilities.

Modern mines can be deployed using air, surface, or undersea military assets, but in an era of rapidly growing maritime domain awareness and expanding

The CUBE from SH Defence, a Danish provider of turnkey maritime equipment solutions, is a containerized minelaying system using a conveyor belt to deploy different mine types.

(Photo courtesy SH Defence)

weapon engagement zones (WEZs), conventional minelaying will be increasingly risky. Submarines are highly effective covert minelaying platforms, but their multi-mission profile will place them in high demand, and the increasing presence of littoral anti-submarine networks could constrain their use in a mine warfare role. Aircraft can rapidly deploy mines over large areas, but are vulnerable to modern air defenses, while minelaying ships face threats from land, sea, and air. Mine stocks and minelaying platforms could also be preemptively targeted, effectively removing them from the board before the game even begins. Of course, overt minelaying can serve as a valuable deterrent, signaling an adversary before hostilities begin, but it is covert expeditionary mining, designed to achieve objectives within or near adversary waters, that can effectively disrupt, delay, or deny an enemy freedom of movement in the maritime domain.

If conventional minelaying methods can be blunted by enemy sensors and weapons, how could mine warfare play a role in future conflict? Because mines can be deployed covertly from a wide range of non-military platforms - commercial cargo vessels, fishing boats, passenger vessels, and even unmanned surface vehicles (USVs). This flexibility, in addition to its highly advanced capabilities, makes the modern sea mine a persistent, insidious, and evolving challenge.

A potential cross-strait conflict between China and Taiwan provides a compelling case study. Defense analysts have raised alarms over China's rapid shipbuilding, warning that any large-scale Chinese amphibious assault could involve civilian RORO ferries. If Chinese civil-military integration could enable such a dual-use amphibious fleet, it is entirely plausible that it could also enable commercial cargo vessels to serve as cover for clandestine Chinese minelaying operations. Despite heightened tensions, Taiwan remains one of China's largest trading partners, and Chinese flagged cargo ships originating in Dalian, Ningbo, and other Chinese ports routinely pass within ten nautical miles of Zuoying Naval Base while enroute to Kaohsiung, Taiwan's "Maritime Capital." These waters are less than 300 meters deep, well within the WEZ of modern bottom mines.

Deploying from Ships

Three commercial-off-the-shelf containerized mine warfare solutions already exist, and can provide insight into a notional Chinese deployment system. The CUBE from SH Defence, a Danish provider of turnkey maritime equipment solutions, is a containerized minelaying system using a conveyor belt to deploy different mine types. Finnish munitions company Forcit Defence produces SUMICO, a minelaying system designed to fit inside a 40-foot shipping container that can deploy var-

The CUBE from SH Defence is a containerized minelaying system using a conveyor belt to deploy different mine types.

(Photo courtesy SH Defence)

ious types of bottom mines, including Forcit's Blocker mine, which can be deployed at depths of up to 200 meters for up to two years. And Rheinmetall Defence Australia, through a partnership with Supashock, has developed the Mine Rail Deployment System (MRDS) to deploy cylindrical bottom mines, such as Rheinmetall's Murena and Asteria mines, which can operate at depths up to 300 meters. Strategically positioned at a cargo ship's stern, containerized systems like these could discreetly deploy mines while transiting the shipping lanes along the west coast of Taiwan, making multiple passes over weeks or months. The mines would then lie in wait, dormant, until activated by an acoustic signal. This concept could apply to other strategic waterways, such as the Baltic Sea, where commercial vessels are already widely suspected to be engaging in seabed warfare by sabotaging submarine cables. With the ability to covertly deploy mines from civilian ships, any port or maritime chokepoint could potentially be vulnerable.

Unmanned surface vehicles (USVs) may also play a role in future minelaying. Ukrainian Sea Baby USVs have been observed carrying pairs of Italian-made Manta bottom mines, and there are reports that minelaying Ukrainian USVs may have been responsible for damaging the Russian guided missile corvette Samum. The destructive power of Mantas is well known. During Operation Desert Storm, two Iraqi Manta mines armed with just 325 pounds of explosives each achieved a mission kill on the USS Princeton, a 9,800 ton guided missile cruiser. If a small USV like Sea Baby can deploy two Manta mines, a medium USV could accommodate even larger payloads, perhaps by integrating a Cube- or SUMICO-style containerized mechanical conveyor, or an angled, gravity-assisted deployment system, for remotely controlled or semi-autonomous minelaying. Disguised as fishing boats, port security vessels, or high-speed recreational watercraft, unmanned minelayers could reseed or saturate existing minefields at minimum risk. Covertly laid minefields allow naval forces to be "near while appearing far," and the ability to deploy advanced sea mines from civilian and unmanned platforms would be a key operational enabler. As maritime competition intensifies in contested regions like the Taiwan Strait and the Baltic Sea, mine warfare will likely play a role in shaping future conflicts, and the ability to leverage deception for minelaying at scale could provide a decisive asymmetric advantage.

An ST Engineering vessel equipped with the AUTONOMAST system, conducts autonomous navigation and force protection maneuvers during an Unmanned Surface Vessel (USV) capabilities demonstration at Marine Corps Base Hawaii (MCBH).

U.S. Marine Corps photo by Lance Cpl. Terry Stennett

UNCREWED MARITIME VESSELS *MUST* LEVERAGE AI

By George Galdorisi

In September 2024, the 33rd Chief of Naval Operations, **Admiral Lisa Franchetti**, issued her *Chief of Naval Operations Navigation Plan for America's Warfighting Navy.* This Navigation Plan embodies "Project 33" in recognition of the fact that Admiral Franchetti is the 33rd Chief of Naval Operations. Project 33 sets targets for enabling the U.S. Navy to make strategically meaningful gains in the fastest possible time. This Plan has several components:

– The readiness component of the Navigation Plan has the goal of eliminating ship, submarine and aircraft maintenance delays and restoring critical infrastructure that sustains and projects the fight from shore.

– The people component of the Navigation Plan notes the goal of recruiting and retaining the force needed to fill officer, chief petty officer and enlisted ranks and delivering a quality of service for Navy personnel.

– The operational component of the Navigation Plan involves creating upgraded command centers for the Navy Fleet commanders and training for combat to ensure that the Navy has a warfighting advantage over its adversaries.

– Finally, the goal to scale robotic and autonomous systems to integrate more platforms at speed focuses on capitalizing on the inherent advantages that uncrewed systems bring to any navy.

While the first three components of Project 33 represent areas that the Navy has been seeking to improve for some time, the most intriguing part of the CNO's Navigation Plan is the goal of scaling robotic and autonomous systems to integrate more platforms at speed.

The "Why" Behind the Commitment to Uncrewed Systems

Unmanned capabilities not only keep sailors out of harm's way, but they provide opportunities to greatly expand the sea service's warfighting capacity at less cost than traditional Navy vessels. The Navigation Plan adds more granularity to the "why" behind the Navy's commitment to unmanned surface vessels. It notes that robotic and autonomous systems, by augmenting the multi-mission conventional force, will provide opportunities to expand the reach, resilience, and lethality of the combined manned-unmanned Navy team.

A short-term goal articled in the Navigation Plan is to integrate proven robotic and autonomous systems for routine use by the commanders who will employ them and to incorporate mature unmanned capabilities into all deploying carrier and expeditionary strike groups by 2027. The anticipated use of these unmanned capabilities will focus on key operational challenges across critical mission areas.

Focus On the Hybrid Fleet

The Navigation Plan puts special emphasis on the Hybrid Fleet. As Admiral Franchetti noted, absent a large infusion of resources, it will not be possible to build a bigger traditional navy in a few short years. Therefore, the Hybrid Fleet concept—a mix of 350 crewed ships and 150 uncrewed maritime vessels—is seen as a viable path to put enough hulls in the water to accomplish the Navy's myriad global missions.

Navy officials have been laying the keel for the future Hybrid Fleet via experimentation and other efforts, such as standing up Task Force 59 and Task Force 59.1 in the Arabian Gulf, establishing the disruptive capabilities office, and "operationalizing" the integration of unmanned platforms into numbered fleets beginning with the U.S. 4th Fleet. The Navy is moving from experimentation to integrating robotic and autonomous systems across other numbered fleets.

The U.S. Navy's commitment to a Hybrid Fleet represents a sound concept-of-operations to put more hulls in the water by fielding relatively inexpensive large- and medium-size unmanned maritime systems in lieu of trying to build more expensive surface combatants. Indeed, the unit price of an Arleigh Burke destroyer is $2.2 billion in 2024 dollars, while the cost of large- and medium-size unmanned maritime systems is a fraction of that cost.

Making Uncrewed Systems Affordable

While the unit cost of uncrewed systems makes them a seemingly affordable option, the devil is in the details. For years, if not decades, uncrewed systems of all kinds, especially uncrewed maritime systems, have been mired in a manpower-intensive paradigm.

One of the most pressing challenges for all navies is to reduce the prohibitively burdensome manpower footprint currently necessary to operate uncrewed systems. Manpower makes up the largest part of the total ownership cost of naval systems. If uncrewed maritime systems are to make up a significant part of any navy, the need to move beyond the "many operators, many-joysticks, one-vehicle" paradigm that has existed during the past decades for most uncrewed systems is clear and compelling.

For this reason, uncrewed systems (and especially uncrewed surface vessels) manufacturers are not only focused on the performance characteristics of their platforms (speed, endurance, stealth and other attributes), but are now inserting AI-technologies into their boats in order to make them more autonomous, aiming for a new concept of operations where one operator can effectively control multiple uncrewed surface vessels, which, themselves, will be "working together and communicating with each other" through the use of advanced AI concepts.

While the list of companies that produce uncrewed surface vessels is large—and growing—there are some that have been leading this effort. These manufacturers have fielded USVs (such as Saildrone, MANTAS, Devil Ray, Corsair, GARC, LRUSV and others) that have—or are planned to have—various levels of autonomy "baked in."

It is beyond the scope of this article to do a deep dive into how all these uncrewed surface vessels will operate more autonomously than earlier generations of USVs. As just one example, the T12 MANTAS and T38 Devil Ray, both built by Maritime Tactical Systems, Inc. (MARTAC), have demonstrated various levels of autonomy in a number of U.S. Navy and Marine Corps exercises, experiments and demonstrations.

For example, the MANTAS and Devil Ray both have AI-technologies that enable them to abide by the Convention on the International Regulations for Preventing Collisions at Sea (COLREGS). In one Navy exercise, a MANTAS ran a 25-waypoint autonomous mission around San Diego harbor, demonstrating COLREGS compliance.

As these events continued, Navy event planners were keen to explore even more ambitious uses of AI-enabled technologies for USVs. During exercise Integrated Battle Problem 21, a T38 Devil Ray made a 150-mile round trip autonomous transit from San Diego to San Clemente Island while autonomously dropping two objects.

Working with U.S. Fourth Fleet, a T38 Devil Ray made autonomous, high-speed intercepts at more than 70 knots, as well as follow-on demonstrations designed to show how autonomous craft could trail and intercept drug-smuggling vessels. High speed for the uncrewed surface vessels are key to keeping up with narco "go fast" boats. For this mission, the intercept speeds need to be performed at, or in excess of, 50kts.

More Uncrewed Surface Vessels & More Autonomy

To be clear, this is not a shout-out to one USV manufacturer, but simply "grabbing the headlines" from several transparent and well-chronicled Navy and Marine Corps events. The Sea Services have plans for an ambitious series of exercises, experiments and demonstrations this year and beyond that are intended to further "wring out" AI-enabled technologies.

If the uncrewed surface vessel industry is to thrive, it must leverage what the U.S. Navy and Marine Corps have achieved during these events and others and find ways to leverage AI-technologies more fully going forward. As the ability of these uncrewed maritime systems to perform a plethora of missions becomes increasingly dependent on a high degree of autonomy, we will likely see more emphasis on what's inside the craft, not just attributes highlighted at trade shows. Whether used in the military or private sector, needing fewer operators will make uncrewed surface vessels increasingly affordable.

About the Author

George Galdorisi is a retired naval aviator. He enjoys writing, especially speculative fiction about the future of warfare. The opinions expressed in his article are solely those of the author. Reference to any specific commercial companies, products, process, or service does not imply its endorsement by the Department of Defense or Department of the Navy.

Figure 1

A pull test frame for testing ocean lander components that see tension can be made inexpensively, provides good results, is made without any welds, and is adjustable for different length components. Its thin cross-section doesn't take up much space when stored.

BUILD A PULL TESTER ON A BUDGET

By Kevin Hardy, Global Ocean Design LLC, MTR columnist

“N***ature sides with the hidden flaw***,” was an adage shared by an old school Scripps’ engineer, Dr. Frank Snodgrass. I never forgot that wisdom. “A wreck at sea can ruin your whole day,” was a plaque centered at eye level over my desk. Another friend and shipmate, Scripps EE Doug Peckham, had his own workbench plaque: “If it’s not tested, it won’t work.”

Failure is always an option. The secret of the most successful groups I know at Scripps, WHOI, UW, JHU, Cornell and elsewhere is making certain the first time their system sees tension, pressure, low temperature, or any other environmental condition, is before it goes over the fantail. Testing is a critical element of their success. “It should work” only plays into the hands of Davy Jones.

At Global Ocean Design, we built a simple mechanical Pull-Test system as a means to QC critical ocean lander terminations, burnwires, and other tension elements under forces up to 1,200-lbs. Critical components receive 100% testing before they leave the building. The QC loop ends at our door.

The static pull test system gives confidence in the performance of tension elements used in landers, lightweight moorings, AUVs, and other small-to-medium scale undersea projects.

We’ve discovered links of steel chain that were not welded, and pulled open under tension. Visual inspection was not helpful as the chain had been galvanized, covering the missing weld with zinc. We found the weakest link. Doesn’t happen often, but that’s definitely a wreck at sea that was avoided. Likewise, we can assure swage terminations and rope splices are done to our specification. We did the homework and knew what to expect. We once got rid of an expensive swage tool because it gave unreliable results.

We can confidently determine a safety factor for tension elements by taking a reasonable statistical sample to failure. It’s wise to have that margin when unpredictable sea states and ship motion may induce a snap load that could exceed 2x or more the static load.

The pull tester is a flat frame 18” wide x 5-ft tall x 2” deep. The top and bottom rails are steel U-Channel, 2” wide, x 1” leg x 3/16” thick. These are separated by two lengths of ¾-16” x 5-ft threaded rod. Hex nuts on the threaded rod sandwich the U-channel top and bottom. Three ½” steel shoulder eyebolts are located across the top. The center eye bolt is for hanging the frame from an overhead beam, a 6-ft or taller step ladder, or a steel storage shelf. The other two are for suspending the tensioning system inside the frame. (See Figure 1)

The lower U-Channel has a single ½” steel shoulder eyebolt in the center to attach to the bottom of the test sample.

Tension is generated by a turnbuckle. The larger the thread, the more load it can handle. The finer the thread the more mechanical advantage, making it easier to generate a load. I used a forged galvanized steel closed body eye-to-eye turnbuckle, ½-20 thread with a maximum adjustment range of 4-3/4”. Di-

Figure 2

The tensioning system of the pull tester. Because of the two-leg arrangement and small included angle, the digital scale reads ½ of the load on the test sample below the pully. Note the label above the digital scale, “2X SCALE READING.”

vided between the two legs, that's 2-3/8" pull on the test sample. The chain below the test sample allows positioning within the length of one link. The lower ½" eye bolt can be raised or lowered to provide vernier adjustment if needed.

A 3/16" wire rope leader from the turnbuckle passes through the sheave of a 3-1/2" diameter pully, and connects to a digital hanging scale. (See Figure 2)

Force can be measured in pounds, kilograms, or Newtons. (See Figure 3) A "hold" feature is helpful if the sample fails, as the display will still show the maximum tension recorded.

The eye of the pully connects to the top of the pull test sample. The bottom of the sample is connected by a length of chain to an eye at the bottom center of the lower frame. The chain allows for different sample lengths. A string of smaller tension elements, like a daisy chain of burnwires, can be easily accommodated. (See Figure 4)

This fairly simple design does not provide a means to test cyclic loads. There are examples on YouTube of systems using pneumatic or hydraulic rams to test sail rigging and rock-climbing rigs that could be adapted to a computer-controlled system. Go to YouTube and search for "How to Build a Pull Tester." If anyone does this, or has done this, please write us and send a photo or two to share with your fellow Landereans.

Figure 3

The digital scale of the pull tester reads ½ the force on the test sample.

Figure 4

Five burnwire elements are daisy chained together to proof test multiple units with a single tension test.

We've made larger portable tensioning systems using a 12v automotive electric winch between a pair of stanchions. We've also used a mechanical come-along on another system. There is lots of room for invention. On higher test loads, a remote winch control is valuable for keeping the operator to the side, out of the path of the snap back of a parted cable. A load cell with a remote readout is also necessary to position the operator at a safe distance. Never use synthetic line as part of the pull test rig. Its stretch may exceed the range of your pull test system, and is a source of stored energy. The snap back can be more violent. If you're load testing a length of synthetic line, the remote winch control and remote load cell read-out are definitely advisable. The collaborative Scripps/WHOI mooring group I was a part of tested every shackle, pear link, chain, and terminated cable, both wire rope and synthetic, before we went to sea. While our success rate was still not perfect, we had more than one ship's captain compliment us on our professionalism.

All the preparation and checklists flash through your mind as you pull the quick-release and send your ocean lander to the bottom. "When you stare into the abyss," wrote 19th century German philosopher Friedrich Nietzsche, "the abyss stares into you."

It's only your diligence that brings that lander back.

A PDF report with application tips, schematics, and Bill of Materials for making your own pull tester is available free to ***MTR*** *readers by contacting the author, Kevin Hardy <khardy@marinelink.com>.*

"Lander Lab" is a hands-on column of Ocean Lander technologies, an often-overlooked class of unmanned undersea vehicles. It is meant to serve the ocean lander community in the manner of Make Magazine and other DIY communities.

Comments on this article, or suggestions for stories of interest to other Landereans are welcome. ***MTR*** *invites you write to Kevin Hardy <khardy@marinelink.com>.*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THE FUTURE OF OCEANOGRAPHIC RESEARCH:

A CONVERSATION WITH

BRUCE APPELGATE OF UNOLS

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The U.S. oceanographic research community depends on a complex network of ships and institutions for scientific discovery at sea. The University-National Oceanographic Laboratory System (UNOLS) is the central organization that provides scientists with access to advanced research ships and technology to explore the world's oceans. We recently spoke with *Bruce Appelgate, Chair of the UNOLS Council and Associate Director at Scripps Institution of Oceanography*, to explore UNOLS' operations and future plans.

By Rhonda Moniz

UNDERSTANDING UNOLS AND THE U.S. ACADEMIC RESEARCH FLEET

Contrary to common misconception, UNOLS does not own or operate a fleet. Instead, it facilitates coordination among the U.S. Academic Research Fleet (ARF). ARF includes 17 ships that fall into the global, ocean and coastal/regional class vessels. UNOLS's main objective is to provide equal access to research vessels for federally funded scientists across all institutions. "The great thing about our ships is that everyone involved in their operations and management shares a singular focus—supporting the best possible oceanographic research," Appelgate explained. "From physical oceanography to geophysics and marine ecology, our fleet enables groundbreaking science."

Technological innovation significantly enhances oceanographic research capabilities. UNOLS is implementing new technologies to improve operational efficiency and broaden research possibilities. Woods Hole Oceanographic Institution is developing two smaller containerized remotely operated vehicles (ROVs) as a significant advancement. The new ROVs will enhance the widely used Jason system by offering greater flexibility and deeper access for deep-sea research tasks.

Another area of focus is the continued improvement of seabed mapping technology. "Mapping sonars and multibeam echo sounders have been around for a while, but we are continuously upgrading these tools to enhance resolution and data quality," Appelgate noted.

Moreover, autonomous systems are increasingly being used to supplement traditional ship-based research. "With autonomy, we can deploy a swarm of sensors alongside ships, transforming data collection from a single track-line profile to a broad swath of information," he said. However, challenges such as range, power supply, and system reliability mean that ships will remain indispensable as mobile command centers for these autonomous platforms.

FLEET OPS AND WORKFORCE DEVELOPMENT

The decline in available research vessels is one of the most pressing issues facing UNOLS and the ARF. Over the past few decades, the U.S. fleet has shrunk from 34 ships to just 17, limiting research opportunities. "The demand for sea-based research far exceeds our capacity," Appelgate said. "We need more global-class vessels that can work in the world's harshest conditions."

Workforce shortages present a significant challenge in addition to fleet size constraints. Hiring and keeping mariners, technicians, and scientists in their positions becomes more challenging over time. UNOLS tackles workforce shortages by supporting the Marine Advanced Technology Education (MATE) program and STEMSEAS initiative that educate students about oceanographic research careers.

Students spent the day aboard the Robert Gordon Sproul as part of Fiamma Straneo's Observational Physical Oceanography 176 class. The purpose of the cruise was to train and expose students to the collection of physical oceanographic observations including CTDs, shipboard ADCP, underway data, surface ocean data, bathymetry, and surface drifters. As well as the ships safety protocol and hand on experience with the ships equipment. Students spent the day launching, retrieving, testing and calibrating small scale CTDs they built in the Scripps Makerspace and comparing their data to the larger CTD.

RVs ADDRESSING GLOBAL CHALLENGES

Research vessels play a critical role in tackling pressing marine science challenges. Oceanographic research informs policies that protect marine ecosystems and coastal communities, from studying climate change impacts and ocean acidification to assessing earthquake risks along fault zones.

Applegate highlighted how past missions have led to significant discoveries, including hydrothermal vents, deep-sea ecosystems, and insights into earthquake mechanics. “Some of the greatest discoveries in ocean science have been serendipitous,” he said. “Being at sea with the right tools and people allows us to make observations that fundamentally change our understanding of the planet.”

FUNDING AND THE FUTURE OF UNOLS

Oceanographic research holds significant value yet continues to struggle with ongoing funding difficulties. UNOLS depends mainly on financial backing from the National Science Foundation (NSF) and the Office of Naval Research (ONR) yet existing funding fails to satisfy expanding research needs. “If we doubled our budget tomorrow, we would still have enough scientific projects ready to use that additional capacity immediately,” Appelgate emphasized.

UNOLS has identified fleet recapitalization as its primary focus for future development. A significant investment will be required for replacements as several top-tier vessels will complete their service life by the end of the next decade. Applegate alerts that the United States trails its global peers in oceanographic capability as China rapidly builds its fleet. “If we want to maintain our leadership in ocean science, we need a stronger commitment to fleet renewal,” he stated.

UNOLS maintains its dedication to providing U.S. scientists with essential tools, technology, and access that enable them to achieve revolutionary findings as oceanographic research advances. UNOLS helps define ocean research’s trajectory by integrating advanced sensors, expanding autonomous systems capabilities, and pushing for greater federal support.

“The work we do impacts everything from weather forecasting to national security,” Appelgate concluded. “Investing in ocean science today ensures a better understanding of our planet for future generations.”

Scripps’ Jennifer Mackinnon and Drew Lucas were among an international team of oceanographers and meteorologists who took part in an Office of Naval Research-funded project called MISO-BoB (Monsoon Intra-seasonal Oscillations in the Tropical Indian Ocean and the Bay of Bengal). It was one of the most comprehensive attempts to understand the South Asian monsoon, one of the most economically important natural events in the world. MISO-BoB broke ground in its use of specialized technology and cooperation among researchers in India and the United States among other countries.

Undergrad Students spend the day aboard the R/V Robert Gordon Sproul.

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SHIPBUILD

INSIDE THE MAKIN
A MODERN HYDRO
HYBRID RESEARCH V

The Scripps Institution of Oceanography is in the midst of developing a groundbreaking hydrogen-hybrid Coastal Class Research Vessel (CCRV). Designed in collaboration with Glosten and supported by Siemens, this will be the first of its kind, using liquid hydrogen as a primary fuel source. With the potential to revolutionize oceanographic research, the vessel will provide a silent, emissions-free platform for scientists while pioneering new sustainable maritime technologies.

The journey to the hydrogen-hybrid CCRV began with planning and collaboration among leading naval architects, regulatory bodies, and industry partners. "We selected Glosten in Seattle as our naval architect, and they contracted Siemens as their integrator," said Bruce Appelgate, Associate Director of Scripps Oceanography. "We also partnered with the American Bureau of Shipping (ABS) and the U.S. Coast Guard, since the regulatory framework for liquid hydrogen at sea was virtually nonexistent."

Hydrogen has long been utilized in industrial applications, making it a well-documented fuel source with a strong safety record. However, adapting it for maritime use presented challenges. The team worked closely with regulators to establish safety protocols, achieving preliminary approval under the Safety of Life at Sea (SOLAS) convention in December. With these milestones reached, Scripps recently issued a Request for Proposal (RFP) to shipyards.

FUEL ASIDE, RESEARCH IS ITS CORE

At its core, the hydrogen-hybrid CCRV is designed to be a top-tier oceanographic research vessel. "No matter what the propulsion system, it has to be an exceptionally capable research ship," Appelgate said. "Our ships last 40 to 45 years, so we need to ensure it meets the needs of both current and future scientific missions."

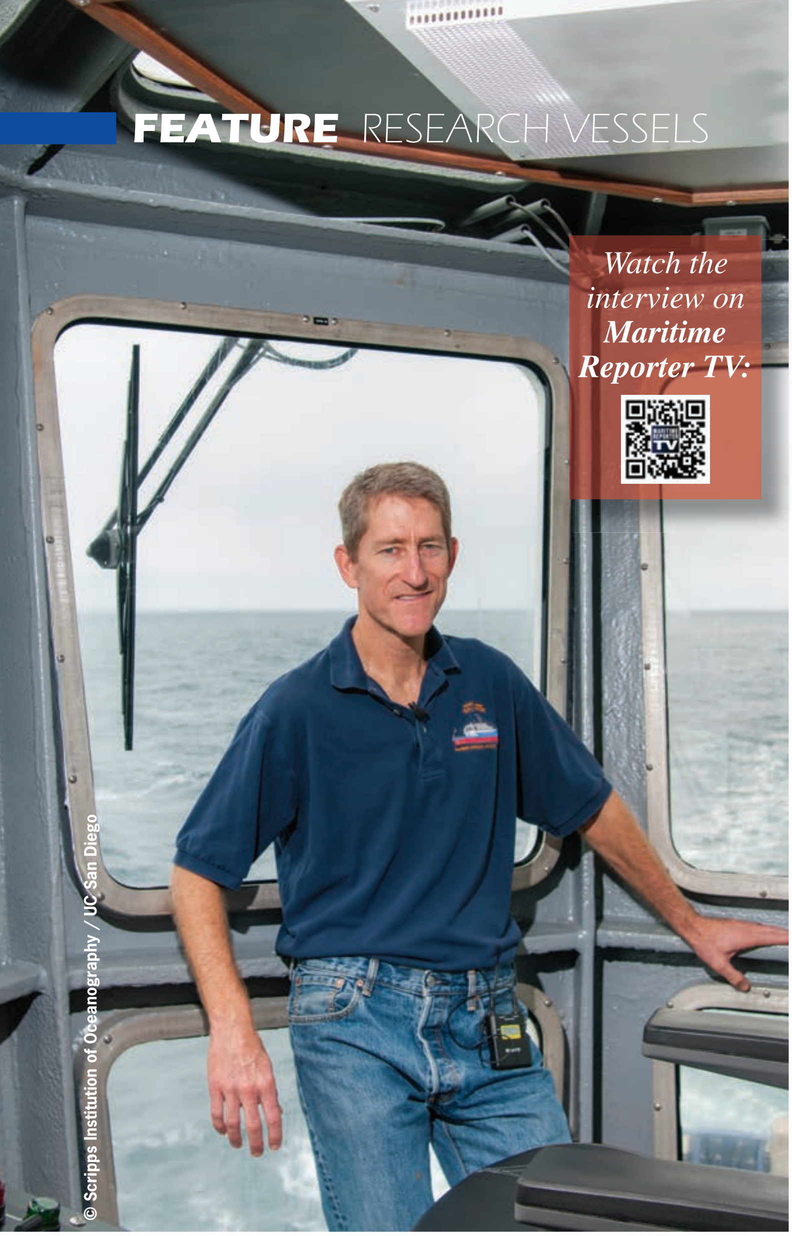
The vessel will be outfitted with cutting-edge oceanographic technology, including overboard handling systems for deploying and retrieving instruments, dynamic positioning with azimuthing stern thrusters, and advanced sonar and mapping equipment. "We don't need to be fast; we need to be precise," Appelgate notes. The ship's capability to hold station with minimal movement is crucial for lowering CTD rosettes, which gather water samples from varying depths over extended periods.

Onboard laboratory space will more than double that of Scripps' existing research vessels, providing scientists with ample room for analysis. Deck space has also been expanded, a decision influenced by the vessel's future-proofing efforts. Initially designed to run on a combination of liquid hydrogen and diesel, the ship is being constructed with additional fuel storage to accommodate methanol in the future. "Methanol presents a viable long-term alternative due to California's evolving emissions regulations. To make that transition feasible, we needed additional tank space—hence the ship is 10 meters longer than its predecessor," said Appelgate.

THE HYDROGEN-HYBRID PROPULSION SYSTEM

California's robust hydrogen economy made the fuel an obvious choice for this vessel. "Hydrogen is already used across the state in cars and buses, and there's an established infrastructure for supply and distribution," Appelgate said. Beyond its environmental benefits, hydrogen-powered propulsion provides unique scientific advantages. "Just like an electric car, it's incredibly quiet. This means we can meet underwater radiated noise standards effortlessly, which is essential for acoustics-based research."

The propulsion system consists of a cryogenic liquid hydrogen tank, located on the vessel's upper level, which feeds into a series of Ballard fuel cells. These cells convert hydrogen into electricity to power the ship's motors, producing only water as a byproduct. The vessel's six 200-kilowatt fuel cell stacks generate a total of 1.2 megawatts of power. In a surprising bonus, the ultra-pure water



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Watch the interview on **Maritime Reporter TV:**

"No matter what the propulsion system, it has to be an exceptionally capable research ship. Our ships last 40 to 45 years, so we need to ensure it meets the needs of both current and future scientific missions."

– Bruce Appelgate,
Associate Director of Scripps Oceanography

produced can be used directly in onboard laboratories—eliminating the need for complex seawater purification systems.

The ship's operational range was another key design consideration. The hydrogen tank will store enough fuel for over two days of continuous operation—sufficient to complete 75% of the research missions typically conducted by Scripps. For longer expeditions, the hybrid system will rely on diesel generators, with plans to transition to methanol within five years. "It's about demonstrating that these new fuels work in real-world conditions, paving the way for broader adoption across the maritime industry," said Appelgate.

OVERCOMING CHALLENGES IN MARITIME HYDROGEN ADOPTION

The pioneering nature of this vessel has required overcoming significant regulatory and technical hurdles. "The biggest challenge has been the regulatory framework—or rather, the lack of one," Appelgate admits. "We've had to work closely with ABS and the Coast Guard to establish safety guidelines from scratch."

Ensuring the safe storage and use of liquid hydrogen—a cryogenic fuel kept at extremely low temperatures—has been another priority. The team engaged Chart Industries to develop the cryogenic fuel tank and gas system, ensuring the fuel could be stored, vaporized, and delivered to the fuel cells safely and efficiently.

To validate the feasibility of a hydrogen-powered vessel, Scripps visited the Norwegian ferry Hydra, which operates entirely on liquid hydrogen. "What struck us was how normal it felt—it was just a routine ship operation," recalls Appelgate. "And of course, how quiet it was, both above deck and in the machinery spaces."

A PATHWAY TO THE FUTURE

With the RFP process underway, responses from shipyards have been overwhelmingly positive. "We anticipate finalizing a contract within the next few months," Appelgate shares. Once a shipyard is selected, the project will enter a detailed design phase lasting approximately 9-12 months before construction begins. The build process itself is expected to take around two years, followed by extensive testing and commissioning of both propulsion and scientific systems.

Scripps plans to dedicate the first six to twelve months post-delivery to fine-tuning the vessel's operations before integrating it into the U.S. Academic Research Fleet. "This isn't just a research ship—it's a demonstration platform for the future of sustainable maritime propulsion," Appelgate said.

By pioneering hydrogen-hybrid technology in oceanographic research, Scripps Institution of Oceanography is not only ensuring continued access to the sea for scientists but also charting a path toward a cleaner, more sustainable future for the entire maritime industry.

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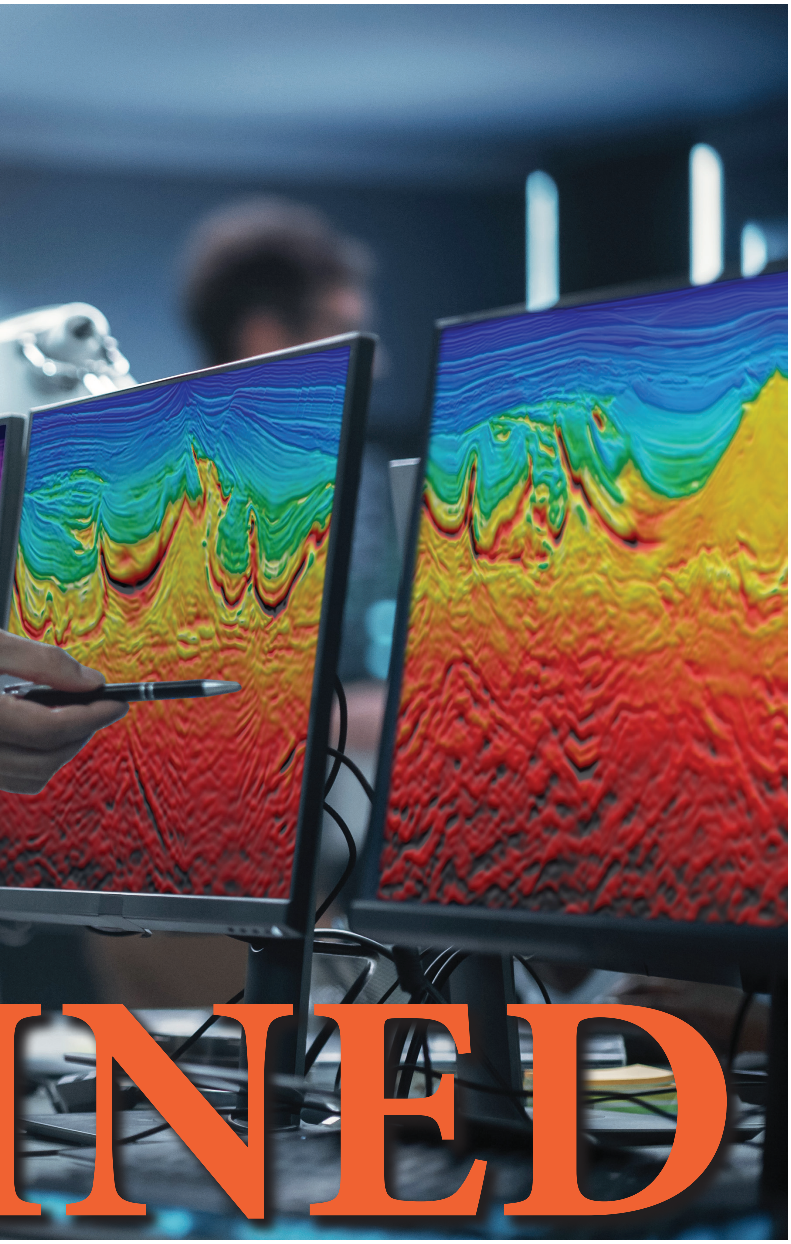
Survey Data RE-IMAG

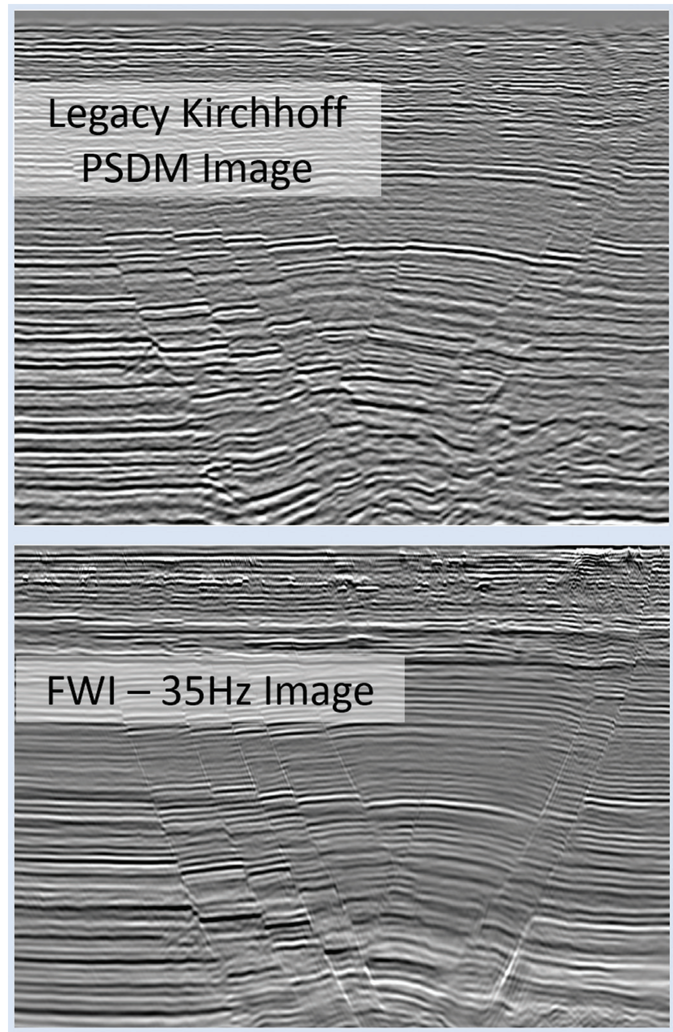
LEGACY DATA CONTINUES TO ADD VALUE TO OIL, GAS AND CCS PROJECTS.

By Wendy Laursen



NED

With the latest seismic processing technologies, legacy seismic data can provide good resolution images of the target formation and its overburden.



* All images courtesy Viridien

More than 10 million wells have been drilled globally to date, costing hundreds of billions of dollars. Yet, data from old wells can quickly be devalued: it didn't lead to financial gains before, so it's easily forgotten.

"Even successful historical wells can fall into the folklore category," says Ceri Davies, digital geology manager, Earth Data at Viridien, who looks after the company's well library database which contains searchable, detailed information from millions of well reports and documents worldwide. "Every one of these wells provides a direct window into the subsurface at their location. By reprocessing, collating and curating this legacy data, we provide explorationists with the opportunity to revisit the excitement that drove the initial investment in the well." And in the future, says Davies, AI will also be used to identify trends and missed opportunities.

Well library data has already been combined with other legacy data to screen for carbon storage sites in the GoM. To do this, Viridien employed many different types of well data as part of a Storge Play Quality Index assessment including well log suites, check shot surveys, well test data, core data, biostratigraphy, water chemistry and formation pressure data.

Following an initial screening of sites, the data was used to create a structural framework for imaging legacy seismic data to enable storage potential to be characterized in 3D. "With the latest seismic processing technologies, legacy seismic data can provide good resolution images of the target formation and its overburden," says Gregor Duval, carbon storage man-

"Every one of these wells provides a direct window into the subsurface at their location. By reprocessing, collating and curating this legacy data, we provide explorationists with the opportunity to revisit the excitement that drove the initial investment in the well."

– Ceri Davies,
Digital Geology Manager, Earth Data, Viridien

"We were able to enhance the legacy streamer data with significant uplift to the final images."

– Hari Krishna,
Director Europe, North Africa & Middle East, Earth Data, Viridien

"With the latest seismic processing technologies, legacy seismic data can provide good resolution images of the target formation and its overburden."

– Gregor Duval,
Carbon Storage Manager, Earth Data, Viridien

"TLFWI and FWI Imaging, whether in their acoustic or elastic versions, have brought tremendous value to the reprocessing of legacy seismic data."

– Rongxin Huang,
VP, US Imaging, Subsurface Imaging, Viridien

ager, Earth Data at Viridien. "The most recently awarded storage licenses include a commitment from developers to reprocess legacy seismic data."

New oil and gas discoveries are also sparking interest in legacy data. The play-opening giant discoveries of Baleine and Murene-1 (Calao) offshore Tano Basin, Côte d'Ivoire, have reinvigorated exploration in the equatorial margin of Africa, and in 2024, Viridien merged and re-imaged a seamless and contiguous volume of 6,434 km2 of 3D multi-client seismic data in the basin.

The data included four separate surveys acquired over multiple blocks between 2000 and 2014 from the shelf to the outer slope domain. These four surveys with differing cable depths and streamer profiles, along with significant variations in legacy processing workflows, were merged to create a contiguous seismic volume. The new re-imaging was undertaken from field tapes using proprietary technologies such as time-lag full-waveform inversion velocity model building.

In the North Sea, Viridien recently reprocessed multi-client seismic streamer data to create value for clients evaluating the Central North Sea and the Southern North Sea. "We were able to enhance the legacy streamer data with significant uplift to the final images," said Hari Krishna, Director Europe, North Africa & Middle East, Earth Data, Viridien.

Clients found the new depth models to be accurate within 1% of the target depth for exploration wells, enabling them to place their wells optimally. "All of our reprocessing projects in the past 5-6 years have been very well funded. In our estimates, more than 70% of active blocks in the Central North Sea use Viridien data as their primary database.

"In the Southern North Sea, our reprocessing of streamer data from 2014 fundamentally changed the reservoir model. As a result, the client changed the infill well locations and improved their production and reserve estimates."

Krishna expects new streamer acquisition to decrease in volume and go more hybrid (Ocean Bottom Node (OBN) + streamer data) or fully OBN to provide enhanced reservoir imaging.

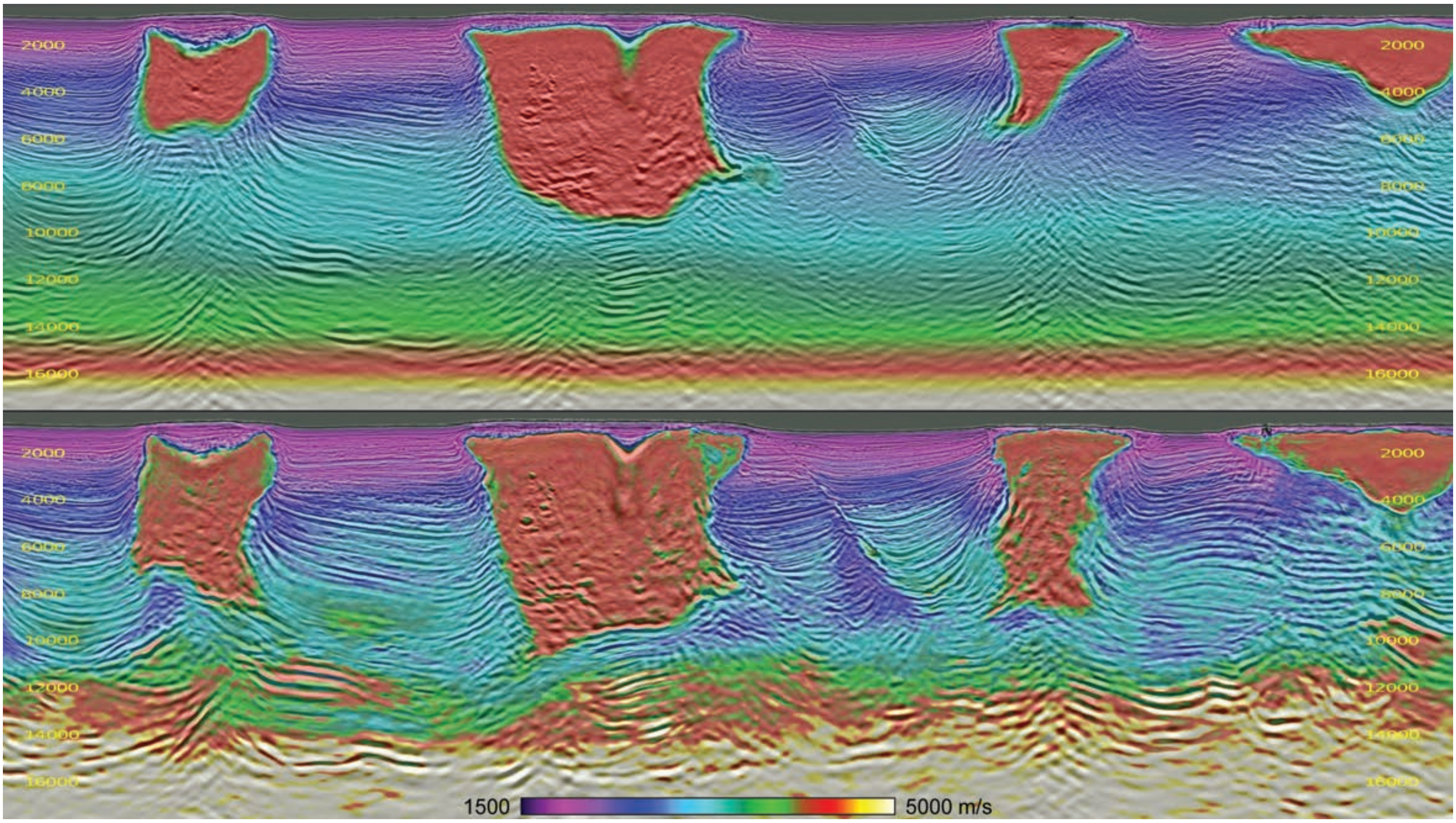
OBN data is generally considered better than streamer data because it provides a much richer subsurface image due to its ability to capture a wider range of seismic wave arrivals, including longer offsets, full azimuthal coverage and better low-frequency information.

Seismic imaging is constantly advancing. Viridien uses full-waveform inversion (FWI) algorithms that produce highly detailed, data-driven models of subsurface velocity, absorption (Q) and reflectivity by minimizing the difference between observed and modeled seismic waveforms. FWI is now the industry standard for velocity model building and has been applied to legacy and new seismic survey configurations.

Time-lag FWI (TLFWI) is a proprietary Viridien technology that addresses issues which plagued earlier FWI algorithms, such as cycle-skipping issues related to an inaccurate initial model, amplitude mismatches between observed and modeled seismic and a poor low-frequency signal-to-noise ratio of field data. TLFWI has been highly successful in velocity model building for complex geological settings around the world, including sub-salt, carbonates, thrust belts and shallow gas. It is often used in conjunction with OBN data sets and as a way of improving the image on legacy seismic data.

FWI Imaging takes the process a step further by outputting an image of subsurface reflectivity directly, often providing a superior result in complex areas where migration algorithms struggle.

"TLFWI and FWI Imaging, whether



Reprocessing of legacy wide-azimuth towed streamer data acquired in 2010 using TLFWI resulted in significant improvements in subsalt imaging. Top - 2010 legacy velocity model overlaid with RTM; Bottom - 2024 8Hz TLFWI velocity and its RTM.

in their acoustic or elastic versions, have brought tremendous value to the reprocessing of legacy seismic data," says Rongxin Huang, VP, US Imaging, Subsurface Imaging, Viridien. "Although TLFWI and FWI imaging were initially developed for the most advanced data, i.e. OBN data with good low frequencies, long offsets, and excellent spatial and azimuthal sampling, applying these technologies to legacy seismic data, which are sometimes more than 25 years old and often have poor low frequencies, short offsets, and limited spatial sampling, still generates step-change improvements in the seismic images.

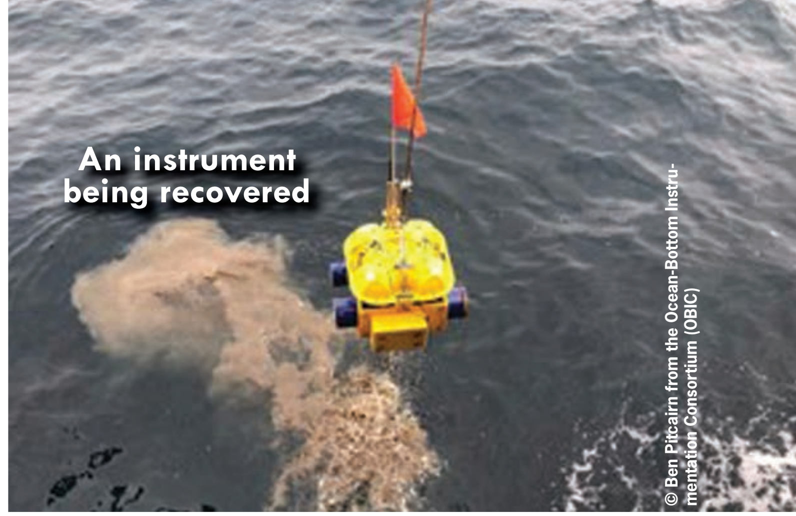
"The application of TLFWI and FWI Imaging has greatly unlocked the value of legacy data, allowing operators to reduce costs and shorten turnaround times (compared to acquiring new seismic surveys) when better seismic images are needed to make important decisions for their prospects and reservoirs."

Seismic imaging is moving towards even more advanced algorithms, such as high-frequency multi-parameter elastic FWI, with the aim of deriving accurate seismic reservoir attributes (compressional wave velocity (Vp), shear wave velocity (Vs), and density) directly. Legacy data on its own is increasingly insufficient to meet these advanced demands, says Huang.

"New acquisitions providing better data, such as OBN, are expected to become mainstream in operators' exploration and development programs in the next 5–10 years. This will be facilitated by decreasing acquisition costs as new acquisition technologies and more streamlined operations continue to improve acquisition efficiency."

This means that, while there is still considerable value in legacy data, in challenging geological areas it needs to be complemented by new acquisition for seismic imaging.

OCEAN-BOTTOM SEISMOGRAPHS SHAKE UP TUR CURRENT MONI



An instrument being recovered

By Celia Konowe

Turbidity currents, underwater flows of sediment and water, are difficult to monitor, but technological adaptations at Durham University have revealed new discoveries and may have unlocked opportunities for further research.

The currents are significant on a global scale for multiple reasons, explained research fellow Dr. Meg Baker. They serve as a significant sediment transport process, capable of transporting huge volumes from the coast to the deep sea—more than smaller fluxes like rivers and glacial processes. Alongside sediment, turbidity currents can transport nutrients, feeding benthic communities. Plus, they can create hydrocarbon reservoirs, ideal for oil and gas exploration and exploitation. However, the currents also can carry litter like plastics, contributing to global pollution streams.

Additionally, turbidity currents can transport large amounts of organic carbon to the deep sea, where it can be sequestered for long periods of time. While this doesn't solve short-term problems posed by the climate crisis, they do play a crucial role in the long-term carbon cycle. This information is also necessary for accurate carbon cycling models, explained Baker. For all the beneficial roles played by turbidity currents, they can also be destructive, destroying some deep-sea ecosystems and marine infrastructure like underwater cables and pipelines.

Generating New Knowledge

Our understanding of turbidity currents has evolved, Baker explained, with significant findings starting about 20 years ago with the development of Acoustic Doppler Current Profilers (ADCPs), which use sound waves to measure the speed and direction of currents. While ADCPs were fundamental in understanding turbidity currents, they work better on small scale systems; faster flows were often destructive to the instruments. As such, gaps remain in understanding large-scale turbidity currents.

"We wanted to look at the Congo system because it's a huge submarine system," explained Baker. "You have the Congo River, which is unique in that it's directly connected to the Congo Canyon." Previous work in Monterey Canyon, offshore California, had covered a few kilometers and a couple of hundred meters of water depth. Monitoring turbidity currents in the

Congo Canyon, offshore West Africa, would require hundreds of kilometers and thousands of meters of water depth. "We kind of knew the velocity profile of flows and how often they happen for smaller systems, but we didn't know how often they might happen in the Congo system," said Baker. "It was really a case of, how does the smallest stuff scale to the bigger?"

A Nod to Terrestrial Research

Instead of using ADCPs, the research team used seismographs, which detect and record ground motion—typically used to measure earthquakes. "It really came from people doing research in the terrestrial realm," Baker explained. Terrestrial geographers and geologists face similar struggles when measuring geomorphic events like landslides, but they've found success in using seismographs. "I think that's what kind of inspired us to think, okay, this has worked really well on land—let's try it in the marine environment." Turbidity currents generate ground vibrations as they travel, which are measurable using seismographs on the seafloor placed outside the flow's destructive path.

At the data collection site, the seismographs are winched off the side of a boat, where they fall quickly to seafloor. Strapped to a concrete base, the instruments can sit for months or years collecting information. When it's time to retrieve the seismograph, acoustic signals can be used to communicate with the device, signaling for its release from the seafloor.

Findings Abound

Researchers recorded the longest runout sediment flows ever measured in action on Earth, which travelled more than a thousand kilometers along the Congo Canyon-Channel. As explained in the team's paper, the data informed models of turbidity current flow behavior, showing that the front of the flows contain a fast frontal-zone with high sediment concentrations. This can be up to 400 kilometers long, while the whole duration of the flow can last for more than three weeks.

In addition, researchers measured two different types of turbidity current events, canyon filling and canyon flushing flows. The former describes the smaller flows that might happen more often, transporting sediment and depositing it within the canyon. Smaller , canyon filling events had been recorded previously. Canyon flushing flows, however, are big events that will erode material from the canyon and carry it all the way to the deep sea. While a spectrum between the two exists, Baker explained, canyon flushing events had not been measured directly before. "This was exciting because we didn't really know how canyon flushing flows behaved compared to filling flows. They're bigger, but can you just scale one up, or are they different?" she said.

The seismographs were also able to record the internal structure of the turbidity currents. "That's really important for understanding how these processes work," said Baker. "To make models understand how far these flows might travel, you need to have a better understanding of the structure."

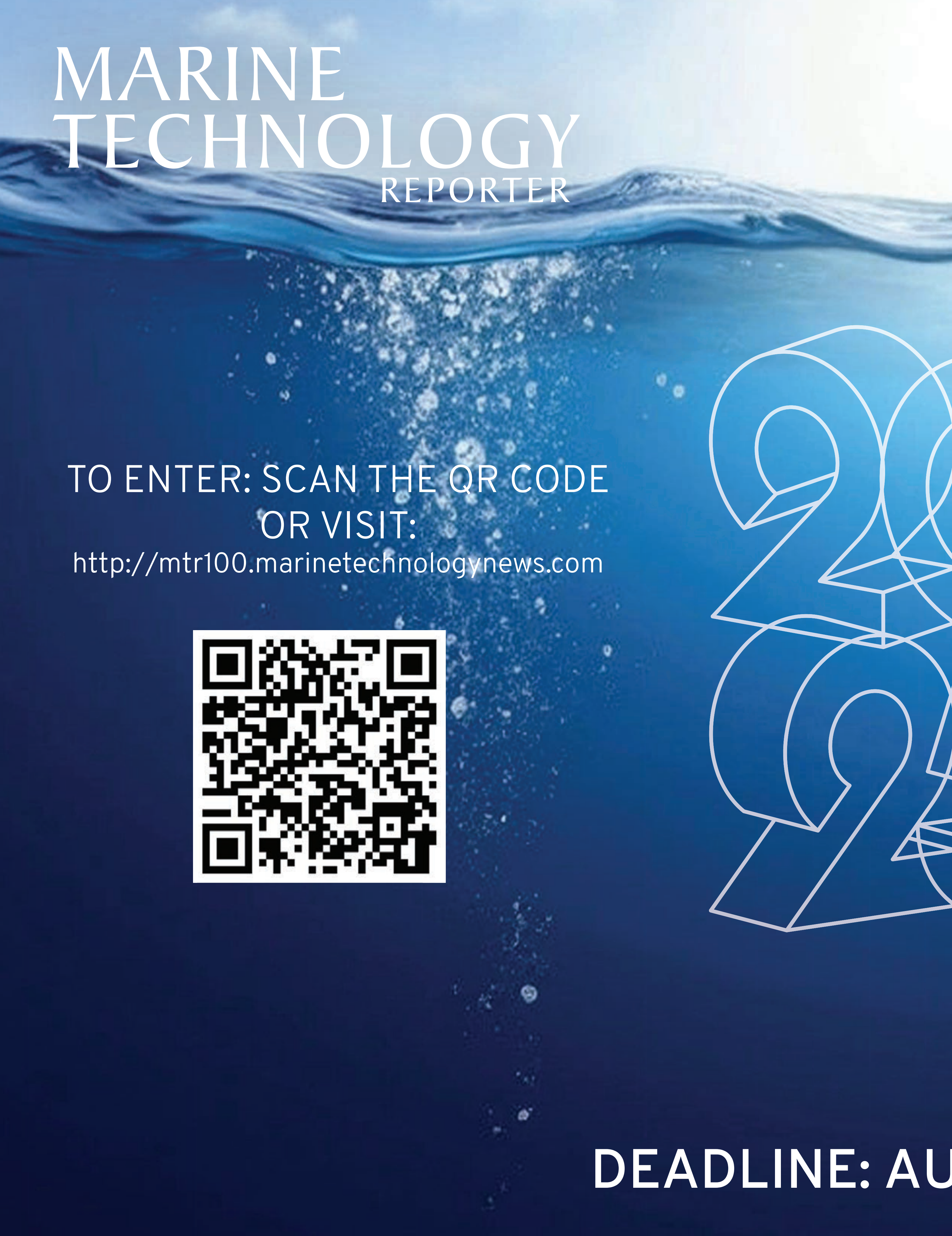
In the face of climate change, it's also important to note the role turbidity currents play in organic carbon transport. From previous work, researchers knew how much organic carbon was transported. However, with a better idea of current duration from the new data, it's possible to calculate how quickly that carbon was transported and sequestered in the deep sea, contributing to long term carbon cycle.

Current duration may also indicate prolonged flow of nutrients and warmer water. "We realized that if a turbidity current lasted for 21 days, it might be bringing warm water to the deep ocean for that whole time period," said Baker. This raises questions regarding ocean ventilation and the connectivity between land and sea. "We know these big turbidity currents were triggered by floods in the Congo River. And then you can start to think, well if there are more river floods due to changing climates, could that cause more turbidity currents? Could that cause more warm water going to the sea? What could the impacts of that be?"

Flowing forward

"Our question now is trying to use seismographs to monitor turbidity currents in other places," said Baker. "We want to have a better understanding of how turbidity current signals might be different." The Congo system is muddy, while that in Monterey is very sandy. "What do the seismic signals of turbidity currents look like from different locations where you have flows behaving differently and made up of different mixtures of sediment?"

Much about turbidity currents remain to be discovered. However, with ocean-bottom seismographs, data collection appears to be safer, more reliable, and more robust. Turbidity currents may yet reveal more about sediment flow and organic carbon transport, contributing to global knowledge of Earth's intertwined processes. Seismographs, too, have likely only begun fulfill their role in marine environments.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Multi-Use of Ocean Space for Sustainable Exploration and Monitoring with Small and Agile Underwater Robots

By Ivan Stenius, Fredrik Gröndahl, John Folkesson, Ignacio Torroba

Abstract: *The increasing demand for ocean space due to offshore energy production, aquaculture expansion, and critical subsea infrastructure necessitates innovative and sustainable monitoring solutions. Traditional monitoring approaches using large remotely operated vehicles (ROVs) and support vessels are costly and inefficient. This article explores how small, agile autonomous underwater vehicles (AUVs) are transforming ocean monitoring by providing persistent, cost-effective, and environmentally responsible solutions. These AUVs integrate with offshore wind farms, aquaculture systems, and subsea infrastructure to enable real-time inspections, biodiversity assessments, and predictive maintenance. The discussion highlights key technological advancements, sustainability benefits, and future challenges in deploying autonomous marine robotics for multi-use ocean space monitoring. By leveraging intelligent underwater systems, industries can enhance operational efficiency while ensuring the long-term health of marine ecosystems.*

Introduction

The world's oceans are becoming increasingly crowded with human activities, from aquaculture and offshore energy production to critical civil infrastructure. With the rapid expansion of offshore wind farms, wave and current energy harvesting systems, and the continued deployment of undersea cables and pipelines, sustainable management and monitoring of these assets are more crucial than ever. Traditional monitoring solutions often involve large, costly, and resource-intensive systems, but a new paradigm is emerging—leveraging small, agile, and intelligent underwater robots for persistent and cost-effective ocean monitoring.

The Growing Demand for Ocean Monitoring

The need for a comprehensive and continuous monitoring of marine installations is increasing. Offshore wind farms are expanding rapidly, with new floating wind turbine technology that allows deployment in deeper waters. Meanwhile, aquaculture is moving further offshore to reduce the environmental impact on coastal areas, increasing the demand for robust monitoring of fish health, biofouling, and environmental conditions. These developments require reliable inspection and maintenance solutions that do not disrupt operations or pose excessive costs.

FIG 1: Nordic Seafarm; Seaweed farm, Grebbestad, Sweden

Photo: Fredrik Gröndahl

At the same time, the seabed is dotted with thousands of kilometers of critical infrastructure, including telecommunication cables, oil and gas pipelines, and emerging power transmission lines connecting offshore energy farms to mainland grids. Ensuring their long-term integrity requires a shift from periodic manned inspections to resident autonomous monitoring systems that can operate continuously with minimal human intervention.

The Rise of Smart Underwater Robots

Traditionally, large remotely operated vehicles (ROVs) and crewed support vessels have been used for ocean monitoring tasks. However, these systems are expensive to operate, require significant logistic support, and are often limited in their deployment frequency. Advances in marine robotics are now enabling the use of small, agile, and cost-effective underwater vehicles capable of autonomous operation for extended periods of time.

These systems, which include autonomous underwater vehicles (AUVs) and resident ROVs, are equipped with advanced sensors for high-resolution imaging, sonar mapping, and environmental monitoring. By using edge computing and artificial intelligence (AI), these robots can process data in real-time, identifying anomalies in structures, detecting biofouling, and even classifying marine species to assess biodiversity around installations.

One examples is SAM, the Small and Affordable Maritime AUV, developed by researchers at the Royal Institute of Technology (KTH) in Sweden. Unlike traditional underwater vehicles, SAM is designed for hydrobatic maneuvering, meaning

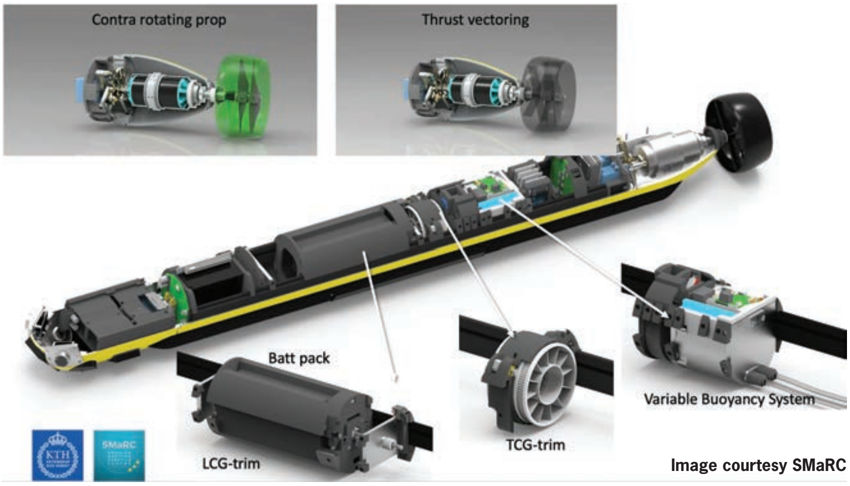


FIG 2: The SAM AUV developed at KTH

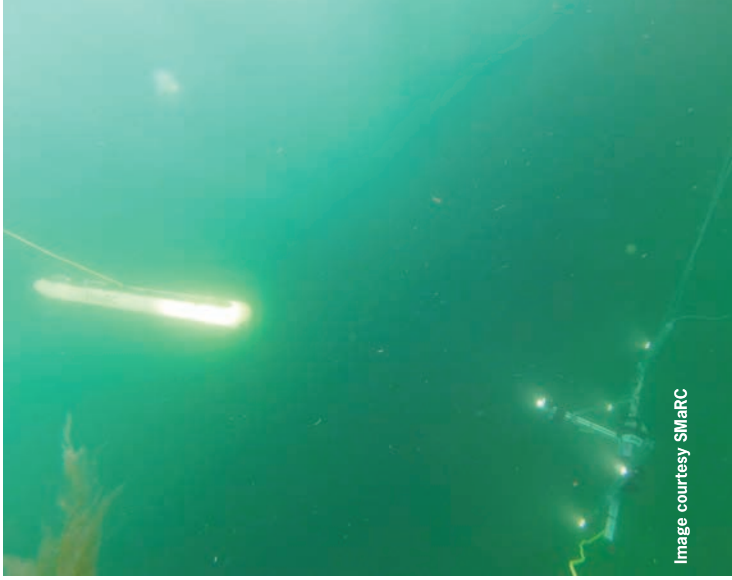


FIG 3: AUV SAM at test site on the Swedish west coast.

it can roll, loop, and hover like an underwater acrobat. This level of agility is crucial for inspecting offshore wind turbine foundations, monitoring fish farms, and tracking the health of marine ecosystems.

The research goals are to push the boundaries of technologies that are not just maneuverability but also tightly coupled with its intelligence. Equipped with AI-driven navigation, real-time data processing, and autonomous docking capabilities, this extends the operability to long periods of time without human intervention. With autonomous docking at underwater charging stations, recharge, offload data, and continue missions—making it a game-changer for long-term ocean monitoring.

Integration with Existing and Emerging Infrastructure

One of the key advantages of deploying small underwater robots is their ability to integrate seamlessly with existing and emerging offshore infrastructure. Subsea docking stations allow resident AUVs and ROVs to remain in the field for extended periods, recharging and transmitting data back to shore-based operators or cloud-based analytics platforms.

For offshore wind farms, these robots can play a crucial role in monitoring turbine foundations for structural integrity, inspecting mooring lines in floating wind installations, and assessing the seabed impact of operations. In aquaculture, they can autonomously inspect fish cages, detect leaks in net enclosures, and monitor water quality without requiring divers or frequent human intervention. Figure 4 shows an example figure that illustrates a long-term system for an AUV in a seaweed farm.

For undersea cables and pipelines, resident monitoring systems can detect shifts in seabed topography, identify early signs of structural fatigue, and even assist in predictive maintenance to prevent costly failures. This capability is especially valuable in deep-sea environments, where human access is limited, and intervention costs are high.

From Wind Farms to Seaweed Forests: Multi-Use Ocean Spaces

As industries expand into deeper waters, the idea of multi-use ocean space is gaining momentum. Instead of dedicating large marine areas to just one function—such as wind energy or aquaculture—scientists and engineers are exploring ways to combine different activities in synergistic ecosystems.

A prime example is the combination of offshore wind farms and seaweed farming. Wind turbines require vast open water spaces, and beneath them, the water column is often underutilized. KTH researchers are exploring ways to integrate large-

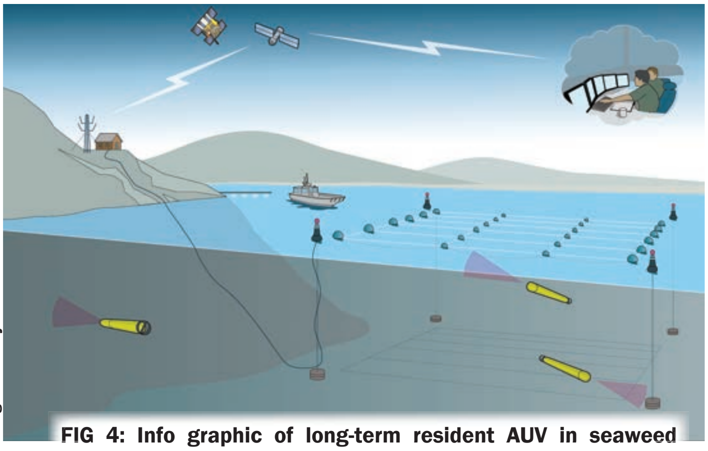


Image courtesy SMaRC

FIG 4: Info graphic of long-term resident AUV in seaweed farm. The mobility and autonomy are important to both move between and find the elements to inspect while satellite communications make remote presence possible.

Image courtesy SMaRC

FIG 5: AUV SAM at test site on the Swedish west coast. In such limited visibility conditions sonar becomes the main perception sensor (SMaRC).

scale seaweed farms in combination with offshore turbines, turning these areas into multi-functional hubs of sustainability. Seaweed cultivation is not just about food; it has potential for carbon sequestration, nutrient uptake, biofuel production, cosmetics, and biodegradable plastics.

But growing seaweed in dynamic offshore environments is no simple task. That's where underwater robots like SAM come in. Researchers are developing automated monitoring systems where AUVs track seaweed growth, detect biofouling, and assess environmental changes in real-time. This technology could revolutionize ocean farming, making it more efficient, scalable, and environmentally friendly.

A Sustainable Future, Powered by Robots

Beyond seaweed, underwater robots are becoming essential tools for preserving marine ecosystems. With declining fish stocks and increasing pollution, continuous environmental monitoring is more critical than ever. Using advanced imaging systems and AI-driven pattern recognition, AUVs can help scientists track biodiversity, detect early signs of ecosystem collapse, and map changes in underwater landscapes.

KTH's research extends beyond engineering; it is deeply rooted in sustainability. The university is pioneering research on eco-friendly aquaculture, marine habitat restoration, and the role of underwater robots in climate mitigation. By integrating robotics with environmental science and sustainable ocean farming, KTH is shaping the future of our relationship with the sea.

The operational efficiencies with small and agile underwater robots contribute to sustainable ocean management in several ways:

- Reduced Carbon Footprint: Unlike traditional monitoring solutions that rely on large vessels burning fossil fuels, resident and autonomous underwater systems can operate with minimal energy consumption.

- Lower Environmental Disturbance: Frequent and localized monitoring allows for early detection of issues such as oil leaks, habitat degradation, or biofouling before they escalate into major environmental concerns.

- Enhanced Biodiversity Monitoring: With AI-driven image recognition and acoustic sensing, these robots can serve as non-invasive tools for assessing marine life around offshore installations, helping to inform ecosystem-based management approaches.

Portable Science: Bringing Robotics Anywhere

One of the most exciting aspects of small AUVs like SAM is their portability. Unlike larger submersibles that require specialized transport, SAM is light enough to be carried on commercial airlines as luggage. This makes it possible for researchers to deploy advanced marine robots in remote locations without the need for massive logistical operations.

From coral reef restoration in tropical waters to scientific missions in the Arctic, the portability of these new robotic systems opens up unprecedented opportunities for global ocean exploration.

Challenges and Future Prospects

While small underwater robots offer transformative benefits, challenges remain in widespread adoption. Energy efficiency and battery life constraints limit mission endurance, though advances in wireless underwater charging and energy-harvesting technologies are addressing these limitations. Communication in the underwater domain remains a challenge, necessitating innovative approaches such as acoustic modems, optical communication, and satellite-assisted data transfer when vehicles surface.

Precise underwater navigation and positioning, particularly for small vehicles, is another key challenge. Unlike large systems that can carry more advanced inertial measurement units (IMUs) and navigation sensors, smaller AUVs must rely on compact and energy-efficient positioning solutions. Advances in acoustic localization, simultaneous localization and mapping (SLAM), and machine-learning-based sensor fusion are being explored to improve navigation accuracy and operational reliability in complex underwater environments.

Photo: Ivan Stenius

FIG 6: AUV SAM packaged for travel.

Regulatory frameworks also need to evolve to accommodate autonomous monitoring solutions. As these systems become more prevalent, standardized protocols for data sharing, cybersecurity, and operational integration with offshore industries will be essential.

Looking ahead, the next generation of marine robotics will likely incorporate swarming capabilities, allowing multiple small robots to collaborate in monitoring large-scale offshore sites. Machine learning-driven analytics will enable predictive maintenance strategies, further enhancing the economic viability of autonomous ocean monitoring.

Conclusion

As the ocean space becomes increasingly vital for energy production, food security, and global communications, the need for sustainable monitoring solutions is greater than ever. Small and agile underwater robots represent a paradigm shift in how we manage and protect critical offshore assets. By integrating these intelligent systems with emerging infrastructure, industries can achieve cost-effective, continuous, and environmentally responsible ocean monitoring.

With ongoing advancements in autonomy, AI, and energy management, the future of ocean monitoring is poised for a revolution—one where intelligent underwater robots become a ubiquitous presence beneath the waves, ensuring the sustainable use of our planet's last frontier.

MASSA PRODUCTS CORPORATION:

INNOVATING SONAR TECHNOLOGY & SECURING THE FUTURE OF THE MARITIME WORKFORCE

*All image courtesy Massa Products Corporation

***Dawn Massa Stancavish**, President, CEO, and Chief Innovation Officer, Massa Products Corporation, recently joined Rhonda Moniz on the DEEP DIVE podcast to discuss this innovative company's rich history and its role in helping to inspire a new generation of technology workers.*

Massa Products Corporation has been a cornerstone of sonar technology for nearly eight decades, shaping advancements in U.S. naval defense and maritime innovation. Massa's impact on national security is undeniable as a premier supplier of sonar transducers and arrays for U.S. Navy submarines. However, beyond its technological prowess, Massa is also tackling one of the industry's most pressing concerns: the future of the maritime workforce.

Under the leadership of Dawn Massa Stancavish, President, CEO, and Chief Innovation Officer, Massa continues to drive advancements in sonar technology while investing in workforce development to ensure a sustainable pipeline of skilled professionals. As the maritime defense sector faces growing workforce shortages and global defense collaborations like AUKUS reshape industry dynamics, Massa is poised to play a pivotal role in innovation and workforce training.

A Legacy of Sonar Innovation and Naval Defense

Founded in 1945 by Frank Massa, a pioneer in sonar technology, Massa Products Corporation has long been at the forefront of U.S. naval defense initiatives. During World War II, Frank Massa's contributions were instrumental in developing sonar transducers, producing over 200 unique designs that significantly expanded the Navy's sonar capabilities.

Today, Massa remains a critical supplier for the U.S. Navy's Virginia-class attack submarines (SSNs), Columbia-class and Ohio-class ballistic missile submarines (SSBNs), and guided missile submarines (SSGNs). The company supplies over 60% of the sonar transducers and arrays used in these advanced platforms, ensuring superior underwater situational awareness.

Unlike many firms specializing in either R&D or production, Massa has maintained a fully integrated approach—designing, engineering, and manufacturing all in-house. This streamlined process allows for:

- **Rapid prototyping and problem-solving** in response to evolving naval requirements.
- **Strict quality control** across all phases of production.
- **Innovative applications of sound technology** across both **defense and commercial sectors.**

With 170 patents and counting, Massa's commitment to sonar and acoustic innovation remains as strong as ever.

BRIDGING THE WORKFORCE GAP: Training the Next Generation

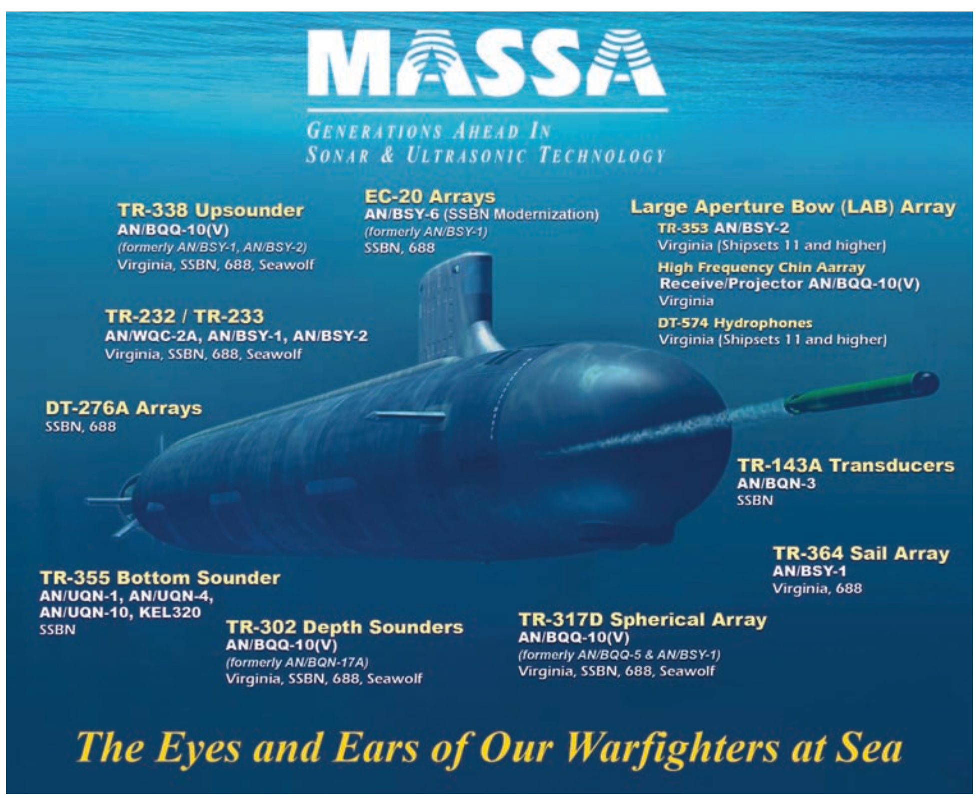
While Massa's technological expertise keeps it at the cutting edge, the company is equally committed to tackling one of the biggest challenges in the maritime industry: the shortage of skilled technical workers.

Across the submarine industrial base, companies struggle to fill roles in manufacturing, precision machining, electrical work, and other skilled trades—positions critical to national security. This workforce shortage was exacerbated by COVID-19, which accelerated retirements and disrupted technical training pipelines.

"For years, the message has been 'go to college, go to college,'" explains Dawn Massa Stancavish. "That created a shortage of skilled tradespeople in fields like welding, cable manufacturing, and precision machining—jobs essential to building submarines and supporting national defense."

To address this, the U.S. Navy launched the Submarine Industrial Base (SIB) initiative, now expanded into the Maritime Industrial Base (MIB), to build a stronger workforce pipeline. Programs like BuildSubmarines.com are also raising awareness of career opportunities in submarine manufacturing, connecting job seekers with companies like Massa.

Massa has fully embraced these efforts, achieving 50% workforce growth during COVID-19 by investing in training, retention, and apprenticeship programs. The company collaborates with local high schools, vocational programs, and industry partners to provide hands-



on training, reinforcing that a college degree is not the only path to success in the defense industry.

"There's a misconception that your career options are limited if you don't go to college. That's just not true," says Stancavish. "Defense manufacturing offers stable, well-paying, and meaningful careers in CNC machining, assembly, and quality control."

For those interested in engineering degrees, many defense firms, including Massa, support employees in pursuing higher education while working, creating upward mobility within the industry.

AUKUS and the Future of Global Defense Collaboration

Massa's influence isn't confined to the U.S. domestic market. The AUKUS agreement, a strategic defense partnership between Australia, the United Kingdom, and the United States, transforms global naval operations by bolstering submarine capabilities among allied nations.

As part of the AUKUS initiative, the U.S. defense industry is set to receive $3 billion in Australian investment, with $500 million already allocated to strengthen the American submarine supply chain. This investment will strengthen supply chains, expand production, create new jobs, and require a larger skilled workforce.

"There could be opportunities for skilled tradespeople to work internationally, whether in the U.S., Australia, or the U.K.," notes Stancavish. "The defense sector isn't just about technology—it's about strengthening global relationships and security."

For maritime industry workers, this means more career opportunities, expanded training programs, and increased demand for skilled labor in the submarine and defense sectors.

MASSA'S VISION: Innovation, Training, and Collaboration

The maritime defense sector stands at a crossroads, balancing the integration of emerging technologies like AI, additive manufacturing, and robotics with the need for human expertise in precision manufacturing and assembly. Massa's strategy addresses both challenges:

1. **Investing in Workforce Development**
   - Expanding apprenticeship programs to train the next generation of skilled technicians.
   - Partnering with industry organizations to raise awareness about maritime careers.
   - Supporting employees in continuing education and career advancement.
2. **Advancing Sonar Technology**
   - Driving new research and development in underwater acoustics.
   - Expanding patent portfolio to enhance naval and commercial applications.
   - Maintaining a fully integrated engineering and manufacturing process for quality control and rapid innovation.
3. **Strengthening Industry Collaborations**
   - Engaging in AUKUS and Maritime Industrial Base workforce initiatives.
   - Partnering with defense and commercial firms to expand sonar applications.
   - Supporting U.S. Navy and allied forces through continued innovation and production.

"Adaptability is key for companies and workers alike," says Stancavish. "Companies need to invest in skill-building, and workers need to be willing to learn new trades and take on new challenges. The defense industry offers career paths in machining, assembly, quality control, engineering, and beyond."

Her final advice for those considering careers in maritime defense manufacturing:

"Find a company where you feel a connection. The right culture matters as much as the right job."

Massa Products Corporation continues to prove that the future of defense is not just about technology—it's about the people who build it. Through innovation in sonar technology, commitment to workforce development, and active participation in global defense collaborations, Massa is securing not just the future of U.S. naval operations, but the careers of those who power them.

As the maritime industry navigates workforce shortages, international partnerships, and technological shifts, Massa's dual focus on innovation and training ensures it remains a leader in the evolving landscape of maritime defense.

For those seeking careers in sonar technology, precision manufacturing, or naval defense, Massa offers more than just a job—it offers a mission, a legacy, and a future.

The Cane Institute SeaPerch Teams:

ENGINEERING THE FUTURE BENEATH THE WAVES

Photo courtesy Mike Kozlowski

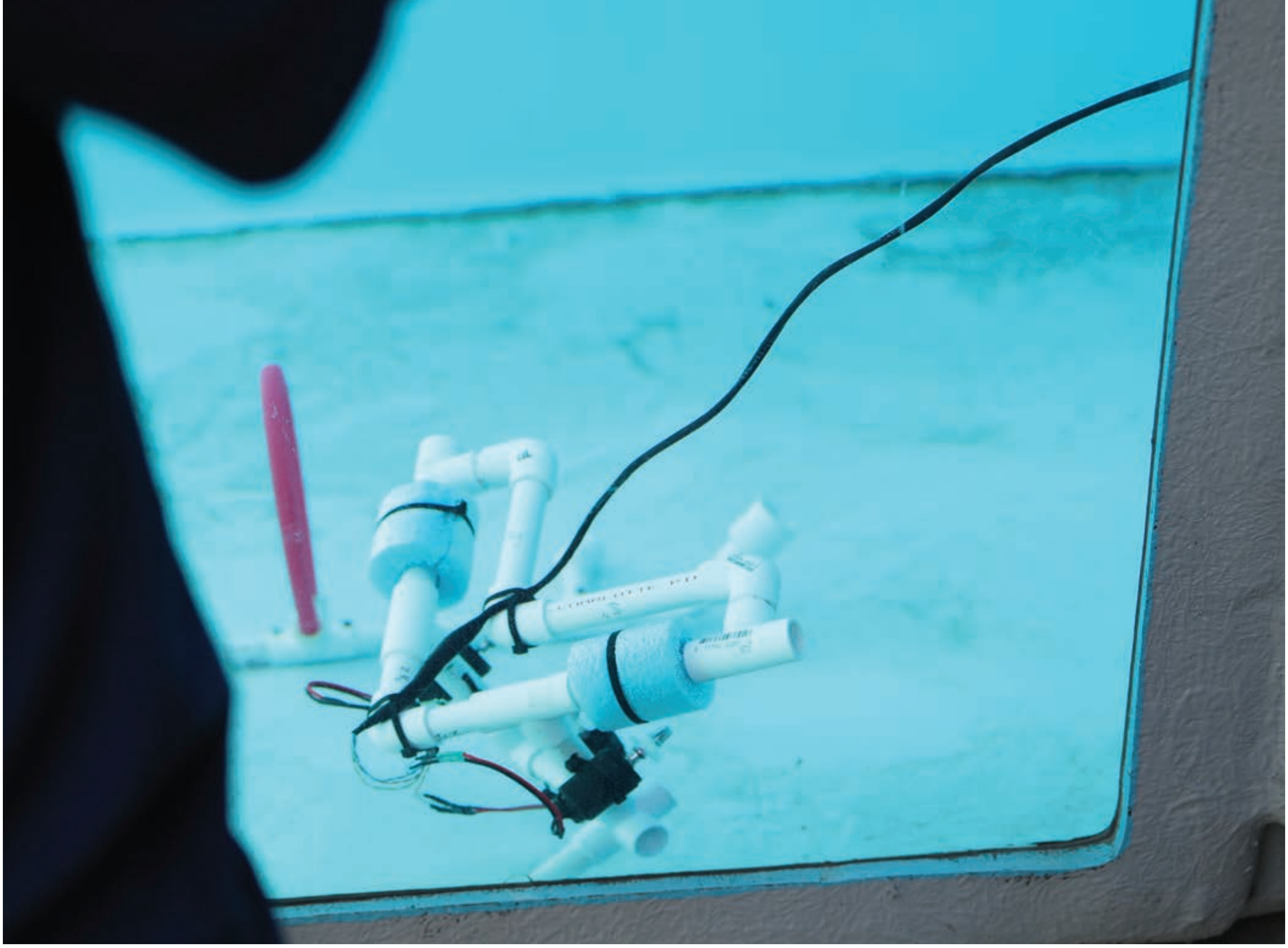


Photo courtesy Valerie Rivera, Florida Atlantic Laboratory Schools

In the depths of A.D. Henderson University School's training tank, a group of young engineers is making waves—literally. The Cane Institute's elementary SeaPerch team is diving headfirst into the world of marine robotics, tackling real-world challenges with their remotely operated vehicles (ROVs). These students aren't just building robots; they're developing the problem-solving, critical thinking, and teamwork skills necessary to become the next generation of innovators.

SeaPerch is a hands-on, K-12 immersive underwater robotics program sponsored by the Office of Naval Research. Designed to inspire students through marine engineering-based challenges, the program equips them with the knowledge to construct ROVs that can navigate complex underwater environments and complete mission-based tasks. Through this process, students gain a deeper understanding of engineering principles, scientific concepts, and the importance of collaboration.

Recently, the Cane Institute's elementary team invited their parents to witness the fruits of their labor. Parents had the unique opportunity to learn from their children as the students guided them through the intricacies of the ROVs and demonstrated how they navigate key training exercises, modeled after the events in the official competition: the obstacle course, the challenge, and the design documentation process. It was a proud moment as parents watched their children display both technical expertise and leadership.

The Cane Institute teams have a tradition of excellence on the international stage. At the 2022 International Competition, three teams placed in the top 10, with one team, SeaOwls GoFish, earning first place overall in the middle school division. While the elementary team will not be competing this year—since there is no elementary division in the SeaPerch competition—they will continue training and refining their skills, preparing to carry on this legacy in the years to come.

The 2025 SeaPerch competition brings a crucial environmental theme: Environmental Monitoring – Coral Restoration. With coral reefs facing unprecedented threats from climate change, pollution, and habitat destruction, students will use their ROVs to simulate real-world marine conservation efforts. This year's mission will challenge teams to design and deploy their ROVs for tasks such as bio-bucket access, marine life management, coral restoration, coral sample collection, and marine monitoring. Each aspect of the competition presents a unique test of skill and innovation.

While the elementary team won't be competing this year, their rigorous training will lay the foundation for future success. By developing their technical skills and learning the complexities of underwater robotics, these young engineers will continue to grow their passion for robotics and their commitment to solving real-world challenges. We are excited to witness the legacy of the Florida Atlantic Laboratory Schools underwater robotics program remains strong for years to come.

Courtesy Captain Sid Hynes

OFFSHORE MULTIBEAM SURVEYS: THE COST AND PERFORMANCE OF MOTION COMPENSATION

Inspired by the proactive work of a hands-on end-user, Kiwi multibeam manufacturer **WASSP** and Motion Reference Unit provider **Norwegian Subsea** have developed a solution which promises to ensure all important bathymetric heave data accuracy in real-time, even when operating outside of RTK coverage.

By Fredrik Dukan, *Norwegian Subsea*

For marine surveyors, professional fishermen, and offshore operators, accurate multibeam echosounder data is crucial. Whether mapping the seafloor, detecting shipwrecks, or surveying to locate optimal fishing grounds, precision depends heavily on the type of motion compensation technology integrated with the chosen multibeam system. Established motion compensation solutions that can be augmented with Real-Time Kinematic (RTK) corrections and high-end Motion Reference Units (MRUs) have long dominated the market. The coverage limitations of the former and premium cost of the latter, make them inaccessible for many users, however.

A collaboration between Norwegian Subsea and WASSP is aiming to upset this status quo. Following a 2024 development project, Norwegian Subsea's MRU technology can now be easily integrated with WASSP's multibeam sonar systems. The combination delivers survey-grade bathymetric data accuracy with height accuracy equivalent to RTK corrected data and overall data quality comparable to more premium priced MRUs, offering offshore users a cost-effective solution that rivals the high-end motion sensor alternatives. This development is particularly significant for users who operate in locations further from shore, in deeper waters beyond the reach of RTK signals, where maintaining precision motion compensation on a budget has always been a major challenge.

The Need for Multibeam Motion Compensation

Multibeam echosounders rely on precise motion compensation to generate accurate seabed maps. These systems send out multiple sonar beams in a wide swath and measure their reflections to determine depth and seafloor features. However, vessel motion – heave (vertical movement), pitch (tilt forward and backward), and roll (tilt side to side) – creates distortions in the data. Without an external correction service like RTK, the inaccuracies caused by vessel movement make multibeam data unreliable, particularly in rough sea states where waves impact vessel stability. A high quality MRU can provide the same function for heave, continuously measuring and correcting in real time, ensuring that the sonar returns are accurately positioned relative to the seabed.

RTK positioning is an established method for precise external corrections including heave, using land-based stations to refine accuracy to within a few centimeters. However, RTK is limited to nearshore environments, and requires base station ownership, or subscription services. This means that offshore users, particularly those conducting surveys in deeper waters, often struggle to obtain the necessary heave data accuracy without incurring significant costs.

The challenge is further compounded, as other MRUs capable of providing the level of motion compensation that a multibeam survey requires, can be prohibitively expensive. These top-end motion sensors offer exceptional heave accuracy, but their price tag places them out of reach for many operators. Norwegian Subsea's MRU technology platform was designed to bridge this gap, delivering comparable accuracy at less than half the cost, while requiring no external infrastructure for maximum height data accuracy. For surveyors and commercial mariners looking to maintain precise data collection without the constraints of adding RTK services or the most costly motion sensors, this represents a substantial opportunity to improve data quality.

A New Motion Compensation Alogrithm

Norwegian Subsea MRUs are able to offer such high performance while reducing costs at the same time thanks to the company's proprietary algorithm. The motion sensor algorithm adapts automatically to give optimized performance for the given sea condition. By using motion constraints for floating vessels, it can accurately compensate for residual sensor errors such as gyroscope and accelerometer bias and estimate the local gravity. The algorithms are also robust to horizontal accelerations and will output accurate roll and pitch even under difficult conditions with sideways motion. This is key to delivering accurate and robust motion measurements for any condition.

The superior heave compensation offered by Norwegian Sub-

Courtesy Captain Sid Hynes

THE PRODUCT

Courtesy Norwegian Subsea

sea's MRU ensures that even in the most unpredictable offshore conditions, depth (height/heave) data remains accurate. Sid Hynes, a seasoned mariner using the system to locate shipwrecks, has extensively tested the MRU capabilities. According to him, heave correction is the key factor that determines the reliability of multibeam sonar data. Without accurate heave compensation, depth measurements can fluctuate wildly, making it nearly impossible to distinguish real features from data noise.

In his operations in the Grand Banks of Newfoundland, Hynes has compared Norwegian Subsea's MRU against other motion sensors and correctional systems. His findings confirm that the MRU provides motion accuracy comparable to more expensive alternatives, while eliminating any need to rely on external correctional services for heave. He describes how his vessel, operating in 40-45 knot winds and 20-foot swells, continues to deliver highly precise multibeam readings thanks to the MRU's real-time motion compensation.

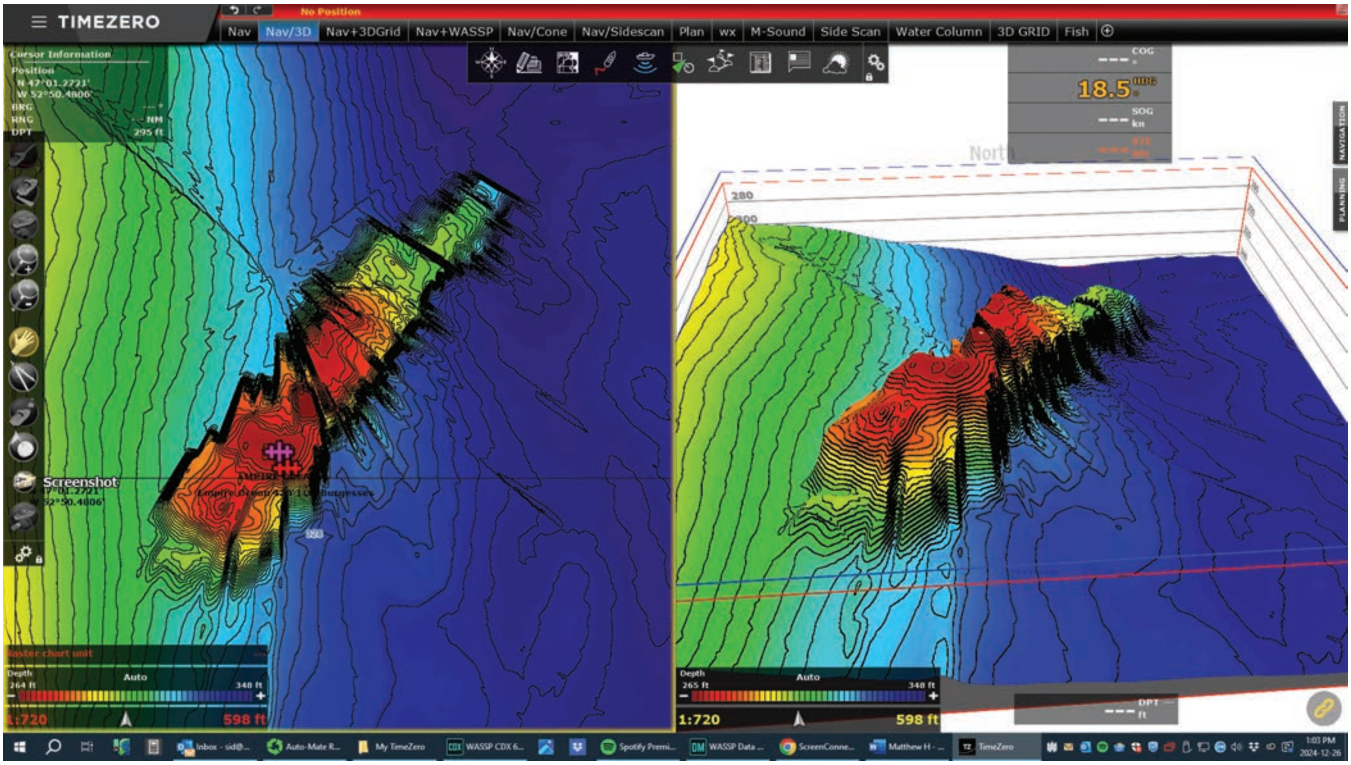
Norwegian Subsea's MRU technology is designed to perform well in real-world sea conditions, rather than just in controlled test environments. Many traditional motion sensors are optimized for predictable wave patterns but struggle when faced with chaotic multi-directional swells. WASSP's Senior Product Manager, Nick Fogarty, has highlighted how Norwegian Subsea's MRU outperforms other options in real-world scenarios. According to him, the plug-and-play nature of the system makes it easy to integrate, but its superior handling of irregular wave motion provides users with reliable results even in challenging offshore environments.

Beyond data accuracy, the MRU's ease of use and maintenance-free operation make it particularly valuable for offshore applications and WASSP's multibeam users. Unlike some motion sensors that may drift over time and require factory recalibration, Norwegian Subsea's units maintain their accuracy indefinitely. This ensures that surveyors and offshore operators can focus on their work without worrying about frequent recalibrations or system maintenance, reducing both operational costs and downtime.

Expanded Applications for WASSP Multibeam Systems

It was in fact, Sid Hynes' work with his WASSP's multibeam and Norwegian Subsea MRU that catalysed the collaboration between the companies. In starting his own work to improve the accuracy of data in his search for shipwrecks, he connected the companies and inspired a new solution that will lower costs while providing improved performance for many more WASSP customers.

Now augmented by Norwegian Subsea's MRU, WASSP multibeams users are set to transform diverse offshore surveying and fishing applications. Commercial fishing companies benefit from more accurate seabed mapping, which helps identify new fishing grounds and understand habitat structures with greater detail. Trawlers captains can distinguish between different seabed types, allowing them to target specific species more efficiently while minimizing environmental impact. Additionally, offshore wind farm developers can use multibeam surveys to precisely map seabed conditions for turbine place-



Courtesy Captain Sid Hynes

ment, reducing risks and ensuring stable installations with considerable savings on Capex and Opex.

For offshore infrastructure inspections, multibeam echosounders provide data that assists in monitoring pipelines, cables, and underwater structures. The application of Norwegian Subsea MRUs ensures that this data remains highly accurate even in dynamic sea conditions. Marine researchers, often constrained by limited grants and government budgets, will benefit from the ability to study deep-sea ecosystems with greater precision while keeping costs lower than ever before, ultimately enhancing conservation efforts.

And while this MRU technology is only now coming to subsea data circles, it is well proven in other applications. For instance, many offshore helideck monitoring systems are equipped with Norwegian Subsea MRUs.

From Shipwreck Hunting to Commercial Solution

Sid Hynes originally tested the MRU and multibeam combination in one of the most challenging survey environments in the world. The Grand Banks of Newfoundland, known for its unpredictable wave patterns and severe weather conditions, presents a unique set of challenges for any surveyor.

His work has resulted in remarkable discoveries, including the identification of multiple shipwrecks that had remained undetected for decades. One of his most significant finds involved two sister ships that sank two years apart, located just miles from each other. This discovery underscores the critical role that high-accuracy motion compensation plays in uncovering underwater structures, particularly in deep waters where visibility is limited and every small fluctuation in data can impact survey outcomes.

For commercial users, the ability to achieve near-survey-grade heave accuracy without the need for RTK (or more expensive MRUs) is potentially game changing, or at least a positively disruptive force. WASSP's integration of Norwegian Subsea's MRU has now made this level of performance accessible to a much wider audience. By providing a cost-effective alternative to high-end motion sensors, this collaboration is enabling more operators to conduct precision surveys without the traditional barriers of cost and technical complexity.

WASSP's Nick Fogarty has emphasized the importance of making advanced technology accessible to a broader user base, stating that the goal has always been to ensure that high-end capabilities are not restricted to only the most well-funded operators.

As offshore industries continue to demand greater accuracy and efficiency at lower costs, solutions like Norwegian Subsea's MRU are becoming increasingly valuable. With WASSP now offering the Norwegian Subsea MRU as a recommended motion compensation solution, more users than ever can benefit from stable, high-quality multibeam data. Whether for deep-water surveying, fisheries management, or shipwreck detection, the combination of WASSP's multibeam technology and Norwegian Subsea's motion compensation is proving that cutting-edge performance does not always have to come at a premium price.

■ ecoSUB Robotics Micro-AUV

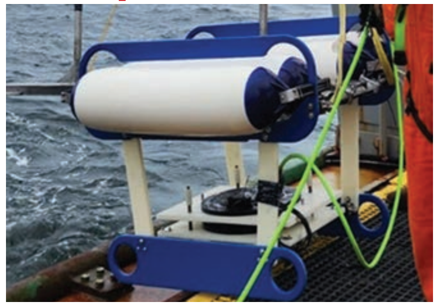
■ ecoSUB Robotics Micro-AUV

ecoSUB Robotics launched a next-gen AUV platform, the ecoSUBm-Power+ v2 features twice as much stored energy on board as its previous iteration, increasing mission time up to 20 hours. The new **ecoSUB AUV** is available with a **Sonardyne** SPRINT-Nav hybrid navigator, providing FOG Inertial Navigation System with DVL and USBL. ecoSUB are releasing its own repackaged and integrated **Geometrics Magnetometer**, coupled with Side Scan Sonar for UXO surveys and marine archaeology applications. Integration of the **Imagenex** Delta-T 837XBi MBES, **ecoCAM** 4k camera, and the **Wavefront** Solstice Multi-Aperture Sonar system.

■ FSI AquaStack

Falmouth Scientific announced the **AquaStack Acoustic Multi-Spectrum Source (AMS)**, the latest in FSI's AquaPulse series for seismic, sub-bottom, and 3DUHR survey applications. Developed with patented technology, AquaStack allows operators to switch its output spectrum on the fly, enabling users to select a lower frequency mode for deeper penetration when surveying challenging geologic formations or a standard frequency for higher resolution imaging — all from a single, versatile source. Available double stacked configurations include 18" Standard Displacement, 18" High Displacement, 36" Standard Displacement, and 36" High Displacement. The 36" models, weighing 350 kg, deliver higher power and lower frequency than the portable 18" 55 kg models, while the HD models feature a longer cycle time.

■ FSI AquaStack



■ Sonardyne SPRINT-Nav DP

Sonardyne launched its new shallow water dynamic positioning (DP) reference system. **SPRINT-Nav DP** integrates high-grade inertial navigation with doppler velocity log (DVL) technology in a single, pre-calibrated unit.

■ Autonomous Oceanus12 USV

Zero USV launched its **Oceanus12** unmanned surface vessel (USV). The launching of the first Oceanus12 represents the culmination of nearly 18 months of design, engineering and build effort from the team at Zero USV which has been built on the success of the **Mayflower 400's** transatlantic autonomous voyage - a milestone achieved through the same inter-company collaborations between Zero USV's parent company **MSubs**, its non-profit **Promare**, and sister marine software company **MarineAI**. The 12-m USV features hybrid-electric drive system, with twin drives for redundancy and efficiency coupled with sufficient onboard fuel for a cruising range of more than 2500 nautical miles, and fully autonomous software stack on the market – MarineAI's Guardian software.

■ Picotech Podlet for BlueBoat

Picotech debuts **Podlet** - a turnkey survey package for IHO Special Order Multibeam Surveys onboard **BlueRobotics' BlueBoat**. BlueBoat+Podlet fits fully rigged in the trunk of a small hatchback and can be hand-launched and recovered at the point of survey by one person. It is supported by BeamworX, EIVA NaviSuite, Xylem HYPACK, Teledyne PDS and QPS QINSy.

■ Autonomous Oceanus12 USV

■ Novacavi Hybrid Cable

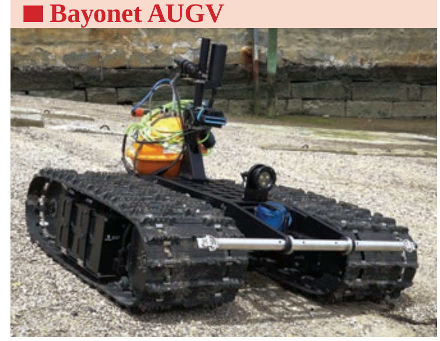
Novacavi supported the deep mine shaft test of **Image Soft's UNWAS** – an underwater surveillance system – with a special fiber optic cable. This underwater cable solution acted as a strategic component to detect and warn of any potential actions against sensitive critical infrastructure.

■ Bayonet AUGV

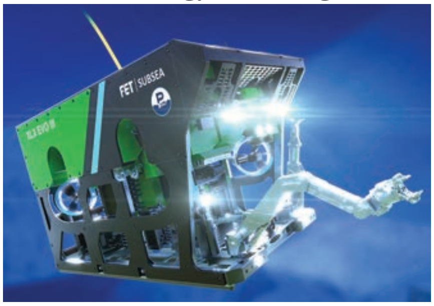
Greensea IQ's Bayonet series of autonomous underwater ground vehicles (AUGVs) thrives in nearshore environments. Key features include:

- Amphibious Capability: Designed to traverse surf zones and operate in water depths of up to 100m.
- When equipped with RTK antenna and advanced navigation, Bayonet AUGVs demonstrated a total vertical uncertainty (TVU) of less than 6 cm.
- Payload Flexibility: With a large open deck and modular design, it can accommodate a variety of sensors and tools, including forward-looking sonar, magnetometers, and sub-bottom profilers.
- Robust Construction: Built to withstand harsh environments, the vehicle's rugged design ensures reliability during extended missions.

■ Bayonet AUGV



■ Forum Energy Technologies



■ Exail

■ SMD

■ FET brings new generation Work Class ROV to market

Forum Energy Technologies (FET) launched its latest work class Remotely Operated Vehicle (ROV), the XLX EVO III, marking a new generation in Ultra-Heavy-Duty subsea vehicle technology. Designed to undertake a broad spectrum of underwater tasks, the new vehicle is equipped with larger thrusters for increased through water performance and an improved buoyancy package, facilitating a market leading 500kg payload.

The vehicle has a new frame, which is now CNC machined and provides an improved layout both for maintenance access and tooling capability. Through-frame-lift has increased to 4000kg, a rise of over 30% from the EVO II.

The XLX EVO III also comes with updated pilot chairs or console as well as FET's latest control software, ICE Unity, enabling remote operations. Further enhancements are planned by the FET team.

Built at the firm's UK manufacturing facility at Kirkbymoorside in Yorkshire and supported by organization's global network of bases, the ROV is now available to order.

■ Exail integrates Elwave's electromagnetic sensing technology into R7 ROVs

Exail selected Elwave's advanced electromagnetic sensing technology to equip its R7 Remotely Operated Vehicles (ROVs) for an undisclosed client. As part of this collaboration, Exail will integrate Elwave's Tetrapulse sensors—powered by the innovative CEDAR (Controlled Electric Detection And Ranging) technology—into multiple R7 ROVs.

Enhanced target detection with electromagnetic sensing

This next-generation biomimicry sensing capability offers significant advantages in subaquatic electrical resistivity mapping. "In the context of target identification and neutralization missions, the integration of CEDAR technology enables superior operational performance in challenging environments, including turbid waters", explained Gary Bagot, Sales Director at Elwave. The R7 ROVs equipped with Elwave's Tetrapulse sensors will improve the detection, localization, and characterization of both metallic and non-metallic underwater and buried targets, including steel, aluminum, and fiberglass composites.

The R7 ROV: A compact and versatile solution for underwater operations

Combining the agility of a mini-ROV with the capabilities of an observation-class system, the R7's modular design supports a range of sensors, tools, and payloads. This versatility makes it particularly well-suited for underwater security missions, including hazardous terrain navigation, UXO detection, and disposal operations.

"By integrating CEDAR technology into the R7 ROV, Exail and Elwave are delivering an advanced solution that strengthens operational effectiveness for underwater exploration, defense, and security applications" said Nicolas Astruc, ROV Managing Director at Exail. "This collaboration combines Exail's expertise in maritime robotics with Elwave's electromagnetic sensing technology to provide customers with a unique and powerful tool for operations in complex environments".

■ SMD's ROV Trencher to Work in Japan's Offshore Wind Farms

Toyo Construction has invested in Japan's emerging offshore wind sector by purchasing a trenching remotely operated vehicle (ROV) from underwater technology and services company SMD.

The ROV will form part of Toyo's expanding fleet of assets, with the business having also invested in a custom-built cable-lay vessel late in 2024.

The new SMD trencher will be used alongside the vessel to facilitate the safe and efficient burial of subsea cables.

SMD's tailor-made trenching product range caters for a variety of different markets and end uses.

The self-propelled systems include the QTrencher (QT) and heavy tracked trencher ranges. QTrenchers are SMD's fourth generation trenching ROV.

Subsea power available ranges from 400hp through to 2800hp all able to free fly with track upgrades. Heavy

■ Beam

■ Kystdesign

■ MATCOR

tracked trenchers are available in a range of chassis sizes and power ratings to suit trenching in hard ground up to 50MPa.

Trenchers can be configured to carry multiple tools, simultaneously or in interchangeable cartridges, including rock and clay chains, jetters, dredges, eductors and backfill tools to suit every soil combination.

"We chose to invest in this technology because of SMD's prolific track recording in offshore wind, and of engineering excellence underwater globally. The team understood our unique requirements and adapted this vehicle into a bespoke product, suitable for our challenging operations," said Tatsuyoshi Nakamura, COO at Toyo Construction.

■ Beam's New 3D Mapping System

Beam, a company created by the merger of Rovco and Vaarst, has unveiled SubSLAM X3, a new subsea 3D mapping system which can be integrated to both work class and observation class remotely operated vehicles (ROVs).

SubSLAM X3 offers real-time, high-resolution 3D mapping, designed to enhance the monitoring and maintenance of offshore wind farms.

The system integrates artificial intelligence (AI), robotics, and advanced simultaneous localization and mapping (SLAM) technologies.

This integration is said to be critical for streamlining the development, construction, and maintenance phases of offshore wind projects.

The system provides 4K resolution video and precise 3D reconstructions, allowing for detailed inspection of underwater assets and intelligent autonomous control of underwater vehicles.

The newly designed SubSLAM X3 is more compact and lightweight than its previous version, making it suitable for integration into smaller observation-class ROVs as well as larger work-class ROVs.

Despite its reduced size, the system is capable of operating at depths up to 3000 meters and features enhanced sensor technology for improved image quality, especially in low-light conditions.

■ Kystdesign's ROV Orderbook

Norwegian engineering firm Kystdesign has marked the successful start of 2025, having booked the largest order to date in the company's history for its remotely operated vehicles (ROVs) and associated equipment.

In February 2025, Steading signed an agreement with an undisclosed client for the supply of four work class ROVs, including Constructor and Constructor Compact models, along with Launch and Recovery systems (LARS), Remote Operating Centres (ROC), additional spares and extra equipment.

The order is the largest to date in the company's history, and is scheduled for delivery in the fourth quarter of 2025.

A month earlier, Kystdesign signed a contract with the Royal Netherlands Institute for Sea Research (NIOZ) for the construction of the advanced ROV, the Supporter 6000.

The Supporter 6000, designed for ultra-deepwater operations, will be delivered in June 2026 and will serve the entire Dutch marine research community.

The Constructor ROV is a powerful construction ROV uniquely designed to carry and operate large tools and modules

Kystdesingn's Constructor ROV accommodates up to 41 electrical connectors for interface of external equipment, such as tooling, survey sensors and cameras, and all electrical power supplies are ground-fault monitored.

The ROV also features 24 hydraulic functions, all proportionally controlled. The ROV control system is prepared for a variety of auto functions like AutoPOS and AutoTRACK capabilities, in addition to over-the-horizon control from a Remote Operation Center (ROC) onshore.

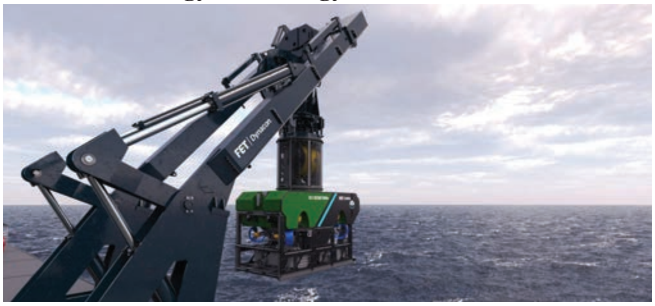
■ MATCOR's Iron Gopher

Cathodic protection and AC mitigation solutions supplier MATCOR, a BrandSafway company, has relaunched its patented Iron Gopher linear anode for horizontal directional drilling (HDD) projects, with a significantly reduced price.

The price reduction is the result of MATCOR's move to in-house production, reducing reliance on third-party suppliers and shipping delays while ensuring superior quality control.

The result is said to be a stronger,

■ Forum Energy Technology



more reliable linear anode that minimizes the risk of breakage during installation, helping you avoid idle crews and project delays.

"By bringing production in-house, we've cut costs dramatically, allowing us to offer this premium solution at just a small premium over standard linear anode products.

"When we introduced the Iron Gopher, its cost limited adoption despite its superior performance. By bringing production in-house, we've cut costs dramatically, allowing us to offer this premium solution at just a small premium over standard linear anode products," said Ted Huck, Director of Sales at MATCOR.

■ Spanish Subsea Services Firm Orders FET's Latest Work Class ROV

Forum Energy Technology (FET) has secured a contract to provide a work class remotely operated vehicle (ROV) system and a Dynacon Launch and Recovery System (LARS) to Spanish-based subsea services provider ACSM.

FET's XLX EVO II ROV system represents the latest evolution in the highly successful Perry XLX series and is equipped with the latest ICE Unity Control System, incorporating remote operations and machine learning.

It features significantly enhanced performance across the full range of demanding intervention and survey tasks without compromise to the outstanding reliability for which FET vehicles are renowned throughout the world.

Building on a long-term relationship, the FET Perry XLX EVO II will be delivered in the third quarter 2025 to support construction, drilling, pipeline and platform inspection, survey, salvage, cleaning and dredging.

"We are proud of the longstanding relationship we have with ACSM and look forward to continuing work with our peers in delivering cutting edge ROV operations in the energy sector.

"Our Perry XLX EVO II, coupled with the robust Dynacon LARS system, is built to provide innovative solutions to challenging subsea operations and is equipped to perform reliably in hostile environments around the world," said Kevin Taylor, FET's Vice President Operations – Subsea.

Tritech's New Gemini Sonar

Subsea imaging technology provider Tritech International has launched a new dual frequency Gemini 1200id sonar, said to offer higher resolution imaging for work class remotely operated vehicles (ROVs).

The Gemini 1200id is built on the same robust platform as the industry standard Gemini 720is sonar. It features a wide 120° horizontal field of view when operating at both 720 kHz and 1200 kHz acoustic frequencies and offers improved attenuation of waterborne electrical noise for optimal imaging performance.

An integrated speed-of-sound sensor ensures that targets are displayed to a high degree of positional accuracy. CHIRP processing provides improved target separation over longer ranges, according to Tritech.

The 1200id is fully compatible with Tritech's software package, Genesis. This ensures improved user interaction and allows for control of multiple Tritech products from within one software package. Software development kits (SDKs) are also available for Windows and Linux operating systems.

The Gemini 1200id employs a completely in-house developed analogue front-end solution that incorporates fully differential receiver channels for enhanced acoustic reception. Internal electronic circuits have been optimized and where necessary additional filtering exclusively employed to minimize self-generated noise.

These enhancements enable the Gemini 1200id to produce sonar images displaying sharp and bright acoustic returns on a noise reduced background resulting in crisp sonar images of impressive clarity.

"With its ultra-low-noise differential analogue front-end supporting a wide dynamic range optimized for sonar imaging applications, and with its ability to actively attenuate waterborne electrical noise from other subsea equipment, the Gemini 1200id provides work class ROV operators the clarity and confidence necessary for mission critical operations," said Asim Azad, Hardware Engineering Manager.

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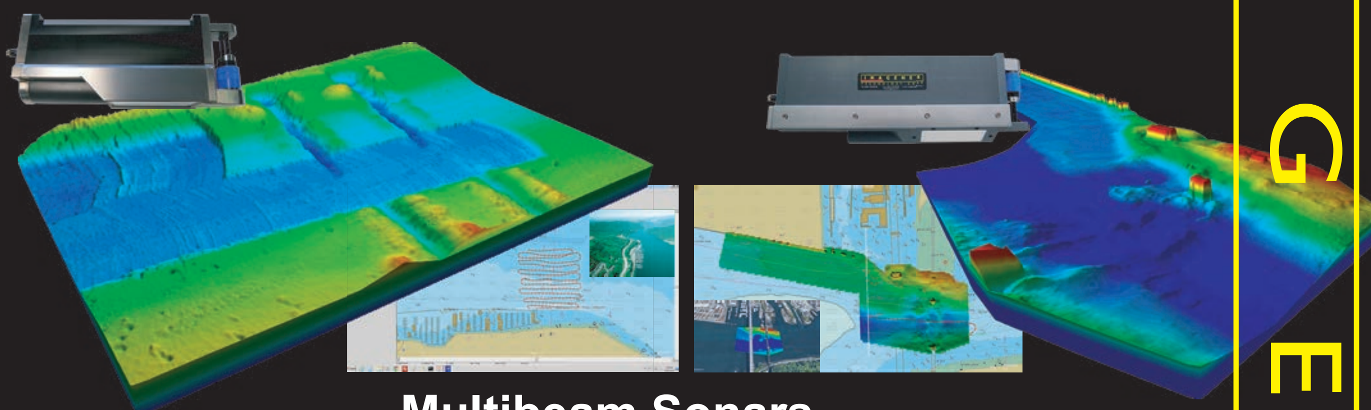
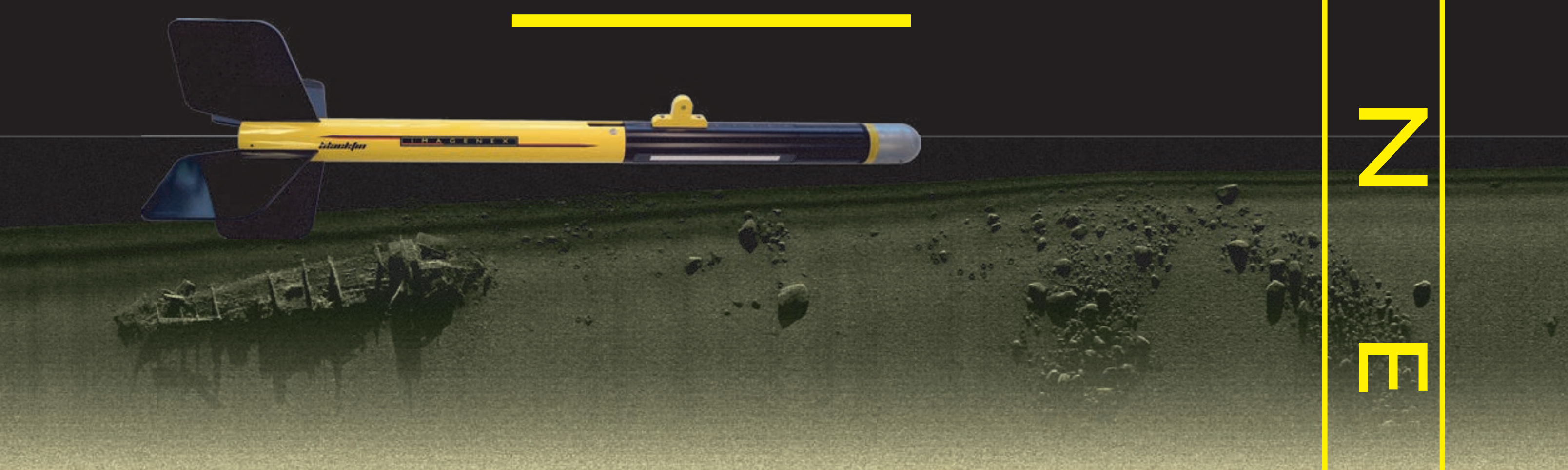


Multibeam Sonars



Sidescan Sonars

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