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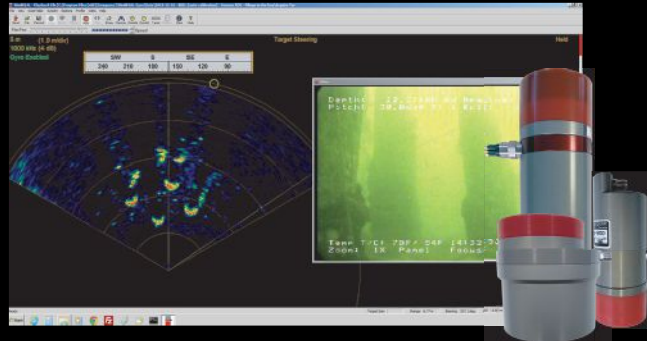
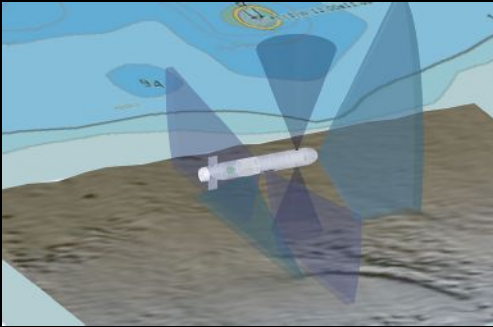
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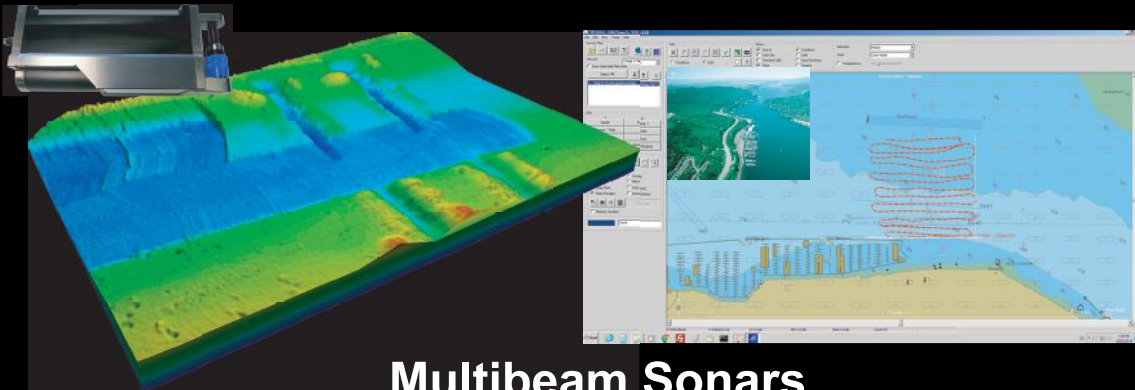
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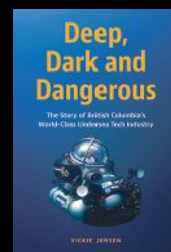


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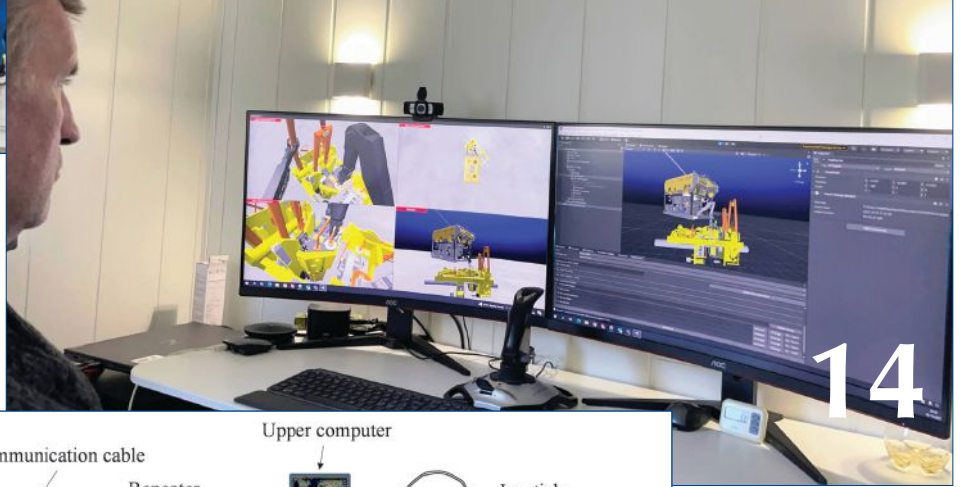
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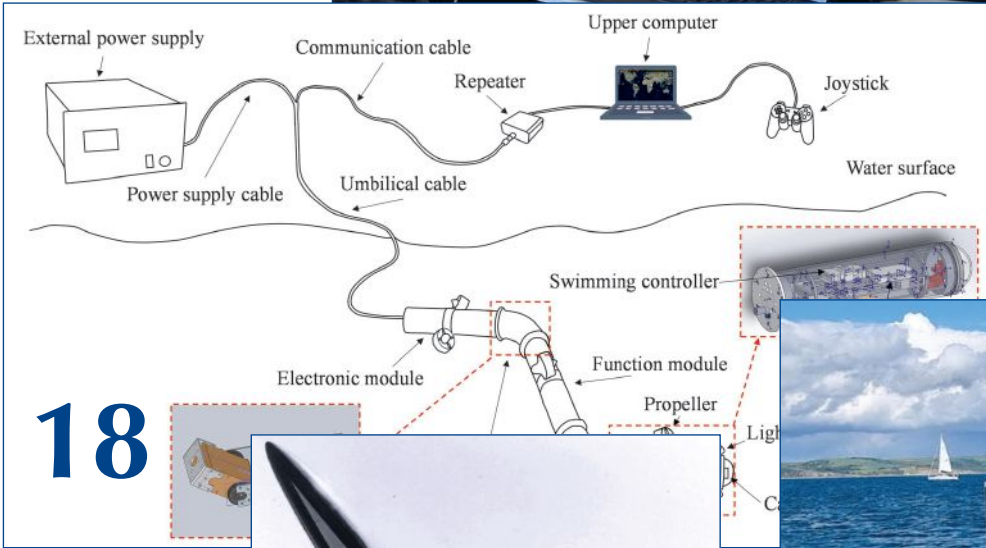
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COVER IMAGE

The Nekton Maldives Mission set out to establish the status of the Maldives to enable the protection of critical nurseries, spawning habitats and related ecosystems. Nekton is a research foundation working with the University of Oxford. Saab Seaeeye, as an official partner of the mission, donated the use of a Seaeeye Falcon to gather data to establish vast new marine protected areas across the Maldives. The ROV is pictured in the Maldives October 2022. (Credit: Nekton Foundation)

NEXT MONTH

Annual Review & Forecast.

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)) US Marine Sanctuary System Turns 50. The U.S. National Marine Sanctuary System is celebrating its 50th anniversary. Starting with just 1 sq. mi. off the shore of North Carolina, the National Marine Sanctuary System has expanded to protect over 620,000 sq. mi. of ocean, coasts and Great Lakes waters. As of October 2022, there have been 15 national marine sanctuaries and two marine national monuments designated in the National Marine Sanctuary System. National marine sanctuaries span from the central Pacific across to the North Atlantic, and from the Great Lakes down to the Gulf of Mexico and the Florida Keys. Before the National Marine Sanctuaries Act, there were only piecemeal ocean protections and relatively few marine conservation laws in place in the U.S., with a patchwork of small and isolated marine protected areas. In 1972, a century after the U.S. National Park System was established, the Marine Protection, Research and Sanctuaries Act became law. Now known as the National Marine Sanctuaries Act, it continues to be the only authority to address marine conservation of U.S. national waters from a holistic, ecosystem perspective.

)) MTS-MATE Integration. The Marine Technology Society (MTS) and MATE Inspiration for Innovation (MATE II), two long-standing nonprofits in the marine technology space, will join forces to foster the next generation of ocean leaders and advance both STEM education and cutting-edge technologies to solve global issues. Through an integration of MATE II, the managing organization behind the MATE ROV Competition, into MTS, the combined organization will be able to expand its efforts to raise awareness of the importance of marine technology, lower the barriers of entry to underwater robotics and related industries, support students, and help them develop the confidence and skills needed to carry these fields into the future. The dynamic, design-build-perform competition gives children, youth and young adults an inclusive platform to think critically about real-world problems in a way that strengthens communication, peer-to-peer community and entrepreneurship. The MATE ROV competition will operate as a division within MTS. The integration will also provide an avenue to develop MTS chapters in new locations, expand member benefits, and bring enriching opportunities for MTS members to mentor and support younger students. Jill Zande will continue to lead the competition and will join MTS as the executive director of MATE. The agreement is subject to receipt of regulatory approvals and other conditions and is expected to close in 2023.

)) Europe Leads in Decarbonization. The heightened focus on energy security and the rising cost of energy is reinforcing the difference in decarbonization speed between Europe and the rest of the world, according to the sixth edition of DNV's Energy Transition Outlook. Europe, which can be regarded as the leader of the energy transition, will double down on renewables and energy efficiency to increase its energy independence. European gas consumption will fall dramatically as a result of the war in Ukraine. Compared to last year's forecast, DNV sees the continent consuming almost half the amount of natural gas in 2050. Gas will meet just 10 percent of Europe's energy demand in 2050, compared with 25 percent today. Lower-income countries, where cost is the main driver of energy policy, are seeing a different trend: High energy and food prices are reversing the coal-to-gas switch and putting a dampener on decarbonization investments. For example, the share of gas in the Indian subcontinent's energy mix will reduce from 11 to 7 percent in the next five years, while the share of coal will increase. For the first time, DNV's forecast sees nonfossil energy nudge slightly above 50 percent of the global energy mix by 2050. This is mainly because of the growing and greening of electricity production. Electricity production will more than double, and its share will grow from 19 to 36 percent of the global energy mix over the next 30 years. Solar photovoltaic and wind are already the cheapest form of electricity in most locations, and by 2050 they will grow 20-fold and 10-fold, respectively, and will dominate electricity production with 38 and 31 percent shares, respectively.

)) BOEM Completes Environmental Review for Morro Bay Wind Energy Area. The U.S. Bureau of Ocean Energy Management (BOEM) has completed its environmental review of potential impacts from offshore wind energy leasing activities in the Morro Bay Wind Energy Area (WEA), located 20 mi. offshore central California. The EA reflects close coordination and engagement with the state of California, the Department of Defense, tribes, ocean users (including the fishing community) and coastal communities. The final environmental assessment (EA) assesses potential impacts from the issuance of leases within nearly 240,898 acres (376 sq. mi.) of the Morro Bay WEA off the coast of San Luis Obispo County, California. The Morro Bay WEA, if developed, could bring up to 3 GW of clean energy to the grid, enough to power more than 1 million homes. Based on the analysis in the EA, BOEM has issued a finding of no significant impacts (FONSI) to environmental resources. The EA considers potential environmental consequences of site characterization activities (i.e., biological, archeological, geological and geophysical surveys and core samples) and site assessment activities (i.e., installation of meteorological buoys). The EA also considers project easements associated with potential leases and related right-of-way grants for subsea cable corridors in the Morro Bay WEA. If BOEM decides to conduct a lease sale in the Morro Bay WEA, it will develop an environmental impact statement (EIS) before approving the construction of any offshore wind energy facility. The EA, FONSI and detailed information about the proposed leasing in the Morro Bay WEA are available at: www.boem.gov/California. **ST**

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Attracting the Next Generation of Talent

As technology advances and the shipping industry looks to decarbonize effectively, we hear a lot about "future-proof" solutions. To truly future-proof the industry, we need to understand the needs of seafarers and shore-based staff today so we can invest in the next generation and our future leaders.

The shipping industry is one of the oldest industries in the world, and its vast range of shore-based and at-sea job roles offers a huge variety of career opportunities. A global labor shortage means that there is strong competition from other industries for new talent. To attract that talent, we first need to understand what motivates the next generation. Deloitte's 2022 Gen Z and Millennial Survey provides some interesting insights. In uncertain times, the survey puts cost of living and climate change as top current concerns overall.

In selecting an employer, work/life balance and learning/development opportunities are the top criteria, closely followed by salary and benefits. Diversity and inclusion, and the societal and environmental impact of organizations are also key factors for retention; many respondents said they would turn down a job if it failed to align with their personal values.

To attract the next generation of leaders, shipping would be well advised to redouble efforts to collaborate with educational institutions so that training and career development paths reflect today's priorities. The work WISTA does to support women in shipping is relevant here, as it facilitates continuous professional development and training courses to help equip women and others with the skills they need to progress in their careers.

WISTA Hellas, for example, is working closely with prominent educational institutions and offers full- and part-time scholarships to women working in the maritime industry, as well as a leadership program. Scholarships could go toward an M.B.A. in shipping, an M.S. in logistics and supply chain management, or an M.S. in ship management, for instance. Globally, WISTA International has launched the Maritime SheEO Leadership Accelerator Programme in partnership with the International Maritime Organization.

The 2021 BIMCO/ICS Seafarer Workforce Report predicted that by 2026, there will be a need for almost 90,000 additional STCW (Standards of Training, Certification and Watchkeeping) certified officers as demand for seafarers to operate the world's merchant fleet continues to outstrip supply. COVID-19 exacerbated demand by highlighting unappealing aspects of a career at sea. For example, work/life balance, crew connectivity, security on board, and differing legal systems around the world are just some of the challenges faced by seafarers that can have a negative impact on job satisfaction or crew retention.

As an industry, we need to find solutions to provide seafarers with greater support, such as implementing work patterns that increase shore leave; investing in policies and processes that promote greater diversity and inclusion; enabling existing crew to receive training and upskilling as new technologies are introduced; and ensuring a safe and secure working environment for all.

The introduction of new technologies should create roles more in tune with the skill sets of younger generations, making the industry a more attractive option, particularly when digital solutions can address issues such as decarbonization. The demand for digital skills in the global workforce will only continue to increase. Digitalization also provides a level playing field. More women will be recruited into maritime technology roles as they become increasingly qualified to embark on such careers.

An ambitious and tech-savvy cohort of young professionals with a desire to make a difference exists. As an industry, we must raise awareness of career opportunities and engage with the next generation for a sustainable future. **ST**

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****** *Oceanology International Americas*, February 14-16, San Diego, CA

FEBRUARY

Instrumentation: Measurement, Processing & Analysis

****** *US Hydro*, March 13-19, Mobile, AL

MARCH

Electronic Charting/Vessel Management/ Ports & Harbors/Dredging/Homeland Security

****** *Ocean Business 23*, April 18-20, Southampton, U.K.

APRIL

Offshore Technology/Alternative Energy & Ocean Engineering

****** *Offshore Technology Conference*, May 1-4, Houston, TX

****** *XPONENTIAL 2023*, May 8-11, Denver, CO

****** *UDT 2023*, May 9-11, Rostock, Germany

MAY

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Deepest Shipwreck Discovery

WWII Wreck of USS Samuel B. Roberts Found in Philippine Sea

By Kyriakos Tsangaris • Johann Meyer

CSM Energy's deep submersible support vessel (DSSV) *Pressure Drop* has played a significant role in locating the deepest shipwreck that has ever been discovered, as part of an expedition led by Texan financier and adventurer Victor Vescovo.

CSM Energy has sent the DSSV out with Vescovo for

many of his previous expeditions. With an experienced and colorful background, Vescovo's passion for adventure is infectious. Forbes has recognized Vescovo as the "First to Climb Everest, Visit Ocean's Deepest Depth and Fly to the Final Frontier." Vescovo served for 20 years in the U.S. Navy Reserve as an intelligence officer, has set

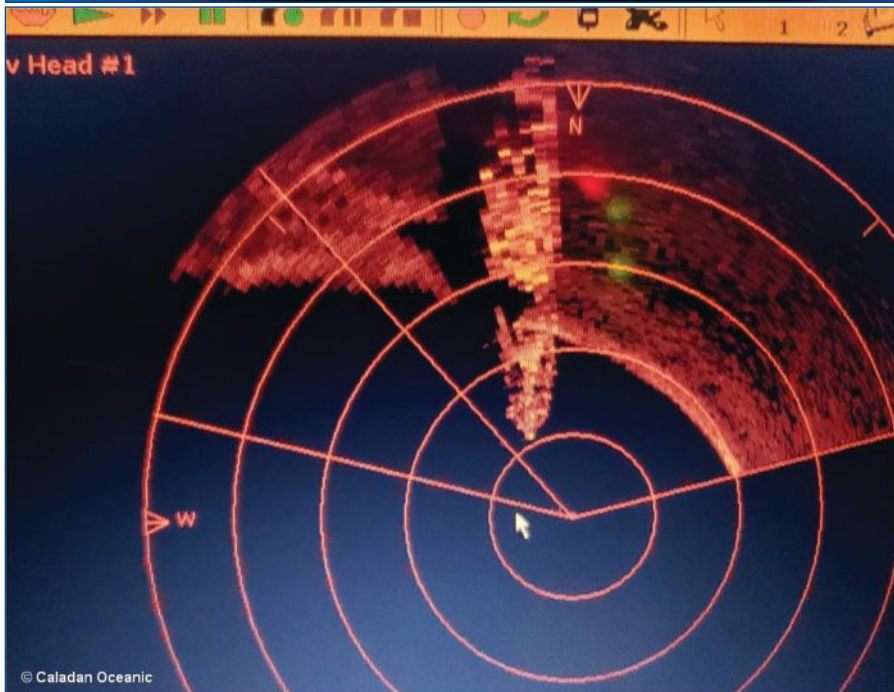


Adventurer Victor Vescovo led the expedition that discovered the wreck of the Sammy B.



The bow of the Sammy B.
(Below) A sonar image of the bow of the shipwreck.

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look for warship wrecks resulting from the World War II Battle off Samar, he had only about “50 percent hope” that he would find what he was looking for.

Vescovo was surprised and delighted when that hope came alive at the sight of a piece of the USS *Samuel B. Roberts*, a ship that went down during the Battle off Samar in the Philippine Sea in October 1944. The warship was found heavily battered but largely intact at 6,895 m.

The Battle off Samar was fought between the U.S. Navy and Japan. It was a hotspot of the larger Battle of Leyte Gulf, which is among the largest naval battles that have ever taken place.

Vescovo’s expedition this year followed on from an expedition last year to search for the wrecks from the Battle off Samar. During the last expedition to the Philippine Trench, the team discovered the main hull of the USS *Johnston*, which, at the time, became the deepest wreck ever discovered at 6,500 m.

When the team set off in July 2022, the goal was to discover the USS *Samuel B. Roberts* and *Gambier Bay*, which they believed to be even deeper in the ocean. Vescovo’s team discovered the *Sammy B.* during a 10-day expedition that marked a return to the Philippine Trench.

“I was so incredibly happy to find her,” Vescovo said. “She is only 93 meters long, and it turned out that she was resting on a broken, steep slope, which made her even harder to locate by sonar because she blended in a bit with the local terrain.

“But to see the intact hull, her weapons still loaded with live ammunition, her broken mast and shattered stern—it was like seeing history come alive. We were the first people to see her since she

a Guinness World Record as the person who has covered the greatest vertical distance without leaving Earth’s surface, has reached the top of Mount Everest, and has dove to the deepest point of the sea in the Mariana Trench. He has also flown to space on board New Shepard, as part of the Blue Origin NS-21 mission in 2022.

When Vescovo set off with his team in July 2022 to

sank below the waves that day [October 25] in 1944, and it was such a privilege to be the ones that found her.

“Her crew was extraordinarily brave, and if any ship rivaled the USS *Johnston* in its bravery of captain and crew, it was the *Sammy B.* I was so glad that we would get to use the discovery as an opportunity to retell her heroic history again.”

Midsection of the Sammy B. with fallen mast. (Below) CSM Energy's DSSV Pressure Drop vessel was used during the expedition.



Discovery Dives

The discovery didn't come without its challenges. The first two search dives for the *Sammy B.* turned up nothing, and the team believed the ship was just too small to locate. They moved on and tried to find the small aircraft carrier *Gambier Bay* instead. However, during this search, the team was able to locate some definitive wreckage from the *Sammy B.*

On the first discovery dive of the *Sammy B.*, the main hull of the ship was not located but its unique torpedo rack was, which enabled the team to verify that the wreck is indeed that of the *Sammy B.* (steel wreckage doesn't drift far).

On the second dive, which Vescovo piloted, the team located the main hull within just 20 min. of reaching the seafloor, based on an analysis of where they thought the ship might be given the location of the other wreckage and estimated drift.

DSSV Pressure Drop

The DSSV *Pressure Drop*, which has been used on many of Vescovo's previous expeditions, and its crew enabled the expedition team to stay out at sea for the length of time needed, with the use of specialized equipment to search for, locate and survey the wreck. The vessel carried the deep-ocean submersible Limiting Factor—which has visited the deepest points of all five of the world's oceans and was partially built and is piloted by Vescovo—to the where the wreckage was discovered. The vessel also supported the expedition team during the whole ocean journey.

In general, the DSSV *Pressure Drop* serves as the mothership for deep-ocean landers that are used for navigation on the seafloor. The vessel also holds a powerful Kongsberg EM 124 multibeam sonar that enables mapping of the geological features of the seafloor in detail.

DSSV *Pressure Drop* holds up to 49 people, so it can provide a full ship crew, enabling the vessel to be used to research and locate wrecks on the high seas during stints that can last weeks at a time. As a former U.S. Navy submarine hunter, the vessel is no luxury yacht but a working research vessel with a priority on mission capability and accomplishment.



“To see the intact hull, her weapons still loaded with live ammunition, her broken mast and shattered stern—it was like seeing history come alive.”

CSM Energy considers it an honor that the DSSV *Pressure Drop* has been involved yet again in such a remarkable expedition to explore some of the hardest to reach parts of our magnificent oceans. It is great to see such worthwhile expeditions taking place to explore the combined military history of Allied forces in WWII.

CSM Energy's experienced crew have made many of the aspects of this project a reality and have contributed to keeping history alive as they aim to investigate the deepest, most inaccessible parts of our oceans while at the same time inspiring the next generation of curious and resilient seafarers.

The company is committed to using its expertise and experienced crew to continue to aid in such pioneering expeditions, aiming to investigate the parts of our oceans that have never been explored, for the purposes of science and adventure, collecting vital information about our planet.

The *Pressure Drop* and CSM Energy's dedication supported Vescovo and his team to stay out at sea for an extended period of time, carrying all the necessary specialized equipment, a full ship crew, submersible tending team, sonar team, science team, members of the press, and even historians. The discovery of the wreck of the *Sammy B.* helps keep history alive.

Acknowledgments

The authors would like to thank Victor Vescovo for contributing to this article. **ST**

Kyriakos Tsangaris is the technical director of CSM Energy. He graduated from the naval architect school of the National Technical University of Athens. He has worked with Greek shipowning companies on many newbuild and retrofit projects, and he entered the offshore market in 2012.



Johann Meyer is the managing director at CSM Energy (CSME). He has over 20 years of experience in the shipping industry, holding a variety of operational level positions before joining CSM in 2020 and CSME in 2021.



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ROV Simulator

Collaboration Improves Design with Updated Functionalities

By Snorre Balkøy • Dr. Felix Gorbatshevich

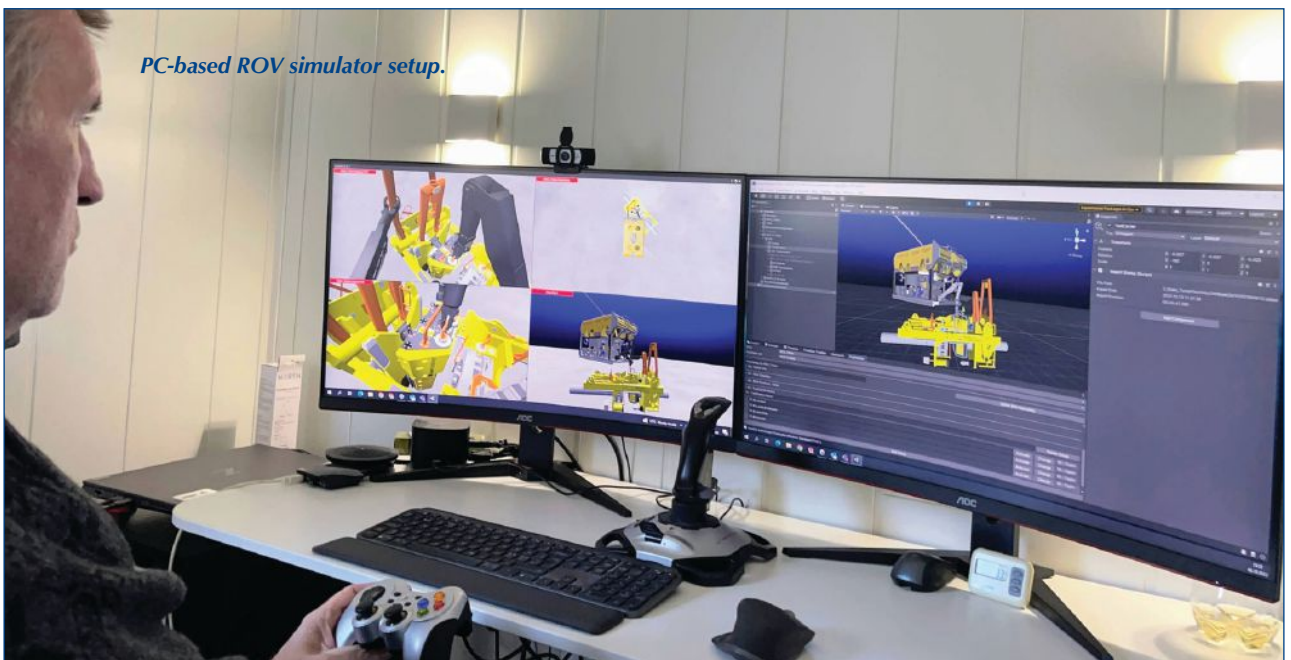
The ROV Access department is a part of the system analysis group at Aker Solutions. Over the years, this department has used different simulation software to verify ROV interfaces, design ROV safety envelopes and plan maneuvers in relation to subsea structures. Over and over, the department has struggled with the same issues of these ROV software packages: performance and complexity. Low performance and high software complexity have both contributed to project execution times that were longer than ideal.

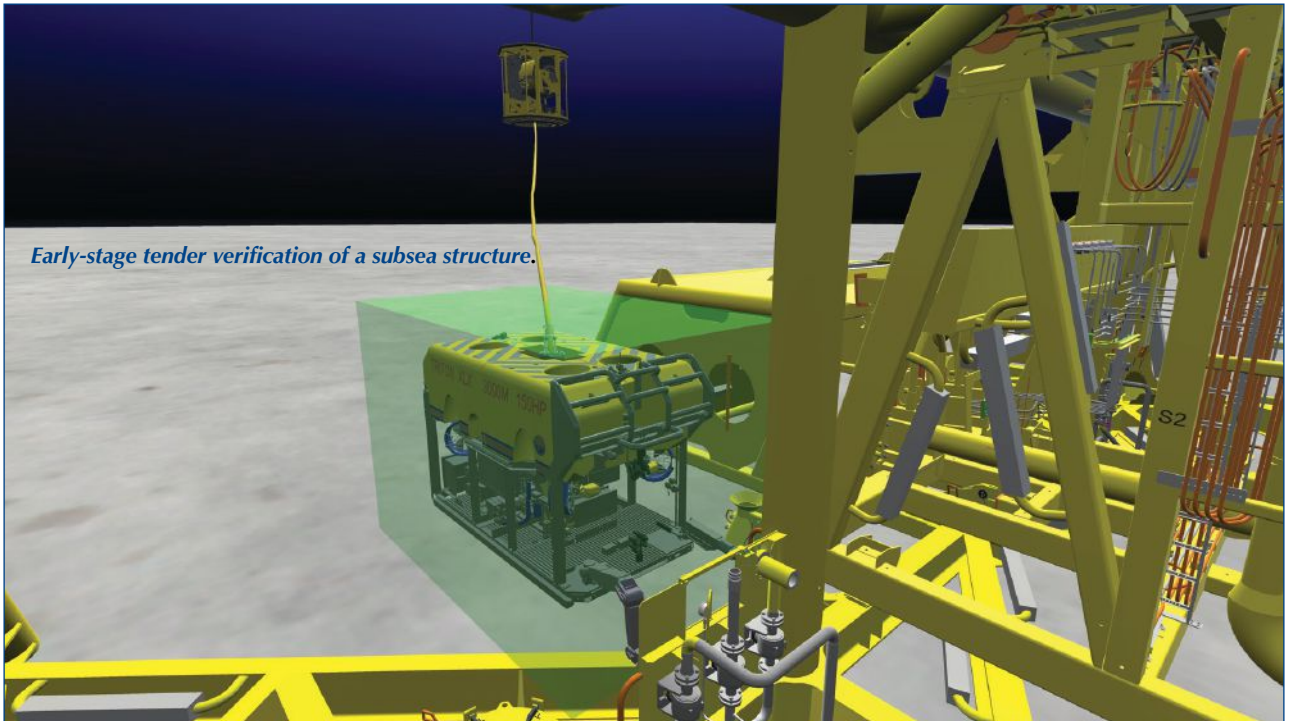
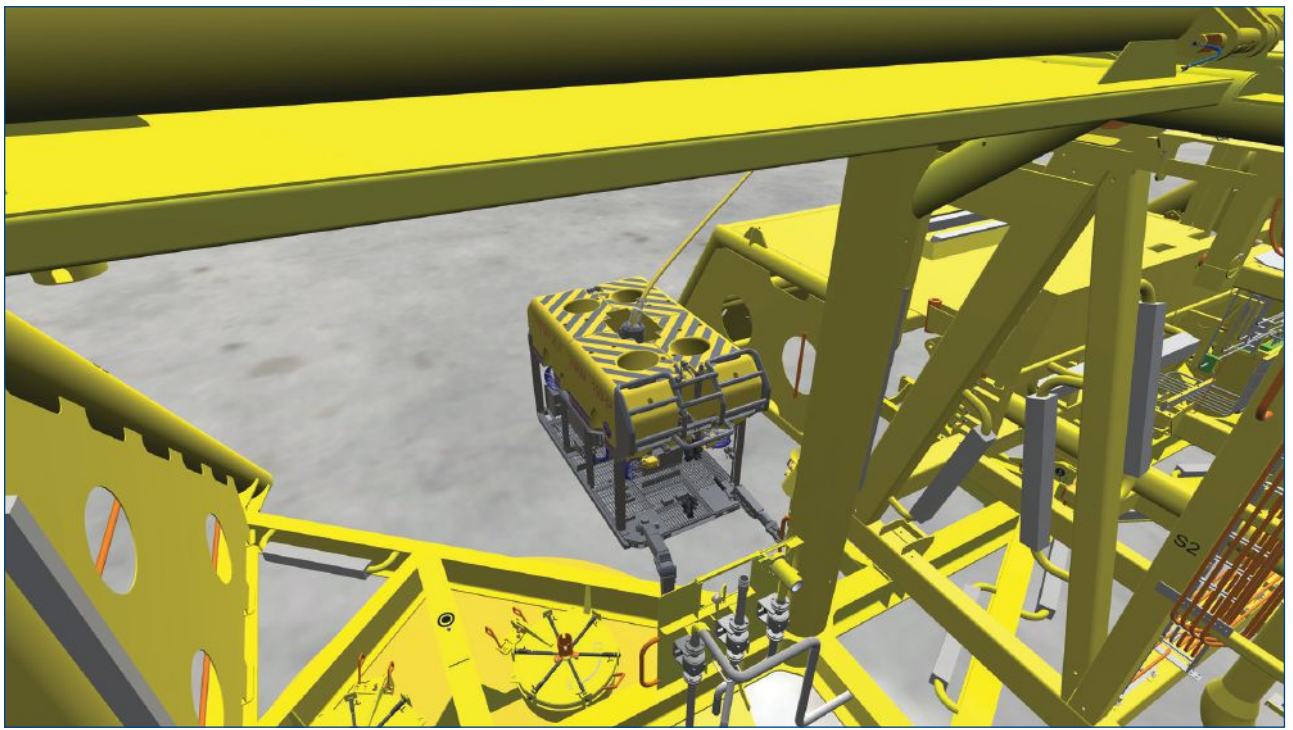
Traditional ROV simulators require CAD models to be converted and optimized in third-party software before being added into the simulator. This is a cumbersome and time-consuming task. Optimizing 3D CAD models

for performance usually meant removing important details. After a 3D model is finally imported into the simulation software, the next stage would be to add physical characteristics to the models for interaction, which also is a time-consuming task and impacts performance of the simulation.

The ROV team at Aker Solutions works with CAD designers on the various structure parts, receiving CAD models during the development process and adding them into the simulator for evaluation of integrity and ensuring their operability. The design process goes through several iterations to tweak and optimize the subsea structure.

Sometimes, the ROV Access department sees several iterations in a single day. It's important to be able to reuse





as much of the work done in earlier iterations as possible. The team also likes to limit the new verifications to what has changed since the last iteration while still being able to recheck all ROV interfaces to ensure changes did not affect anything else.

To be able to do this, Aker's ROV team developed functionality based on "keyframes," or snapshots of every ROV interface check that has been performed. Previously, a long time had to be spent between receiving models from CAD designers and giving feedback to them on ROV access check. Now, the keyframes can be used to recheck all interfaces of new designs in minutes, rather

than the hours or days and weeks it would have taken in the "old days." And since these keyframes are kept updated during the design phase, doing the final verification report is simple.

Simplifying the Process

One of the biggest challenges is the fact that the complexity of ROV access checks grows every year. Ever so smaller details and a higher number of parts need to be present. It's no longer sufficient to simulate access to just one module. A future-proof system needs to be able to simulate a whole subsea field in a good amount of detail.

“This is not just a generic simulator. By working with PaleBlue directly, Aker Solutions is incorporating specific functions that will truly add value to its projects and benefit its clients.”

The typical simulation tools on the market were not working for Aker’s ROV Access department. After the team analyzed how it works and how to achieve the best quality and speed of simulation verifications, the team tried to identify which functionalities in a simulator software would add value to its process: for example, the ability to import CAD models in most formats directly into the simulator’s editor; being able to optimize models during import; quickly adding physical characteristics to the areas where needed for the verification; the ability to manipulate models in runtime; and a strong focus on reusability of models and their parts and using these in the process of verification.

The authors of this article got in touch with each other to work on these challenges. PaleBlue, a simulator company based in Norway, has a history of working with Aker’s ROV Access department on simulator projects.

The PaleBlue team is not new to simulators. The company’s simulation solutions are preferred by some of the biggest industrial companies. Having delivered projects to NASA, Saudi Aramco, and Neptune Energy, PaleBlue has developed a robust simulator technology platform. A number of simulator products from PaleBlue are focused on personnel training, while others focus on robotics and autonomy.

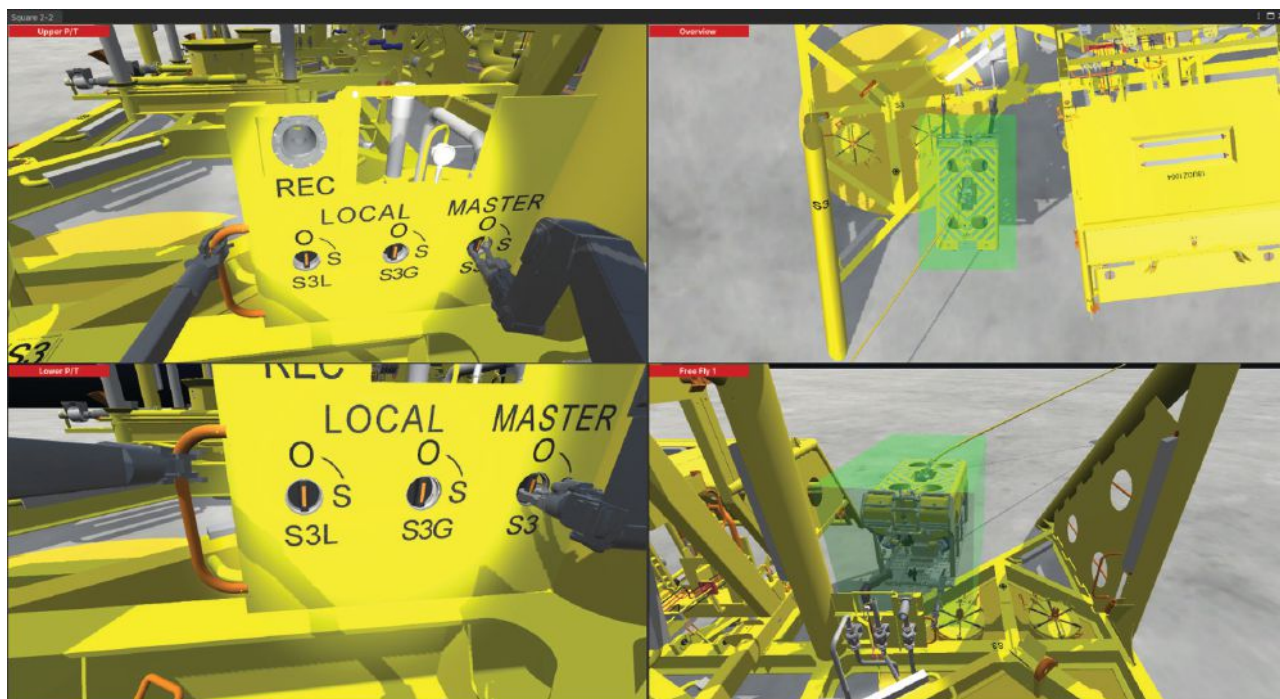
Based on Aker Solutions’ observations and ideas, a new ROV simulator began to be developed that would allow for 3D model import and optimization, model manipulation and configuring physics. All in all, it needed to be future-proof.

Subsea Projects

The simulator project was started in early 2021, and soon after, the first functionality was complete. Aker Solutions’ ROV team was able to start using the software when running subsea projects. As more and more functions were introduced, Aker Solutions and PaleBlue worked closely together to review the changes and make adjustments to make sure the simulator was aligned with the requirements of demanding, large-scale subsea projects.

Once Aker saw the first results, the company realized that there is much more possible to develop on this platform. The simulator is now in active use, and it has been for over a year. Its development is a step-by-step process with incremental improvements.

This is not just a generic simulator. By working with PaleBlue directly, Aker Solutions is incorporating specific functions that will truly add value to its projects and benefit its clients. Over the last year, Aker has been using this



Interface verification with ROV in the simulator.

simulator for all its subsea projects for clients including Equinor, Total, Aker BP and Chevron, to mention a few. The projects are based all around the world.

By introducing this new simulator, Aker's working routine has seen a significant improvement, with the team constantly seeing new opportunities on how to add value to the ROV verification process or how to save time. The time saved when using the simulator turns into higher quality of deliverables.

Doing this from the early stages of the design phase gives Aker a better chance of getting a job done right the first time, avoiding rework and cost in later stages of the project. The company is constantly trying to work smarter, reduce waste and add value.

Conclusion

ROV simulators are very different today from what they used to be five to 10 years ago. The growing complexity of subsea installations brings a number of technological challenges. A simulator also has to be more flexible, not locking the users into a predefined set of ROVs or arms. Extensibility and configurability are required, while being able to handle huge models and whole subsea fields with high performance.

The technology established by PaleBlue is now serving Aker's ROV Access team. In working hands-on with Aker Solutions, PaleBlue is able to continue developing a tool with the exact feature set needed for ROV verification,

thanks to the professional input and guidance from Aker Solutions. Aker's clients appreciate a future-proof simulator such as PaleBlue's new platform because it enables higher productivity and allows for possibilities not previously envisioned. **ST**

Working at Aker Solutions in the ROV department for the last 12 years, Snorre Balkøy focuses on ensuring ROV access and operability of designs for the subsea market. He has led Aker's ROV Access group for the last 10 years. Prior to working at Aker Solutions, Balkøy worked offshore for seven years, operating ROVs and working on AUVs and trenchers. He also has experience in the aviation industry as a system avionic for SAS and later for the Royal Norwegian Air Force. He studied system avionics and dynamic web design.



Dr. Felix Gorbatshevich is the co-founder and CEO of PaleBlue, a company producing simulators and training solutions. He has worked previously at technology and software companies, including Aker Solutions, MHWirth, Sun Microsystems, and small and medium enterprises in roles ranging from software engineer and systems architect to project manager and managing director. Now at PaleBlue, Gorbatshevich leads the development of 3D simulators and virtual reality solutions for PaleBlue's clients, including Saudi Aramco, Neptune Energy and the European Space Agency. He holds a Ph.D. in computer science.



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Flexible Underwater Drone

Snake-Like Robot for Subsea Infrastructure Maintenance

By Zuo Li • Feng Lyu • Xin Xu

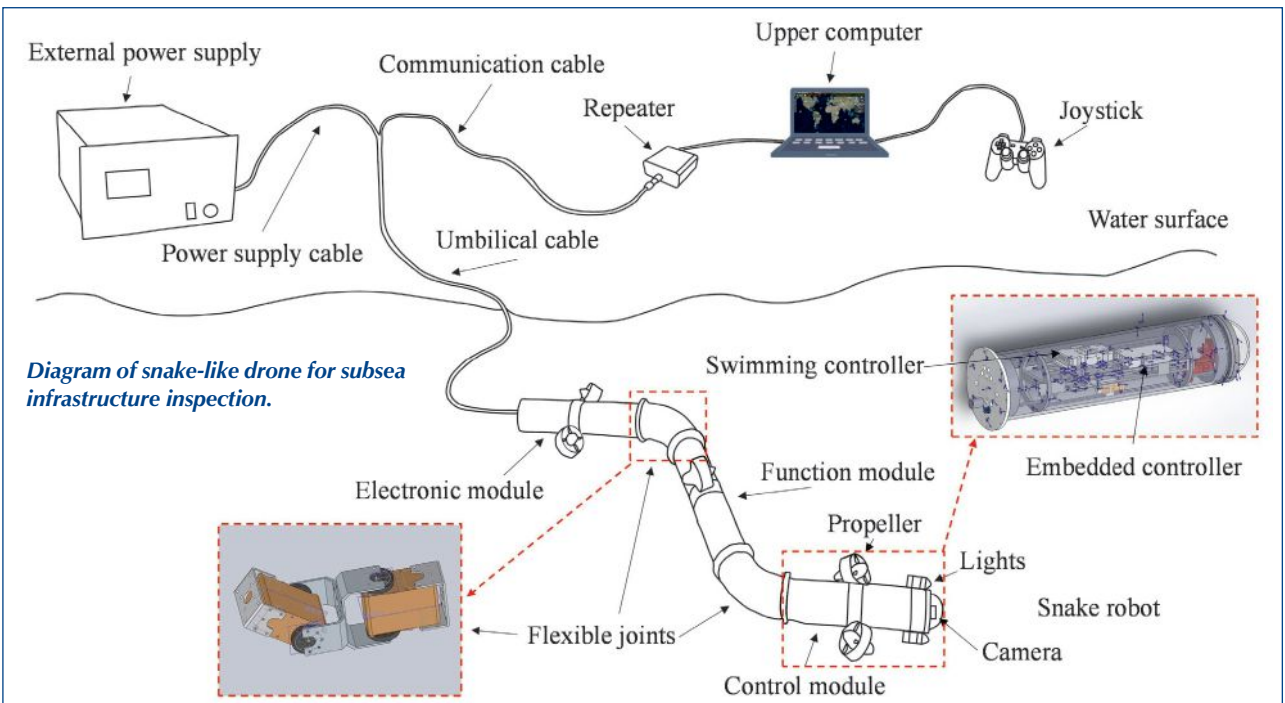
Given the harsh ocean environment, seafloor observatory networks and subsea production systems are prone to corrosion, deformation and biofouling, leading to performance degradation or service life reduction over time. These subsea infrastructures need regular inspection and intervention to mitigate operational risks and for general maintenance.

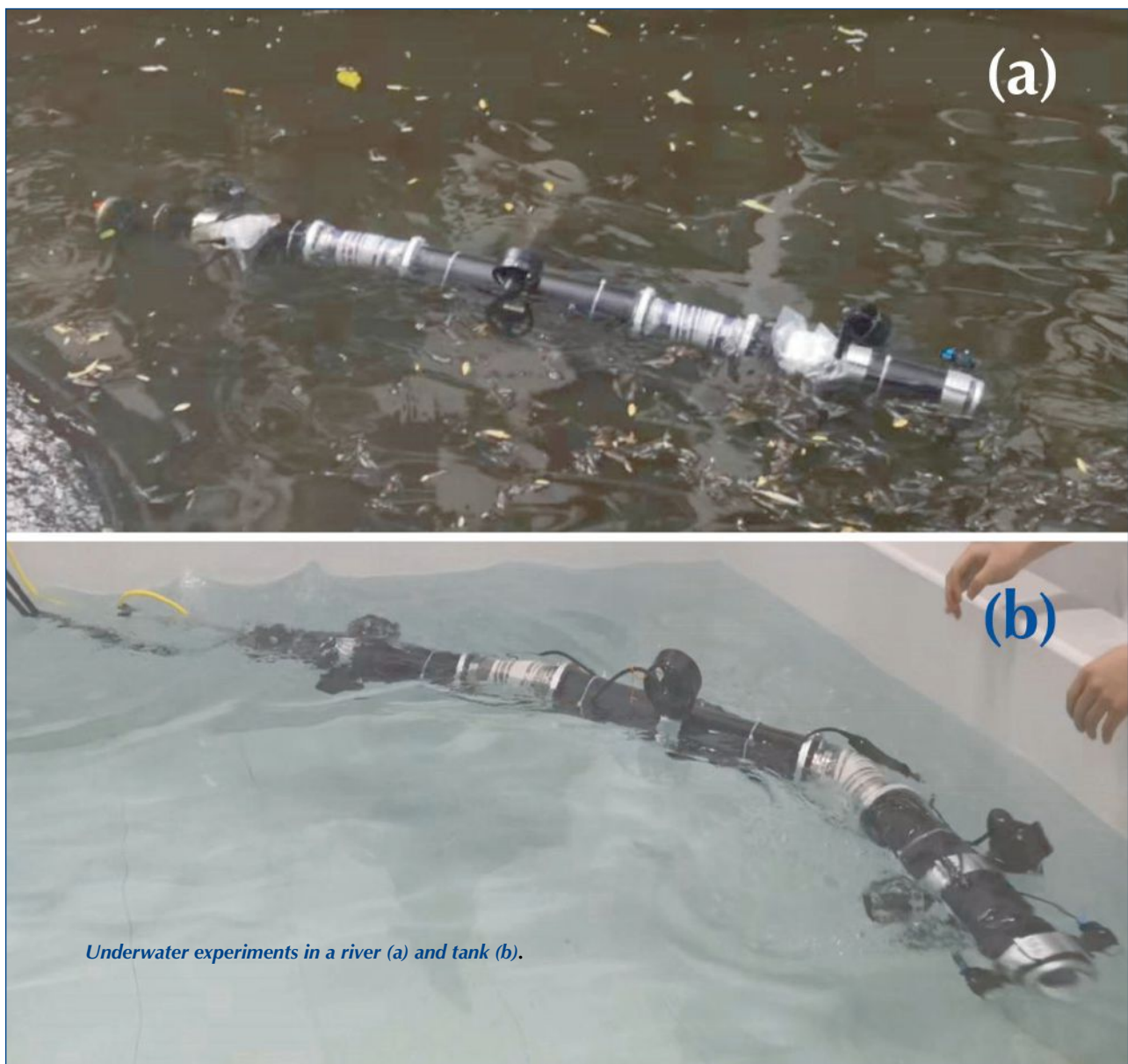
The space constraints and structural complexity that marine infrastructure may have could pose a challenge to maintenance. Conventional ROVs or AUVs might not be able to handle comprehensive inspection tasks in complex undersea facilities due to their rigid designs. Therefore, more dexterous inspection tools with greater access capability are needed.

We have designed a multi-joint robotic underwater unmanned system with a slender and flexible body, inspired by sea snakes, to meet this challenge. The system uses propellers for maneuverability, stability and energy efficiency.

System Design

The total length of the robot is about 1.8 m, and the diameter is 0.11 m, excluding propellers. It is currently depth rated to 300 m. The drone's control system comprises a remote joystick, an upper computer, a repeater and an external power supply, which are used to issue commands, transmit data and provide electrical power. The control signals are sent from the joystick to the





upper computer running the QGC ground station, then transmitted to the snake robot underwater through the repeater and an umbilical cable. The data collected by the robot can be transmitted back to the upper computer. A thin and neutrally buoyant umbilical cable connects the control system to the drone.

The robot has a control module, a function module and an electronic module. The control module contains a swimming controller, an embedded controller, a camera and two lights. It controls the robot according to the task instructions from the upper computer and transmits underwater video signals to the upper computer. The function module will be able to carry inspection and intervention tools as development of the drone advances. The electronic module contains speed controllers for the propellers and battery elimination circuits for all steering gears. The three modules are connected by two flexible joints, and each joint is composed of two orthogonally combined steering gears to achieve the motions of 2° of freedom (DOF). The power supply and data communica-

tion cables pass internally through the joints, connecting the modules electronically.

Each module has two symmetrically placed external propellers with opposite rotation directions, which produce opposing torque to offset the motion influence of torque generated by a single propeller. Six propellers provide power for the robot and realize the motions of 6 DOF. A camera and two underwater lights are installed on the head of the control module to capture video and provide lighting. The robot is powered and transmits data through the umbilical cable connected to the surface.

MATLAB Simulink was used to simulate stress on the robot's design to test its strength for shallow-water applications.

Motion Control

The control system includes a swimming controller and an embedded controller. The embedded controller is mainly used to transmit video signals to the upper computer and to receive control signals from the upper com-

“There is a need for more flexible inspection and intervention tools for subsea infrastructure maintenance. In response, we designed a multi-joint unmanned system, inspired by sea snakes.”

puter and transmit them to the swimming controller. The controller runs a swimming control program developed for the snake robot. The program controls the underwater lights, joints, propellers and other electronic components.

The challenge of motion control is to determine the influence of the propellers on various DOF motions according to current joint angles. The core of the motion control program is a 6 DOF influence factor matrix (SDIFM), which is a 6-by-6 matrix. The SDIFM was calculated using the thrust component, thrust arm and thrust torque of the propellers according to current joint angles, and the influence factors of the various propellers on each DOF. In the SDIFM matrix, each row corresponds to the influence of one propeller on 6 DOF, and each column corresponds to the influence of the propellers on 1 DOF. Because the SDIFM calculation is complex and the embedded hardware is a computation constraint, the discretization method was adopted for different joint angles.

The robot has four motion modes: basic, roll, bending basic and bending roll. In the basic mode, the robot can perform three-axis translation and yaw angle rotation. In the roll mode, the robot can translate and rotate on three axes. In the basic and roll modes, all steering gears always hold the stop position during motion. The bending basic and the bending roll modes are advanced modes of the basic mode and roll mode, respectively. In the bending basic mode, the steering gears rotate with the yaw angle. In the bending roll mode, the steering gears rotate with the yaw angle and pitch angle.

The motion control program calculates the 6 DOF control expectation and the expected angles of the steering gears through a PID (proportional–integral–derivative) algorithm, according to the control signals, current motion attitude and motion mode. Then, it calculates the rotation speed of the propellers and the angles of the steering gears, according to the SDIFM of the current attitude. The converted PWM (pulse-width modulation) signals are output to the propellers and steering gears.

The motion control program was simulated by MATLAB and Adams to test for stable and flexible control of multi-DOF motions of the robot, realized through the upper computer and the joystick.

Preliminary Underwater Experiments

Underwater experiments were carried out to verify the control ability of the unmanned system. A tank experiment in March 2020 tested the control ability for different DOF motions by inputting motion control signals on each DOF to control the robot's motions. The

experimental data were obtained by an inertial measurement unit. The acceleration and gyroscope data were integrated to obtain three-axis translation displacement and rotation angle curves, respectively. The actual motion trajectory of the robot on each DOF was compared with the input motion trajectory. The change trend of the three-axis translation position and rotation angle curves were the same as the input signals, indicating that the control of 6 DOF is effective.

In the river experiment in May 2020, the robot's control for forward, lateral and turning motions was tested. Moreover, multiple real-time positioning modules, with ranging accuracy of ± 5 cm, were placed at equal intervals on both sides of the river to record the displacement data of the robot's motions. During the forward and lateral motions of the robot, there was a very small offset to other directions, and the turning arc was smooth during the turning motion. In general, the system design and robot control proved satisfactory during the river demonstration.

Conclusion

There is a need for more flexible inspection and intervention tools for subsea infrastructure maintenance. In response, we designed a multi-joint unmanned system, inspired by sea snakes. The robotic system can realize stable and flexible motion with high maneuverability. The drone has three modules and two flexible joints. It is driven by propellers to enhance mobility and stability in four modes of motion. Underwater experiments have verified the feasibility of the system design.

We believe this snake-like drone will be a powerful tool for subsea infrastructure maintenance. We are continuing to develop this drone, with a focus on enhancing autonomous operation and intervention capabilities. A deep-sea version will be developed to 3,000 m.

References

For a list of references, contact Feng Lyu at: LF@tongji.edu.cn. **ST**

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5G at Sea

JET Buoy Network Brings Optimal Connectivity

By James Thomas

Around the world, technological advances are promising to revolutionize every industry, from energy and healthcare services to transport and food production. Industry 4.0 promises everything from greater data processing, informed decision making and remote operations to artificial intelligence (AI) and machine learning-led innovations that will boost productivity, reduce downtime and even offer environmental benefits on the road to Net Zero.

But none of this progress would be possible without significant advances in connectivity, such as the development of 5G networks that offer higher speeds, lower latency and greater capacity than existing networks.

With speed and bandwidths offering a 10-to-100-fold speed increase over 4G, latency under 5 milliseconds, capacity to connect up to 100 times more devices in a physical area than 4G, and an estimated 90 percent reduction in power consumption for devices, it's easy to see how this next-generation technology holds the potential to fuel a new industrial revolution of internet-of-things (IoT) devices.

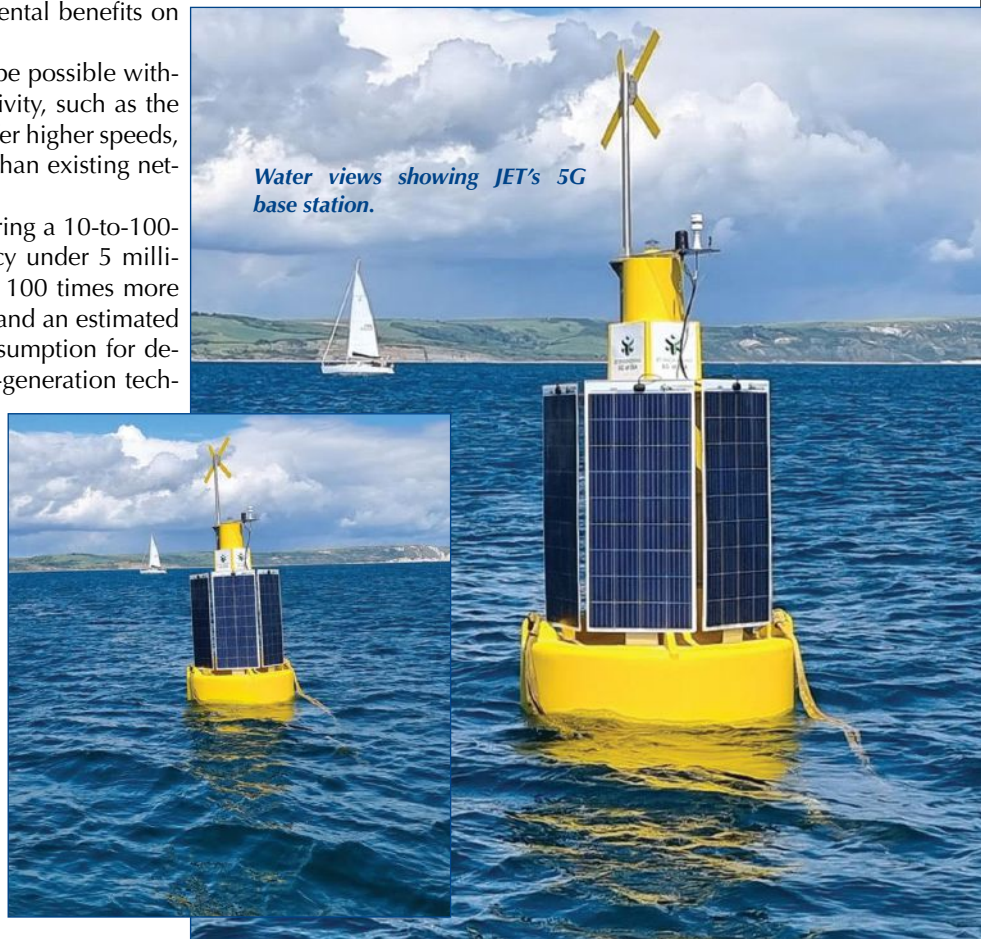
For the blue economy to take advantage of IoT, it is crucial to achieve reliable, secure connectivity at sea. This is far harder to achieve than on land, and bringing connectivity to coastal and offshore area that don't currently have 4G or even 3G will be critical to enabling the sector to take advantage of the benefits connectivity offers.

Fishing for Greater Returns

As just one example of enhanced connectivity benefiting the blue economy, let's take a look at the

aquaculture sector. Being able to establish a network of interconnected devices at sea could open up a wealth of data-driven analysis and management of sea-farming installations. This network would enable improved ecosystem management, leading to greater yields, reduced costs and improved carbon management.

Water views showing JET's 5G base station.



5G floating buoy (wide angle and closeup).



Aquaculture in the ocean can be unpredictable. Wind, tide and wave behavior influence the quality of the end product, and biofouling and disease can wipe out entire crops. Being able to protect livestock and equipment from the worst effects of Mother Nature is a key component of running a successful aquaculture company. This means monitoring an extensive array of metrics in order to make smart decisions. However, the remote location of many installations means this is typically a time- and resource-intensive exercise.

Creating networks of connected sensors enables companies to acquire large volumes of continuous, real-time data across multiple sites remotely. This supports real-time decisions based on the latest environmental and operational data, such as oxygen levels, sea temperature, salinity, pH balance, barometric pressure, wave height and strength, currents, the tension on mooring lines, and so on.

This not only reduces the operational costs involved in monitoring sites but also enables increased responsiveness and efficiency. For example, the oxygen levels and other chemistry of a site can change within a matter of minutes, putting livestock at risk. Employing real-time, auto-mated monitoring solutions to detect when something is awry means controls can inject more oxygen at critical moments before a situation gets out of hand. Similarly, should a particular area of a farm be affected by a tidal influx of plankton, this can be identified quickly—even predicted—with measures put into place straight away to mitigate the impact.

The benefits extend not only to protecting animal welfare but also making improvements to preventative maintenance models. Rather than sending an engineer

to physically inspect equipment once a month, sensors monitoring equipment conditions can provide real-time data to management teams, allowing them to schedule maintenance visits only when they are truly required, saving time and money.

Biomass estimation, currently a difficult and labor-intensive process, could be similarly revolutionized by the use of smart technology that uses artificial intelligence, machine learning and advanced data analytics to predict and provide insights that help aquaculture operators understand opportunities across different sites and locations in a timely manner to maximize returns.

All of which sounds wonderful. But, with a recent feasibility study carried out by the UK Seafood Innovation Fund suggesting that the availability and quality of connectivity is the single biggest barrier to adoption of digital technologies across the sector, what can be done to make this vision become a reality?

5G at Sea: Realizing the Vision

Just as remote, water-based locations make accessing aquaculture settings a challenge in the physical world, they also pose challenges for the telecom industry. Whereas public and private, indoor or outdoor 5G networks are relatively straightforward to set up on land, signals do not travel so well in water, with sea state and environmental conditions having a significant impact on connectivity. For example, existing networks tend to be set up for hosting on towers, which isn't possible in places without fixed structures, and the harsh physical environment of an ocean setting creates its own equipment protection and maintenance challenges.

Currently, the farther away from shore an aquaculture

“JET’s floating network extends 5G capabilities out to sea by hosting technology on a series of 5G-enabled, self-powered buoys that can be deployed exactly where they are required.”

farm is located, the harder it is to set up an effective 5G network. This is where new buoy-based networks, developed by JET Engineering System Solutions in the U.K. and successfully trialled off the U.K. coast, look set to change the game.

JET’s floating network extends 5G capabilities out to sea by hosting technology on a series of 5G-enabled, self-powered buoys that can be deployed exactly where they are required. This creates a fully functioning, flexible, floating network that can extend for miles offshore, delivering a high-bandwidth, secure, high-speed connection across significant distances and unlocking a host of possibilities to make everyday work easier, reduce costs and improve efficiencies.

At the heart of the system is a custom 5G router, built in house, that provides high-speed connectivity, with high-bandwidth, multichannel hybrid comms capability that can be integrated into most system architectures to provide Industry 4.0 connectivity in the most challenging environments.

Deployed as part of a fixed wireless access (FWA), it can be used as a customer’s primary 5G connection or as a backup when primary connections drop. Specif-

ically designed to support alternative modes to connect multiple devices without the risk of performance issues, it supports multiple sensor integration to most data types, including Ethernet, I2C, NMEA, CAN, USB, Blue-tooth and Wi-Fi.

The JET buoy is believed to be the only frontier data-transmission solution in the world that delivers the required bandwidth, low latency and resilience to support Industry 4.0 at sea, with its 5G mesh capability opening up a host of potential applications for sea-based industries, including aquaculture and offshore energy, to name just two.

Livestreaming on 5G Buoy

In partnership with 5G RuralDorset in the U.K., JET successfully deployed and demonstrated a livestreaming underwater 4K camera on one of its 5G-connected buoys, exhibiting a capability that could drive efficiencies and information delivery for many sectors in the marine environment.

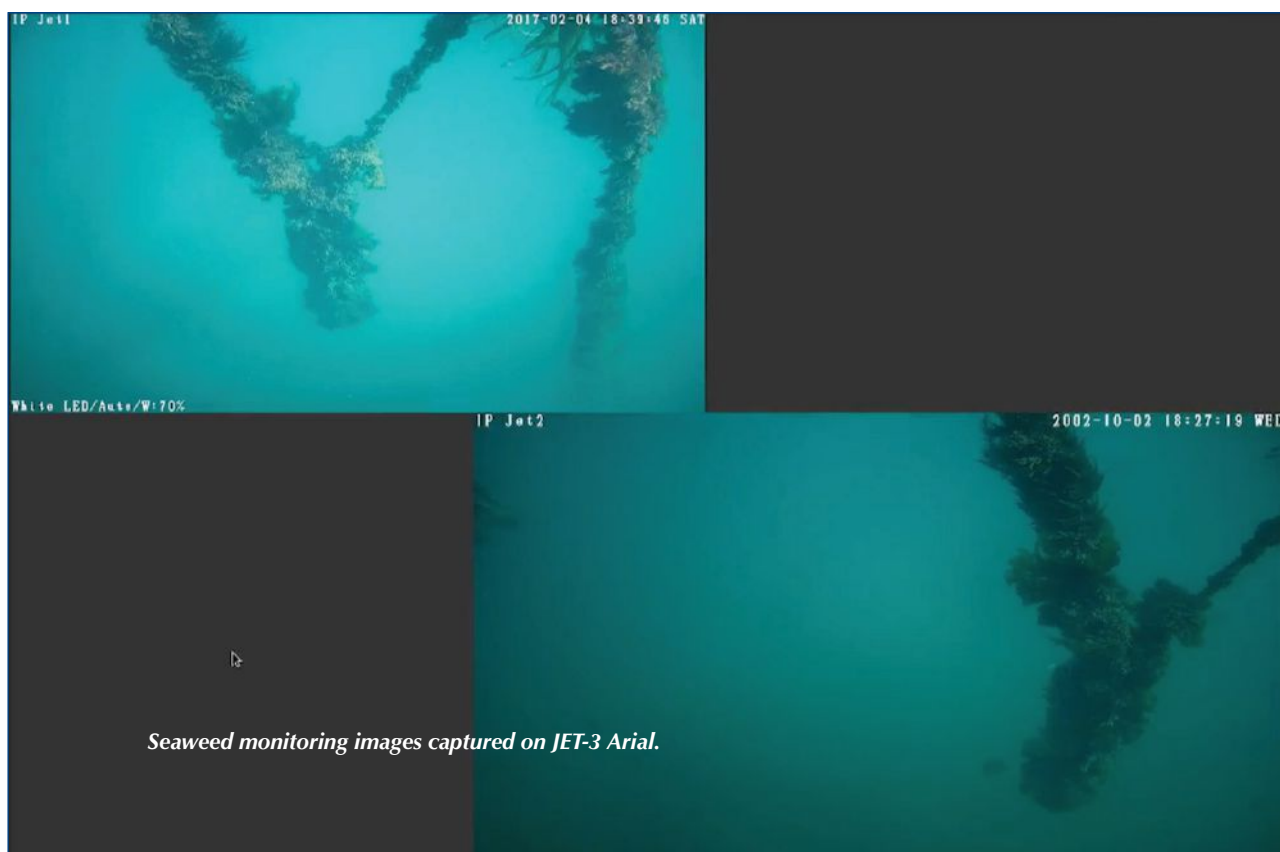
Continual video streaming over 5G from underwater is a brand-new concept and a major mile-stone in JET’s product development, building on last year’s world-first demonstration of its standalone 5G-at-sea connection, using its flagship buoy, JET-1 Nemo.

The host buoy for the most recent trial, JET-3 Ariel, was launched May 2022, connected to a private 5G network provided by Wessex Internet, and it transmitted a live video feed from underwater near Portland, Dorset, to the JET team. Two cameras below the buoy streamed live footage of seaweed at Jurassic Sea Farms, which has been supporting aquaculture trials.

Such a system could have big benefits for the wider industry, not only maximizing the economic benefit sea-



From left to right: Izzy Taylor, Louis Stag and James Thomas of JET, with one of the 5G buoys.



weed could offer, but also the environmental and social contributions it can bring through carbon capture and as a healthy food source.

“Livestreaming of how the seaweed crop is developing allows us to optimize the point of harvest and to better understand the environmental factors affecting the quality, such as growth of epiphytes and interactions with other forms of marine life,” Richard Prickett, CEO at Jurassic Sea Farms, said.

“Dorset has been recognized by the government as having high potential opportunity for aquaculture in the U.K.,” Councillor Jill Haynes, cabinet member for Corporate Development and Transformation for Dorset Council, which leads the 5G RuralDorset project, said. “This technological milestone is an important first step in the modernization of one of our traditional industries and will help to future-proof and grow the sector, thereby continuing to provide jobs for years to come.”

Pushing Technological Frontiers

With the technology now proven, JET has created an aquaculture monitoring system made from sustainable materials and harnessing 5G network connectivity that is now in use in Portland Harbour in Dorset.

JET’s aquaculture monitoring system is analyzing sea and environmental conditions, visually tracking seaweed growth and monitoring shellfish biofouling indicators using two subsurface cameras. The data are processed using AI/machine learning to better inform farming practices, reduce labor/operating costs and increase productivity.

Low-profile buoys livestream video and measure sea state 24/7, communicating this information via 5G to

project partners. This includes video streams, temperature and wave height data, which are analyzed in conjunction with wider project parameters, such as oxygen and algae levels. Aquaculture data are then transmitted into the cloud as raw data or through a dashboard.

The team has also constructed its buoys in a sustainable way, which will allow customers to access new and critical data streams, powered by solar and wind energy, and provide active industry leadership toward decarbonization and the achievement of Net Zero.

Smart antennas are being developed to determine the range of power usage that is best for maritime environments, ensuring reliable 5G data links at maximum range. These antennas allow energy to be directed where it is required to increase signal-to-noise ratio and improve the capacity of wireless communication networks significantly, as well as increasing the spectrum efficiency and reducing the power required to transmit.

The ocean remains one of the least explored and most challenging frontiers on Earth, but with innovative companies such as JET leading the way, a range of sea-based industries will soon be able to benefit from secure, high-bandwidth, real-time data transmission in even the most challenging of environments. The IoT revolution is coming to sea technology. Are you ready to take advantage? **ST**

James Thomas is the founder and CEO of JET Engineering System Solutions Ltd., based in Worcestershire, U.K. With a wealth of experience in senior engineering positions around the world, he brings his technical, operational and leadership expertise to bear, delivering next-generation systems for connected 5G environments.

Q&A: Wings of Gold

The Story of the First Women Naval Aviators

Beverly Weintraub's new book, "Wings of Gold: The Story of the First Women Naval Aviators" (Lyons Press), chronicles the journey of the pioneering six women who were recruited into U.S. Navy flight training in 1972. It was a long, hard road to prove themselves on the job, and Weintraub's book details their professional struggles, as well as the enduring legacy that resulted from their trailblazing work. Weintraub discussed her new book with *Sea Technology*.

What made you want to write this book?

The story found me. I'm a journalist and a pilot, and a former colleague of mine works for the opinion section of *The Washington Post*, so occasionally, when there's news about women and aviation, she'll ask me to write.

When Captain Rosemary Mariner, the most prominent of the original six female naval aviators, died in 2019, the Navy did the first-ever all-women Missing Man Formation flyover at her funeral. It made national headlines, and my colleague asked if I'd write something for the *Post*. A few months later, an editor at Lyons Press emailed that she'd read the op-ed and thought it might make for an interesting book.

Can you briefly introduce for our readers the six women who became the U.S. Navy's first female aviators?

The Navy originally wanted eight officers/officer trainees but could find only four, so recruiters were asked to find four civilians. One from each group dropped out, so the original female naval aviators consisted of six women. Most came from military families and had at least some flight experience.

Barbara Allen Rainey, the first to win her Wings of Gold, was a lieutenant serving as a communications watch officer when the Navy opened flight training to women. She flew the C-1 Trader and the T-39 Sabreliner



Lt. Barbara Allen (left) and Lt. Judith Neuffer as new student naval aviators, posing for publicity photos at Pensacola. (Credit: U.S. Navy/Photo courtesy: Judith Neuffer Bruner)

and was one of the Navy's first female flight instructors. She was killed in a crash during a training flight in 1982 and is buried at Arlington National Cemetery.

Judith Neuffer Bruner, the first woman to solo a Navy aircraft, learned to fly in her dad's Piper Cub and soloed at 16. She was a lieutenant working as a computer programmer when the word went out about flight training, and she was the first to sign up. Navy Secretary John Warner himself signed her training orders at a huge press conference at the Pentagon. Judy flew the P-3 Ori-

