MARINE TECHNOLOGY REPORTER

September/October 2021
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The 16th Annual
MTR100
Insights on Subsea leaders, innovators & technologies

Rick Spinrad
The NOAA Administrator is *MTR's* 2021 #1 Ocean Influencer

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AUV swarm tech emerges

Residency
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What's new from the halls of higher learning?

Volume 64 Number 7

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On the Cover: Richard (Rick) W. Spinrad, Ph.D., was sworn in on June 22, 2021 as the Under Secretary of Commerce for Oceans and Atmosphere and the 11th NOAA Administrator. Photo courtesy NOAA

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

FLORIDA
215 NW 3rd St., Boynton Beach, FL 33435
Tel: (561) 732-4368; Fax: (561) 732-6984

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

Associate Publisher & Editor
Gregory R. Trauthwein
trauthwein@marinelink.com

Contributing Writers
Justin Manley, U.S.
Edward Lundquist, U.S.
Elaine Maslin, Aberdeen
Tom Mulligan, Ireland

Production Manager
Irina Vasilets
vasilets@marinelink.com

Production & Graphic Design
Nicole Ventimiglia
nicole@marinelink.com

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

Accounting
Esther Rothenberger
rothenberger@marinelink.com

Manager, Information Technology Services
Vladimir Bibik
bibik@marinelink.com

Circulation
Kathleen Hickey
mtrcirc@marinelink.com

Advertising
Vice President, Sales and Marketing
Rob Howard
howard@marinelink.com
Tel: (561) 732-4368 • Fax: (561) 732-6984

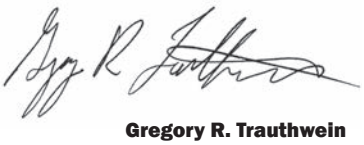
Advertising Sales Manager
Mike Kozlowski
kozlowski@marinelink.com
Tel: (561) 733-2477 • Fax: (561) 732-9670

Editorial

"Go to Sea"

Welcome to the **16th Annual MTR100**, our annual look at 100 subsea industry leaders, innovators and technologies. Despite the lingering COVID pandemic challenges – or perhaps more accurately because of it – the pace of innovation and technology development continues at warp speed. Organizations, from corporations to government to academia, increasingly aim to leverage the increased speed of technical evolution in tandem with the need to find ever more sophisticated and reliable autonomous solutions to get work in the oceans done efficiently, effectively and safely.

Special thanks this year to **Rick Spinrad**, NOAA Administrator and the NOAA staff for working with us to put together an insightful look at how this Federal agency is helping to drive subsea technology across the spectrum, culminating in our one-on-one with Spinrad, our **#1 Ocean Influencer for 2021**. Rick Spinrad certainly needs no introduction to this audience, with a distinguished career spanning four decades. I caught up with Rick very recently … to be accurate via our *Marine Technology TV* web channel the day before this edition went to press … for his insights on priorities for NOAA, and also for his take on the top technologies and issues that will dominate our headlines and your workspace in the years to come. Fast evolving uncrewed systems in the air, on the water and under the water; the evolution of swarm vessel technology; the maturation of the 'Blue Economy' here and abroad; and the need to inspire and attract a broad swath of the next generation are all covered in our interview starting on page 36. While the bulk of our coverage here and daily on **MarineTechnologyNews.com** is focused on the tech and the autonomy, one of the biggest takeaways for me from the Spinrad interview was his advice to young people considering a career in this industry: *"**The first bit of advice I have is go to sea.** I worked for an admiral once who said, 'Let's make sure we don't all turn into cubicle scientists or cubicle technologists.' You do need the experience; you need to understand the environment; you need to understand how difficult it is to collect information about the ocean. **Go to sea.**"*



Gregory R. Trauthwein
Associate Publisher & Editor

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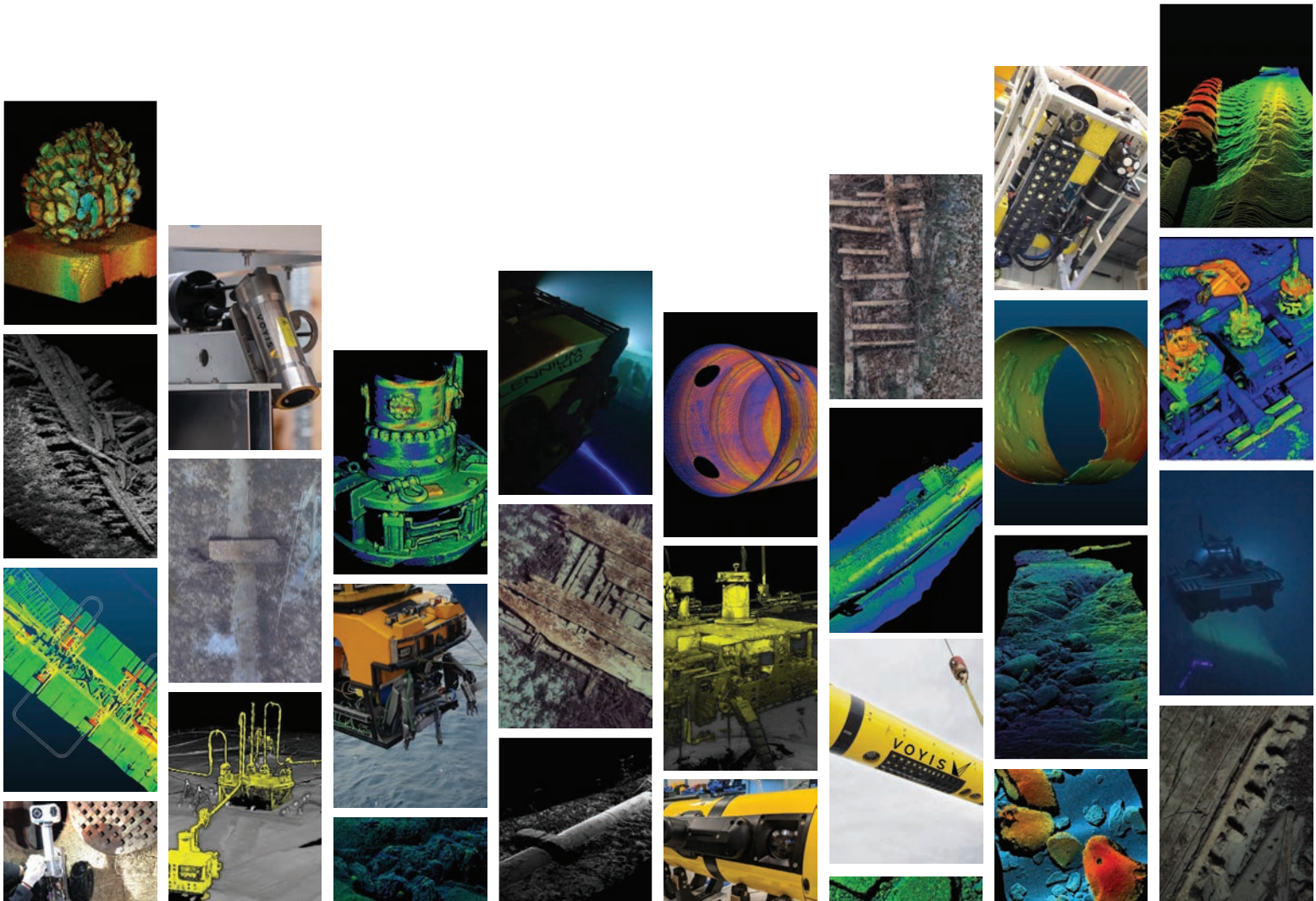

Authors & Contributors

Fisher

Gilson

Kaplan

Konowe

Lundquist

Maslin

Thorn

Fisher

Genene Fisher, PhD, is Acting Director of NOAA Ocean Exploration and joined the office in 2020 as the Deputy Director. She is the co-chair of the interagency NOMEC Council.

Gilson

Chris Gilson is the CEO of Voyis and has been with the company since 2013 in past roles of mechanical engineer and product manager.

Kaplan

Marlene Kaplan, D.Env., is a Senior Advisor for NOAA's Office of Education. She was instrumental in creating NOAA's Environmental Literacy Program and the Ernest F. Hollings Scholarship. She co-chairs the NOMEC interagency working group on ocean education.

Konowe

Celia Konowe is a college senior from Reston, Virginia, majoring in environmental studies at the University of Rochester with minors in French and theatre. This past semester, prior to the COVID-19 lockdown, she studied abroad in Ecuador through the Universidad de San Francisco Quito as part of its GAIAS (Galápagos Institute for the Arts and Sciences) program.

Lundquist

Edward Lundquist is a retired naval officer who writes on naval, maritime, defense and security issues. He is a regular contributor to Maritime Reporter and MTR.

Maslin

Elaine Maslin is an offshore upstream and renewables focused journalist, based in Scotland, covering technologies, from well intervention to subsea robotics.

Thorn

Aidan Thorn is the Business Development Manager, Marine Robotics, Sonardyne.

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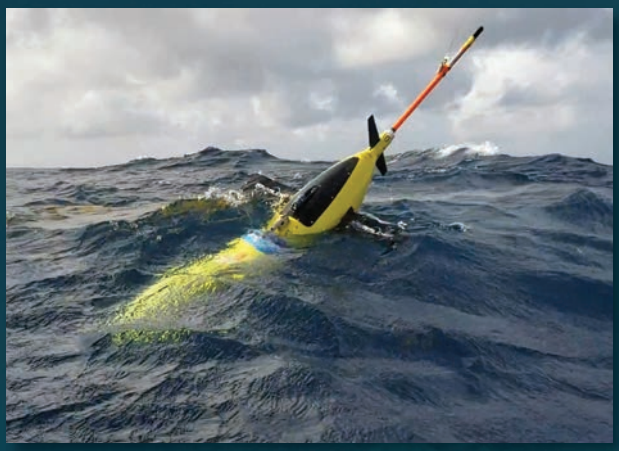

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Learn more at tsd.huntingtoningalls.com/unmanned.

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ARV-i: Boxfish Research & Transmark Subsea

Boxfish Research and Transmark Subsea signed a partnership agreement in October 2020 to deliver a fully autonomous resident observation ROV, the ARV-i. The ARV-i combines underwater vehicle, photography and robotics technology from Boxfish Research and underwater power and communications from Transmark Subsea. The goal is for it to be able to spend up to 12 months per deployment underwater, based out of a subsea docking station with battery charging, with wireless communication of data during dive excursions. Every 12 months, it would be exchanged with a replacement and the original refurbished.

"In resident mode, ARV-i can be fully autonomous with its self-piloting systems taking advantage of the existing Boxfish ROV platform, such as the advanced stability and maneuverability of its eight-thruster design," says Craig

Anderson of Boxfish Research. "Additional proprietary artificial intelligence onboard enables the ARV-i to optimize movements within its environment."

Anderson says the vehicle has an array of up to six machine vision cameras and one live 4K navigation camera, and it can deliver 17,000 lumens of lighting for high quality observation underwater. The vehicle weighs only 25kg, making deployment and entry to confined spaces easier, while maximizing the power-to-weight ratio and enabling extended excursion time and range.

The ARV-i can carry a range of sensors to monitor underwater assets and assist in navigation.

ARV-i can also be manually piloted using live video or via a digital twin of the environment, enabled by high-speed optical and acoustic communications between the dock and the vehicle. Piloting of the ROV away from and back to its offshore dock may be performed from distant, land-based locations.

The ARV-i is also available as a tethered solution, adds Anderson, in conjunction with a subsea tether management system. Up to 8K / 50MP camera systems are be supported in the ARV-i tethered solution

Boxfish's ARV-i prototype successfully completed trials in May 2021. Sea trials are now underway, with official market release scheduled for October 2021.

Saipem SpA

www.saipem.com

Headquartered in San Donato Milanese (Milan), Italy, Saipem is an advanced technological and engineering platform for the design, construction and operation of complex, safe and sustainable infrastructures and plants. Led by Francesco Caio with 32,000 employees worldwide, Saipem is committed to supporting its clients on the frontier of the energy transition with assets, technologies and processes that are increasingly digital and oriented towards environmental sustainability.

The FlatFish is a resident and fully autonomous vehicle able to autonomously perform complex subsea inspection tasks. The FlatFish program was started by Shell in 2013 with the partnership of Senai Cimatec and DFKI, funded by EMBRAPII and by Shell through a four years ANP R&D program. Saipem is enhancing the FlatFish features with capabilities for pipeline autonomous tracking and inspection, risers inspection, data harvesting from IoT subsea sensors, contactless monitoring of cathodic protection systems and a flying-hanging garage for the launching/recovering and subsea recharging/reprogramming. During the first period of open water tests, several functionalities have been assessed, both in remote and in autonomous operative mode, and others will be tested in the next months until early 2022: navigation capabilities, autonomous and remote controlled, wired and wireless (by means of optical link); communication, both acoustic and optical; subsea docking/undocking on the resident HyBase and on the Flying Garage for recharge and data exchange; autonomous missions, such as way to point with multiple targets, collision avoidance and obstacle avoidance, horizontal and vertical pipe following and feature recognitions (by means of visual markers), depth map to develop 3D reconstruction and advanced feature recognition, data harvesting from subsea seismic on-bottom nodes; and subsea exchange and operation of payload module (CP skid) for contactless CP measurement of pipelines and fixed structures.

FarSounder

www.farsounder.com

FarSounder celebrated its 20th anniversary in 2021, two decades under its belt for this innovator of 3D Forward Looking Sonar.

"Farsounder is a company that develops and manufactures 3D forward looking sonars for ship navigation," said Matthew Zimmerman, Executive Vice President of Engineering and Co-Founder, in an interview earlier this year with MTR TV. "Our products basically provide the most useful information for vessel operators, which is what is under the water in front of me before I get there."

The Argo series has three models that are designed for vessels from about 17 meters in length to about 200 meters in length. The Argos 350, is the newest model, and goes out 350 meters maximum range. The Argos 500 goes about 500 meters maximum range. And the Argos 1000 goes 1000 meters maximum range. The Argos 350 was developed and

The Argos 350

delivered to open up new 'smaller big boat' markets for the company. "Also, the Argos 350 is a great match for a lot of the unmanned surface vessels that are being developed," said Zimmerman.

"Our sonars have a portion that's in the water, the sensor, which we call the transducer module," said Zimmerman. "The transducer module, transmits a ping, that signal goes out, bounces off the obstacles and targets underwater. And then those echoes come back to the sonar system. Inside our transducer modules we have a separate receiver array with up to 200 channels, depending on the model type. With all of those receivers, we're able to listen to thousands of different directions, both in the horizontal and the vertical simultaneously. So with one ping, we're able to image in true 3D what is in front of the ship underwater out to navigationally significant ranges."

The market for Farsounder is as diverse as the types of ships in the world. "It turns out that almost every type of ship and boat wants to know what's underwater so they can avoid hitting things," said Zimmerman, noting that the company has customers in the yachting, expedition cruise ship, coast guards, navies and other government vessel markets. "Over the past few years we've been installing more of our systems on well-known research vessels, such as the Sir David Attenborough."

AIRMAR Technology Corporation

www.airmar.com

Led by Stephen Boucher, AIRMAR Technology is a company 350 employees strong that is dedicated to the development and manufacture of marine electronics for nearly 40 years. AIRMAR's technological partnerships with subsidiaries have enabled the evolution of its ultrasonic transducers and WeatherStation Multisensors. Working with Marport has provided AIRMAR with access to technologies originally developed for the commercial fishing industry, while working with MSI Transducers has provided AIRMAR with material initially created by MSI for defense contract projects, which we are now using to develop the industry's next-level of transducers. AIRMAR's wholly owned distributors, Gemeco and AIRMAR EMEA, allow its product lines to be sold and supported worldwide.

In addition to continuing to develop and improve ultrasonic transducers and sensor products within its core competencies, AIRMAR entered the sensor management market this year with our new SmartBoat system, a vessel-management solution for all marine sensor protocols and network types.

SmartBoat Modules offer a configurable sensor interface, support a wide range of sensors and protocols, and provide remote discovery, management, programming, and wireless features. These capabilities significantly reduce the equipment, gateways, cabling, complexity, and labor associated with the installation of conventional networking products.

The modules connect to sensors such as current-loop, thermistors, thermocouples, resistive, voltage and fuel-flow, and convert their protocols to NMEA 2000. Once connected, the status and control of the sensors are managed via AIRMAR's SmartFlex View, a browser-based tool embedded in each module. Designed to meet electronics installers' and boatbuilders' requirements, SmartBoat Modules also include features like pluggable connectors, full electrical isolation of each bus, remote access through connected networks, built-in diagnostic tools, and the ability to easily back up and clone modules for the next install.

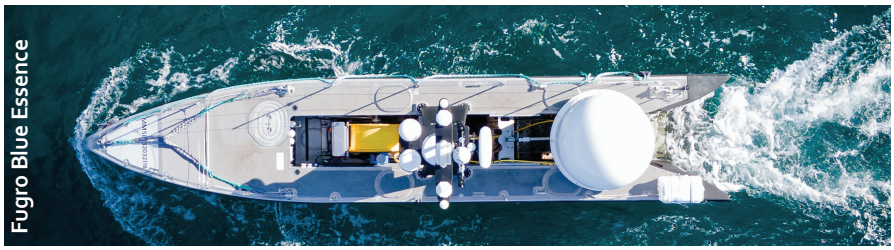
Fugro

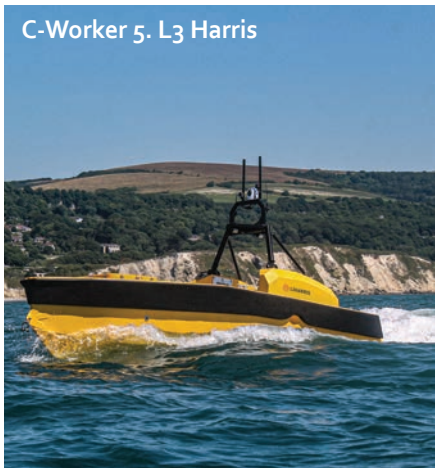
Fugro started working on USVs six to seven years ago, said Ivar de Josselin de Jong, director of remote inspection at Fugro, with the goal to make operations more effective and more efficient. One of the first initiatives was a 2m-long prototype with an MBES and remote-control capabilities for inland waters. Fugro also converted a small survey boat to uncrewed for cable landing surveys and shallow water activities. Seabed mapping followed, in partnership with ASV Global Ltd., now L3 Harris ASV, with whom Fugro developed its 9m-long diesel-powered Blue Shadow vessel, equipped with an EM 2040 MBES and "developed to provide a high-speed hydrography solution," said de Jong. Fugro envisions multiple Blue Shadows operating as force multipliers from a parent vessel – covering more area without additional people offshore.

Part of that development meant developing an adaptive line planning system, which recognizes the data and water depth and then automatically applies the right line spacing in the survey program to comply with whatever the level of quality of data is required for any specific job.

"These units are operational and we are delivering two large survey scopes in Australia for the Australian Hydrographic Office," said de Jong. The first was a 1,000 sq. km survey in the Gulf of St Vincent the second was in the Torres Strait in northern Queensland covering 1,200 sq. km. Over four months (starting May) another survey is being done north of Broome. Both have seen a parent vessel and USV deployed from that vessel, using a dedicated LARS, performing survey operations, as part of Australia's HydroScheme Industry Partnership Program (HIPP).

Meanwhile, the first of Fugro's 12m, SEA-KIT-built Blue Essence hybrid USVs, which come with a Blue Volta eROV, have also gone into operation on pipeline inspection work off Australia.


Fugro Blue Essence


C-Worker 5. L3 Harris

XOcean USV


Kongsberg Ferrotech

L3Harris

Founded in 2010, ASV Global was early on the scene as a USV developer. Now part of L3Harris, the firm has more than 125 USVs in operation and 2,100+ hours at sea. The firm's USVs use its ASView platform, which uses artificial intelligence and machine learning for its mission and situation awareness autonomy. L3Harris's 5.5m-long, diesel powered C-Worker 5, designed to operate for up to seven days at 7kts, with a variety of payloads, including multibeam sonar, side scan sonar and sub-bottom profilers, has become a regular hydrographic survey platform. "Since 2015, a NOAA contractor uses our C-Worker 5 platform each year in Alaska as a force multiplier, with over 20,000km of operational experience to date, to update nautical charts in remote areas," said Williams. L3harris USVs have also been used to update nautical charts along Florida's Gulf Coast for NOAA.

Silicon Sensing Systems Ltd.

www.siliconsensing.com

Based in Plymouth, UK, Silicon Sensing is a leader in high performance silicon MEMS gyroscopes, accelerometers and inertial measurement systems. The company launched a new generation of far more compact, lower power consumption and higher performance devices that have particular application in the tough ocean surface and subsurface environment. The company has supplied more than 40 million MEMS sensors to thousands of customers worldwide and has a heritage in inertial sensing that can be traced back to the birth of the gyroscope over 100 years ago. All its inertial sensors and systems are based on in-house, patented designs that are manufactured in the company's MEMS foundry.

Silicon Sensing has recently launched a number of new products particularly suited to the maritime environment. DMU41 is a new 9 degrees of freedom (DoF) inertial measurement unit (IMU). Measuring just 50x50x50mm and weighing 200g, its volume is 54% lower and weight 42% less than its predecessor. The new CRH03 is a high-performance/low-noise single axis gyroscope that consumes 30% less power than its predecessor and incorporates improvements in both micro electro-mechanical systems (MEMS) and electronics with new drive electronics and upgrades to the sensor head. Available in five rate ranges it is highly tolerant to external vibration and delivers excellent bias instability and angle random walk. For severe environments such as downhole drilling, the new CRS39A includes a move to a single board from two which has reduced mass by 40% allowing the device to be more easily installed in space-limited applications, such as the 25m cylinders typical to downhole drilling equipment.

XOCEAN

Founded in 2017, XOCEAN has done more than 100 projects, largely covering bathymetric surveys for hydrographic offices and site-investigation surveys, many for offshore wind companies, with its XO-450, a 4.5m-long diesel-electric USV with 18-day/1,512m-range, at 4 knots. It recently delivered a site investigation survey on Ørsted's Hornsea One Offshore Wind Farm, the world's biggest offshore wind farm. One of its XO-450s was launched and recovered from shore, transiting over 120km to the survey location to complete the survey in up to 1.9m max wave heights, providing high-resolution seabed data in 30m water depth, says XOCEAN. The firm has its sights on growth. Having doubled its staff to 82 over the last 12 months, it's on target to quadruple revenue in 2021 and is looking to grow its fleet from 14 USVs to 40 by the end of 2022.

Kongsberg Ferrotech

Kongsberg Ferrotech has joined forces with Equinor, SINTEF and Gassco to develop 3D printing technologies for subsea equipment repair and maintenance. The company has already developed a subsea robotic system, Nautilus, that can be used to carry out remotely operated composite repairs on subsea pipelines. Now the Kongsberg Ferrotech wants to add additive printing capability to these systems, using metallic media to repair defects, with support from the Research Council of Norway through the PETROMAKS 2 program. The company will use 3D printing to rebuild damaged metal structures – layer by layer – allowing permanent repairs and implementing new functionality as needed. Kongsberg Ferrotech's technology is based on versatile underwater robots that offers a complete toolbox for inspection and repair of equipment and their components in subsea environments. The inspection, maintenance and repair (IMR) robots are exceptional in the way they perform repairs and modifications in a dry environment while completely submerged, the firm says.

Deep water testing on the composite repair has been completed in the Trondheim Fjord in Norway and the technology is ready to be deployed on commercial applications and operations in the Southeast Asian market in Q3 2021, the company says.

Development of the 3D printing capability will run concurrently with an expectation a first application will be possible in 2022.

MARINE TECHNOLOGY TV
Watch the video @ bit.ly/3hUpaPn

Terradepth

Terradepth

A pair of ex-Navy Seals, Judson Kaufman and Joe Wolfel, are the co-founders and the co-CEOs of Terradepth, a company with an unmanned submersible system that is showing promise to deliver ocean data – economically – at scale. "The vision of the company is to create a complete, accurate and immersive virtual ocean experience, to connect humanity with what is the last frontier on earth," said Wolfel. "The mission then becomes: how do you drastically scale ocean data collection while simultaneously, radically improving the user data experience with that now scaled data? So that's the mission, two-fold – data collection, data interface."

Earlier this year Terradepth completed Phase 1 trials to put its system to the test on Lake Travis in Texas. "The focus really was just to prove to ourselves and to our stakeholders that the robot that we build could operate fully autonomously, end-to-end," said Kauffman. "Could the robot go into the water, see something, and then make a decision based on what it sees and about what it should do next, without contacting a human and saying, "hey, here's a picture of something. I don't know what it is, but standing by for further for their mission tasking."

The test was a success, as Kaufman explained: "So it was in-situ data processing at the edge decision-making, that's really what we proved."

The next step for the Terradepth team will be to prove the ability for that same robot to recharge its own batteries while deployed at sea, which was scheduled to trial in the summer of 2021.

iXblue

iXblue, based in Saint-Germain-en-Laye, France and led by Fabien Napolitano, is a global high-tech company employing 750, specializing in the design and manufacturing of advanced marine, autonomy and photonics technologies. Leveraging cutting-edge expertise in the fields of shipbuilding and robotics, iXblue designs autonomous maritime platforms that are increasingly efficient, economical and environmentally friendly.

DriX is an 8m unmanned surface vehicle (USV) developed and built in France by iXblue. The USV conducts hydrographic surveys in order to map the oceans, 85% of which remain unknown to this day. Equipped with sensors (radar, lidar, cameras, etc.) and its own artificial intelligence, DriX analyzes its environment, avoids obstacles and carries out its missions autonomously. The USV can autonomously map large areas in a reduced amount of time, contributing to the rapid improvement of the understanding of our planet's oceans. Lighter than traditional vessels, and particularly hydrodynamic, DriX helps reduce hydrographic surveys' environmental footprint. Compared to traditional survey vessels, DriX decreases fuel consumption and greenhouse gas emissions by a factor of 50 and reduces radiated noise for greater respect of marine wildlife.

OSIL

Ocean Scientific International Ltd. reported that one of its Giant Piston Corer systems has broken two records in scientific ocean drilling & coring on the International Ocean Discovery Program (IODP) Expedition 386. The expedition has been staged by the European Consortium for Ocean Research Drilling (ECORD) to gain an insight into the seismic history of the study region off the Japanese coast, and is supported by the Japan Agency for Marine-Earth Science and Technology (Jamstec). In May 2021 the team on board the RV Kaimei recorded an historic sampling water depth of 8,023m (26,322ft), and recovered a 37.74m core in a 40m barrel string, a 94.3% recovery rate and record deepest sub-sea level sample (from 8060.74 metres below sea level) from the Giant Piston Corer that was produced, installed and supported by OSIL.

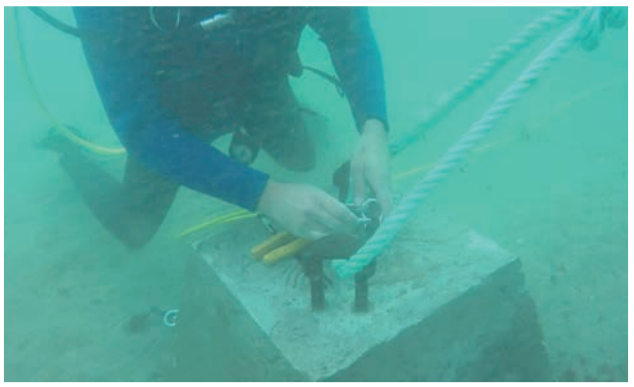
The Giant Piston Corer operates in a very similar manner to traditional gravity coring systems, with the exception of the piston itself, which plugs the core barrel once the corer has been fully deployed into the sediment and, in combination with the core catcher, holds the sample more securely inside the core liner than in a regular gravity corer system and prevents sediment slump. The piston also reduces internal friction within the core liner and prevents clumping of the sample. This ensures that the OSIL Piston Corer systems deliver a more well-defined sediment sample to the operator.

Piston Corers are one of the most important basic tools used in the study of marine sediments. OSIL offers customisable systems (including Launch and Recovery Systems and Winches) from 4m to 60m in length.


OSIL

Sofar Ocean Technologies

www.sofarocean.com



Based in San Francisco, CA, Sofar's Spotters and Smart Mooring devices are designed to bring real-time, accurate and planet-scale coverage of ocean intelligence across all five of the world's oceans. Led by Tim Janssen with 45 employees, Sofar has created global network of IoT-enabled Spotter buoys primed with Smart Mooring subsea capabilities, representing the largest source of real-time ocean intelligence available to governments, companies and scientists. Together, Sofar's Spotters and Smart Mooring systems are powering Aqualink, the largest coral reef monitoring system in the world. The Aqualink conservation project is critical to protecting more than 200 sensitive coral reef sites globally, and Sofar expects to deploy across all 200 sites by the end of 2021. Sofar also launched a non-commercial license program in June 2021, making the data gathered from its Spotter and Smart Mooring devices freely available to scientists for research and educational purposes.

Like the innovation trend of low-cost nano-satellites with modular payload capabilities dominating space, the Sofar team is playing out a similar concept in the ocean. Sofar now maintains 100% global coverage across all five oceans, with thousands of sensors deployed at any given time. With Sofar's Spotter and Smart Mooring devices, scientists and ocean industries can quickly configure sensor payloads to collect real-time physical, biological and chemical data from the ocean at very low cost.

Balmoral

www.balmoraloffshore.com

MARINE TECHNOLOGY TV

Watch the video @ bit.ly/3EEPx5N

Established in 1980, Balmoral today is 350-employees strong and is led by Jim Milne, President and CEO. Balmoral works in the design, development and delivery of buoyancy, protection and insulation products for the offshore energy sector.

The oil and gas industry has been likened to the space race in its never-ending quest for enhanced products, progressive operating procedures and materials development to improve performance and maximize returns. This philosophy is now being adopted by the renewables sector, particularly in offshore wind. Balmoral invests in R&D and the company continues to lead the subsea buoyancy and elastomer solutions market with industry-leading product and materials development. The following products are provided to the offshore wind sector: Cable protection systems (CPS); Surface/subsurface buoyancy; Bend stiffeners/restrictors; Flexible and retrofit J-tubes Product solutions for offshore oil and gas; Drilling/distributed riser buoyancy; Thermal insulation; ROV/AUV buoyancy; Cable protection; Bend restrictors/stiffeners; and Riser protection guards. Many of Balmoral's SURF-related products are accredited by Bureau Veritas to API 17L standards.

Developed for the offshore wind sector, Balmoral FibreFlex cable protection technology utilizes a novel composite of polyurethane and polyester fibers to create a braided hose style system for the protection of subsea fixed wind power cables. Cable protection systems were designed to protect the cable during installation with little to no protection made available over the operational lifetime. Ultimately, this significantly increased the OPEX costs of offshore windfarms by increasing service requirements and equipment replacement on failure. The technology objectives of Balmoral FibreFlex include: increasing cable stiffness; managing cable curvature over life of field operations; avoiding introducing a thermal barrier to the cable; improving axial and torsional stiffness, scour erosion and burial-point migration; creeping and stressing relaxation response controlled and minimized; prevention of long-term component failure; and corrosion-resistance.

Blueprint Lab

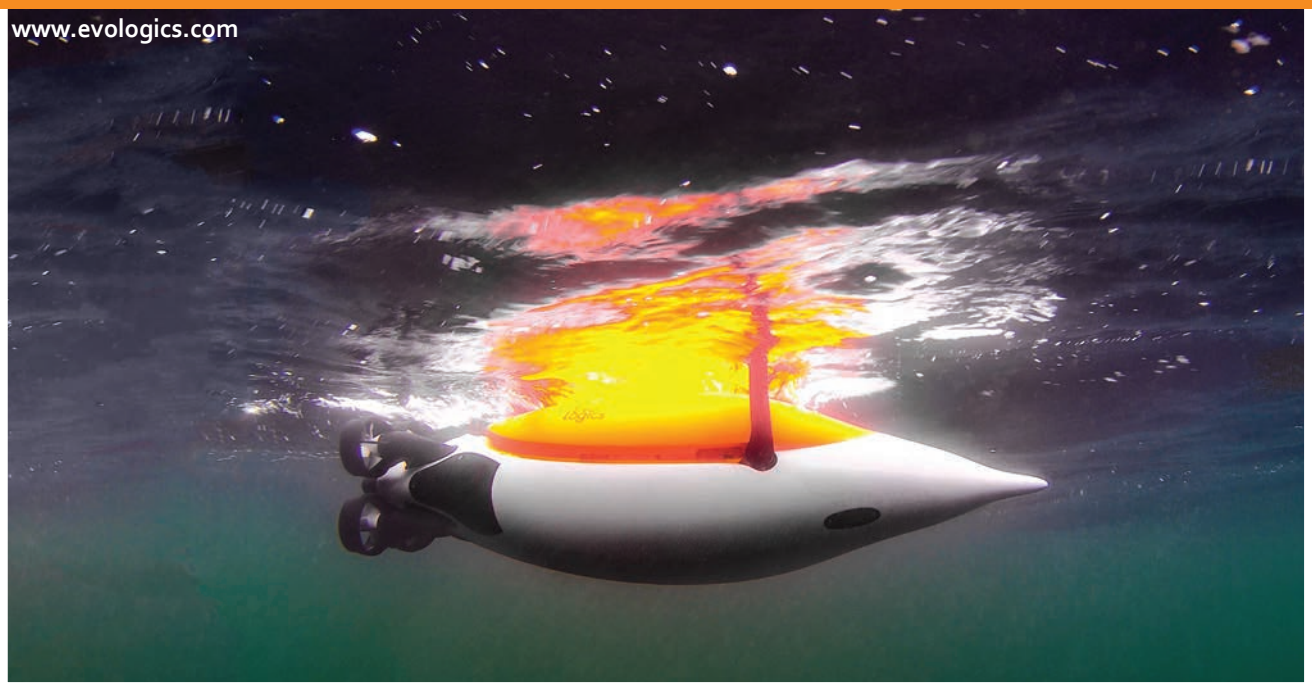
www.blueprintlab.com

Based in Sydney, Australia, and led by Paul Phillips, President & CEO Blueprint Lab's vision shared amongst its 25 employees is to extend human reach in places humans cannot go. To do this, it creates advanced manipulator systems for harsh environments, predominantly subsea but also land and nuclear environments. It is also known for its flagship manipulators, the Reach Alpha 5 and the Reach Bravo 7, each providing a stronger, faster, lighter and more dexterous robotic arm capability for their class of vehicle. It manufactures rotators, rotating grabbers, and other high-performance subsea electric actuators, too.

In the last six months, significant improvements have been made to the Reach Bravo manipulator range. Two notable examples are the release of the High-Force Electric Cutter designed to cut 1-in. conduit cable, and a new depth rating of 450m for the entire Bravo range. To improve suitability for offshore clients, the Reach Bravo Spares Package and Operator Tool Kit have also been released. The Reach Bravo, making use of these improvements, continues to be a significant subsea tool for offshore energy and military operators. The Bravo 7, flagship of the range, is a robust, electric 7-function manipulator designed for Inspection-Class ROVs. With 10-20kg lift capacity and almost 1m of reach, this dexterous manipulator makes complex tasks possible while also having a low logistics footprint for easy retrofitting to existing vehicles. The Reach Bravo range of manipulators are designed for control with Blueprint Lab master arm controller technology.

EvoLogics

www.evologics.com



EvoLogics GmbH is a German-based high-tech enterprise, founded in 2000 by a group of scientists and R&D experts aimed to develop key technologies for the maritime and offshore industries through interdisciplinary cooperation between engineering and life sciences. EvoLogics GmbH designs and manufactures underwater information systems and novel robotic solutions based on bionic concepts, combining cutting edge engineering with the best ideas found in nature. EvoLogics provides cutting-edge underwater communication and positioning systems, as well as novel robotic solutions. The company's spread-spectrum technology allows it to deliver optimal results for various subsea applications. EvoLogics products include several series of underwater acoustic modems, underwater acoustic positioning systems (USBL, LBL), and the Sonobot surface vehicle for surveying and monitoring.

EvoLogics aims to offer solutions for multiple underwater communication, positioning, navigation and monitoring applications. EvoLogics' developments are based on the patented S2C (Sweep Spread Carrier) technology – the acoustic telemetry that provides an independent bidirectional data link along with positioning, broadcasting and networking capabilities. S2C devices can simultaneously facilitate telemetry and navigation of unmanned underwater vehicles. They enable retrieving information from various sensors and allow controlling complex processes by seamlessly combining communication with highly accurate positioning. Moreover, EvoLogics caters to the needs of scientists, developers and commercial customers with a series of underwater acoustic devices and software tools that offer an open development and testing framework, providing endless opportunities for new implementations.

S2C systems have been designed for operations in harsh underwater environments and enhanced with special algorithms for signal processing and data management. The company's extensive experience with sensor integration allows it to provide customers with turn-key solutions ranging from initial deployment up to recovering the equipment.

EvoLogics' robotic solutions include the SONOBOT 5 uncrewed surface vehicle. The USV is a fast, compact and robust platform for planning and executing bathymetric and side-scan sonar surveys that can deliver accurate geo-referenced bathymetry and high-quality imagery with minimum transport, launch and recovery efforts.

The company recently introduced uncrewed underwater vehicles with bionic designs, inspired by real-nature conuterparts. Envisioned as sensor carriers for automated monitoring missions, these include the Manta Ray, Poggy and PingGuin robots that are currently undergoing further development for self-coordinating swarm operation.

Turn to page 21 for more informaton on EvoLogics

RBR

www.rbr-global.com

Since 1973, RBR has been designing and manufacturing oceanographic instruments in Ottawa, Canada, and has steadily expanded globally. From the ocean abyss to the polar ice cap; lakes, rivers and coastal zones, RBR's sensors and loggers track water parameters including conductivity, temperature, depth, salinity, dissolved gases, pH, and many others.

In the first part of 2021, RBR launhed the new RBRquartz3 Q|plus pressure logger to meet the demands for high-accuracy, long-term measurements of sea level, tidal, and wave dynamics by coastal oceanographers worldwide. At the heart of the RBRquartz3 Q|plus is an integrated Paroscientific Digiquartz pressure gauge for best-in-class initial accuracy, resolution, and low-drift performance. Intended for long-term autonomous or real-time observations, the RBRquartz3 Q|plus has high stability and can resolve water level changes as small as 100ppb at 16Hz sampling rate - for example, at 50m depth that would be a resolution of ±0.005mm. In combination with RBR's Ruskin software, the end-user has the availability of flexible measurement schedules, burst sampling, and configurable integration times to allow for a broad range of applications in coastal dynamics.

RBR continued this theme of innovation in 2021 when it won funding from Canada's Ocean Supercluster's Accelerated Ocean Solutions Program (AOSP) for a new project to develop integrated biogeochemical (BGC) sensors for autonomous ocean platforms in collaboration with Canada's Department of Fisheries and Oceans (DFO) and Dalhousie University's Department of Oceanography (DAL). In this AOSP project, RBR is undertaking the technology development and productization of the new BGC sensors while collaborators at DFO and DAL provide scientific and technical resources for the testing, operation, and subsequent data analysis of BGC sensors in the lab and through ocean deployments.

Big is good. <1m is better.

Over the last couple of decades, AUVs have become fully established work horses of ocean mapping and surveillance, but there's still room for innovation. **Elaine Maslin** ***looks at activity in the sub-1m collaborative drone market.***

New breeds of AUV are on their way. Some are bigger, but there's also a host of companies developing small (<1m), lower-cost AUVs to use in swarms, allowing either faster aerial coverage of the seabed or faster more three-dimensional sampling of bodies of water in shorter periods of time.

It's been a pipe dream for some time, and some have fallen by the wayside trying to make it happen. Despite having won U.S. Navy contracts to support its SwarmDiver development, Australian firm Aquabotix, quietly went into liquidation in December 2020 having struggled to get funding to continue its work (it had gone down a stock market listing route, leaving it open to more impatient investors).

ecoSUB Robotics

But others are now seeing success. In November last year, UK-based ecoSUB Robotics started selling its micro AUVs to customers and there are now 50-60 out in the wild with various payloads, says Terry Sloane, managing director at parent company Planet Ocean. Customers spread from Africa to Japan include Plymouth Marine Laboratory and Dalhousie University.

The company was set up in 2015 and has had Innovate UK and Defence Science and Technology Laboratory (UK MOD) funding and has collaborated with the Marine Autonomous Robotics Systems Group at the UK's National Oceanography Centre.

Its now commercial ecoSUBμ5 Micro-AUV is 92cm long,

Photo courtesy ecoSUB

4 kg in air, rated to 500 m depth, and able to operate for 12-20 hours (depending on battery type) at 1 m/s. The slightly larger ecoSUBm5 Small-AUV is 1m long, weighing 12 kg, rated at 500 m and 1200 m depth, and able to operate for 18-30 hours at 1 m/s.

ecoSUBs work together largely through acoustic positioning, using GPS at the surface and acoustics underwater (with modems developed by the University of Newscastle) in an inverted long baseline array (LBL) type arrangement. Vehicles at the surface (with a GPS signal), broadcast their position to the underwater vehicles, which triangulate their positions relative to the surface position and feeds that information into onboard dead reckoning. ecoSUB has now also added Water Linked Doppler velocity logs (DVLs), to further improve positioning accuracy, making them suitable for operations where greater accuracy is required, such as mine counter measures using side scan sonar, says Sloane.

"We're able to put 10 ecoSUBS in the water doing a lawn mower survey at five different depths over two, three, four hours and really get a picture of that chunk of water in three dimensions," he says. "That's attractive to science, but also oil and gas, when looking at process water or a leak event or oil spill dispersant. They're also affordable," noting that "at £10,000 a pop for a Micro-AUV" organizations can affordably put 10 or more in the water.

The company has also been exploring alternative surface nodes, such as USVs. Having already worked with a C-Worker 6 to trial ecoSUB deployment, and with AutoNauts, to act as a surface node, it's now working on Autonauts carrying multiple ecoSUBs to a specific location or carrying them and deploying them when asked, as well as being a surface node and communications gateway.

The next step is another Innovate UK project, as yet unannounced, which will start bringing artificial intelligence to the vehicles (AI), so that the vehicles can "shoal" independently, says Sloane. "The benefit of a shoal is that, as each vehicle understands how it's being effected by the environment, as a group they can figure out the best way to approach the mission."

EvoLogics

While EvoLogics' main products are underwater communications and positioning, the company has also been developing its own vehicles and now also navigation software, so that they can work together in swarms, react to changing conditions and communicate with a main control center. These capabilities are being combined into vehicles like its PingGuin, a penguin shape-vehicle, but will also be able to

be used with other vehicles it's launching, as well as others' vehicles, says Francisco Bustamante, Sr. Operations Manager, EvoLogics.

"Having more vehicles means you can cover a larger area, but instead of one larger vehicle you can have smaller more compact and perhaps more general vehicles that can be adapted for different missions using these behaviours and being more flexible," he says, and allowing economies of scale in production.

The core design of the PingGuin is something EvoLogics has been working on for years, following one of the co-founders' research into penguin locomotion and how efficient the animals at swimming through water. The vehicle is just under 1m long, max 45cm diameter, weighs under 25kg with 3 kg payload, and can travel at up to 5kts. EvoLogics has operated swarms of up to five of them to date and the vehicle is set for an official commercial launch in Q1 next year.

"We have achieved a quite successful tests of swarm operations," says Bustamante, "multiple vehicles able to communicate amongst themselves and coordinate. Even having a heterogenous combination of vehicles, with a surface vehicle as a command centre and interface between underwater and air, and GPS to georeference activities. This vehicle can be the master of a swarm and they can follow the surface vehicle in formation, as well."

PingGuin is involved in thyssenkrupp Marine Systems' Modifiable Underwater Mothership (MUM) project, the MUM2navigate part of which will see the PingGuin accompany the MUM vehicle's mission as an intelligent swarm, forming an adaptive communications network. The latest phase of this project is to create a docking system to accommodate 5-6 of these vehicles, deploying and recovering them as necessary for recharging and data exchange. The project has 13.2 million funding from the German Federal Ministry for Economic Affairs and Energy.

Another low-drag penguin-shaped vehicle has been developed by EvoLogics as a project with Helmholtz-Zentrum Heroen research institute in Germany. This one, the Quadrion, has been designed to work in swarms to collect data in ocean eddies as part of MOSES (Modular Observation Solutions for Earth System) – a novel observing system. It will carry a payload of fast Sea & Sun sensors to measure temperature, pressure, oxygen, conductivity and fluorescence, and move at up to 5 m/sec for 6-8 hours and down to 150 m. As a swarm, the vehicles will scan a body of water layer by layer, collecting geo-referenced data on the physical

TDSX developed 4a in-diameter, 1m-long, 12 kg in air, 500 m depth man-portable Barracuda AUV.
Photo courtesy Tampa Deep Sea Explorers.

Evologics Quadroin penguin inspired underwater vehicle. *Image courtesy Hereon - Florian Büttner.*

water parameters at different depth horizons. Data is to be transmitted to Hereon over a base station at the surface. The Quadroin project has completed and the vehicle can go into production and this is expected in Q1 next year, says Bustamante. Again, five vehicles have been trialled together.

Tampa Deep Sea Xplorers

Florida-based Tampa Deep Sea Xplorers (TDSX) was set up to enter the Shell Ocean Xprize and despite not winning the main prize it was a semi-finalist in the overall competition, second place in the National Oceanic and Atmospheric Administration (NOAA) challenge (a vehicle that could trace biological or chemical signals to their source under water) and came away with a $200,000 bonus prize. It's cash that's been used to continue the vehicle development – resulting in the 4 in-diameter, 1m-long, 12 kg in air, 500 m depth man-portable Barracuda AUV. It's also had a further grant from NOAA to develop a compact underwater lidar system to go on the AUV or other man-portable AUVs.

The group is run by Ed Larson, a former deep sea diver in the Gulf of Mexico who moved into project management, but has always had a passion for robots, especially those underwater. He was part of Atlanta Hobby Robot Club and in the 1990s he had an idea to development a deep-water vehicle. When the Shell Ocean Xprize was launched, he decided to go for it and the team had great help from the Tampa Hackerspace, where Larson is a member and got access to wood and metal working facilities, 26 willing helpers and a wider pool of 200 experts from programmers and metal workers.

"What came out of the Xprize was that we saw the need for hand portable, hand launchable systems," says Larson. "The deepwater ones (for Xprize) were about 90lb and that's really not easily transportable. And we see that commercially the need for the mini AUV is greater than large ones – there are larger ones already and they require crew and a crane and that requires a boat and you're starting to get into real money."

The Barracuda has been designed to be easy to move around and then operate in pseudo swarms, to increase data collection speed, says Larson. Pseudo swarm means that multiple systems are deployed and programmed to go to way points. Then they have obstacle detection and avoidance on board using the visual aids and an Nvidia GPU, so if two are about to collide they're programmed to avoid each other. The GPU will also support image recognition for search, find or follow missions, he says.

The vehicle itself is easy to transport, says Larson. "It breaks down into a duffle bag, and can be assembled in minutes," he says. The vehicle has been tested in shallow fresh water and salt water, including the obstacle avoidance, and to tested to 500 psi (300 m).

Hydromea

Swiss firm Hydromea has developed Vertex, a small AUV for swarm operations to gather 3D environmental water column data at 10 to 100 times less than traditional methods.

"The only way to get temporally consistent snapshots across a water volume is to deploy as many sensors in parallel as possible," says the company. "Our drones are designed to carry these sensors to where they need to be and efficiently scan a body of water simultaneously collecting thousands of data points."

The vehicle, which is currently in development (its first dive was seven years ago and it's been tested under ice), is 70 cm-long and weighs about. It uses an LF RF system for communications and an acoustic system for localisation within the swarm, similar to an LBL concept and all developed by Hydromea. "One Vertex is either constantly tracking the swarm from the surface or coming up to pick up the GPS signal and to recalibrate the entire swarm down," says Hydromea. But it's likely that the technology developed for swarm operations with Vertex will first see commercial use in another of Hydromea's development; ExRay, a small inspection ROV that's initially being developed for flooded, confined space inspections before being deployed in open water, initially down to 400 m.

Bedrock Ocean Exploration

www.bedrockocean.com

Brooklyn, New York-based Bedrock Ocean Exploration (which is billed as a public benefit corporation) in August announced it had launched a "full service" ocean survey offering, using "fleets" of its own man-portable AUV platform and Mosaic, a survey cloud-based (subscription-based) data platform – to solve data gathering and processing/use problems.

The firm, founded in 2019 by CEO Anthony DiMare and former SpaceX and submarine engineer CTO Charles Chiau. Before co-founding Bedrock, DiMare co-founded Nautilus Labs, a technology company focused on maritime transportation. Before that he was a mechanical engineer at various tech start-up companies.

Bedrock, which says it's offering technology that can speed up the time it takes to get seabed data by a factor of 10, raised $8 million in a seed round from Eniac Ventures, Primary Venture Partners, Quiet Capital and R7 in March

Bedrock's goal is a commercial service, but also to provide a free public map of our oceans" and as part of this they've started ingesting NOAA National Centers for Environmental Information Data Center for Digital Bathymetry's survey database.

Little information is available about the firm's self-designed AUV, but visuals show a DVL and DiMare has said it can carry MBES, side scan sonar, magnetometer and sub-bottom profiler and makes operations easier because they can be shipped or flown more easily, and don't need to be in containers or deployed by ships, like traditional survey AUVs. An August CNBC article shared by Bedrock says that the vehicles run for 12- or 24-hour missions, typically at a speed of 2 to 3 knots (or less than 5 mph) to conduct surveys up to 300 meters in depth. It also says the firm currently has just one vehicle, but plans to build and send fleets of them into the water and plans to double its staffing from 25 now to 50 in the next year. In June the firm took on Jim Snyder, formerly Field Engineering Manager at OceanServer, an L3Harris business.

BIRNS

www.birns.com

Established in 1954, BIRNS is a global leader in the design and manufacturing of high-performance connectors, penetrators, cable assemblies and lighting systems for deep ocean use. BIRNS solutions are found worldwide on submarines and submersibles, diving bells and decompression chambers; ROVs, AUVs and UUVs; and on everything from massive manned systems to photonics masts and intricate towed arrays. BIRNS interconnect products deliver superior performance: faster data transfer for better telemetry and communications, and safer, more reliable power distribution in severely demanding environments, and its lighting systems illuminate the depths for challenging applications worldwide.

BIRNS is deeply committed to quality—with a quality management system certified to ISO 9001:2015 by DNV GL. Its Oxnard, CA facility is certified by the US Navy's Submarine Maintenance Engineering, Planning and Procurement (SUBMEPP) division to NAVSEA S9320-AM-PRO-020, and the company is DD-2345-certified and DOS/DDTC/ITAR registered.

The 6km-rated BIRNS Millennium connector series has featured some major breakthroughs in technology and innovation recently, including a range of ground-breaking RF performance characteristics. These pressure-rated, low-loss RF (coax) connectors are ideal for GPS-frequency systems up to SHF (centimeter wave) in IEEE bands S and C, and can be hybridized with electrical contacts and/or optical ferrules. BIRNS new 1C and 1V series assemblies offer low insertion loss even up to GPS frequencies, while BIRNS 1B units are capable of 18HGz and beyond. BIRNS Millennium RF connectors are the most advanced and best-performing units on the market, with proprietary new RF technology providing low insertion loss, high frequency capability, open face pressure resistance, and 50Ω and 75Ω configurations. BIRNS exclusive RF contacts even withstand open face pressure to depths of 1400m.

The company launched the 1V series in 2021, with a compact 75Ω RF contact in a 50Ω footprint. It's ideal for HD/SD video with signal frequencies to 3GHz, for shortwave antennas, or for low-power RF needing minimal signal attenuation. And, due to its extraordinarily compact size, the 1V fits into many BIRNS coax pin configurations. BIRNS 1C (50Ω) and 1V (75Ω) contacts can be combined in the same connector, offering a range of flexible, powerful new options in a small space.

In 2020, BIRNS developed exclusive deep submergence cable constructed for Cat 8.2 use, and now leads the industry with deep submergence cable assemblies with data transfer rates of 9.4+/- 0.1 Gigabits per second. Performance testing proved that data consistently transmitted at this rate over the entire range of pressures from 0 to 8700 PSI/600 bar (6000m equivalent depth).

Greensea Systems, Inc.

Richmond, VT-based Greensea Systems under the leadership of Ben Kinnaman, founder and CEO, continues on a strong growth trajectory and with 45 employees now has become a global leader in advanced robotic systems for high-level tasking, interoperability, and intervention. Greensea's OPENSEA operating platform provides a fully-distributed, open software framework for highly integrated systems across all brands of sensors, devices, and equipment while cutting-edge technologies for navigation and autonomy elevate system intelligence. One operator interface, Workspace, fuses system data into a comprehensive command and control center for streamlined workflow and improved productivity.

Greensea's core technology, OPENSEA, is designed to reduce cost, reduce risk, and accelerate technology insertion within the marine industry. Its library-based, open architecture is fully distributed and includes all of the interfaces and utilities essential to robotics and the unmanned systems community including navigation, autonomy, and mission planning. New vehicles, equipment, and devices are easily integrated, minimizing risk and expense, by leveraging the robust, OPENSEA library which confines new software to small, independent applications that are separate from proven, robust software. Deriving from the OPENSEA library, the OPENSEA application suite provides hundreds of distributed independent applications that work together as building blocks for a complete system. These applications communicate with each other through the OPENSEA network and provide discrete capabilities required to integrate a system that is scalable, flexible, and severable.

- **Autonomy and Vehicle Control:** surface, subsea, and terrestrial vehicle control & autonomy; payload control and system management; manipulator and reverse kinematics; multi-vehicle coordination for vehicle interoperability; target tracking; homing and docking; and obstacle avoidance.
- **Human-Machine Interface:** Intuitive and easy-to-learn operator interface; multi-operator environment; remote workstations; and multi-asset tracking and communication.
- **Navigation and localization:** navigation and localization within complex or ferrous environments; Proprietary Kalman-based estimation; SWaP-C optimized navigation; and customized navigation for specific platforms and/or applications.

EdgeTech

www.edgetech.com

Based in W. Wareham, MA and led by R. Jablonski, President and CEO, EdgeTech is a manufacturer 100-employees strong of underwater technology solutions. The company is known worldwide for its high-quality products which include: side scan sonars, sub-bottom profilers, bathymetry systems, AUV, USV and ROV-based sonar systems, combined and customized solutions. In addition to the full line of underwater survey products, EdgeTech provides transponder beacons, deep sea acoustic releases, shallow water and long life acoustic releases, ropeless fishing systems and customized underwater acoustic command and control systems and USBL systems.

EdgeTech has introduced a number of new products over the past 12 months including: A 540/850kHz frequency windfarm version of the 4205 side scan sonar, a new 2050-DSS combined tri-frequency side scan sonar and high resolution sub-bottom profiling system, two new 3400-OTS (over the side) pole mount sub-bottom profilers, new variants of the 2205 AUV/USV-based sonars and new configurations for the Ropeless Fishing Systems. Additionally, in the next few months the company will release a newer lighter weight version of our shallow water wide swath bathymetry/side scan sonar, the 6205s2. The new 6205s2 produces real time, high resolution, side scan imagery and three-dimensional maps of the seafloor. Building on the 3400 Sub-bottom profiler solution EdgeTech has developed a new group of unique over-the-side (OTS) pole-mounted sub-bottom profiling systems. The new EdgeTech 3400 OTS provides users many enhancements to current sub-bottom profiler systems by offering multiple transducer configurations and PVDF receivers. The system generates high resolution images of the sub-bottom stratigraphy in oceans, lakes, and rivers and provides

The EdgeTech 2050-DSS is the latest in combined side scan sonar/sub-bottom profiler systems. This is especially useful where high resolution sub-bottom profiler data, that requires the system to be towed near the seabed, is required. The 2050-DSS is also a tri-frequency side scan sonar system, where any two, operator selectable, frequencies can be operated simultaneously. The system can be provided with either a 120, 410 & 850 kHz towfish, or a 230, 540 & 850 kHz towfish. Both towfish options are equipped with a 2-16 kHz sub-bottom profiler that utilizes a PVDF panel receive hydrophone. Use of an area based receive hydrophone panel provides improved beam patterns and therefore improved signal to noise ratios, which in turn means cleaner data. EdgeTech's Ropeless Fishing System with embedded acoustic release technology was developed to eliminate vertical lines connecting a surface buoy to bottom fishing gear. Over the past year the system has expanded to include different trap configurations for various types and depths of fishing. Additionally, the Trap Tracker app was launched and can be easily used on any phone or table.

HydroComp, Inc.

www.hydrocompinc.com

HydroComp, Inc. based in Durham, NH was established in 1984 to provide engineering tools to develop marine vehicles—and their propellers—more efficiently and responsibly. The Vessel-Propulsor-Drive system model is the foundation of optimized performance via the industry's gold-standard tool for Speed/Power Prediction, Operational Energy Analysis, and Propulsion System Sizing. HydroComp's flagship product NavCad, and now PropElements, provides operators and designers with tools to determine their carbon footprint, identify fuel-efficient systems, and in the mitigation of underwater radiated noise. HydroComp Propeller Tools, PropCad and PropExpert, offer commercial systems for propeller design for manufacture and propeller application sizing.

A recent focused development for HydroComp's NavCad software has delivered new capabilities for the prediction of drag and propulsor interaction for body-of-revolution "torpedo-like" submersibles. On the propulsion side, a new electric motor module for NavCad 2021 is nearing completion. UV thruster and propeller component design has been a particular focus of new development for HydroComp PropElements. This includes significant work into the prediction of hydroacoustic metrics for noise sensitive applications. Both tools also now provide UV product developers with a convenient workflow from design to CFD analysis, as new collaborations with Orca3D, Simerics, and Numeca leverage.

Sonardyne

Collaborative Autonomy, Rising up the Ranks.

By Aidan Thorn

Underwater survey or data gathering operations using autonomous or unmanned underwater vehicles (AUV/UUVs) is now an established practice. These vehicles are routinely used in operations around the world across oil and gas through defense and ocean science. A trend that is emerging is for them to cover more ground – or ocean volume – faster and remotely, whether that's to detect mines or gather research data. This trend creates several challenges that many have been trying to address for a number of years. Working in collaboration – or as swarms – to be able to gather more data or respond to local events and adapt the mission from remote operations centers (ROCs) poses challenges. Escalate that to collaborative behaviour between heterogenous groups of robots, on and beneath the surface, and the challenges increase.

With those challenges come a new set of solutions. Using Sonardyne's positioning and communications technologies, companies like Blue Ocean Seismic Services are working to create swarms of ocean bottom seismic (OBS) UUVs that could disrupt the marine seismic acquisition industry by no longer requiring an ROV to place OBS nodes. Their prototype recently passed its sea trials in Perth.

Terradepth in the USA has developed a robotic platform that's both unmanned surface vehicle (USV) and AUV and can work collaboratively in fleets of two or more with vehicles switching roles. The topside UxVs provides sea surface data collection, communications and navigation assistance, while the submerged UxVs conducts its submerged mission. The UxVs switch roles once the submerged vehicle's energy is expended to a predetermined level. Once surfaced, the vehicle employs a hybrid system of rechargeable lithium batteries and an air-dependent power plant.

The Shell Ocean Discovery XPrize spurred a lot of innovation in this area, with entrants like Team Tao from Newcastle, UK, using a swarm of subsea drones deployed from a USV to target features of interest, supported with Sonardyne systems. The system even included an aerial drone for air support. There are also now multiple commercially available examples of USVs collaborating with UUVs. For example, Fugro controlling their Blue Volta ROV from their Blue Essence USV and Ocean Infinity's Armada fleet which will see USVs deploying UUVs, all remotely controlled from ROCs – and, again, using Sonardyne for underwater positioning and communications.

And the boundaries continue to be pushed. Under an Innovate UK-funded project, awarded earlier this year, ecoSUB Robotics will be working with Sonardyne to integrate into a

HydroSurv's REAV-40

Photo courtesy HydroSurv

heterogeneous fleet of robots, including larger AUVs and a HydroSurv USV.

The UK's Ministry of Defense has funded demonstrator programs for industry and academia to showcase collaborative robot capabilities, like the geo-intelligence gathering Marine Autonomous Systems in Support of Maritime Observations missions and the 2016 Unmanned Warrior exercise. Earlier this year, the Royal Navy's First Sea Lord Admiral Sir Tony Radakin announced that they will be replacing their minesweepers with unmanned and autonomous systems, citing the time, safety and cost advantages.

It's clear that truly autonomous missions with multiple robotic platforms are the future. To get there, it is important to think not just about the robots, but the whole system and infrastructure that will be needed. That spans from ROCs through to launch and recovery methodologies, marine and autonomous systems regulations through to in-mission recharging, data relay and re-tasking in a communications hostile environment. For operations in defence – or where the data being gathered might be commercially sensitive there's also a need to ensure that vehicles can communicate securely and even interact with other networks of vehicles.

Sonardyne is addressing many of these challenges. Its Mini-Ranger 2 Ultra-Short Baseline (USBL) system is already supporting multi-AUV missions. It's able to track and communicate with 10 AUVs at a time and we're currently working on technologies to extend that to up to 200. That's as many as any one operator has right now. Sonardyne is also collaborating with developers to enable the complete marine autonomous system. It's been working with partners on subsea docking capabilities and industry leading underwater navigation and positioning and high bandwidth communications.

Working with Thales UK and Defence Science and Technology Laboratory (Dstl) we are going to develop Phorcys, an open standard for secure acoustic communications, enabling collaboration and interoperability between uncrewed fleets.

However, this is just one part of the collaborative autonomy puzzle. For collaborative autonomy to work we need to see the triple-helix of industry developers and users, academia and governments working collaboratively themselves to enable a regulatory framework, an infrastructure and even more use cases to drive this innovation forward.

Hydromea

https://hydromea.com

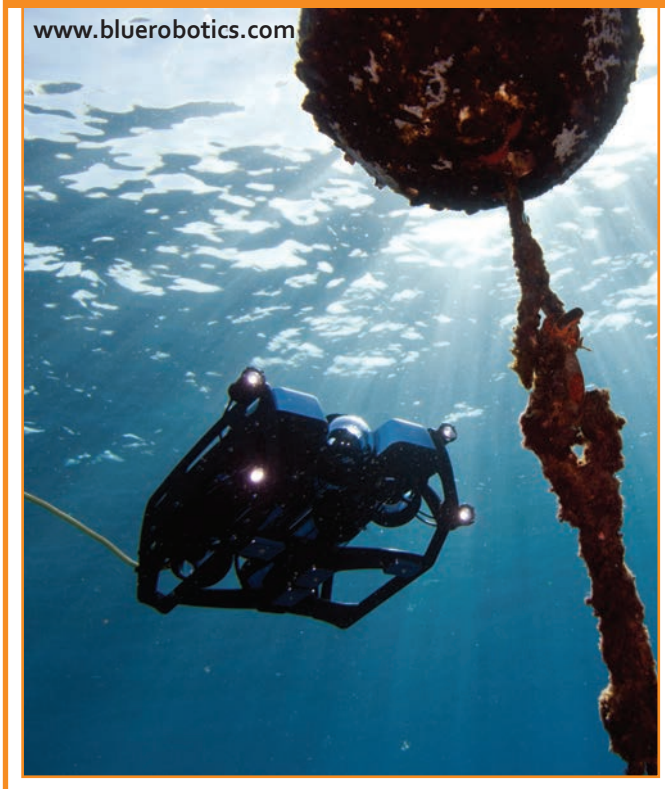
Based in Renens, Switzerland and led by Igor Martin, Hydromea is a 10-person company designed to disrupt the underwater inspection and monitoring market with its miniaturized technology. The company's products are designed to reduce the cost of inspections (up to 90%), eliminate safety risks associated with people entering into confined spaces for inspections, and provide an ad-hoc inspection tool for emergencies and reduce CO2 emissions in the offshore energy. Hydromea is an emerging leader in the free-space-optics (FSO) domain and it lead the development of the industry standard within Subsea Wireless Industry Group (SWiG).

Hydromea's technology can be deployed at 6,000m depth and can send up to 10Mbps, enabling real-time HD video stream within a distance of 50-100m.

Over the last 12 months it has commercially launched its patent-pending optical wireless modem LUMA X that is capable of sending up to 10Mpbs across 50-100m at the depths down to 6,000m, all in a compact form factor the size of a soda can and titanium housing. This is the first step in distributed network systems underwater. Also, it has tested its prototype of what it calls the world's first wireless underwater drone. The prototype was showcased in its own pool in May 2021. This project is co-funded by the Net Zero Technology Center and sponsored by Total Energies. The drone can be controlled and send HD video data in real time back to the pilot without any tether attached. The drone is initially going to be deployed in confined flooded spaces. It features our patented thruster technology (DiskDrive), has a number of autonomous features built-in and has a slim profile for accessing tight spaces.

Blue Robotics

www.bluerobotics.com



Since its founding in 2014, Blue Robotics' mission has been to provide low-cost, high-quality components for marine robotics. Starting with the T100 and T200 Thrusters, its product line has now grown to over 250 enabling components.

Led by Rustom Jehangir, Torrance, CA-based Blue Robotics has rapidly grown to 50 employees with a product line spanning a wide range of technology areas with a common theme of cost-consciousness and innovative design. Its core technology is its patented thruster design, which is compact, inherently pressure tolerant, and more affordable than other thrusters on the market. In addition to its thrusters, Blue Robotics have actuators, watertight enclosures, buoyancy foam, sensors, lights, cables, control system electronics, sonars, and our flagship product, the BlueROV2 subsea vehicle. The BlueROV2 is designed to be the most affordable and capable mini-ROV in the world, and it has several expansion options including additional thrusters for 6-degree-of-freedom maneuvering capability, a tether spool, and a low-cost single-function manipulator. In the last year, Blue Robotics added the WetLink Penetrator, a game-changing product for creating high-pressure cable pass throughs for subsea applications. It was proven to have extreme reliability by subjecting thousands of sample articles to harsh environment conditions and pressure cycling.

South Bay Cable

www.southbaycable.com

Established in 1957 with corporate headquarters located in Idyllwild, California along with additional production facilities in Temecula, California. South Bay Cable was founded to provide purpose-built cables, specific to customer requirements. South Bay Cable continues to focus on highly engineered cables for use in a wide range of highly dynamic applications. It designs, tests and produces Electro Optical Mechanical Cables withstanding the harshest of environments, supporting a wide range of ocean applications; from Towed Arrays to Side Scan Sonar's, ROV Tethers and Umbilical's to Seismic Lead-in's and MUX BOP Control cables and a host of other underwater uses. From the drawing of the copper rod to the jacketing of the finished cable, South Bay Cable has the production capabilities necessary to perform nearly all manufacturing operations in-house. As technology continues to advance, the push is on to build deeper systems, which require longer cables. At greater depths the cable weight becomes a challenge, and many of these longer cables are now designed with high strength light weight synthetic materials. Fiber optics are often incorporated within our cable designs. Fiber optics eliminate the needless copper weights of coaxial and traditional communication lines. These advancements along with the improvements in materials and manufacturing techniques allow South Bay to design and build cables for use to full ocean depths.

Huntington Ingalls Industries,
Technical Solutions, Unmanned Systems business group

tsd.huntingtoningalls.com/unmanned

Led by Duane Fotheringham, president of the Unmanned Systems business group in Huntington Ingalls Industries's (HII) Technical Solutions division, Unmanned Systems, a business group 360 employees strong, creates advanced unmanned maritime solutions for defense, marine research and commercial applications. Serving customers in more than 30 countries, HII provides design, autonomy, manufacturing, testing, operations and sustainment of unmanned systems, including unmanned underwater vehicles (UUVs) and unmanned surface vessels (USVs).

Huntington Ingalls Industries' (HII) Technical Solutions division has rapidly entered the unmanned systems industry with strategic acquisitions and investments. The division's Unmanned Systems business group designs and manufactures advanced unmanned underwater vehicles (UUVs), including REMUS and Seaglider, and provides autonomy solutions for unmanned systems in the maritime, ground and aerial domains. To further its unmanned systems capabilities, in 2020 the company broke ground on a new Unmanned Systems Center of Excellence in Hampton, Va., and the first phase of the center is now complete. The U.S. Navy's first Orca XLUUV is currently being assembled there as part of HII's partnership with Boeing. At the end of this year, the center's second building will become operational, completing the 155,000 sq. ft.-facility on a 20-acre campus. An overview of capabilities include:

- **Unmanned Underwater Vehicles**
- **Design, Development, Production & Sustainment**
- **Advanced Autonomy Solutions**
- **Unmanned Surface Vessel Autonomy**
- **Engineering, Manufacturing & Support Services**

The REMUS 300 unmanned underwater vehicle (UUV) is the newest addition to HII's REMUS family of systems, commercially launched in April 2021. The REMUS 300 a small-class UUV that combines modularity and flexibility in a two-man portable platform that can be deployed from any vessel of opportunity. The 7.5-in. diameter strengthened hull allows the vehicle to reach depths of 305m (1,000 ft.). With the added modularity, the REMUS 300 can be reconfigured for different missions, from a 100-pound expeditionary configuration to a 149-pound long-endurance configuration. REMUS 300 has options for 1.5, 3.0 or 4.5 kWh lithium-ion battery sections that correspond to up to 10, 20 or 30 hours of endurance. Blind-mated end caps allow for field-expedient battery exchange during missions.

The REMUS 300 follows open systems architecture standards with a Data Distribution System (DDS) based architecture platform. This open architecture is the backbone of our REMUS Technology Platform, enables rapid integration of new modules and software, and decreases risk in meeting schedule and cost objectives. HII is also developing a Software Development Kit (SDK) and Hardware Development Kit (HDK) for third-party software and payload development.

The REMUS 300 integrates capabilities that are typically only in medium- or large-class UUVs, including longer endurance and advanced modular payload options. The REMUS 300 has exchangeable battery and payload modules to meet specific mission requirements. The open architecture and modularity of the REMUS 300 facilitates rapid spiral development, ensuring technology flexibility and longevity. The REMUS 300 design is scalable and will be applied to future UUV designs.

JW Fishers Mfg., Inc

www.jwfishers.com

Based in East Taunton, MA and led by Brian Smith-Fisher, JW Fishers Mfg. has been in business for over five decades and continues to specialize in the design and manufacture of high-tech, reasonably priced underwater search equipment. Its sonar systems, underwater metal detectors, ROVs, and magnetometers are in use by commercial diving companies, public safety dive teams, government agencies, police and military units worldwide.

The line includes hand-held and boat-towed metal detectors, magnetometers, underwater video systems, ROVs, sonar systems, acoustic pingers & receivers, pipe & cable trackers, a sub bottom profiler system and the Pulse 8X underwater metal detector. The engineering team also worked on finalizing the new CHIRP 450/900 kHz Side Scan Sonar system coming in January 2022.

McLane Research Laboratories, Inc.

www.mclanelabs.com

Based in Falmouth, MA and led by President and CEO Yuki A. Honjo, McLane Research Laboratories, Inc. is a 21-person company founded in 1983 to manufacture and develop advanced time-series instrumentation for the international oceanographic community. It is a leader in time-series in-situ oceanographic profilers, samplers, and flotation. Recently, McLane launched the commercial model of the Prawler, which is a low-cost, wave-actuated vehicle that moves along the mooring wire, collecting data from the surface to 500m of the water column. The Prawler is a field-proven instrument originally developed by NOAA's Pacific Marine Environmental Lab with support primarily from NOAA's Office of Oceanic and Atmospheric Research Climate Program Office.

McLane instruments are all designed to withstand the rigors of long-term open ocean and freshwater deployments. The company produces three main product lines: Profilers, Samplers, and Flotation. The McLane Profiler line includes its newest instrument, the Prawler, as well as the Ice Tethered Profiler (ITP) and the McLane Moored Profiler (MMP). Samplers include flagship Sediment Traps, as well as the Remote Access Sampler (RAS), Phytoplankton Sampler (PPS), and Large Volume Pumps. In addition, McLane's in-situ laboratory platforms, Environmental Sample Processor (ESP) and Imaging FlowCytobot (IFCB), support emerging genomic and optical research methods for automated time-series oceanography and limnology. McLane also manufactures glass and steel flotation, as well as custom instrument housings. McLane instruments are central to many long-term global projects and cruises, including such initiatives as OOI, GEOTRACES, and the RAPID array.

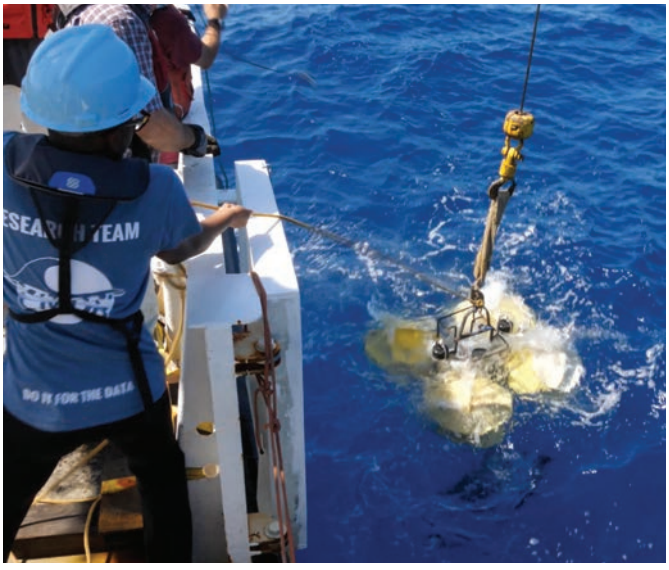
NOAA

Working at the Interface of Exploration and Education

By Genene Fisher, PhD & Marlene Kaplan, D.Env.

The **National Oceanic and Atmospheric Administration (NOAA)** is the only federal agency with a program dedicated to exploring the deep ocean, closing gaps in our basic understanding of U.S. deep waters and the seafloor, and delivering the ocean information needed to strengthen the economy, health, and security of our nation. Inspiring and engaging the next generation are fundamental to the operations of the agency's ocean exploration program. Missions aboard NOAA Ship Okeanos Explorer — the only federal vessel dedicated to exploring the deep ocean — include mapping, ocean characterization, reconnaissance, advancing technology, and educational outreach with an emphasis on collecting baseline information in never-before-explored areas. Characterization involves taking an in-depth look at a region or specific site and gathering data of the seafloor, sub-bottom, and/or water column. Data are collected using a variety of advanced technologies to explore and characterize unknown or poorly known deepwater ocean areas, features, and phenomena at depths ranging from 250 to 6,000 meters. Expeditions are planned collaboratively, with input from partners and stakeholders, enabling broad scientific participation. Through telepresence technology, scientists and students participating in missions primarily remain on shore and are able to add their expertise to missions no matter where in the world the ship, or they, are located. Simultaneously, public viewers can watch and listen to live expeditions online, bringing the excitement of ocean exploration and discoveries into classrooms and homes. The vessel is managed by the NOAA Office of Marine and Aviation Operations and mission equipment is operated by NOAA in partnership with the **Global Foundation for Ocean Exploration (GFOE)**.

OECI supports marine S&T internships for students, including a program with Tuskegee University, a member of Historically Black Colleges and Universities. Intern Darrielle Williams participating in the search for SS Norlindo.



Credit: NOAA OECI, ISC, Patrick Flanagan

Advancing Technology

Okeanos Explorer is also a platform for technology development and in May 2021 it hosted field engineering trials for Woods Hole Oceanographic Institution's new **Orpheus** autonomous underwater vehicle (AUV), which was supported through the **Ocean Exploration Cooperative Institute (OECI)**. Designed to withstand pressure down to 11,000 meters, it will provide access to some of the deepest parts of our ocean. Integration of a vision-based system for estimating relative position developed by NASA's Jet Propulsion Laboratory, similar to the Terrain-Relative Navigation system used on the Mars Perseverance rover and Helicopter Ingenuity, will allow the AUV to sense its location relative to the seafloor and avoid hazards, and recognize seafloor features that may be of scientific interest.

NOAA Ocean Exploration is using new autonomous technologies to meet ambitious mapping and exploration goals. Through the National Oceanographic Partnership Program (NOPP), a multi-year grant was provided to the University of New Hampshire, Saildrone, and the Monterey Bay Aquarium Research Institute to test and integrate acoustic and other sensors into a new larger class of uncrewed surface vehicles powered by wind and solar power. The 22m Saildrone Surveyor is designed to collect bathymetry of the seafloor, water column data, and other priority environmental measurements and recently completed a successful unassisted transit from California to Hawaii. NOAA continues to support this technology through the OECI for new mission plans, post-mission data analysis, and data distribution. With the University of New Hampshire and OECI, Saildrone Surveyor will map the seafloor and collect oceanographic data offshore of Alaska in 2022.

Blue Economy

America's blue economy is expected to double in value to $3 trillion over the next decade and ocean exploration is a crucial pillar. Creation of seafloor maps and characterization data are needed to support decisions about stewardship of ocean resources such as energy sources, minerals, and pharmaceuticals — all vital to U.S. industries, human health, and national security. The National Strategy for Mapping, Exploring, and Characterizing the U.S. Exclusive Economic Zone (NOMEC Strategy, June 2020) was developed with NOAA and other federal agencies to help coordinate map-

ping and exploration activities for the U.S., develop new and emerging science and mapping technologies, build public-private partnerships, explore and characterize priority ocean areas, and complete mapping of the deep water of the U.S. EEZ by 2030 and the near shore by 2040.

Workforce Development

NOAA Ocean Exploration collaborates with the agency's Office of Education which advances America's blue economy through innovative STEM education and outreach efforts to inspire and train future blue economy leaders. NOAA's Environmental Literacy Program provides grants and in-kind support for programs that educate and inspire people to use Earth system science to improve ecosystem stewardship and increase resilience to environmental hazards. The José E. Serrano Educational Partnership Program with Minority Serving Institutions (EPP/MSI) trains and graduates students from traditionally underrepresented minority communities. More than 2,000 students have received Ernest F. Hollings and EPP/MSI undergraduate scholarships, which train the next generation in NOAA mission fields. NOAA also works with the Bureau of Ocean Energy Management, NASA, Navy and other NOMEC agencies to enhance collaborative innovation and promote work-based learning opportunities associated with the NOMEC Strategy. Additionally, NOAA Ocean Exploration has a long history of promoting training opportunities by hosting students and early career professionals through agency-wide programs, leveraging partnerships, and managing an in-house internship opportunity, the Explorer-in-Training Program. Enabling a workforce that can create and drive science and technology projects and the machine and digital elements needed for the rapid-growth blue economy is a NOAA priority and in partnership with NOAA Education, the agency's Ocean Exploration program is doing that in the subsea. For more information on ocean exploration and training opportunities, visit

https://oceanexplorer.noaa.gov/about/welcome.html

Credit: Art Howard Photography/GFOE

Orpheus AUV was one of several technologies tested aboard Okeanos Explorer in 2021 to enable deeper and more comprehensive exploration than previously possible.

Credit: Art Howard Photography/GFOE

ROV Deep Discoverer (D2) being recovered aboard NOAA Ship Okeanos Explorer. Telepresence technology allows scientists ashore to see D2s real-time video and provide guidance to pilots on where to go and what to collect.

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Richard W. Spinrad, Ph.D.

Richard (Rick) W. Spinrad, Ph.D., *was sworn in on June 22, 2021 as the Under Secretary of Commerce for Oceans and Atmosphere and the 11th NOAA Administrator. Dr. Spinrad has a long and distinguished career, and he certainly needs no introduction to the MTR audience, or explanation for our rationale in making him our* **Number One Ocean Influencer of 2021.**

Rick to start, please give a "By the Numbers" overview of NOAA today.

I have to start with the workforce, which is 12,000 passionate career professionals scattered all around the world. We map and chart the U.S. EEZ – almost 3.5 million square miles – and we have responsibility for 95,000 miles of coastline. In 2019 our ships cruised for more than a quarter million miles conducting hydrographic survey, fisheries survey and research. We protect species, with responsibility for 164 endangered or threatened species. We have recovered 47 fish stocks in the last decade or so. We protect more than 600,000 square miles of what we could call underwater parks. Our Marine Debris Program has pulled out 22,000 tons of debris since 2006, and that's all just the ocean side. And then of course, look at our responsibilities in weather: we're getting about 6.5 billion weather observations and putting out well over a million forecasts to the American public.

Using the start of your career to today as bookends, can you put in perspective how the focus on ocean issues has changed the most?

Well it's over 40 years now if you go back to my undergraduate days. But I think about it in the sense that ocean science back when I was an undergrad was really oriented towards getting measurements to the best of our abilities. It was extraordinarily difficult to get measurements. We didn't have satellites. Going to sea took a lot of effort, but the dollars per bit of data was extraordinarily high, and it was really around pretty fundamental applications. Can we help the shipping industry get a better handle on surface currents? Can we help the fishing industry have a safer working environment?

And what's changed, in my opinion, is that we're doing a much better job. We've got much more robust observations. We have an Integrated Ocean Observing System. We have more diverse and better data and information to support a much broader set of needs.

And then we also have enhanced computational capability, so we can make forecasts better than we could before. And here's another real kicker I never would have imagined back when I started in this: Now we're starting to see this fully coupled integration of ocean science and business. And in fact, some universities now have started what they call Blue MBA programs, where students can go in and get a master's or PhD in some aspect of ocean science and also a business degree. And that's one of the things we're seeing. It's part of what I call the new blue economy, taking advantage of these observations, of these predictive capabilities, to build out a new economic sector.

Which technologies do you believe will have the greatest impact in the coming decade to efficiently, effectively, and safely study our oceans?

One of the most dramatic changes in technology that we are exploiting right now in the ocean world is associated with autonomous or uncrewed systems: underwater, aerial and surface. That ability allows us to have a persistent presence in the ocean. It also gives us a capability for, if you will, adaptive sampling. No longer are we constrained to have the ship running at eight to 10 knots doing a lawnmower pattern in the ocean, only to find that we've missed a particular feature because we couldn't adaptively sample, and we weren't there. Uncrewed systems allow us to do that. I would also point out these underwater gliders right now are demonstrating an extraordinary capability for acquiring data to improve our forecast of hurricanes, hurricane intensity, to some extent track. But the ability to have a picket line of these as the hurricane is coming through is dramatically improving the quality and the accuracy of our hurricane forecast. If you look at what we're doing with surface vehicles, we're now realizing we might be able to complement the traditional approaches to fishery stock assessments using acoustic sensors put on these surface vehicles. In the air, uncrewed aerial systems can collect high-resolution imagery. They can even collect DNA from the breath of a whale to give us some sense of the health of that particular animal. So in any part of the environment, above the water or on the surface or underneath the surface, these uncrewed systems are truly proving to be a force multiplier.

When you look at uncrewed maritime systems, how are they deployed today, and how do you see UMS expanding in the future?

Uncrewed systems are being used for an extraordinary array of applications. I mentioned the application of complementing our stock assessments. But the idea of uncrewed systems initially being developed to address the 3 Ds, dull, dirty, and dangerous. I would add now another D: 'difficult.' It's difficult to conduct missions in the high Arctic

01 Spinrad, NOAA

MARINE TECHNOLOGY TV

Watch the full video interview with Rick Spinrad @ https://youtu.be/BhZUpoL1JMU

Photo courtesy NOAA

at certain times of the year or in the Southern ocean, and we now know that we can use uncrewed surface vehicles to do exactly that. So if you think about all of the potential applications associated with fisheries, with general oceanography, with endangered species, with marine debris, all of these missions can be complemented, if not completely addressed, through the use of uncrewed systems.

What I think we're going to see in the future is some dramatic enhancements and increases of using these platforms for things like mapping. That's a tough challenge with all of the 3.5 million square miles we've got just in the U.S. EEZ and our commitment under Seabed 2030 to completely map and chart our EEZ by the year 2030. We are going to have to do that with the traditional approaches, but also with the exploitation of uncrewed systems.

We're also going to see uncrewed systems used as data relays, I think, much more aggressively than we have in the past. In fact, I remember years ago talking about whether we could start getting rid of the open-ocean buoys that we have relied on for years and years as data receivers and transmitters. An open-ocean buoy is an expensive, difficult thing to deploy and maintain. Perhaps you don't need to have that catenary mooring going 4,000 meters down. Perhaps you could use a surface vehicle that is station-keeping to acquire the data, transmit it, and also receive instructions for tasking what could be resident systems.

I also believe that we are going to see an explosion of use of swarmed uncrewed vessels, uncrewed systems that are using artificial intelligence applications to determine how to deploy, how to swarm, where to go, when to sample, how to sample, when to send data back, when to ask for new instructions. So I'm really excited about the potential application of AI, ML to the use of uncrewed systems and the potential for downstream resident systems of uncrewed, underwater vehicles ready to respond to the needs at a moment's notice.

When you look at the full scope of your responsibilities under your command, can you distill for me your top priorities?

NOAA is positioned to be seen as the authoritative source for climate information products and services. That's priority one. Demonstrate that. Don't simply say we think we ought to have it. But through our actions, through our programs, through our engagement, through our solicitation of requirements, demonstrate that we are the authoritative source of climate products and services.

The second element is integrating eq-

"I believe that we are going to see an explosion of the use of **swarmed uncrewed vessels,** *uncrewed systems that are using artificial intelligence applications to determine how to deploy, how to swarm, where to go, when to sample, how to sample and when to send data back."*

Rick Spinrad,
NOAA Administrator

uity into our internal and external operations, equity in terms of ensuring that our products and services are provided to all communities, but a special focus on those most vulnerable communities. Internally, we need to take a big leap in diversifying the workforce at NOAA, so we're undertaking a number of workforce development activities to make sure we are representative of the public whom we serve.

And the third priority, which I think will really resonate with a lot of your audience and leadership, is advancing what I call the new Blue Economy. That is to say the economy that's based on data, information, and knowledge about the ocean, supporting some aspects of the traditional blue economy, but also supporting other emerging sectors, like public health, for example, and the reinsurance and insurance industries. So we can make possible this new blue economy because of the advances we've made in ocean observations and ocean prediction.

We've already touched on many of the technology points, but in your career to date, what do you count as the number-one technology evolution that has helped oceanographers to do their business more safely and efficiently?

I would have to say, coarsely defined, miniaturization. In terms of platforms, for example, I worked for Navy for many years in my career, and I remember one of the original autonomous underwater vehicles the Navy operated was powered with somewhere between 5,000 and 10,000 D cells. It had a lot of functions to do. But miniaturization of the platform now. If you look at all of the commercial developers of uncrewed, underwater vehicles, they're remarkably small, nimble, and powerful.

Look at the sensors, what we've done. Early in my career, I was the president of Sea Tech Incorporated. We developed the fluorometer. The original fluorometers were about the size of a 30-gallon garbage can, and now they're more the size of a D cell battery. Look at what we've done with dissolved oxygen sensors. Look at eDNA. For crying out loud, we can do virtually real-time analyses of the DNA content in the ocean using a relatively small sensor package that sits on an underwater or an uncrewed underwater vehicle. And then onboard processing is the last part of that. The ability to power, collect data, transmit data can be done with a lot less real estate.

If you had the best advice for young people thinking of pursuing a career in oceanography, what would that advice be?

Well, the first bit of advice I have is go to sea. I worked for an admiral once who said, "Let's make sure we don't all turn into cubicle scientists or cubicle technologists." You do need the experience. You do need to understand the environment. You actually need to understand how difficult it is to collect information about the ocean. And so I would say go to sea, whether it's going out on a two-week cruise with your academic institution or participating in some experiments with non-governmental organizations or even doing one of the seagoing camps or summers at sea, that kind of thing. Go to sea.

The second thing I'd say is get out of your comfort zone. I would suggest if you're oriented toward physics, for example, study a little biology. If you're a biologist, study economics. Take some coursework out of your straight-line trajectory in a particular field. You will find that because Earth's systems are inherently transdisciplinary, it'll pay off enormously if you have some diversity in your educational experience.

Then the last thing I'd say, a lot of people say, "Well, get a good mentor." I actually think the message is find three mentors, because you're going to find that the lens that each mentor looks through in terms of their experiences, their advice, each one is going to be fundamentally different. And if you can find... It doesn't have to be three, but two or three or four people whom you respect, people who will take some time to work with you, advise you, guide you over a relatively long period of time, you will find a real richness in that experience. So go to sea, get outside your comfort zone, and find three mentors would be the advice I'd give young people.

Dr. Robert D. Ballard

Scientist • Ocean Explorer

Dr. Robert D. Ballard needs no introduction to the MTR audience. With a life dedicated to ocean exploration, a career spanning 62 years, 158 expeditions and a long list of 'world first' deep ocean discoveries under his guise, he was a natural for inclusion as an Ocean Influencer in the 2021 MTR100. Earlier this year Ballard opened up on his personal life and his world-famous ocean discoveries like never before in his new book, "Into the Deep." Best known as 'the man who found the Titanic,' *Marine Technology Reporter* had the opportunity to interview Ballard on the contents of the book and the follow-up National Geographic television special, taking a deep dive into his dyslexia, the importance of his family throughout his career, and reflections on what's important – and what is not. At the age of 78, Robert D. Ballard is and always will be a scientist, an ocean explorer intrigued by finding clues to the unknown. Currently engaged in a 10-year, $100m program with NOAA's Office of Ocean Exploration to map and characterize the US EEZ, a project which teams his ocean exploration trust with Woods Hole, the University of Rhode Island, the University of New Hampshire and the University of Southern Mississippi, Ballard has not been on the sea for nearly two years due to the impact of COVID.

But Ballard – the author of multiple books, papers and articles, the subject of TV and film – took the time to take a different path of discovery and reflection, into not just his career but also his personal life.

"I didn't know I was dyslexic until I read the book The Dyslexic Advantage. It explained me to me for the first time," said Ballard. "And now I've really embraced it. And I realize why I was able to do what I've been able to do, because I'm such a vigil creature. I can imagine things in my mind, and it's perfect when I go down to the darkest depths, I look at my sensor systems and I can form a mental image in a world of eternal darkness. I think it explains how I tick." As Ballard gets closer to his 80th birthday, he has become more reflective on the balance of personal and work. "Two years ago I was in a Redwood forest

MARINE TECHNOLOGY TV
Watch the interview with Ballard @ bit.ly/2RtX0AX

(Gabriel Scarlett/National Geographic Image Collection)

02 Ballard

In 2019, Nautilus plied the Pacific waters off the island of Nikumaroro, searching for any sign of Amelia Earhart's lost plane. In the cool, dark control room, we kept a 24-hour vigil.

and a brilliant professor from Harvard, Arthur Brooks, talked about how to stay happy while you grow old," essentially three things you need to do, said Ballard. First on the list is developing closer bonds with friends, which Ballard has done spending more time "hunting and fishing" rather than academic and professional projects. Second is mentoring the next generation, which led to Ballard hiring a team to help manage his activities across his military, academic, popular science and business endeavors. The third piece of advice has been a bit more difficult for Ballard to enact, as he said with a laugh: "The third thing is the one I'm having a little difficulty with: 'The next time a big project comes along, say no!' I've never said no. So I'm struggling with that one, and you'll have to check back in and see how I do it." The list of discoveries under Ballard's guise is long and distinguished, and while the discovery of Titanic was his most acclaimed among the general population, Ballard calls the discovery of hydrothermal vents – Black Smokers – as the show-stopper. "That rewrote the biology book, that was clearly one of the most significant discoveries ever made in the ocean," said Ballard. "Discovering hydrothermal vents and life system completely opened up prospecting for life throughout the universe and even within our own solar system." Another favorite was the discovery of perfectly preserved ancient shipwrecks in the anoxic bottom waters of the Black Sea. "That was another home run," said Ballard. While Ballard has spent much time at sea, on and below the waters, he sees the future generation 'exploring' the oceans from the comforts of their own offices, labs and homes. Specifically, he sees the evolution of telepresence technology and autonomous systems as working collaboratively to help future scientists and explorers learn even more about what lies in the ocean. "Now with the use of AUVs and autonomous surface vehicles, we have a whole cadre of tools we're using; we call them force multipliers … it's going to be autonomous everything," said Ballard. "I don't expect humans to go to sea much (in the future). I mean, I love horseback riding, but I don't ride a horse to work. We're going to be very much in the world of more and more intelligent autonomous vehicles.

Michael Johnson

Founder & CEO, Sea Machines

03
Johnson, SeaMachines

Michael Johnson is the founder and CEO of Sea Machines, a company that is helping to fast track the age of autonomy in the maritime space. "Technology is not something new for our space," said Johnson, "be it from the lumbering packet ships to heavily canvassed clippers then back to the lumbering, smoking, yet consistent steamers and then on and on. Now it's digital sensing, deep processing and the shift of manual operation to the autonomous."

A native Texan and a marine engineer by education, Johnson has always fancied himself an innovator, but early in his career – from shipyard post to executive leadership at Crowley Maritime – he never imagined in those early years that he would take a leadership role in maritime autonomy. "Mariners aren't usually the type of people that make long-term fixed plans," said Johnson.

Photo courtesy David Shopper

But it was one of his first experiences as a mariner that helped shaped his mission, his company, today. "On my first trip to sea as a cadet, within 10 days of stepping on board my first ship, we were engaged in a major search and rescue operation in the North Atlantic" Johnson remembers. "We were searching for a missing bulker, the Marika 7 that had recently left Nova Scotia, and we were sailing within 12 hours of each other in the same winter storm. Unfortunately, she broke in half and all crew were lost. And we were searching in the waters, in 45-ft. seas. That was when I first learned how dynamic and powerful the seas are."

Fast track to 2012, with Johnson in a leadership position at Crowley and Titan Salvage, where he led the team that wrote the winning bid to recover the wreck of the Costa Concordia. "Over the course of those 19 years from that first voyage to the Costa Concordia, I saw that simple and wrong human decisions can have catastrophic consequences. While humans are great at many things, I see humans as not being optimal in other ways. In our world, the marine world of long duration missions, which are

Image courtesy Sea Machines

often routine, technology can take on more and do it better." With that, Sea Machines was effectively born. Sea Machines in in its seventh year, with offices and facilities in four countries, a team of more than 50 personnel with more than 50 autonomy systems booked by companies in nine different countries. Born in the commercial space, Sea Machines is also making inroads with government customers. "It turns out that the U.S. Department of Defense and their U.S. tax paying stakeholders have an appreciation for homegrown technology that has been proven in the commercial world," said Johnson. When one starts taking the US DoD and autonomy path, one usually starts running into the realm of long-tenured, giant corprations. "A quick-moving venture capital backed company like ours needs to wisely chart our course," said Johnson. "Part of that is through the relationships we have in the industry. And you see the partnerships that we've jointly announced going back to 2018 with AP Moller Maersk, and then last year major strategic alliance with Huntington Ingalls and Hamilton Jet and this year with Damen." *(Note: at press time Rolls-Royce and Sea Machines signed a partnership agreement to cooperate on smart ship and autonomous ship control solutions).*

"Autonomous operations will be mainstream," said Johnson. "I doubt there are many that question that. The challenge, especially for a startup innovation company like ours, is time."

Taking a historical perspective, Johnson reckons that most major technological shifts at that commercial or industrial grade level take 15 to 25 years from beginning to an over 60% adoption rate. As the speed of all technological evolution accelerates, he sees autonomy coming faster than normal. "The challenge for the innovator is being steadfast and being capitalized well enough to weather that period from concept to commercial tipping point. That's probably the reason that a lot of the legacy technology companies that serve our space are mammoths: they have the capital to weather it." In the meantime, Johnson and the Sea Machines team will continue to experiment, trial and innovate.

"We have some great things in the pipeline," said Johnson. "We will also be launching and releasing our computer vision as a navigational sensor, which this will be the first of its kind. With vision technology, your vessel can detect range and classify obstacles in a way that no other sensor on the market can. It was a must for us because we leverage the conventional sensing technologies today, but it's not enough for a system to clearly and competently perceive the full domain. So vision is that answer."

A Hydrogen Hybrid RV

Bruce Appelgate *discusses the quest to design and build a hydrogen-hybrid propulsion RV.*

Research vessels inherently work in some of the most ecologically sensitive and important parts of the planet, so it would stand to reason that the vessels themselves leave as little of a carbon footprint as possible. Over the summer Scripps Institution of Oceanography made news when it received $35 million to design and build a new hydrogen hybrid propulsion research vessel.

"We've been working on this kind of a project since about 2014, when we initially partnered with Sandia Laboratories to look at the feasibility of using hydrogen propulsion on a research vessel," said **Bruce Appelgate**, associate director and head of ship operations at Scripps Oceanography. The conclusion: based on technology maturity and fuel availability, the preferred solution is a hybrid approach, with the ability to run on both hydrogen and traditional diesel if needed.

While early preparation is still underway – with engineering work and detailed design underway – Appelgate reckons this will be an approximate four-year project to get a vessel in the water. "Our objective with this vessel is to build an uncompromising, very capable research vessel," said Appelgate. "An important beginning step is meeting with a science advisory board who is going to be able to provide input from the very beginning so when we design the vessel, it's optimized for the work that we want it to do." When it comes to the detailed design, "some of the technical challenges with things like bunkering and the gas systems on the vessel" still need to be sorted out. "A lot of this hasn't been done at this scale in the marine industry yet, so there's a lot of learning to do," said Appelgate. The new vessel is part of the University of California's a plan to become carbon neutral by 2025. "A huge part of our diesel consumption in the University of California is our research vessels," said Appelgate. "So the emissions impacts of ships are tremendous. We're very interested in reducing our criteria pollutants from our ships because criteria pollutants harm human health, and that's bad. We're very interested in reducing and eliminating CO2 pollution from our ships for the obvious reasons that it's warming our planet, and that's something that we want to support." In its study of options, the partners took a common hull and put four different kinds of propulsion systems into it: conventional diesel-electric; battery-diesel hybrid; hydrogen-diesel hybrid; and, fully hydrogen. "So keeping everything constant except those propulsion systems. And looking at the pros and cons of all four of those, we get the best range and we meet our science mission the best with our emissions target, with a hydrogen hybrid."

"The ship that we're envisioning is a replacement for our little workhorse vessel, Robert Gordon Sproul," said Appelgate. "It's a 125-ft. regional research vessel, and the target work for this vessel is going to be California coastal and offshore work. So we'll range up to 150 miles with a duration of a couple of weeks, that's what we're targeting. The ships that we operate in Scripps are general purpose, shared use vessels so they need to be jacks-of-all-trades. So we're going to be able to do everything from acoustics and sea bed mapping, to mid-water imaging, to surface observations, and then classic things, of course, like CTD profiling and water sampling and net tows. Our vision is to have a suite of sensors onboard from mapping sonars to mid-water images sonars, ADCPs, but also all the overboard handling equipment that comes with the kind of work that we're envisioning for doing net tows and winches."

Neil Gordon

Subsea UK & the "Global Underwater Hub" (GUH)

Led by Neil Gordon, Chief Executive at Subsea UK, the organization is embarking on a new adventure as The Global Underwater Hub, a new organization with already nearly $18 million in funding. 'The Hub' aims to leverage the UK's strong maritime heritage, as well as its underwater expertise that transcends offshore defense and research. Subsea UK has been around nearly 20 years, set up to champion the UK subsea industry. It was fortuitous timing, as that $2.7B CapEx industry in oil and gas grew to more than $12B by 2013.

While Subsea UK was formed in 2003 to champion the UK subsea industry, markets change and evolve, and so too has Subsea UK. The opportunity now – and hence the creation of The Global Underwater Hub – is to leverage all of this accrued subsea expertise, much of it born in the traditional offshore oil and gas environment, and find new 'homes' for it in alternate and emerging offshore industries, from defense to aquaculture to the burgeoning offshore wind market, particularly with the need to chart, understand and build on the seafloor, as well as the more recent emergence and promising future of 'floating wind' that share many similarities to offshore oil and gas.

In motion for a few years, drawing on the resources of Subsea UK and additional entities in Scotland and the UK, The Global Underwater Hub is aiming to harness all that the subsea industry has to offer and leverage it toward future opportunities. "So the challenge was, a few years back, we looked at Subsea UK, which had done a great job up until then, but the future was starting to look slightly different," said Gordon. 'Slightly different' includes the impact of COVID. "Things are changing; we've been through a pandemic and lockdown, and the world looks kind of different as we come out of hibernation. (In addition to the emergence of offshore wind) there are things like carbon capture and utilization and storage, hydrogen production, and many other opportunities."

Cumulatively it is perhaps best described at taking a bigger piece of the 'blue economy' which encompasses all aspects to do with the ocean, driven by the recent Organization for Economic Cooperation and Development (OECD) report that

projects the blue economy is set to grow to about $3 trillion by 2030. "Now that's a massive growth," said Gordon, noting that $1T of that pie are sectors where Subsea UK has already or has targeted to work "We know countries such as Norway, Japan, Canada and the U.S. are all investing in the ocean economies," said Gordon, in discussing the push to develop The Global Underwater Hub, which in its essence is creating value for the UK and Scottish economies. "We are a world leader, but we want to make sure that we can maintain that leadership. So let's get some real focus about the blue economy. How do we create the jobs? How do we develop the technology? How do we encourage exports?" Gordon and his colleagues see The Global Underwater Hub is the answer to those questions and more. Logistically the organization will have three locations: one in Scotland, one in North England and one in South of England, creating "a backbone, a hub and spoke model," said Gordon. "Anyone around the country can access and connect to help them grow their business."

Gordon is particularly clear to point out that The Global Underwater Hub is not an 'Innovation Center.' "It's not an innovation center, because there are lots of innovation centers around," he said. "What we need to do with those innovation centers is make sure that they know where the opportunities are and how to commercialize those opportunities."

The GUH will be an intelligence led and strategically focused organization helping companies to understand new markets and identify opportunities by delivering in four key areas:

- **Collaboration & Innovation:** Creating a multi-sector underwater industry.
- **Capability and Skills:** Developing skills and companies to drive competitive advantage.
- **Accelerate & Scale-up:** Supporting the growth of new and existing companies.
- **International market development:** Increase exports and attract new inward investment.

"The main things that the hub will be able to deliver is help companies identify where are the opportunities and help them navigate, find and win that business," said Gordon. "We've got energy transition, net zero oil and gas, offshore wind [to name a few]. It's for us to try and help articulate the opportunities and help companies make those strategic decisions where they invest in, where they want to do business."

Saildrone

Saildrone takes USVs with full ocean capability to the next level, as Richard Jenkins, Founder & CEO, explains.

Started in 2014, Saildrone has emerged as a leader in the Unmanned Surface Vessel (USV) space, having received more than $100m in venture capital to date with more than 100 vehicles manufactured and 30 in the water. "Saildrones are wind and solar powered USVs, which are augmented by onboard power solutions," said Jenkins. Saildrone has three models of vehicles: the Explorer, the Voyager and the Surveyor. The 23-ft. Explorer is wind and solar powered, designed to conduct long endurance (6 to 12 months) in the open ocean in 10,000 to 15,000 miles voyages. Jenkins said this vehicle is well-suited for applications like maritime domain awareness and bathymetry, which require higher power payloads. The Surveyor is Saildrone's largest vehicle at 72 feet long and 34,000 pounds. "That is a full ocean depth survey vehicle that maps the seabed down about 8,000 meters using a Kongsberg EM 304 multi-beam sonar," said Jenkins. "That was built last year, it's finished its trials. It just sailed from San Francisco to Hawaii on its maiden voyage and it's now making its way back," a voyage on which it will have mapped more than 6,500 square miles of previously unmapped seabed.

The potential for USVs is as big as the ocean itself, with a "huge need from defense, from homeland security, from bathymetry intel and climate reasons," said Jenkins. "We have three verticals to our business. One is ocean data: climate, weather, fisheries, sustainability, carbon, et cetera. Bathymetry is second, so doing multi-beam mapping and mapping the seabed near shore literal conditions and also deep ocean. And then we have NDA-ISR, which is domain awareness above and below the surface of the ocean."

All three sectors have significant needs, said Jenkins, noting that climate is probably the biggest need at the moment, with defense "an ongoing and evolving industry. The U.S. Navy, Coast Guard and Homeland Security are trying to get their head around how to best employ unmanned systems. "Unregulated, illegal fishing is a great threat now."

A big, new commercial driver in the U.S. is offshore wind farms, from sub-bottom profiling, to bottom mapping, to water column analysis, fish stock analysis and wave height.

Jenkins said "we have a very sophisticated machine learning component to our vehicles, too. Every one of our vehicles can spot things autonomously and visually, including vessels, icebergs, sea ice, marine mammals, and birds. Birds and bats are an important aspect of looking at sustainability in wind farms."

While COVID has thrown up road blocks for a number of industries, it has opened many new opportunities in the autonomous, unmanned space.

"As you know, (because of COVID), when everyone was locked down, all the government ships were stuck in port (which presented) huge vulnerabilities to the nation for security rules in fisheries," said Jenkins. "Every year, we do a fish stock survey in the Bering Sea, it's part of the pollock fish stock assessment for NOAA fisheries. And the NOAA ship that normally does that was unable to get to the fisheries' grounds. So they were going to have to essentially guess a fish stock assessment based on previous years. But we managed to sail three vehicles from San Francisco across the Pacific to the Unimak Pass 2200 miles into the Bering Sea, survey the fish stock in the Bering Sea, sail home and deliver the data to NOAA (allowing them to) create a fish stock assessment from actual data from the Bering Sea for 2020."

While a great technology story, it also is a great economic testament, as Jenkins said the new data allowed an additional fish haul worth $100m. "So that's the government allowing the fishing industry to catch an extra $100m worth of fish due to data gathered by an autonomous system," said Jenkins. "That is money in the pockets of people, of seafarers or fishermen, so it's a huge economic benefit to the country which came from an unmanned system data link."

MARINE TECHNOLOGY TV
Watch the video @ bit.ly/3zxKobD

Photos courtesy Saildrone

Nortek

www.nortekgroup.com

Based in Rud, Norway, and led by Finn Ivar Marum, Nortek is a company 130-strong. This year, Nortek released several new product innovations, designed to make ADCP data more accessible or increasing abilities in subsea navigation.

Nortek designs, develops and produces scientific instruments that apply the Doppler principle to underwater acoustics in order to measure water in motion, such as currents and waves. Its exploratory devices help cast light on the workings of the world's oceans, which occupy vast swathes of the planet, but are still little understood. Most of Nortek's technology is based on a scientific physical principle called the Doppler effect. This relates to the change in frequency (or pitch) when a sound source moves with respect to an observer. By measuring these changes in frequency/phase, our instruments accurately measure profiles of speed and direction of complex water motion. Nortek's product portfolio ranges from wave measurement systems to single-point turbulence sensors and oceanic current profilers. Our product range covers four themes: ocean waves, ocean currents, turbulent flow and subsea navigation.

A notable new innovation from Nortek is the Nortek Eco, a fully functional Acoustic Doppler Current Profiler (ADCP) not much bigger than a coffee mug. Eco makes ADCP data available to those who historically may not have had the budget, equipment, or experience to use ADCPs, but would benefit from reliable current velocity data. After users connect the instrument to a WebApp and set their measurement interval, they simply deploy Eco using one of two off-the-shelf deployment solutions specifically designed for Eco. Once in the water, Eco automatically recognizes its position in the water column and measures velocities in three depth layers above the instrument. As part of its auto-configuring nature, Eco also recognizes and filters out data points from when the instrument was out of water, sidelobe interference occurred, fish swam in the way of the beams, and more, leaving users with reliable and easy to read data. The WebApp even auto-generates graphs and reports from the data for easy visualization and sharing.

Remote Ocean Systems

www.rosys.com

Based in San Diego and led by Bob Acks, for more than 40 years Remote Ocean Systems has been a leader in the development and manufacture of latest technology cameras, lighting and positioning systems for the most extreme oceanographic, industrial, commercial and military applications and environments. ROS has 30+ employees and its product line includes underwater video cameras, lights, rugged pan and tilt positioning systems, video inspection systems and control systems manufactured primarily for the oceanographic, nuclear and defense industries.

For 2021 ROS has developed two new products designed for deep ocean applications. The SeaStar is a high-powered, lightweight compact LED light that delivers 10,000 lumens output with full-range dimming capability. The SeaStar is completely Field Serviceable and available with flood or spot reflector options. It is depth rated to 6,000 meters. The Accu-positioner is a new ROS technology Pan & Tilt Positioner that features a reliable and rugged deep ocean design and computer-controlled accuracy to +/- 0.1 degree. The Accu-positioner is controlled with COTS controllers, devices and ROS GUI. It operates with zero backlash and is depth rated to 6000 meters.

Kongsberg Maritime

www.kongsberg.com/maritime

Horten, Norway-headquarteed Kongsberg Maritime, led Egil Haugsdal, President and CEO, is a global force in maritime and subsea technology with more than 7,250 employees in 117 offices across 34 countries. Its products, systems and services cover all industry sectors, from subsea, offshore, naval and merchant market segments to fishing, aquaculture, exploration and scientific research categories. Key projects and concepts which embody this pledge in a subsurface context include the company's ongoing work in the realms of AUVs, multibeam echo sounders, subsea mapping systems, seabed sensor carriers and fishery research equipment, allied with a substantial investment in green initiatives such as ocean farming for climate-friendly food production. The company's Maritime Broadband Radio (MBR) 'information highway', meanwhile, can allow shore-based teams to remotely interact with AUVs and USVs in underwater operations such as pipeline surveying, mine hunting or bathymetric surveying, with no loss of real-time package data.

The last 12 months have seen several innovations from Kongsberg Maritime for the subsea market, chief among which is the HUGIN Endurance. This latest addition to the already successful HUGIN range of AUVs is a real game-changer: with an operational duration of around 15 days, it provides a low-carbon solution for extended shore-to-shore inspection missions which KONGSBERG is confident will revolutionize tasks such as offshore wind surveys. Equally at home in shallow water or depths up to 6,000m, the HUGIN Endurance has 1,200 nautical mile range and can map up to 1,100 square km in a single mission. The AUV is available with a variety of sensors for different applications, including the HISAS1032 dual receiver synthetic aperture sonar and a dual receiver EM2040 multi-beam echo sounder, providing unparalleled seabed mapping efficiency with up to 1000m of continuous swath. Data can be shared with other vessels and shore-based installations using KONGSBERG's Maritime Broadband Radio (MBR). This key enabling technology allows the offload of large volumes of data without need for a physical connection. The long ranges possible with MBR also enable over the horizon operation.

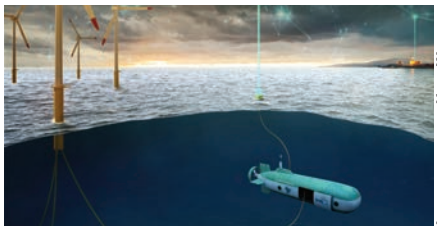


Image courtesy HonuWorx

ORE Catapult

HonuWorx and the **Offshore Renewable Energy (ORE) Catapult** will soon demo a concept for a submersible mothership that the duo claims will make subsea robotics a sustainable and cost-effective solution for offshore wind farms. Funded by Innovate UK, the project will develop a submersible platform dubbed Ridley that will be designed to transport large robots and remote operated vehicles (ROVs) to offshore sites, releasing them directly under the water. A successful outcome to the project will inform HonuWorx' roadmap towards its disruptive Loggerhead concept, which will use an autonomous mothership as a mobile power and communications hub for ROVs and autonomous underwater vehicles (AUVs).

Image courtesy SalMar ASA

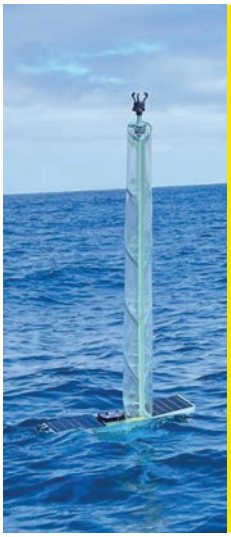
Light Structures AS

Light Structures AS entered an agreement with SalMar ASA for delivery of a Fiber Bragg Grating technology (FBG)-based structural monitoring system for installation on the Ocean Farm 1 aquaculture facility, located in open water near Frohavet on Norway's west coast. Ocean Farm 1 features six huge nets arranged in a circular floating structure, with a total capacity for 1.6 million salmon. Light Structures will deliver a customized monitoring system using its SENSFIBTM technology, alternative to traditional electro-mechanical monitoring designed to deliver better accuracy, dependability and adaptability.

Torqeedo, Inc. www.torqeedo.com

Led by Steve Trkla, President, Torqeedo is a company 200-strong that supplies and integrates all-electric and hybrid propulsion systems for crewed and uncrewed survey boats, as well as ocean/harbor clean-up vessels and a wide range of commercial utility craft worldwide. XOCEAN continues to expand its fleet of Torqeedo-powered uncrewed acoustic survey vessels, as the company now has 13 electric USVs in operation with four more under construction. It aims to have a fleet of 40 vessels by 2022. Sea Robotics worked with Torqeedo to develop a hybrid powertrain for its new class of long-range uncrewed surface vessel for acoustic surveys. Liverpool-based Water Witch continues to expand its fleet of Torqeedo-powered vessel with the Versi-Cat skimmer boat for efficient collection of litter, debris and aquatic vegetation on the water surface. The company this year deployed an electric Versi-Cat multi-mission utility vessel on the pristine waters of Scotland's famous Loch Lomond.

Torqeedo's current Cruise product line incorporates outboards and pod drives from 2 to 10 kW, matched with Power 3,500 Wh or 5000 Wh lithium-ion batteries. The company's high-voltage Deep Blue series encompasses outboards and inboards from 25 to 100 kW, matched with BMW i3 lithium-ion batteries. Deep Blue Hybrid systems include a complete energy management system with generator backup as well as renewable energy sources such as solar or hydrogeneration for recharging underway.



SubSeaSail LLC www.subseasail.com

Based in San Diego, SubSeaSail LLC (SSS) is a four-year-old with five employees and a mission to develop 100% energy harvesting, affordable, long-duration (1+ month) platforms and sensors. SSS is developing three lines of products supported by a growing patent portfolio: 1) monohull, semi-submersible observation vessels; 2) multi-hull, surface cargo vessels; and 3) unique sensors suited for these vessels including rigid Passive Acoustic Monitoring (PAM) Arrays and a weather station. SSS has received a Dept. of Energy Phase 1 SBIR to develop a Gen7 submerging vessel for environmental monitoring of offshore energy installations.

SSS vessels are wind-propelled and solar powered. SSS has received a patent for a sailing vessel with the hull below the surface and the wingsail above. This reduces friction (drag) while producing little-to-no wake and a significantly reduced acoustic, infrared, radar and visual signature. A second patent is for a Passive Mechanical Wingsail Control Mechanism that sets the wingsail at the optimum angle with respect to the wind direction and the desired direction of travel without the use of anemometer, electronics, pulleys or lines. This feature significantly reduces complexity and cost while increasing reliability.

SubCtech GmbH

https://subctech.com

Based in Kiel, Germany with 35 employees, SubCtech develops state-of-the-art maritime technologies. Led by Stefan Marx, SubCtech acts as leading manufacturers in its business units. First is ocean power; SubCtech is a manufacturer of subsea and UPS, ROV and AUV (underwater drones) Li-Ion batteries. SubCtech Li-Ion batteries guarantees high-reliability and high-safety for AUVs, ROVs or offshore subsea oil & gas applications. The second is ocean monitoring. SubCtech manufactures autonomous underway measurement systems for pCO2 and other parameters to measure sea water quality. From ultra-compact instruments to complete rack systems.

SubCtech offers qualifications according to API17F, MIL-STD, DNV-GL, the transport approval UN T38.3 and others.

Recent development of the Subsea UPS, Energy Storage System, which includes the parallel connection of subsea batteries even for high currents in kW range which enables scalable solutions to be implemented at low cost. The German Federal Aviation Office LBA enables SubCtech to carry out air freight even for single quantities including a corresponding DOT import license for the U.S. In addition to the special BMS with multiple protective functions, safety is achieved through the use of small industrial round cells of type 18650. This means that there is little energy per cell and per module. The modules are already inherently safe and voltage-free for installation.

RTsys

https://rtsys.eu

Specialist in underwater acoustics and drones, RTsys is a 40-person company based in Caudan, France, led by Raphaël Bourdon. RTsys manufactures active and passive underwater instruments, compact and powerful underwater drones (AUVs), and portable sonar system for divers. Thanks to its core technology "Powered by SDA", the RTsys product range has grown rapidly, particularly in the civil and defense sectors. Passive Acoustic Monitoring (PAM) obtains valuable data on underwater areas, either by real-time assessment or post-processing analysis. It also handles more specific needs for multiparameter monitoring.

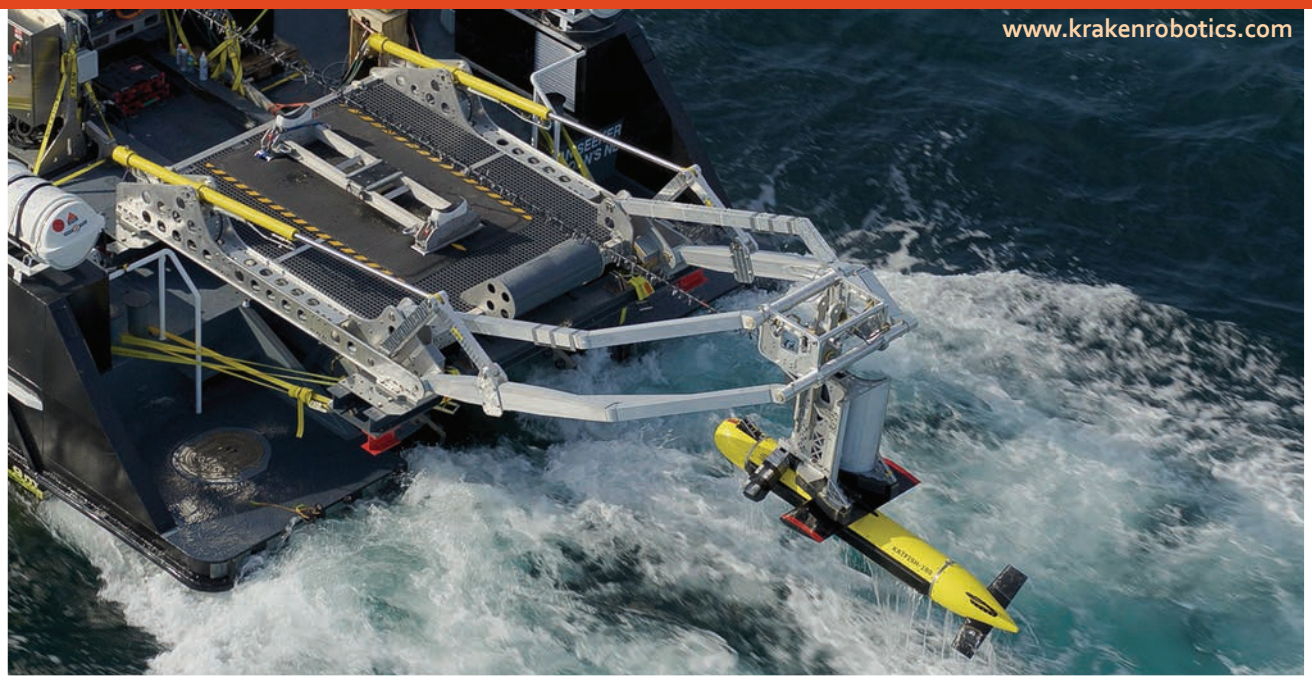
Autonomous Underwater Vehicles (AUV): Although oceans cover more than 70% of our planet, more than 95% of them still remain unexplored. In this regard, AUVs are the best turnkey solutions for military, commercial and scientific applications to perform a wide range of missions, from bathymetry and seabed survey to Unexploded Ordnance (UXO) detection. Additionally, from UXO strewn along European shores to new threats rising around the world, Mine Countermeasures (MCM) are a growing issue that RTsys fully addresses by recreating complete manned and unmanned environments run by underwater acoustics, from diver-held sonars to beacons and AUVs. Lastly, Anti Submarine Warfare (ASW) products are delivered to Navies worldwide for acoustic systems tests and training, torpedo firing exercises, and acoustic signature measurements.

Saab Seaeye

www.saabseaeye.com

Saab Seaeye, led by Jon Robertson, is the world's largest manufacturer of electric underwater robotic vehicles with the world's largest range. For more than 30 years Saab Seaeye has built a reputation as a pioneer of underwater robotic technology that has led the industry by creating innovative solutions trusted to perform complex tasks in the most challenging environments on the planet. A wholly owned subsidiary of Saab, Saab Seaeye has facilities in the U.K., Sweden and the U.S., along with substantial water tank and lake test facilities. More than 80% of its systems are exported to markets that span the globe with representation in 25 countries. Many different market sectors deploy its robotic systems in a vast array of demanding tasks in situations where its vehicles work tirelessly for extended periods in arduous conditions. Saab Seaeye's systems come in wide variety of sizes, power and tasking options. These range from man-portable inspection to deep-rated work systems, and from tethered and autonomous vehicles to remote resident robotics. Its iCON intelligent control architecture aims to accelerate system development and provide customers with easier operation and training, simpler repair and maintenance, easier upgrades and lower real through-life cost. While under operation, iCON effectively 'thinks for itself', leaving the operator free to concentrate on the task at hand. Saab Seaeye is certified by DNV GL to ISO 9001, ISO 14001 and OHSAS 18001.

Kraken Robotics



Since its inception, Kraken Robotics, led by Karl Kenny, has been on the leading edge of development of sensors, software and underwater robotics technology. 2021 was no different as Kraken announced the acquisition of two companies; 13 Robotics Ltda. and PanGeo Subsea Ltd. These acquisitions are aimed to not only bolster Kraken's engineering capacity but also bring additional knowledge in subsea acoustics and the Robotics/Data as a Service business model, accelerating Kraken's move into the provision of vertically integrated offshore survey and inspection services using in-house technology. Kraken received a number of industry accolades in 2020, including:

- Ranked as one of Deloitte's Technology Fast 50 list, Canada's 50 fastest growing technology companies (and ranked 211 / 500 companies in North America)
- Karl Kenny was selected as one of seven Atlantic Canadian winners for EY Entrepreneur of the Year award; the only ocean technology company selected. This will advance to a National Competition in 2021.

In 2020, Kraken landed its largest contract to date, participating in a competitive bidding process to the Royal Danish Navy (RDN), winning a $28.5m contract to upgrade all of the RDN's minehunting sonar systems with Kraken's SeaScout system, including Kraken's KATFISH, Tentacle Winch and ALARS, to be installed on the RDN's unmanned minehunting vessels. Kraken landed another contract for delivering SeaScout systems to the Polish Navy, to be installed on its new Kormoran II class of minehunting vessels.

Throughout 2020-21, Kraken also focused on developing a new division within the company; Robotics as a Service (RaaS) and Data as a Service (DaaS). The RaaS/DaaS division includes a suite of Kraken's own technology products and service offerings, deployed from vessels of opportunity such as Kraken's 20m twin engine high speed survey catamaran known as Ocean Seeker. Kraken also offers its 3D Mooring Chain Inspection Tool (MCIT) which uses the SeaVision laser scanner for asset inspection and creation of a digital twin of the underwater asset.

Krakens SeaScout System consists of the KATFISH towed Synthetic Aperture Sonar vehicle, the Tentacle Winch and Autonomous Launch and Recovery System (ALARS). The SeaScout is targeted to both commercial and defense markets. Kraken has continued development of the SeaVision 3D laser scanning system for the use of creating a digital asset twin of your subsea asset such as mooring chains, pipelines, cables, etc. thus enabling a survey over survey comparison which can detect anomalies or maintenance requirements for targeted segments.

With the acquisition of Pangeo Subsea, Kraken moves beyond seabed imaging into sub-seabed 3D imaging with Pangeo's Sub Bottom Imager (SBI) and Acoustic Corer (AC) technologies, which allow for imaging of centimetric targets buried in the seafloor at depths meters or tens of meters below the seabed.

Based in Totnes, Devon and led by Matthew Quartley, Valeport is one of the foremost manufacturers of oceanographic and hydrographic instrumentation for more than 50 years.

The privately owned, independent family business employs 102 people for the design, manufacture and service of underwater measuring equipment. The company started by making instruments for measuring the speed of water in London's River Thames, and has evolved over more than five decades to house a comprehensive portfolio of underwater measuring equipment across multiple sectors.

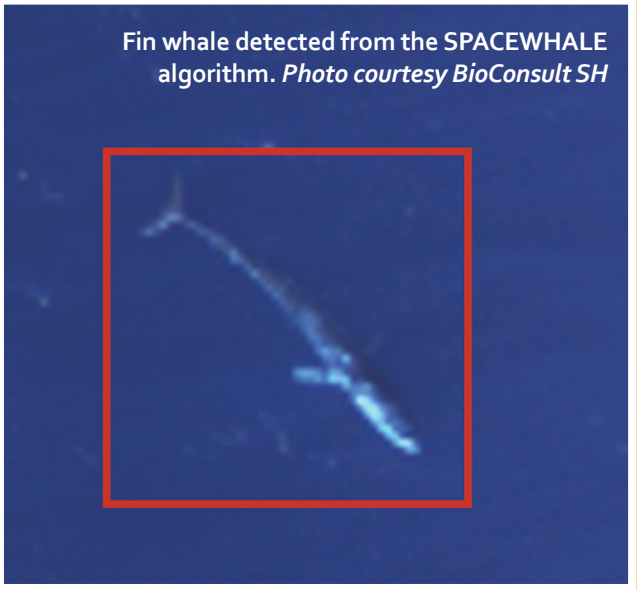
This year Valeport launched a new company, Valeport Water, to service increasing demand from the water industry. Valeport Water draws on the manufacturing capabilities of the original Valeport company and the firm has restructured and expanded its UK HQ base to facilitate the growth of Valeport Water.

In 2021 the SWiFT CTD was launched in response to requests from customers looking for direct CTD readings from an instrument that delivered an improved user experience. Valeport has an established, popular range of SWiFT profilers which are designed with the intention of a seamless workflow at their core. Common to all the SWiFT profilers is the high accuracy sensor technology which has been combined with Bluetooth wireless technology, a rechargeable battery and an integral GPS. The next generation of sensors for ROV/AUV operations have also been launched by Valeport within the last 12 months. The range of instruments with unique interchangeable pressure sensors help users who work at a range of different depths and offer exceptional reliability, precision accuracy and an enhanced and efficient user experience. The new miniIPS2 and uvSVX with field-swappable sensor heads make it easy for users to select the correct pressure range for their work and bring increased accuracy at any depth; benefitting users who previously required different instruments for shallow and deep water. These new compact and robust sensors have been selected by Ocean Infinity to provide sound velocity and bathymetric data for its Armada Fleet.

BioConsult SH & HiDef Aerial Surveying

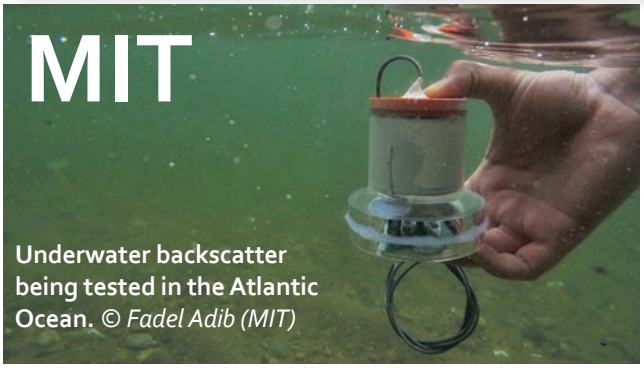
https://www.spacewhales.de/

Space tech and AI have combined to enhance the conservation of marine animals: a new service, **SPACEWHALE**, developed by a team of scientists in Germany and the UK, detects whales from space. Supported by funding from the European Space Agency (ESA) Space Solutions program, this fundamental research enables whales and other large marine megafauna to be surveyed at an unprecedented scale. Earth Observation from satellites is developing fast and within a few years, space technology companies aim to provide daily high-resolution images of the whole globe. SPACEWHALE makes use of this to boost marine research and conservation. "Earth Observation by satellites is currently developing rapidly. It will only take a few more years for space companies to provide high-resolution images of the entire globe on a daily basis," said project manager Caroline Höschle from BioConsult SH. "That makes SPACEWHALE a forward-looking tool, but it already performs fantastically well with the imagery we have today. More than 70% of the Earth's surface is covered by water and thus large areas are still unexplored. The intelligent use of satellite imagery now brings us a lot of previously inaccessible data. SPACEWHALE is part of this revolution. SPACEWHALE is a fast and efficient means of surveying whales - at a comparable cost to traditional methods for only a small area of the oceans. SPACEWHALE uses satellite imagery with a resolution of 31 cm per pixel across the ground, meaning that a 23 m fin whale has a length of around 77 pixels when it fully surfaces. "This is currently the highest commercially available resolution and though the images appear rather coarse, the resolution is just perfect to detect large whales," says data scientist Dr. Grant Humphries from HiDef Aerial Surveying Ltd. Automatic image recognition is now widely used for many applications in our daily life but to be successful, it needs to be based on a large set of training images. So far, there are hardly any satellite images of large whales that could be used as training images. The staff of BioConsult SH and HiDef Aerial Surveying Ltd. found a solution to this problem: they used digital aerial images of the smallest baleen whales, namely the 7 to 10-m-long minke whales, which came from monthly whale monitoring flights of offshore wind farms. The researchers were able to show that the algorithm trained in this way could subsequently recognize 23-m-long fin whales and other whale species on satellite images.



Fin whale detected from the SPACEWHALE algorithm. *Photo courtesy BioConsult SH*

MIT



Underwater backscatter being tested in the Atlantic Ocean. © *Fadel Adib (MIT)*

Underwater acoustics, while excellent at painting an auditory map of the deep sea, can also paint a spatial one. Since GPS doesn't work well underwater, scientists rely on acoustic signaling for locating undersea objects like drones or animals. Motivated by the massive amount of oceanic territory that remains unexplored, researchers at MIT have developed a battery-free pinpointing system called Underwater Backscatter Localization (UBL). When asked to explain the technology, the scientists used the example of an underwater drone trying to determine its location to navigate. With UBL, the drone generates an acoustic signal or some sort of underwater sound, which "then travels and hits one of our battery-free beacons, reflects and comes back. The drone can measure the time it takes the signal to go, reflect and come back to measure the distance." The battery-free beacons, which employ piezoelectric materials, power up by harvesting energy from sound. To do so, the researchers explained, "Our node leverages a piezoceramic unit that is efficiently designed to convert the acoustic energy to electricity." Piezoelectric materials, which are used to both harvest energy and reflect acoustic signals, are key in overcoming the previous challenge of power-hungry tracking devices and deploying underwater GPS.

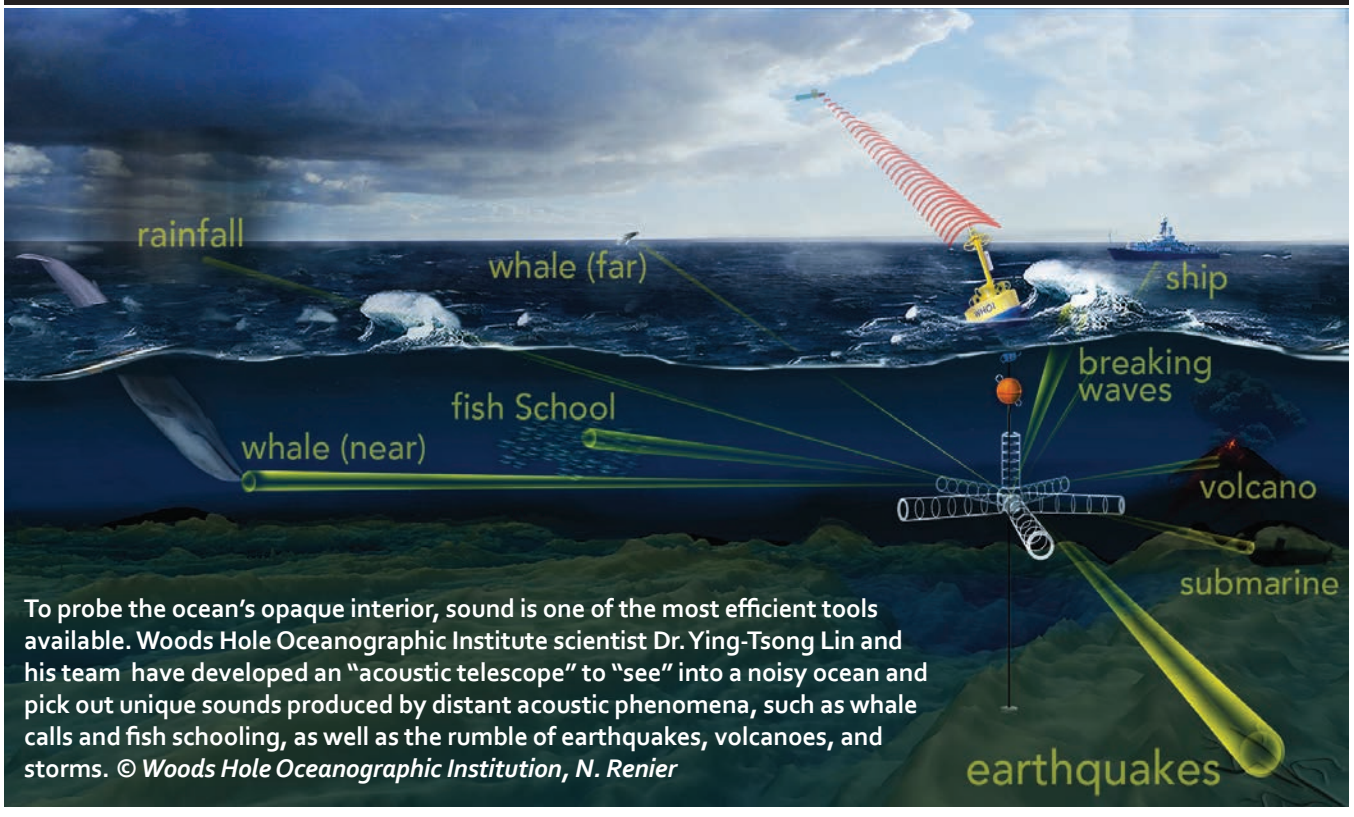
SEA-KIT International

www.sea-kit.com

Based in Essex, UK and led by Ben Simpson, SEA-KIT International is a British SME, 16-employee company providing hi-tech, Uncrewed Surface Vessel (USV) solutions to the maritime and research industries for deployment in harsh offshore environments. SEA-KIT focuses on over-the-horizon deployment of systems and sensors for a range of applications, including maritime logistics, environmental management, security and surveillance, offshore asset monitoring, marine inspection and efficient survey of the ocean floor. SEA-KIT's remotely-controlled USVs have an adaptable payload area and open bay for the effective launch and recovery of autonomous, unmanned and remotely operated underwater vehicles (AUVs/UUVs and ROVs). Through ongoing collaboration with industry partners, SEA-KIT is sharply focused on driving down the cost of geo-data collection and reducing the sector's carbon emissions.

In July 2020, SEA-KIT took part in an uncrewed Atlantic survey mission, co-funded by the European Space Agency, to demonstrate the capabilities of current technologies to survey unexplored ocean frontiers. SEA-KIT's USV 'Maxlimer' demonstrated over-the-horizon survey capability and extended endurance by spending 22 days at sea conducting remote survey operations on Europe's continental margin. 'Maxlimer' travelled 1200+ nautical miles and mapped 400+ square miles of previously uncharted ocean floor during the mission, gathering 1.5 billion data points. Since then, SEA-KIT has delivered the first two in a series of commercial USV builds for leading geo-data specialist, Fugro. The 12m USVs are currently deployed on uncrewed inspections in Australia and Scotland. Multiple additional builds are planned, including a larger vessel later this year.

Woods Hole Oceanographic Institute



To probe the ocean's opaque interior, sound is one of the most efficient tools available. Woods Hole Oceanographic Institute scientist Dr. Ying-Tsong Lin and his team have developed an "acoustic telescope" to "see" into a noisy ocean and pick out unique sounds produced by distant acoustic phenomena, such as whale calls and fish schooling, as well as the rumble of earthquakes, volcanoes, and storms. © *Woods Hole Oceanographic Institution, N. Renier*

Enabling Subsea Autonomy with Complete Optical Payloads

By Chris Gilson, CEO, Voyis

Surveyors have historically been able to easily integrate into their vehicle platforms all the sensors needed to achieve their goals, simply connecting everything though the vehicle tether for surface control. Now however, the industry is seeking fully autonomous remote operations, a goal that requires sensors, navigation, and vehicle control systems to work together as a complex system to deliver unsupervised decision making. This can only be achieved when the sensors instantaneously provide the information and analysis necessary to enable true autonomy.

It is an exciting time in the ocean sector where the combination of emerging robotics technologies and a global pandemic is driving a shift to uncrewed operations. The advent of autonomous systems, and a focus on remote operation, data automation, and smaller low-cost platforms is enabling more efficient and low-cost subsea operations that will open the door to bolder exploration of the depths. But these innovative concepts bring complex challenges that must be overcome.

History of Optical Sensor Development

Voyis led the way in advanced optical sensor development with the integration of its Insight Pro laser scanner into the C&C Technologies (now Oceaneering) HUGIN AUVs in 2012, bringing long range high-resolution 3D laser data and stills images to subsea pipeline inspections. With this new real-time quantifiable data, it enabled reliable pipeline tracking and automated defect detection that was not feasible with multibeam sonar. Because of these developments, optical sensors have now become standard practice for AUV pipeline surveys.

The next step was incorporating these new optical sensors into Work Class ROVs for wide area 3D modelling with the goal of creating digital twins of subsea installations for monitoring assets and conducting dynamic subsea metrologies. In 2016, Voyis worked with Sonardyne to tightly integrate the Insight Pro laser scanner with the Sprint-Nav navigational solution to achieve incredibly accurate 3D models across vast areas. The ROV simply traverses the field, with no asset interaction or requirements to deploy static scanning equipment, and builds up a model of what it sees on the control computer. These instantaneous 3D datasets drastically improved survey efficiency and inspection confidence.

Shifting to Real-time Data Enhancement

Even with these incredible capabilities, a vision of fully autonomous operations requires reliable unsupervised decision

An image of a shipwreck going through Voyis' automated image enhancements and corrections .

Image courtesy VOYIS

making, by which the confidence in these decisions is completely dependent on the quality of the input data. Though laser scanning and stills imaging has always delivered real-time data when compared to photogrammetry, the output can vary with environmental conditions, and machine learning is most robust with consistent datasets. It is therefore imperative that the sensors themselves add real-time processing capability to enable dependable automation.

Voyis is delivering on these requirements by both removing noise from point cloud data with advanced filtering algorithms, and instantly enhancing and correcting images as they are collected. Our robust machine-learning-based colour correction algorithms help us to see consistent true-colour photos of subsea targets.

When combined with navigational data, it is possible to deliver real-time geo-corrected laser models, and consistent images across incredibly long surveys. This uniformity produces wide area consistent image mosaics without variations in quality from image to image. Adding onboard analysis software, like EIVA's Onboard Deep Learning, enables the automated detection of pipeline defects and features, to drastically reduce analysis time.

Miniaturization into Complete Solutions

The final and most significant challenge in subsea operations has remained constant, the cost and inaccessibility of ocean exploration. For our future to see a proliferation of optical sensors documenting our oceans, these high-resolution sensors must be delivered in packages suitable for small, low-cost vehicle platforms that lessen the required deployment infrastructure. The level of complexity now demanded requires not just piecemeal sensors, but complete payload solutions with synergistic integrations between sensors, navigation solutions, and vehicle platforms.

To this end, Voyis has launched the Recon line of AUV payloads, developed in partnership with vehicle manufacturers for common platforms like the HII REMUS 100 and L3Harris IVER 4.

The hydrodynamic modules mount in-line with the vehicle using standard mechanical interfaces, connect to existing electrical inputs, and are controlled with the vehicle's mission planning interface. All data can be saved to the payload's onboard hard drive to simplify data management and the vehicle's navigational data is accessed automatically to geotag images and spatially correct 3D laser data to improve target localization.

Optical payloads are now being combined with side-scan sonar from Wavefront, onboard deep learning from EIVA, and a contactless cathodic protection system from Ocean Floor Geophysics to deliver application specific payloads. This reduces barriers to adoption and makes it easier than ever before for surveyors to adopt new survey technology.

Recent innovations in highly capable small vehicle platforms, miniaturized sensor technologies, and advanced sensor autonomy provide the building blocks to achieve the future vision of fully remote operations. But true autonomy is not achieved in isolation, it will require surveyors, vehicle designers, and sensor manufacturers all working together in partnership to overcome the challenges, and together, Illuminate the Unknown.

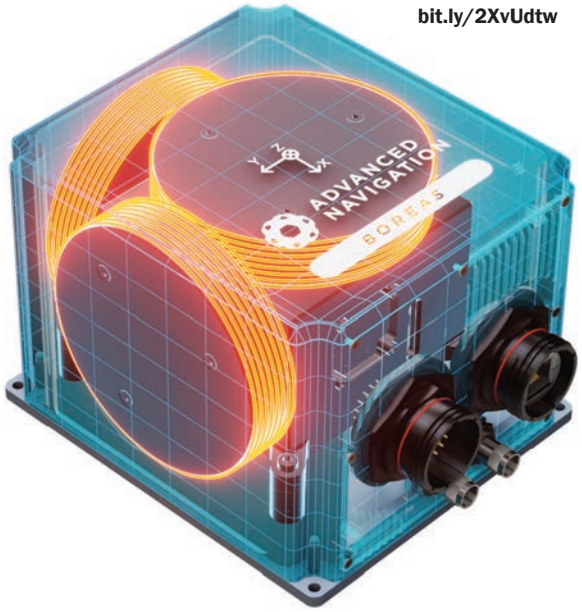
Image courtesy VOYIS

Advanced Navigation

www.advancednavigation.com

MARINE TECHNOLOGY TV

Watch the video @ bit.ly/2XvUdtw



Led by CEO Xavier Orr, Advanced Navigation is a Sydney, Australia-based provider of navigation and robotics solutions. Its solutions are used by top defense companies and car manufacturers, such as NASA, Tesla, Airbus, Boeing, Thales, Lockheed Martin and BAE Systems. Its mission is to develop solutions that perform in the most demanding conditions with the lowest SWaP-C (size, weight, power consumption and cost).

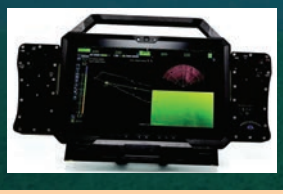
Boreas D90 is an ultra-high accuracy, strategic-grade INS, offering a 40% reduction in size, weight, power and cost, according to the company. Boreas D90 is the first product based on Advanced Navigation's new DFOG (Digital Fiber Optic Gyroscope) technology, which is the culmination of 25 years of development involving two research institutions. The Boreas D90 is targeted at applications requiring always available, ultra-high accuracy, orientation and navigation including marine, surveying, subsea, aerospace, robotics and space. The Boreas D90 delivers a strategic-grade bias stability of 0.001 deg/hr. This allows the Boreas D90 to achieve ultra-high roll/pitch accuracy of 0.005 degrees and heading accuracy of 0.006 degrees. Boreas D90 allows for full GPS independence with dead reckoning accuracy of 0.01% distance travelled with an odometer or DVL. This next generation FOG features ultra-fast gyrocompassing, taking only two minutes to acquire heading in both stationary environments or on the move. The gyrocompassing allows the system to determine a highly accurate heading of 0.01 degrees secant latitude without any reliance on magnetic heading or GPS.

To achieve DFOG, three different, yet complimentary, technologies have been developed to improve the capabilities of FOG.

1. **Digital Modulation Techniques:** DFOG uses a specially developed digital modulation technique passing spread spectrum signals through the coil. The new digital modulation technique introduced in DFOG technology allows in-run variable errors in the coil to be measured and removed from the measurements. This makes DFOG significantly more stable and reliable than traditional FOGs. It also allows a smaller FOG with less coil length to achieve the accuracy of one with a longer coil.
2. **Revolutionary Optical Chip:** By integrating 5 sensitive components into a single chip and removing all the fiber splices, the size, weight and power is reduced considerably while significantly improving reliability and performance.
3. **Specially Designed Optical Coil:** DFOG employs a specially designed closed-loop optical coil, developed to take full advantage of the digital modulation techniques.

VideoRay

www.videoray.com



VideoRay is a long-tenured leader in the ROV market, starting in 1999 selling what then were essentially "swimming video cameras" according to Chris Gibson, VP Sales & Marketing. "But our business has really taken off over the last couple of years. 2020 was a record revenue year for VideoRay, and in 2021 we are projecting 50% growth over 2020," said Gibson, attributing this largely to a strong and growing defense business and a rebounding commercial market, primarily in offshore oil and gas, but also includes renewable civil infrastructure inspection, aquaculture and water management.

Headquartered in Pottstown, Pa., VideoRay is a leader in man-portable ROV market. Its Mission Specialist technology is based on modular components providing maximum flexibility. The largest and most powerful Mission Specialist configuration, the Defender, is optimized for precise control, heavier payloads, lifting, and specialized operations.

The Pro 5 trades off larger payload, massive thrust, and more precise autonomous control for more portability and lower cost. Mission Specialist technology is unique in the ability to add new sensors and accessories from a broad range of manufacturers, as it supports a wide range of power and communications options.

In early 2021, VideoRay launched new expeditionary and workhorse Mission Specialist products. "Many of those were developed in line with what we're trying to do with our defense business; making things rugged, more robust," a toughened system that is proving attractive to a number of commercial clients, too.

Like other companies in the space, investment in improving and refining technology is a constant at VideoRay, and recent investment targets an improved customer experience. "The U.S. Navy measures us on a metric that they call operational availability, and that a key performance indicator that measures how often a system is available," said Gibson. "This has been very good for us because it hits VideoRay right in one of our core strengths; reliability and robustness. But what we've done is we've made it even better."

Central to investment in making the user interface smoother and easier for the user, is pushing the computing power "down through the tether," delivering the power where it's needed most while minimizing the topside footprint. This means the person using the ROV can be positioned on a small boat above, shoreside or half-way around the world.

This also includes investment in autonomy, artificial intelligence and perception technologies. "Those three things are getting worked into almost everything that we do," said Gibson. But at VideoRay, delivering new technologies does not necessarily mean that the end customer must purchase an entirely new system. "The nice thing about it is even with us with these expeditionary and workhorse products, the products that we first delivered, the first Defenders that we shipped to customers years ago, can take these upgrades and basically extend their capabilities without having to buy a new product," said Gibson. "And that's the same way the autonomy, the artificial intelligence and the perceptive technologies will be when they're commercially available."

Academia's climate change challenge is far from Academic

By Celia Konowe

The most recent report released by the UN Intergovernmental Panel on Climate Change emphasized our warming planet, an expected announcement for many in the scientific community. Faced with the confirmation that human activities have caused an increase in global temperatures, research has turned to seeking answers in the planet's natural systems. How does each part of the global carbon cycle work and how may it be impacted by the changing climate? What other trends can be observed across the marine industry and what innovative technologies can make positive change?

Shedding light on the twilight zone

Researchers at **Woods Hole Oceanographic Institution (WHOI)**, in collaboration with **Monterey Bay Aquarium Research Institute** and **Stanford University**, have begun addressing this question by seeking to understand how marine creatures transport carbon dioxide to the deep sea, one of the world's largest carbon sinks. An underwater robot by the name Mesobot is providing scientists with insight into the twilight zone, a vast mid-ocean region.

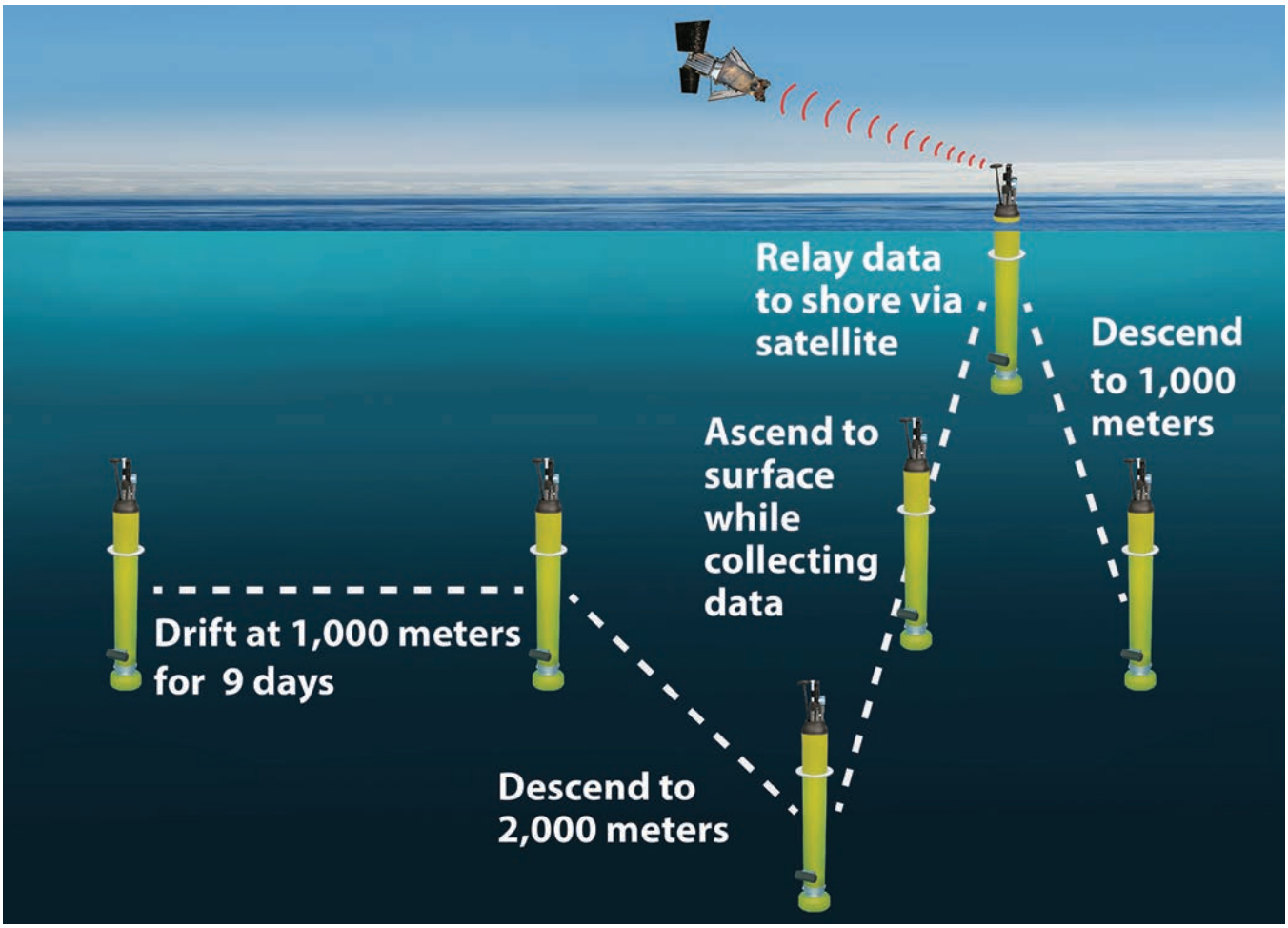
Mesobot is capable of tracking and recording high-resolution images of zooplankton, gelatinous animals and particles, improving scientists' ability to observe creatures in their natural habitat with minimal disturbance. The robot, outfitted with oceanographic and acoustic survey sensors, can be piloted remotely through a fiberoptic cable attached to a ship, follow pre-programmed missions, or autonomously track targets up to 1,000 meters deep. "Mesobot was conceived to complement and fill important gaps not served by existing technologies and platforms," said Yoerger. "Because Mesobot can survey, track and record compelling imagery, we hope to reveal previously unknown behaviors, species interactions, morphological structures and the use of bioluminescence."

Autonomous tracking, the latter of Mesobot's three capabilities, could eventually allow scientists to monitor an organism's behavior during diel vertical migration, a movement pattern during which organisms move to the uppermost layer of the sea at night and return to the twilight zone during the day.

Miniscule, but of sizable importance

Although they exist out of our sight, even microscope marine life plays a crucial role in the health of the oceans—and that of the planet itself—through a biological phenomenon known as marine primary productivity. Through this process, tiny organisms, like phytoplankton, use photosynthesis to consume carbon dioxide and convert it into organic matter and oxygen. The conversion of carbon dioxide into organic matter not only supports oceanic food webs, but contributes significantly to the ocean's biological carbon pump, a part of the global carbon cycle that has become increasingly more important to track and understand in recent years. Researchers at **MBARI**, including senior scientist Ken Johnson, have demonstrated how a fleet of robotic floats can improve our understanding of marine primary production on a global scale. "The technology we use is a big array of biogeochemical-Argo robotic profiling floats that are equipped with chemical and biological sensors. For the productivity work, we used oxygen sensors to detect the increase in oxygen that is created by photosynthesis and the chlorophyll sensors to detect how deep light (needed for photosynthesis) is penetrating," Johnson explained. "Each float profiles from about 2 km depth to the surface every 10 days, making measurements on the way up. At the surface, each float sends the data home through the Iridium satellite network." Phytoplankton consume carbon dioxide and release oxygen at a specific ratio, and by measuring oxygen release over time, scientists can better understand the role played by marine life in the carbon cycle. By combining the work of hundreds of floats that reach the surface at various times of the day, Johnson's team can recreate the daily carbon cycle and calculate a more accurate primary productivity. "This allowed us to get the mean, daily cycle of oxygen over the global ocean and the first, direct measurement of global ocean primary productivity," said Johnson.

Marine primary productivity changes in response to climat-



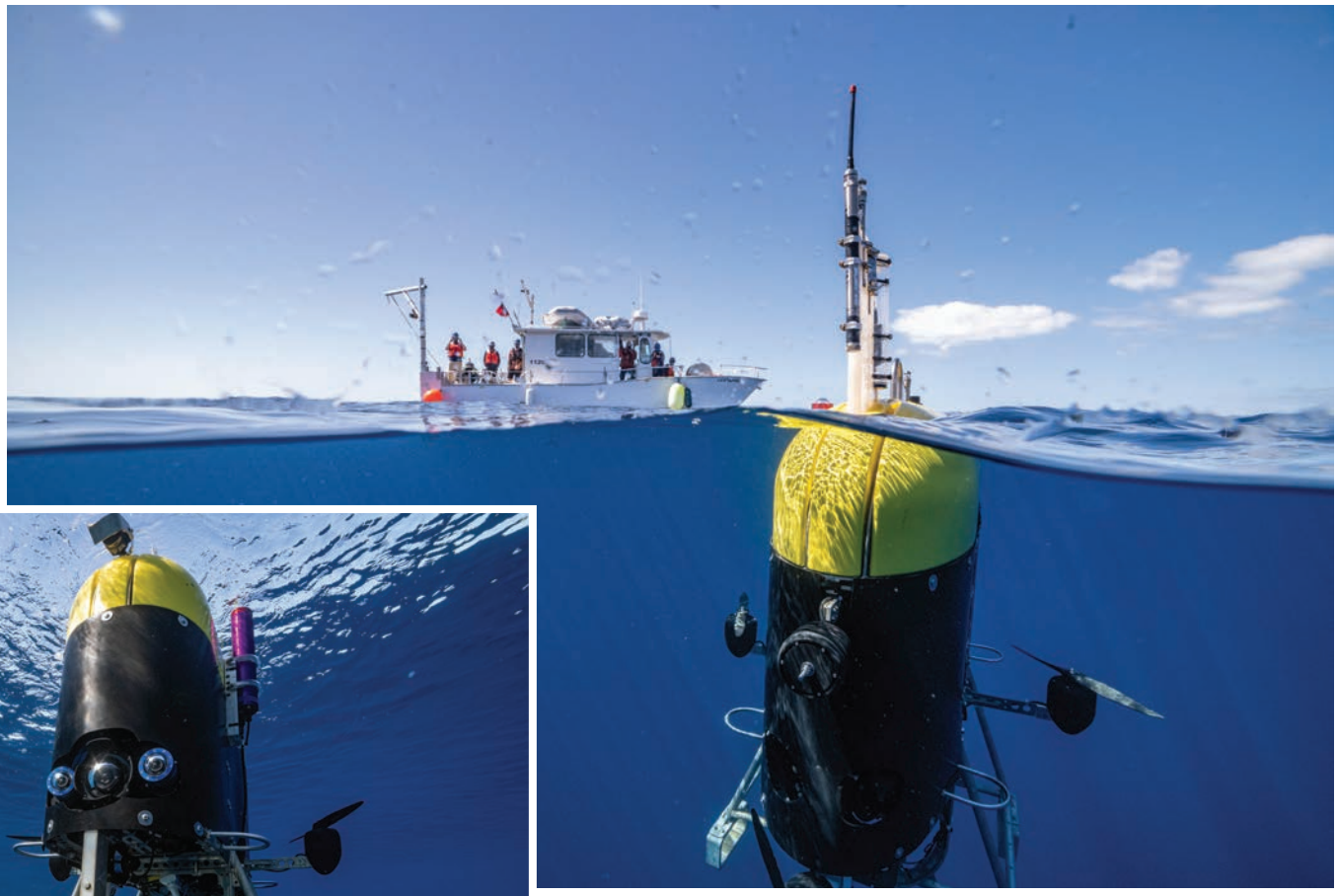
A biogeochemical-Argo (BGC-Argo) float collects data between the surface and 2,000 meters deep over 10 days. © *Kim Fulton-Bennett 2020 MBARI*

ic fluctuations (temperatures, ice, currents, etc.) and monitoring this shift is crucial to understanding climate change. Previously, tracking this response on a global scale has been difficult due to human and technological setbacks. "Primary productivity is the key to ocean ecosystem function and change. Phytoplankton use photosynthesis to create the organic carbon that fuels the whole ocean ecosystem. Lower primary productivity, probably fewer fish. More primary productivity, maybe more fish. But we just don't have direct observations at the global scale to see what is happening," Johnson said. This data will allow scientists to better predict how marine primary productivity may change in response to our changing climate—including warmer waters and ocean acidification. "This is just the start; we don't have enough data to say how primary productivity is changing – we're just establishing a baseline for the modern ocean."

Kelp calm and carry on

Marine plants, too, could provide an answer to the ocean's role as a carbon sink. **New Zealand's National Institute of Water and Atmospheric Research**, with the help of drones and underwater ROVs, is conducting research to assess the health of kelp and seaweed forests. Marine plants play an enormous role in marine ecosystems and the warming climate by absorbing carbon emissions and monitoring their health is crucial to understand the impacts of rising temperatures.

On behalf of the Department of Conservation, marine ecologist Dr. Leigh Tait and environmental monitoring technician Hamish Sutton have launched pre-programmed flights over shallow reef in the Taputeranga Marine Reserve. Hanging off the bottom of the drone is a multispectral camera, able to register colors invisible to the human eye. Throughout its flight, a photo is taken every two seconds. Thanks to rubber maps laid out in the water to relate the images to real features on the ground, the photos are stitched together into 2D or 3D models. The images are then run through computer software training to identify the types of seaweed.



Mesobot, an underwater robot capable of tracking and recording high-resolution images of slow-moving and fragile zooplankton, gelatinous animals, and particles, is providing researchers with deeper insight into the vast mid-ocean region known as the twilight zone.

© Evan Kovacs/©Woods Hole Oceanographic Institution

In the kelp forests of Antarctica's Ross Sea, underwater ROVs are playing a role in ecosystem health assessment, too. The **BoxFish** ROV in question can survey Antarctic marine life more than 100 meters below the surface with its sensors and high-definition cameras, tethered to a surface ship with fiberoptic cables for data transfer. A recent survey uncovered surprisingly deep and dense stands of kelp, furthering questions about their role in the marine carbon cycle. "It really opens up a whole new field of research in how those plants are taking CO2 out of the atmosphere and storing that in the deep cold sea. We really know very little about that," Dr. Leigh Tait said.

A Whale of a Challenge

Recent research in academia also includes marine organisms that exist very much in our sight—whales. A collaborative project between the **Ocean Tracking Network** (OTN), **Dalhousie University**, the **University of New Brunswick** and **Transport Canada**, is working towards their protection. Using a fleet of OTN gliders operated by the Coastal Environmental Observation Technology and Research group (a collaboration between OTN, the Ocean Frontier Institute, and the Marine Environmental Observation Prediction and Response Network), the project monitors North Atlantic right whales in the gulf of the St. Lawrence River using autonomous underwater gliders. OTN executive director Fred Whoriskey explained the technology behind the Teledyne Marine Slocum gliders in use. Each is battery-powered and can remain at sea for up to four months. They contain an engine to adjust buoyancy as needed and move at a speed of about one knot, reaching depths of up to 1,000 meters. The glider can carry various instruments, such as thermometers or conductivity meters, and collects data as it moves through the water column, which is stored to an onboard memory

Dr. Rachel Coppock and Dr Matthew Cole with the experimental equipment in Plymouth. © PML

system until it reaches the surface and transmits all information via satellite. Slocum gliders, as in Dalhousie's case, can also be outfitted with a digital acoustic monitor (DMON), a device developed by **Woods Hole Oceanographic Institution** scientist Mark Baumgartner. The DMON can record the calls of North Atlantic right whales (as well as other large whales) and the transmitted data can help authorities avoid collisions with vessels.

The recent move of the whale species from its traditional seasonal feeding grounds in the Bay of Fundy and the Roseway Basin to the Gulf of St. Lawrence has increased the risk of vessel collisions and fish gear entanglement. "Right whales are critically endangered, and we are at a point where we must do everything possible to avoid human induced mortalities or injuries to the species to help the species recover," Whoriskey said. "The glider program is part of an effort to inform human activities, notably fishing and shipping, that have been shown to be the major causes of right whale mortalities in recent years."

Pervasive plastics

Beyond the questions posed by the global carbon cycle and recent news of the warming planet, other significant marine crises, such as microplastic pollution, remain at the forefront of research. In some cases, solutions to clean our waters of plastic particles go beyond the traditional macro plastic pollution cleanups and sifting through water. On occasion, scientists look towards nature for the answer.

The star of this show, as demonstrated through research conducted by the **Plymouth Marine Lab (PML)**, are mussels. Mussels are hardy and robust, able to survive in polluted waters, and are filter feeders—they get their food by filtering seawater to get plankton and other nutrients while flushing out unwanted particles from their digestive systems. "Several laboratory-based studies have previously shown that mussels can filter microplastics out of the water, so we wanted to take a closer look at exactly how effectively mussels could do this and how this knowledge could be applied in the real world to help provide a nature-based solution to plastic pollution," explained Pennie Lindeque, Head of Science for Marine Ecology and Biodiversity.

Initial experiments involved a specially designed flume tank that circulated water to mimic estuary currents. The blue mussels (Mytilus edulis) were given algae and micro-

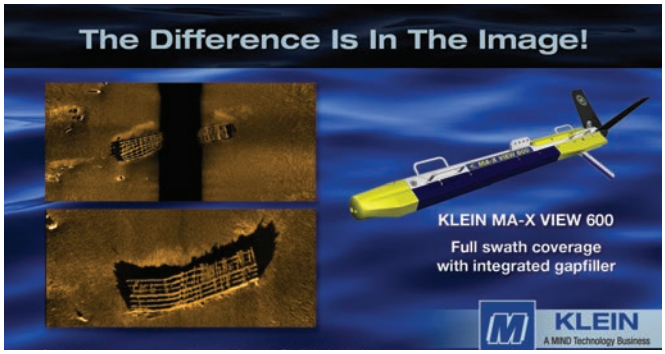
Hydrophone-equipped Slocum gliders are listening for the calls of North Atlantic right whales and transmitting the animals' locations in near-real-time to ships and vessels in the area. Results from the work aim to reduce the number of whale-ship collisions and are assisting with the protection of critical whale habitats. © ***Nicolas Winkler***

Drone pilot Hamish Sutton (left) and Dr Leigh Tait check settings before launching another pre-programmed flight across the Taputeranga Marine Reserve. *© Rebekah Parsons-King, NIWA*

plastics to feed on, and over the course of two hours, the bivalve mollusks had removed half of the microplastics present. The particles are rejected by the mussels as fecal matter, which sinks and can be collected for removal. With this knowledge, PML scientists used computer models to place hypothetical "ropes" of mussels every 100 meters at the mouth of estuaries to predict how much plastic could potentially be removed, Lindeque explained. "These models indicated that mussels situated near the mouths of rivers and estuaries could filter between 20-25% of small, waterborne microplastics." Further tests include a series of trials in a Plymouth marina using clusters of mussels in large baskets; the feces (and microplastics) are collected by net-like receptables below the baskets.

While the factors involved are complex—physical parameters include depth, currents, tides and temperatures—the findings show that a mussel-based cleaning system could provide positive effects in estuarine areas, especially in places were microplastics may accumulate, like harbors or near wastewater treatment plants. "Ultimately, we need to be thinking about making plastics part of a circular economy, where end-of-life plastic is reused, recycled or safely disposed," said Lindeque. "In the meantime, we hope that by using natural ecosystems and processes, like the mussels' filtering ability, we can help stem the flow of microplastics into our oceans.

With the recent IPCC report still fresh in our minds and limitless questions to tackle on the horizon, marine research faces boundless expectations, yet continues to make significant advances. Issues like increasing levels of carbon dioxide, endangered species and plastic pollution are just three of many that face marine ecosystems and coastal communities. In this sense, academia plays a unique role in identifying crucial trends and influencing technological development and societal action. Between innovative solutions and the motivation to understand and protect the planet, research will continue to uncover new findings and pave a path towards a cooler future.



Klein - MIND Technology

Klein Marine Systems, Inc., a MIND Technology company business is a leading sensor technology manufacturer of high-resolution side scan sonar equipment systems, a leading supplier of side scan sonar systems. The KLEIN 4K-SVY is the first in a new series of Professional Survey Side Scan Sonars. Designed to meet the new industry standards for Offshore Renewable Energy and Oil/Gas Survey operations. Survey and High-Definition Simultaneous Modes of operation with optimized range and resolution dependent configurations. MA-X technology is a solution to filling the nadir gap that is characteristic of traditional side scan sonar. By seamlessly covering the nadir region, MA-X based products eliminate the need for overlapping survey lines, resulting in an estimated 40% increase in efficiency.

https://mind-technology.com

Deep Ocean Engineering

Deep Ocean Engineering (DOE) has an electric, light work-class remotely operated underwater vehicle (ROV), the Phantom X8, designed for deep sea exploration and light intervention work. The vehicle is the largest and most heavy-duty ROV manufactured by DOE and packs a robust design for deep sea maneuverability and power. Configured with six vectored horizontal and two vertical 2.2 kW Tecnadyne brushless thrusters, the Phantom X8 has complete control and authority in any given direction, even in the toughest currents. For clarity underwater, the Phantom X8 boasts high definition (1080p) front (+/-90°) (pan optional) and rear (low light) cameras with 3 LED lights emitting 30,000 total Lumens with adjustable brightness controlled by the pilot control box or GUI.

https://www.deepocean.com

Copenhagen Subsea A/S

Headquartered and inspired by its namesake city, Copenhagen Subsea melds the technical with the aesthetic, creating products designed to be reliable, powerful and attractive. Copenhagen Subsea uses the latest manufacturing technology for its thruster and ROV technology; for example, they make diligent use of 3D printing for the propellers. Copenhagen Subsea most recently launched a new powerful ROV, the Gorilla, which uses eight Copenhagen Subsea thrusters, designed to make it reliable and robust while keeping its position in strong currents and allowing for operation in harsh and demanding environments. The Gorilla ROV is equipped as standard with an intelligent Dynamic Positioning (DP) system, enabling automatic control of position, depth, altitude, heading, pitch and roll. The Gorilla ROV is based on industrial hardware from the Japanese industrial electronics company OMRON, built to handle extreme conditions such as high current inrush from the thruster during deceleration and current overload at fast shifting of the thruster direction. Both of these are critical for the ROV to be able to keep its position in strong currents. In short, the Gorilla is tough and strong, works reliably in challenging conditions, is simple to maintain with easy access to spare parts and is easily controlled thanks to Copenhagen Subsea's innovative thruster technology, making it suited for completing any task in tough offshore conditions.

www.copenhagensubsea.com

SEAMOR Marine

www.seamor.com

Led by Robin Li and based in Nanaimo, Canada, SEAMOR Marine, established in 2006 has been in the business of building World Class ROVs for almost 15 years and has been supplying clients around the world, from the Arctic to the Antarctic, with underwater solutions to discover the deep. SEAMOR Marine is one of just a few subsea ROV companies in Canada that exports products all over the world. This year its flagship Chinook ROV was used in July to locate and survey a downed Boeing 737 off Hawaii for the National Transportation Safety Board. Earlier in January this year, a SEAMOR Chinook ROV was able to locate and picture a lost scallop boat during winter storms, in the Bay of Fundy. SEAMOR Marine this year launched the new Sea Otter 50 and Sea Otter 100 tether management systems.

SubC Imaging

www.subcimaging.com

Located in Newfoundland and Labrador, Canada, and led by Chad Collett, SubC Imaging's mission is to continuously create the most technologically advanced and intelligent subsea imaging equipment and software. With a number of unique and highly capable imaging systems and products to choose from, SubC covers a broad range of Ocean Science research applications. Whether being used for marine science observatories or offshore energy using an ROV, SubC products enable researchers to capture the high-quality footage they need no matter the application. High-Quality Cameras: With its proprietary water-corrected LiquidOptics, rugged build, and versatile features, SubC's low-latency cameras are purposely built to withstand severe marine environments. Consistently providing uncompromising 4K and HD video and imaging quality, SubC cameras deliver live HD over Ethernet or coax, and live 4K over fiber optics. All cameras and accessories are certified to 6000m of water. DVR with Overlay Compatible: With all common video standards up to 4K, the DVR with Overlay offers 6 channels of 4K, HD, IP and SD video and can be up and running in less than 1 hour. The DVR with Overlay provides data logging with time-sync events and supports recording, blackboxing and dynamic overlay of all camera feeds. Offshore Real-time Streaming: Conveniently live stream HD subsea video from any ROV or subsea system during offshore and marine operations such as inspection, survey, and more. SubC's Offshore Real-Time Streaming is integrated with SubC's Digital Video Recorder with Overlay and cameras to provide multiple low-latency video sources with two-way audio communication. Systems: All of SubC's products can also be bundled into systems: Digital Stills & 4K: For anomaly identification, clip generation and photogrammetry; Observatory: Reliable multi-purpose Ethernet camera, mux and data-logger for long duration use; Towed Camera: For smaller vessels working in coastal water of under 500 meters. Boost Power Communication (BPC) technology enables low-cost simplification of cables and deployment setup for transmission of video and datal; Autonomous Camera: Timelapse digital stills and 4K video for deployments where live video is not possible or required; Subsea 4K & HD Video Survey: Includes all of the software and hardware required for an effective inspection without all the cost. Available in HD, SD, IP Ethernet, and 4K configurations.

Teledyne Marine's "The Ocean Book"

MARINE TECHNOLOGY TV
https://youtu.be/POUlnhulsgo

Mike Read, President, Teledyne Marine, discusses a recent book from the company – The Ocean Book – written to present the depth and breadth of Teledyne Marine's works in and around the world's waterways.

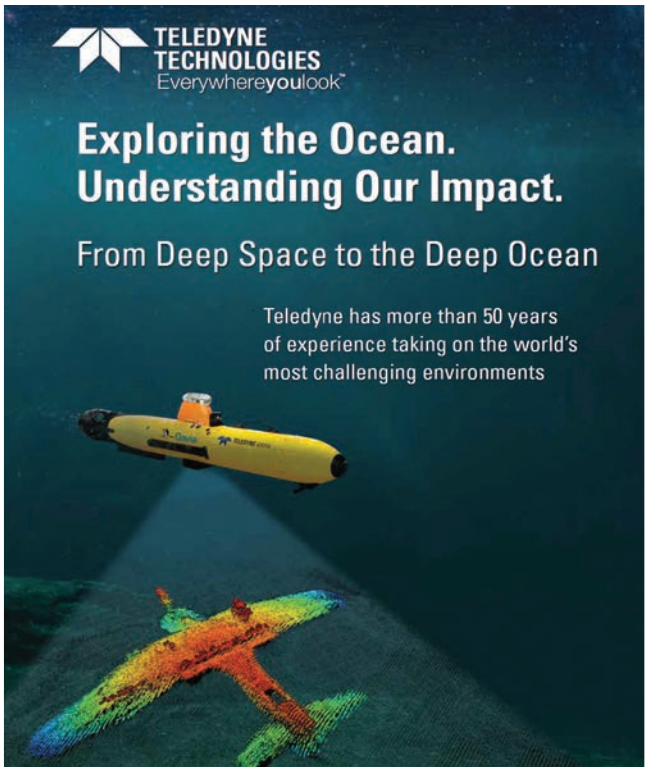
Teledyne Marine has steadily built an armada of companies and technologies serving the global subsea industry, a breadth of offer and capability now captured in *"Exploring the Ocean. Understanding our Impact,"* or more simply put, The Ocean Book, a comprehensive exploration of all that the company has to offer in the space. The idea for the book emanated from the space program side of Teledyne's business, and the company's chairman, Dr. Mehrabian, reportedly was so pleased with that production that he asked the marine team to produce a similar book.

According to Read, nearly a dozen people globally were responsible for pulling together the series of case studies, encompassing 120-pages of "great reading exploring more than 50 years of experience understanding the impact of the ocean." The 'new' Teledyne Marine – the company and all of its current components and structure – recently celebrated its sixth year together. "We finished the integration of the 23 product companies, 22 of which were acquisitions into this one marine company, and we thought that it would be good to look back and pull it all together (in a book)," said Read. The Ocean Book is intended to not only inform clients of Teledyne Marine's breadth, but also to inspire new graduates, employees (both existing and new) in regards to the company's reach.

"To have it as a hard copy is really extraordinary today, because everything's online," said Read. "But we went the other way with this and produced a book."

The book is broken down by the market sectors where Teledyne Marine works, from ocean science to aging infrastructure & marine construction to energy and defense & security.

"I think the most fascinating thing is the variety of case studies," said Read. "The migration of Science and Applications from Ocean Science into infrastructure, into energy, and even into gliders that are mapping weather and climate change are very similar to those that are providing security to the U.S. Navy." Read said the book highlights the linkage between these different market segments, all of which share similarities of the stresses and strains, the need for longevity and reliability for each application. "And then the breadth of the applications around the world," said Read. "That's really what you're going to learn by reading part of it or all of it."



MTR readers can download a digital copy @:
https://go4.teledynemarine.com/Oceanbook

Teledyne Marine Writes the Book on Ocean Technology

Teledyne Marine's team of professionals has quite literally written the book on ocean technology. The book, entitled "Exploring the Ocean. Understanding our Impact." details how Teledyne's vast array of leading-edge marine technology is being used by customers around the globe to better understand and utilize our oceans and waterways.

The 120-page book details more than 40 real-world customer applications. From addressing environmental impacts and preserving safety and peace, to solving challenges with infrastructure and energy source development, you'll see how the work we're doing together today is making a difference for tomorrow. The following are brief synopses of sample case studies to give readers a feel for the content they can expect to encounter in greater detail within the book.

All images courtesy Teledyne Marine

Measuring Ocean Conditions in Storm Tracks

Global concern about Earth's changing climate has gained public attention. For the last decade, Teledyne Slocum gliders have monitored the waters associated with storms. The gliders measure temperature, salinity, and other properties, surfacing periodically to send their measurements to storm- forecasting centers. The data is input to computer models that output predictions about a storm's intensity and trajectory. Gliders have been on duty observing hurricanes Florence, Isaac, and Helene, increasing our understanding of these adverse weather events.

Surveying the Old Town Port in Dubrovnik, Croatia

The Old Town Port at Dubrovnik was surveyed using a Teledyne multibeam echosounder and its related acquisition and image processing software. The dilapidated breakwater had been identified as an interesting cultural-historical asset in need of repair. Indeed, the ancient Walls of Dubrovnik that protected this port, was listed as a UNESCO World Heritage Site in 1979. It was the first time underwater archaeological research had been carried out on the historic Dubrovnik breakwater. Modern hydrographic, geological, and geophysical techniques allowed researchers to study the entire old city harbour in greater detail, and to create a historic timeline of its development without endangering the site itself.

Fun Fact: Dubrovnik was the main filming location in Croatia for King's Landing, a fictional city in *Game of Thrones.*

A Novel Approach to Aqueduct Inspection

The 444-mile Governor Edmund G. Brown California Aqueduct is a system of canals, tunnels, and pipelines running north to south in the state of California. The Department of Water Resources needed to inspect the water-filled channels for cracks, sink holes, and obstructions that may impact the aqueduct's integrity and efficiency. Brown and Caldwell reached out to Teledyne to devise and test a turnkey solution. The result was a custom-built catamaran-style unmanned surface vehicle (USV) (provided by an industry partner) large enough to house a full suite of Teledyne multibeam and scanning sonars to image below the waterline; LiDar to map above the waterline; a GNSS system for georeferencing; and software from Teledyne CARIS to integrate the data to deliver a "fly through" view of canal's conditions.

GOM Fiber Optic Network: Maintaining Offshore Connections

The rising costs of oil and gas development and operation is driving the use of automation in places like offshore platforms. With fewer onsite personnel, the ability to monitor and control the operation from onshore locations in real-time is becoming increasingly essential. With this in mind, BP initiated a project at the time to design and construct a fiber optic network to provide high-quality connectivity among their deep-water wells in the Gulf of Mexico (GoM). The network required operation during even the most severe weather, including hurricanes, common to the GoM. To meet this challenge, Teledyne engineered a new type of distribution unit, with wetmate connectors at key locations throughout the network capable of meeting the high-performance specifications required by BP. Each highly robust optical unit provided four nodes and was fully modular to allow for expansion.

To Be *(resident)*, or Not to Be?

That's the question? *Or, more specifically, are there alternative ways of delivering robotics to where they're needed without having to have seabed docking stations?* ***Elaine Maslin takes a look.***

The idea for some kind of resident subsea vehicle has been around for some time. From BP's considerations in 1986 for an integrated ROV launch system onboard the SWOPS oil production system to support subsea activities through to a Schlumberger patent filed in 2000 for a seafloor station to house an underwater vehicle to service at least one subsea well.

The idea is now closer to reality than ever, with seabed docking demonstrations now done with various vehicles. The first commercial resident drone is also creeping closer to finally going on contract; mid-June, **Saipem's Hydrone-R** was said to be mobilizing to **Equinor's** Njord field in Norway, having proven 4-5 months continuous residency, in tests.

The benefits of resident systems are around reduced reliance on crewed vessels for deployment (lowering risk to humans and GHG emissions), de-linking deployment from being reliant on decent weather, reducing the risks associated with launch and recovery through the splash zone and offering greater time on task. But will all fields justify resident systems and are there alternative ways to deliver subsea robotics?

"We think the subsea docking station is a good idea, but the applicability will be very limited to some offshore fields that are large and concentrated enough to keep that drone busy," says Norwegian subsea service provider **uSEA's** Felipe Lima. "In most fields the drone will be idle most of the time," so why not allow that vehicle to be more mobile and work on other fields using uncrewed surface vessels (USVs)? he says. Helge Sverre Eide, business development manager at underwater interface firm **Blue Logic**, which is working with uSEA on a mid-water towed docking system, agrees; you need to increase the scope the drones do to make the resident business case work.

Lee Wilson at UK start-up **HonuWorx**, which has an idea for a subsea shuttle/deployment system, says, "We think there are very few deployment cases where the economics will stack up for permanent residency. But we share the aim of replacing conventional vessels. And we want to get rid of complex offshore lifting operations."

Another challenge is that if a resident drone can't do one out of 10 tasks and a crewed vessel still has to come out without knowing when, it kills the business case, Steffan Lindsø, Subsea Robotics Product Manager at **Oceaneering**, says. "That's the big challenge. Most fields have a biennial inspection and doesn't require an ROV there at all times." Oceaneering has been developing the Freedom hybrid AUV – an AUV with light intervention capabilities – that could serve as a resident system, but is initially targeting pipeline survey. However, it also has the Liberty E-ROV, a standalone system comprising an electric ROV with deployment cage, batteries and surface communications buoy, so it can be dropped off and left in field for weeks or months at a time without vessel support, offering temporary residency.

"There's not one solution that fits everything," says Graeme Jaques, Sales Manager at UK-based **Modus**, which

Modus' floating dock.

Modus

has developed and has been using a number of different ways to deploy its hybrid AUVs (HAUVs), based on Sabertooth AUVs, at the surface, mid-water and the seabed, and recently agreed to acquire two of **Kawasaki Heavy Industry's** SPICE AUVs. "Some fields or wind farms will lend themselves better to resident vehicles tied to the infrastructure," he says. "Some more remote fields will lend themselves better to vehicles deployed from a USV. I think there will be a mixture."

Modus

Modus has three different deployment methods, all focused on using low logistics vessels, says Jaques, using a flexible vehicle that can operate like an AUV or ROV and carry a manipulator skid. At one end is its single point lift launch and recovery system (LARs), which can be deployed off a small low freeboard vessel (in low sea states), with a simple over boarding system such as a small crane with remote release, and a smart grabber for recovery. This has been used for inter-array cable depth of burial surveys and cable surveys in Europe.

It then has a "floating dock", where the vehicle is launched in a cradle over the side, using a subsea crane. The vehicle drives out of the dock, avoiding a need for heave compensation systems. At the end of a mission, it's driven back in using a Wi-Fi connection to it from the vessel, for recovery. This has been used on pipeline and platform inspections in Australia and wellhead and pipeline surveys in the Mediterranean.

Then there's a subsea dock, based on a single point lift cassette system with beacons to help the vehicle locate it and drive back in, which can be used mid-water or on the seabed. "This lends itself to simultaneous operations," says Jaques, where the vessel can go off and do other work, although position drift then becomes a consideration, when the surface position aid is removed, unless there's an as-built plan of the subsea infrastructure the vehicle can use as guidance or a sparse LBL array. "If it's a deepwater survey, it can be used as an elevator, reducing battery consumption," adds Jacques. This has been used in inter-array cable depth of burial in Europe and cable surveys in Europe. The seabed system could also be deployed with batteries on the cassette and be enabled with communications via a surface buoy or be connected to existing infrastructure for power and communications, Jacques says.

Getting SPICE(y)

By the end of this year, Modus is due to become the first proud owner of the first of two SPICE (Subsea Precise Inspector with Close Eyes) AUVs, developed by Kawasaki (and currently called HAUV-3 by Modus). This will come with a "smart dock", which includes power and communications, says Jaques, eliminating the need to bring the AUV back on deck for charging and data download and reducing HSE risk.

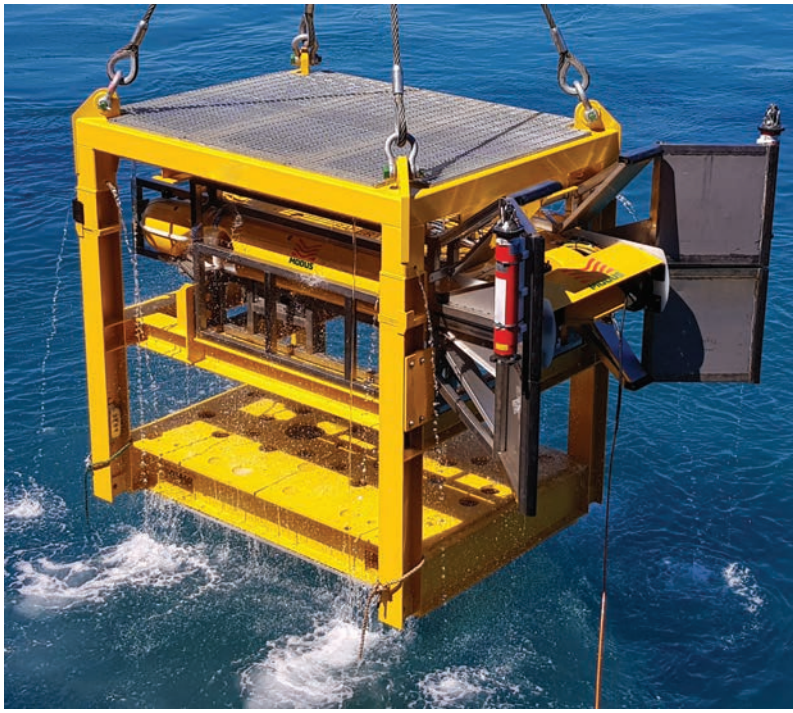
The HAUV-3's docking configuration is on top of the vehicle and will provide in-water charging and communications (using Japanese systems based on inductive power and underwater optical communications), as well as enabling the vehicle to be lifted out of the water. The next step is making it seabed resident and/or able to be deployed from shore via an underwater tractor to get it deep enough for launch, making it "a very flexible AUV deployment system," says Jaques.

Saab Seaeye

Modus' seabed garage is built around a garage built by vehicle manufacturer **Saab Seaeye**. This is based on a standard ROV garage accept it has two transponders at its entrance to guide the vehicle in. "Right now, this acts as a safe haven for the vehicle on the seafloor, but you could put charging on it," says Saab Seaeye chief engineer Jan Siesjö.

Saab Seaeye also has a mid-water docking system, which is a type of cassette but merged with an ROV style top hat tether management system (TMS). The Sabertooth can be flown out of this on a fibre optic tether for full control, or it could use BlueComm on the garage, or it could go off on autonomous missions, says Siesjö. Docking in the water with the garage could be using BlueComm or 3D SLAM, he says, depending on what an operator wants. "Docking underwater has a lot of advantages, especially when combined with a USV," he says. "This allows residency in more than one way. If you want to install the vehicle on the seafloor you get into problems with making sure there's power and communications on the sea-

Modus' H-AUV1 subsea dock.



Modus

floor and that probably gets a bit expensive if you're just wanting something resident for a week or two. Then, semi-resident probably makes more sense, with the USV hovering out there supporting a mid-water garage." Operating ROVs from USVs is also something that's already out there, being done, he says, via military customers, and is soon to be commercialized by Ocean Infinity using Saab Seaeye's Leopard. Siesjö says another way to do it is at the surface, again using a USV but with a LARS on the boat – as is already done with AUVs – and a tether protection system to prevent propeller entanglement.

Saipem

As part of its all-electric Hydrone R resident ROV development, **Saipem** also has a "flying garage" concept (in addition to a seabed garage) and sees USVs as part of the picture. The flying garage is a cassette type structure with ArUco type markers and a funnel entrance for guiding the vehicle in. Matteo Mattioli, life-of-field technical advisor, Hydrone program manager, Saipem, told the Underwater Technology Conference (UTC) in June that a flying garage could allow Hydrone R – and also the firm's FlatFish AUV, which uses the same architecture (and is due to be tested in Brazil in deepwater in Q1 2022) to be based from a surface asset with a LARS. This could be an autonomous vessel, which is part of the firm's vision of the future, and would provide a surface communications link, so the vehicle could be remote controlled, and power. Hydrone R would operate out of these garages either tethered or untethered, using a high bandwidth optical link, while FlatFish would operate untethered, on up to 150km excursions, with a low bandwidth link or no/ limited communications link, he said.

Oceaneering

Oceaneering has also been working on mid-water/suspended docking cage for its Freedom vehicle and it's also looking at USVs as the surface asset to support that docking. "Launch and recovery subsea is an enabler," says Lindsø. "It means we can up that weather window significantly." Instead of having to launch and recover the vehicle to the deck for charging and communications, it can dock 50-60m below the surface, doubling the significant sea state this work can be done in. If deployed via a USV, a subsea vehicle could be brought up to under the hull for transit to another site, while charging, without needing to bring it on deck, with the USV providing a communications gateway to shore.

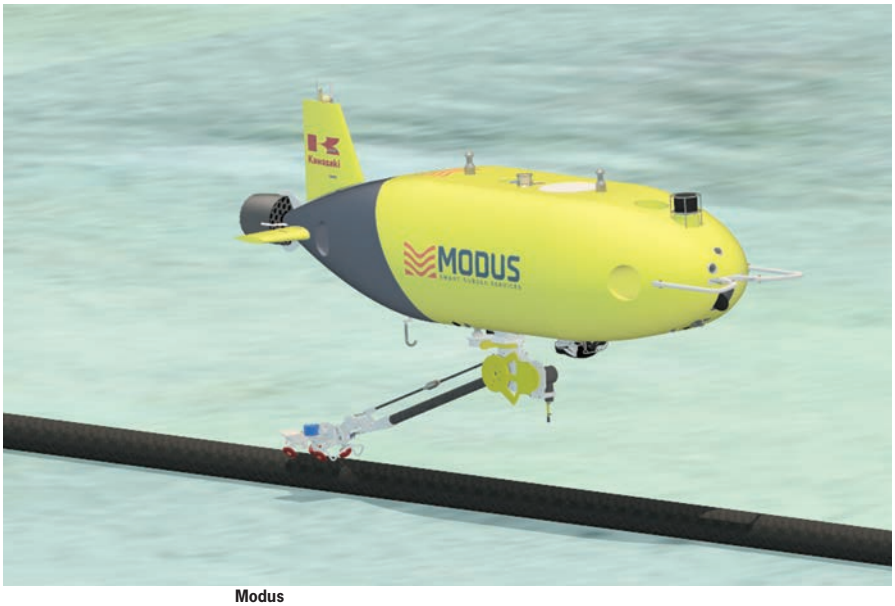
Oceaneering's submerged dock concept is also a cassette type arrangement with a slight funnelled entrance and a mechanical locking mechanism. An acoustic beacon and passive markers (e.g. ArUco) would enable the vehicle to locate the entrance, with USBL guidance from the surface vessel.

It's designed to be simple, so it can be made anywhere, so it's just the vehicle needs to be shipped, he says. It's also designed that it can be single point lifted out of the water to the deck, using just a crane wire (anti-torsion).

uLARS

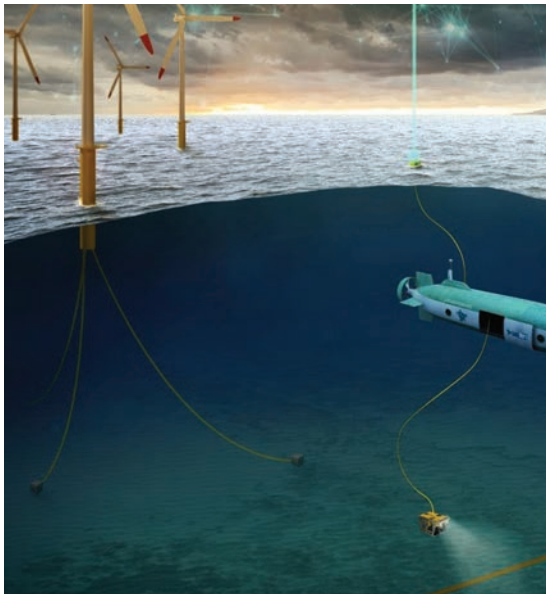
Norway's uSEA is developing both a mid-water LARS for underwater intervention drones (UiDs, as Equinor called them) and a USV to deploy it and act as a shuttle service to take underwater vehicles between work sites. The 24m-long hybrid diesel-electric USV is being designed to support mid-water docking, charging and communications with UiDs or AUVs using uSEA's uLARS, but also to be able to lift them up

Kawasaki's SPICE AUV, acquired by Modus.



Modus

The HonuWorx concep



onto deck, via a handling system through a moonpool, so that, up to four could be hosted by one USV. The idea is to extend the range of the UiD and to force multiply and extend AUV missions outside the concentrated areas.

The uLARS is being designed to do the hard work when it comes to docking, to make it easier to integrate different types of vehicle. It is able to manoeuvre to the UiD or AUV, rather than making the underwater vehicle find the dock. This is done by the uLARs being towed, by the USV, at the same depth and heading as the underwater vehicle, and, using a sensor fusion solution, including acoustics, sonars, cameras and optics, and active control in all axes of the uLARS, so it moves to the vehicle to make the docking.

A key part of the uLARS is a mechanical locking system being developed by Blue Logic, a partner in the project and which has also been involved in designing Equinor's subsea docking station. The locking system, which latches on to the underwater vehicle and pulls it into the handling system of the USV, is based on Blue Logic's MultiDog ROV quick connector for subsea lifting and pulling operations. In addition, a separate Blue Logic inductive underwater power and GB capacity communications connector would provide a charging interface as part of the uLars towed dock. Having multiple vehicles available this way means that more specialist vehicles – 3D scanning or environmental survey, for example – can be used and moved around, says Eide. uSEA has been testing its uLARS system at sea since last year, with work on a USV ongoing concurrently with technology partners. While the initial systems is diesel-electric, with electric propulsion and a diesel generator for generating power for the UiDs/AUVs, Lima says they are looking at zero emission systems.

HonuWorx

Another idea, to deploy underwater vehicles using an underwater vehicle is being designed by Aberdeen-based HonuWorx.

"Our approach is effectively a delivery submersible for underwater vehicles – it transits to the worksite subsea and remains there while the worker vehicle executes the task," says Wilson. "Then it heads back in. We envisage a future where our delivery subs 'loiter' in dense infrastructure areas, waiting for a call-off. The nice thing about our approach is we don't care what kind of vehicle is inside – inspection, intervention, ROV, AUV. Tethered. Untethered. We're just providing the launch craft and the means to communicate and control."

The XLUUV would be a hybrid power system, probably with a diesel generator to support recharging at sea, but with fuel cells in the mix in future, says Wilson. For communications, the XLUUV would, a little like the Liberty system, have a surface buoy, that provides the surface communications gateway and also an absolute position reference from the surface.

Concepts

There is not a lack of concepts. A challenge for the industry – and resident vehicles – is finding a way for different vehicles to be able to operate, using the same infrastructure, so that they can scale and there's not vendor lock-in.

There is work ongoing on standardised, vehicle agnostic subsea docking station, which includes a focus on communications, control and security architectures and standards that will need to support these operations, via the Subsea Wireless Group (SWIG).

These standards could also apply to other types of docking system, but what to do until there's a way forward?

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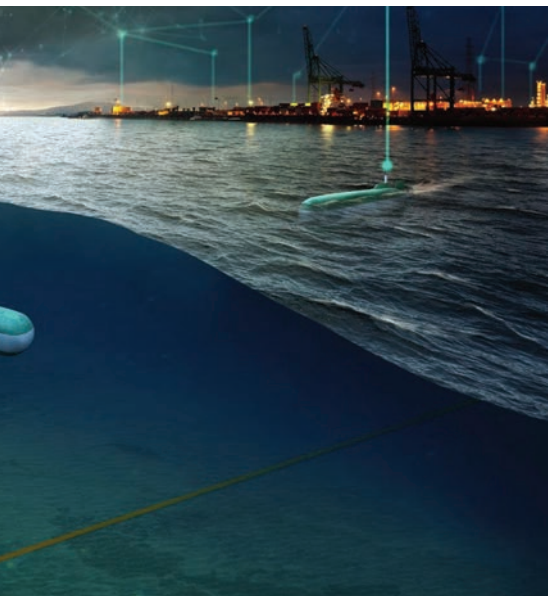
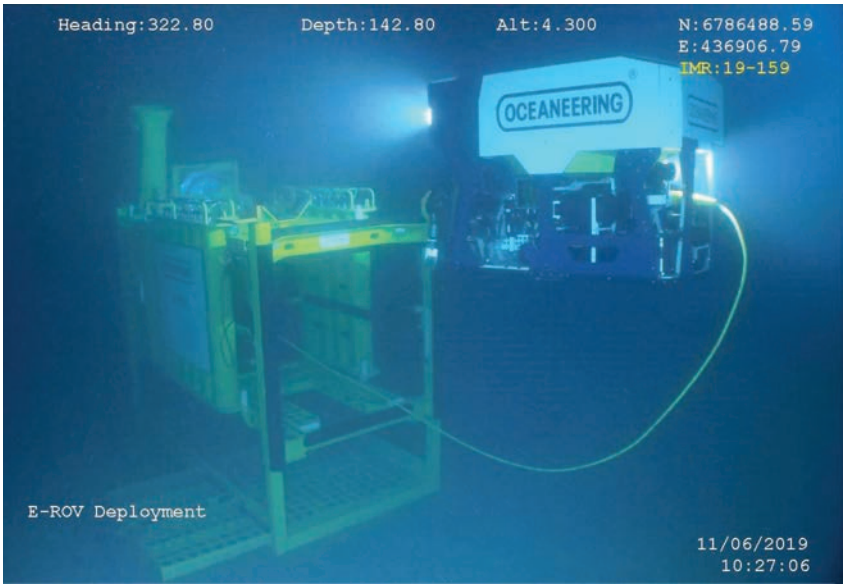


HonuWorx

Oceaneering's Liberty E-ROV system.



Oceaneering

Chesapeake Technology Inc

Led by Eileen Gann, President & CEO with 10 employees, Chesapeake Technology is a privately owned company based in Los Altos, CA, that has been providing its SonarWiz software solution worldwide for more than 25 years, specializing in geophysical and hydrographic software focused on sidescan, sub bottom and bathymetry collection and processing. The software bridges the gap between the sonar and the final product, providing users an easy to use and state-of-the-art software needed for this work. SonarWiz is an all-in-one solution for geophysical, hydrographic, pipeline, and archaeological surveys. The software provides the user the capability to collect and process sidescan, sub bottom, single beam and multibeam bathymetry and magnetometer data. Data acquisition is easy to use and works with most sonars in the market. The post-processing suite has a wide variety of tools and utilities for efficient visualization, analysis and reporting.

www.chesapeaketech.com

Digital Edge Subsea

Digital Edge Subsea is based in Ulverston, UK, a company led by President and CEO John Benson and employing 11. Digital Edge Subsea supplies the digital video recording inspection system, The EdgeDVR. Continuous improvement is the mantra at Digital Edge, and latest developments include EdgeArchive. Following on from the success of Version 5 EdgeDVR, EdgeArchive is the new backup solution and the latest addition to the Version 5 suite. EdgeArchive handles the transfer of data from the internal DVR drives to client storage, either on a NAS, a Raid, or a phased delivery to multiple external hard drives. Archive can act as a simple data mirror of the correct internal drive data folders, or can be used to create multiple simultaneous backups of client deliverables. This can be done in continuous backup or a phased approach i.e., after each dive.

www.digitaledgesubsea.com

Falmouth Scientific Inc.

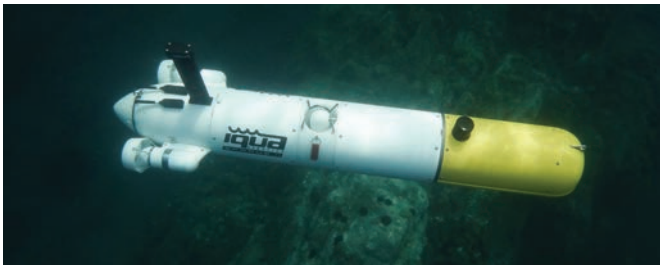
Falmouth Scientific, based in Pocasset, MA with 16 employees and led by John Baker, has more than 30 years of experience in marine acoustic sensors, transducers and seismic sources. FSI was founded in 1989 based on WHOI technology licenses. Since then the focus on FSI products and services has been to focus on sensing and acoustic technologies over a variety of product segments. These product areas include the Hegg Marine Solutions (HMS) Bubble Gun seismic systems, sub-bottom profilers (CHIRPceiver & CHIRPceiver Litt), and combined side scan sonar and sub-bottom profiler systems partnered with Klein Marine Systems, as well as the ACM-PLUS current, wave, and tide monitoring systems; advanced electro-acoustic transducers; and acoustic relocation systems.

www.falmouth.com

Impact Subsea

Based in Aberdeenshire, Scotland, Impact Subsea was founded in 2015 by Ben Grant and Alastair Mclennan-Murray, the company specializes in a range of high-performance sensor solutions for underwater vehicles and associated applications used in the oil and gas, renewables, underwater research and defense sectors. In April 2020, Impact Subsea released the ISA500-11K. Based on the architecture of the ISA500 range, the ISA500-11K has distance measurement capabilities in excess of 120 meters and millimeter accuracy. The ISA500-11K makes use of a newly designed transducer, housing and end cap. Most recently, Impact Subsea released a deep-water version of the ISS360. Designed to provide an ideal obstacle avoidance and target identification sonar for underwater vehicles, the recent addition was developed to meet the demands of deep rated AUV and ROVs for commercial and scientific applications.

www.impactsubsea.com



IQUA robotics

Based in Catalonia, Spain, IQUA Robotics emanated with technology transfer from university to market. Led by Marc Carreras with 11 employees today, the company is a spin-off of the University of Girona, an European higher education institution of reference in underwater autonomous robotics research. The company has made two robotics products out of a set of licensed technologies which were at TRL5 at the University. It also has been able to generate a new software product using the same technology transfer process.

The company designs, manufactures and commercializes two different autonomous underwater vehicles, the Girona 500 and the SPARUS II, both created at the University with a very open conception from both software and hardware points of view. In 2020 the company launched its first stand-alone software product, SoundTiles.

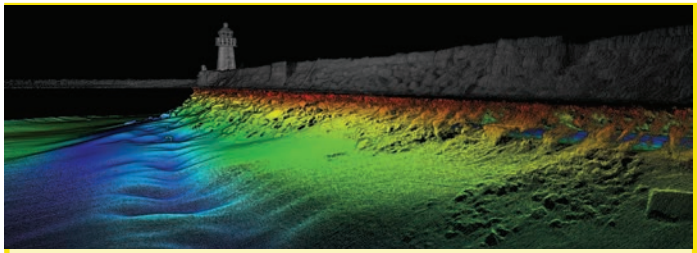
https://iquarobotics.com

MSI Transducers

MSI Transducers based in Littleton, CO, is an Airmar Technology Company that designs and manufactures custom sonar transducers and arrays for a wide range of applications, including harbor defense, side-scan (Synthetic Aperture Sonar), obstacle avoidance, sub-bottom profiling, swath bathymetry, mine hunting, swimmer detection, and acoustic communications.

Led by Matt Boucher with 35 employees, it offers a technical breadth that enables it to provide a complete range of services to meet your requirements, including: custom product design, engineering and measurement, prototyping and development, low or high volume manufacturing, additive manufacturing (3D printed ceramics), injection molded piezocomposite materials, and new material development.

www.msitransducers.com



NORBIT Subsea

Based in Trondheim, Norway, NORBIT is led by Peter K. Eriksen and is a stalwart in the Multibeam Echo Sounder market. In 2020 NORBIT saw significant growth in service and supply offering to multiple marine markets including Renewables; Offshore Construction; Hydrographic Survey; Marine Research, Dredging, Salvage and Environmental Surveys. NORBIT recently launched a new multibeam sonar platform named WINGHEAD. NORBIT offers two main sonar families; all wide band; with integrated positioning, attitude, heading and SVP sensors being part of our now iconic curved arrays. NORBIT Subsea is part of NORBIT Oceans, a developer and supplier of high technology maritime monitoring, visualization, and measurement equipment operating in Defense & Security, Maritime Surveillance, Oil & Gas, Renewables, Transportation and Research applications.

https://norbit.com/subsea/

NOVACAVI

NOVACAVI develops cable solutions to support any form of innovative sustainable energy systems from the initial prototype stage through to design and production. Led by Gianluca Ramploud, President and CEO, this 30-person company is based in Milan, Italy.

Being challenged by specific tough permanent application on top of floating fully supported solar panels above water level, NOVACAVI recently made its own technological-productive contribution to a floating solar solution for the marine environment with high energy production capacity and limited environmental impact installed in the freezing water of the Oslo Fjord, Norway. With long-term technical and manufacturing expertise, NOVACAVI developed and delivered a custom-engineered water blocked composite power and signal cable to ensure maximum performance without losing elasticity in constant cold climates, saltwater splashing or submersion and also sun exposure.

https://www.novacavi.it

Oceanalpha Group Ltd.

Founded in 2010, Hong Kong-based Oceanalpha is an Unmanned Surface Vessel company with more than 350 employees. In 2021, Oceanalpha launched two new large-scale multi-purpose unmanned surface vessels (USVs), the L25 marine survey USV and the M40P multi-purpose USV, designed specifically to overcome various technical limitations currently faced by marine survey professionals. The catamaran design provides enhanced stability, allowing the vessels to roll less than 10 degrees under sea-state 4 conditions. Both USVs feature hybrid-electric propulsion, resulting in improved endurance for long-term survey missions. Reliable autonomous winch retraction has been achieved with cable lengths of up to 200m, and vibration and noise have been reduced.

www.oceanalpha.com

Popoto Modem

delResearch is the parent company of Sandwich, MA-based Popoto Modem, a company with six employees, led by John DellaMorte, and in business since 2003. From 2017 it developed the Popoto Modem Product which is fielded around the world in applications ranging from fishing to research to AUVs. Popoto Modem is an acoustic modem which can serve as an application platform and has leveraged advances in consumer audio and cell phone technology to bring about a reduction in price point, and size of acoustic comms technology, while at the same time advancing the performance. The result is a low-cost modem in a slim line package. The Popoto Mini provides ~190 dBSpl/m in a board set slightly bigger than a business card.

www.popotomodem.com

RJE Oceanbotics

Led by Robert Jechart, President and CEO, RJE Oceanbotics is a 20-person company based in Irvine, CA. The industry segments currently using the Oceanbotics SRV-8 include Search and Rescue (SAR) Teams for Police and Fire Departments, Military, Offshore Energy (Oil & Gas and Wind), Inland Infrastructure, Offshore Pipeline Inspections, Hydroelectric Power, Aquaculture, Science and Research, Treasure Hunting, Recreation, and more. The Oceanbotics SRV-8 is a Profession-Grade Underwater Drone.

www.oceanbotics.com

Seafloor Systems, Inc.

Based in Shingle Springs, CA, Seafloor Systems, Inc. specializes in providing hydrographic survey equipment. Led by John Tamplin, the 30-person company offers a range of solutions from simple single beam echo sounders to complex, integrated multibeam sonar systems with installation and training services. We also make a line of Unmanned Survey Vessels (USVs) outfitted with customized hydrographic, hydraulic, or oceanographic payloads.

We carry several Seafloor products, as well as innovative tech from trusted industry brands. This includes single beam echo sounders, multibeam echosounders, acoustic Doppler current profilers, hydrophones, and USVs.

www.seafloorsystems.com

Sonotronics, Inc.

Led today by Marlin Gregor and based in Tucson, AZ, since 1971, Sonotronics has been a leader in the manufacturing of ultrasonic tracking equipment related to the underwater tracking of marine animals, equipment marking, and other marine applications. Sonotronics specializes in implementing the latest technologies and providing economic solutions to customers research needs. Sonotronics products include a wide variety of ultrasonic transmitters with various combinations of lifetime, size, range, and telemetry options. Sonotronics offers high performance manual tracking systems for real time determination of animal behavior. Sonotronics also offers automated stations for logging animal detections, including cellular uplink and web technologies.

www.sonotronics.com

TSC Subsea

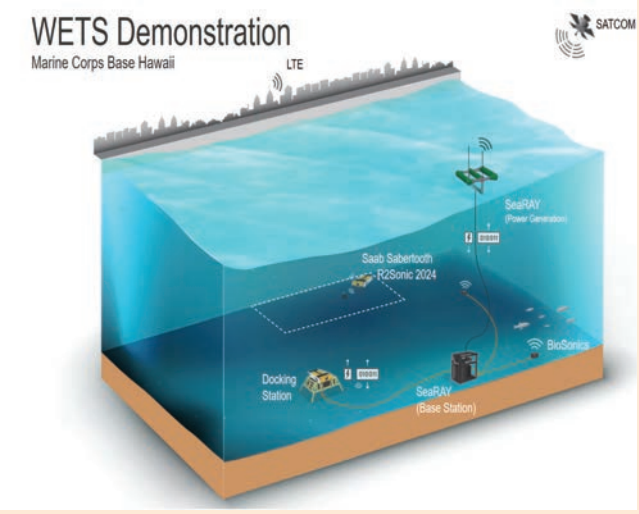
TSC Subsea designed a new ROV-deployed automated scanning tool which addresses the issue of carrying out tight access field joint inspection through difficult to penetrate pipeline coating. The ARTEMIS vCompact, a smaller, lightweight, more-flexible version of the standard ARTEMIS, was designed, developed and built by TSC Subsea's engineers to work in tandem with inspection class ROV for the remote inspection of pipelines and structures.

It was designed and built in a turnaround time of less than six weeks to meet the precise requirements of a project for Beach Energy in Australia's Bass Strait, to carry out wall thickness inspection on the 20" Otway pipeline near the Thylacine A platform. The location of the pipeline joints required the inspection to be conducted remotely within a very narrow field joint section which was too confined for the standard ARTEMIS. The solution, in the form of the ARTEMIS vCompact, was developed.

www.tscsubsea.com

C-Power

www.cpower.co/searay



The 3000m rated Saab Seaeye Sabertooth is a roaming and hovering multi-role vehicle that can operate in both fully autonomous (AUV) and tethered (ROV) modes.

Now it can operated from converted energy from waves operating in seabed residency mode, a renewable energy breakthrough with significant savings in support vessel costs and CO2 emissions. Pioneering the concept is C-Power's SeaRAY Autonomous Offshore Power System (AOPS), which provides offshore power, energy storage, and real-time data communications for resident marine systems.

During trials, the Sabertooth owned by Hibbard Inshore and operated on behalf of C-Power, will repeatedly patrol pre-programmed areas to collect data, before returning to an underwater docking station for cloud upload and battery recharge. Included in the studies will be seabed analysis, fish densities, infrastructure monitoring and water-column data gathering.

The trials come in partnership with the U.S. Department of Energy's Water Power Technologies Office, together with the National Renewable Energy Laboratory and the U.S. Navy.

In particular, testing of the SeaRAY AOPS is included in the Navy's Coastal Trident 2021 program, which is the largest port and maritime security undertaking in the nation.

For the trials, the Sabertooth was equipped with an R2Sonic Sonic 2024 multibeam echosounder, 2G Robotics ULS-500 PRO Laser Scanner and camera, and the ASL AZFP 70,120 & 200 kHz Acoustic Zooplankton Fish Profiler. BIRNS supplied© BIRNS Millennium subsea connectors and cable assemblies for the SeaRAY AOPS being deployed in Hawaii in the summer of 2021.

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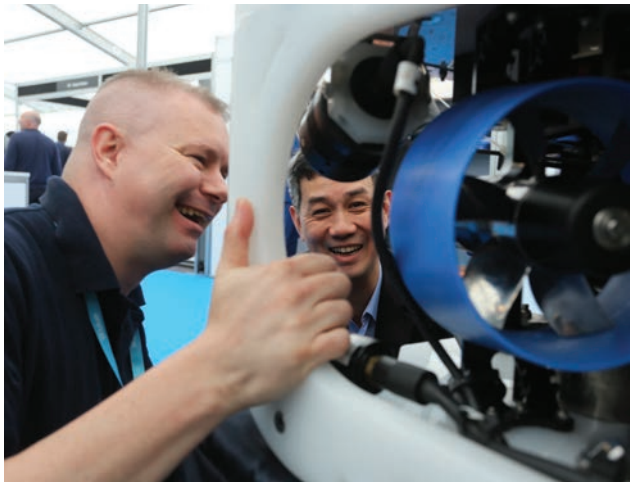

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