MARINE TECHNOLOGY REPORTER

January/February 2020 www.marinetechnologynews.com

UUV Tech

Unmanned Vehicle Technology, Capabilities Advance Rapidly

Science
Science + Autonomy = Answers

In the Field
Measuring Hostile H_2O Under Hurricanes

Autonomous Nav
Robots in the Splash Zone

Volume 63 Number 1

January/February 2020
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Contents

Credit: Mark Schrope

SAMS

Credit: BAE Systems

OceanTech

On the Cover

Seamount 'Poggy' a new bionic AUV from EvoLogics. See story page 12.


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Editor's Note

Technology trend drivers we're seeing today include products and systems that are smaller, lighter, faster, cheaper and more efficient. Now if you think about it, these are likely to be the tech drivers in the vast majority of industries around the globe. What makes our little slice of the pie more interesting is the need and ability to work within one of the harshest, most diverse and rapidly changing environments known to man.

Welcome to 2020 and the 'Vehicles' edition of Marine Technology Reporter, a perennial favorite as there is so much focus and tech development around unmanned underwater systems, from the propulsion to the sensors; from the manipulators to the power pack; to the very materials that are used to make these machines and to keep them running.

Starting on page 34 Justin Manley has a look at four vehicles that fit his informal billing of "good undersea vehicles come in small packages." While this is not intended as the de facto ranking of the best, it provides ample insight to four companies that are leveraging the proliferation of fast-advancing connectivity solutions, melded with smaller, less costly components that collectively help to deliver a powerful UUV package.

Prior to this, starting on page 30, Elaine Maslin examines how combinations of marine autonomous systems and the hybrids they create are increasingly put to the test in the offshore space. Adding urgency to the matter are the oil majors, with BP, for example, speaking the goal of having 100% of its subsea inspection activities with unmanned systems by 2025. All of the sudden, 2025 is in the not-so-distant future!

Finally a note of thanks to Carlie Wiener and the Schmidt Marine Technology Partners (SMTP) crew for their contribution on the funding of emerging technologies, starting on page 16. As most everyone reading these pages knows full well, many of the great, transformational ideas in this space start with individuals or small groups, the literal "garage start-up." SMTP is a relatively new program of the Schmidt Family Foundation, geared to provide funding and business support to help in technology development that is designed to solve ocean problems.

Gregory R. Trauthwein
Associate Publisher & Editor

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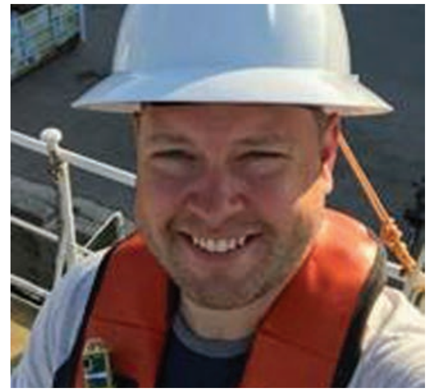

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Justin Manley is a technologist and executive with experience in startups, corporations, academia, and government. At Just Innovation Inc. he supports clients with a focus on unmanned systems.

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

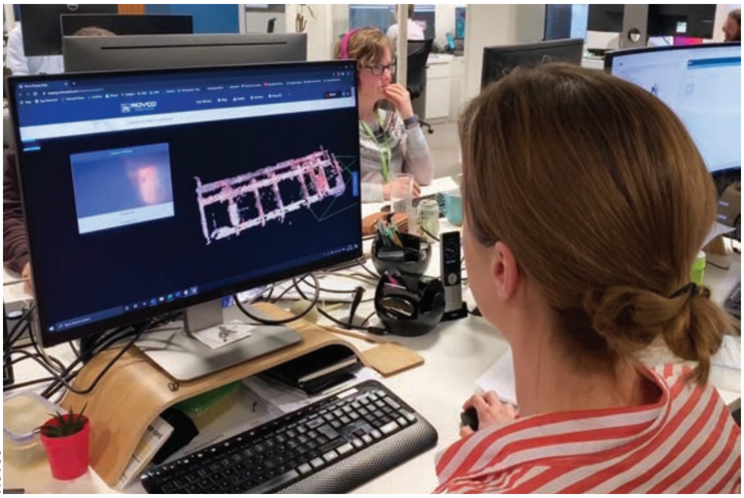
Spain
Hailing from the land down under, Dr. Peter Spain studied Ocean Physics at the Applied Physics Laboratory, University of Washington. He worked with new instruments for measuring ocean currents. After a post-doc at Scripps Institution of Oceanography, Peter joined RD Instruments in 1990. He has worked in Sales & Marketing where he progressed from sales staff to department and business unit management. Today, the common theme to his diverse activities is Technical Marketing.

Stoichevski

Stoichevski
William Stoichevski has written thousands of offshore-focused reports from his North Sea vantage point. William lives and works in Oslo. He started writing for Marine Technology Reporter in 2014.

Tech Files

Innovative products, technologies and concepts



Rovco

SubSLAM Live: 3D Streaming Tech

Rovco launched “SubSLAM Live” a 3D Streaming technology which it says will allow a video live stream 3D underwater point-clouds to any device in the world. According to the company, the stereo camera technology system sends images and 3D models of assets from the seabed to a computer browser in any location globally. This offers customers instantaneous access to information as an inspection or construction activity is taking place. Rovco put the tech on trial earlier in the year with an unnamed oil and gas super major at a renewable wind farm, and more recently in 0.5m of visibility at an ex-naval dockyard owned by Offshore Renewable Energy Catapult.

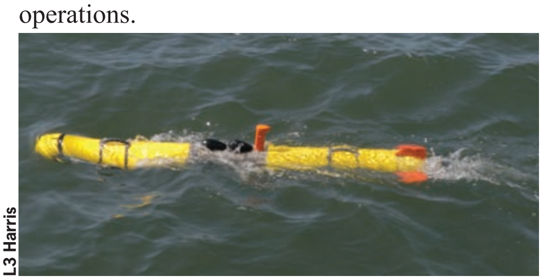
During the final trials, the technology was lowered into a sea-water filled dock which contains sample assets from the subsea industry. Engineers were using Rovco’s stereo camera system to capture high-definition video, which allowed them to use the SLAM (Simultaneous Localization and Mapping) system to build 3D point cloud models while staff back in their office 300 miles away directed the ROV while keeping track of the ROV location and operations via their phones and laptops.

Defense

Iver4 for USN

L3Harris Technologies will provide an unmanned undersea vehicle for expeditionary undersea missions for U.S. military forces by the U.S. Navy and the Defense Innovation Unit (DIU). DIU, which accelerates commercial technology to solve national security solutions, awarded an Other Transaction Agreement (OTA) to L3Harris for the U.S. Navy’s Next Generation Small-Class Maritime Expeditionary Mine Countermeasures Unmanned Undersea Vehicle (MEMUUV) program.

This award includes the delivery and testing of an Iver4 - 900 PW UUV and two field swappable modular payload sections, including real aperture and synthetic aperture sonars. Additional sensors, swappable battery chemistries, and data solutions are included with the prototype system to provide U.S. military forces with a highly capable UUV that can detect, classify, localize, and identify targets on the ocean floor and in the water column in support of Expeditionary Mine Countermeasures (ExMCM), Explosive Ordnance Disposal (EOD), and undersea search operations.

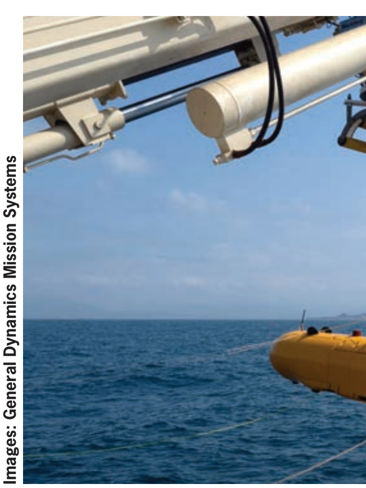


L3 Harris

SeaRaptor AUV Completes Sea Acceptance Test

Teledyne Gavia, a company of Teledyne Marine, announced it has completed the sale and recent sea acceptance testing of the SeaRaptor, 6,000m rated autonomous underwater vehicle (AUV). The client was not disclosed. The SeaRaptor AUV incorporates a broad range of Teledyne content including acoustic modems, ascent and descent weight releases, a black box pinger locator, sub-bottom profiler (Teledyne Benthos), multi-beam echosounders, obstacle avoidance multi-beam sonar (Teledyne RESON), Doppler Velocity Log (DVL), Current, Temperature, and Depth sensor (CTD) (Teledyne RD Instruments), and onboard processing software (Teledyne Caris).

In addition, the vehicle delivered also carried an Edgetech Side Scan Sonar with Dynamic Focus capability, an iXblue Phins 6K INS system, and a CathX Camera and strobe system.

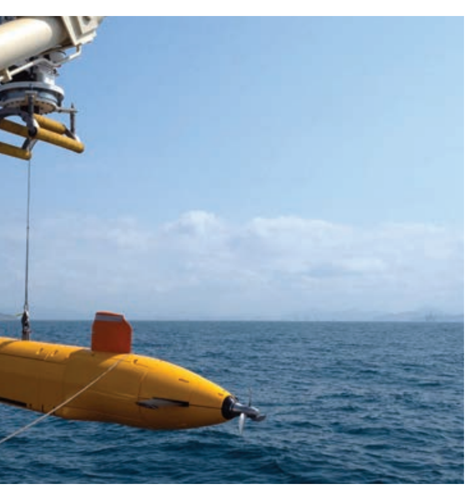


Images: General Dynamics Mission Systems

NOAA

Ocean Infinity, NOAA Parnter

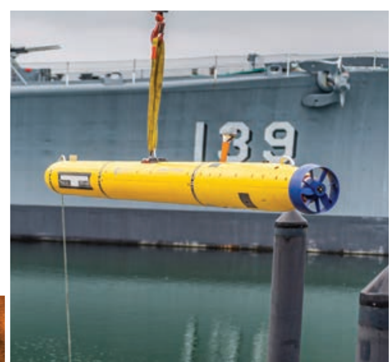
Ocean Infinity will partner with the National Oceanic and Atmospheric Administration (NOAA) Office to develop new tools for ultra-high-resolution ocean exploration and mapping. The four-year Cooperative Research and Development Agreement (CRADA) between Ocean Infinity and NOAA's Ocean Exploration and Research (OER) will aim to expand deepwater autonomous technologies that will help advance the transmission of ocean information and develop new data-collection and processing methods to increase the value and relevance of deep-ocean data. A key focus, NOAA said, will be advancing telepresence or the transmission of ocean video and information in real-time to public and academic audiences.

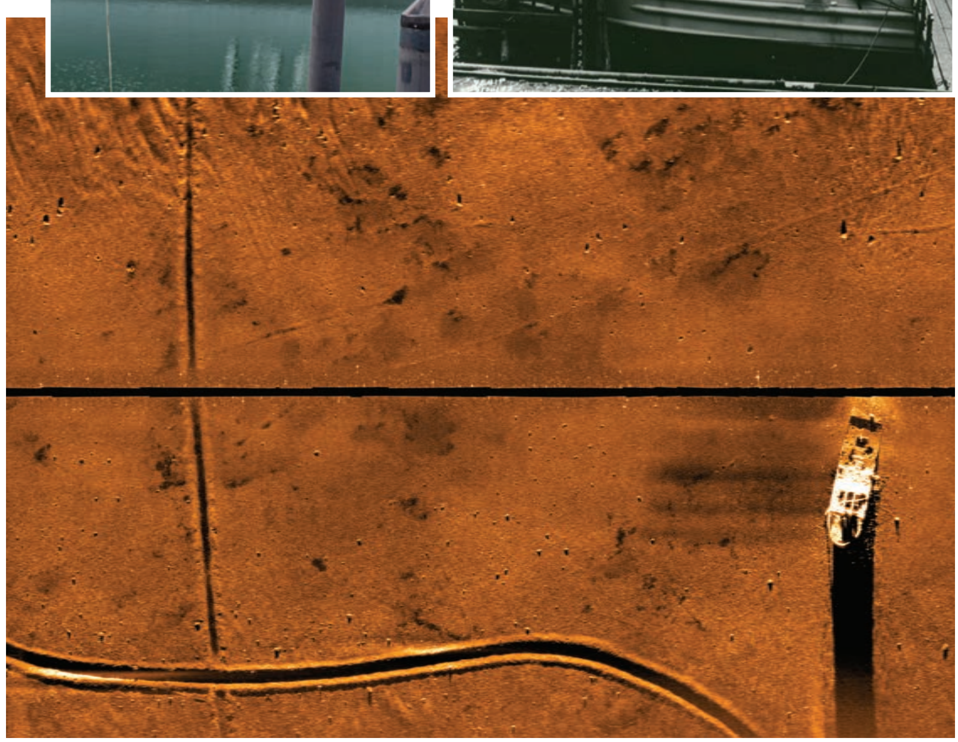


Clear View of YF-415 courtesy Bluefin UUV

In November 2019, a General Dynamics Mission Systems' BluefinTM-12 Unmanned Underwater Vehicle (UUV) captured detailed images of the USS YF-415 during the UUV's Sea Trials in support of the Royal Australian Navy.

Built by the American Shipbuilding Company of Buffalo, NY, and completed in September 1943, the 132 ft. vessel with a crew of 31 and under command of Chief Boatswain's Mate Louis B. Tremblay was laden with 150 tons of ammunition, obsolete pyrotechnics, black powder and various ordnance from the Naval Ammunition Depot in Hingham, MA. On May 10, 1944, the YF-415 and its crew were following standard procedures for the disposal of materials when an accidental ignition occurred. Despite efforts to quell the chain-reaction, the USS YF-415 came to rest off the Boston coast at 42 24.287' N and 70 40.398' W . Of the 31-person crew, 14 were rescued by the USS Zircon. 17 crew members were killed or went missing. The Bluefin-12 UUV is a lightweight, medium-class UUV designed with embedded advanced capabilities insuring accurate navigation (0.1% D.T. CEP 50), high-resolution sonar imagery (Solstice Multi Aperture Side Scan Sonar), and onboard data processing designed for defense, commercial and academic underwater missions. Available with an integrated survey package or as an extendable UUV with more than 4,000cm3 of available sensor and payload capacity.





Images: General Dynamics Mission Systems

WHOI Robot Takes First Known Automated Sample from Ocean

A hybrid remotely operated vehicle developed by Woods Hole Oceanographic Institution (WHOI) took the first known automated sample performed by a robotic arm in the ocean. Last month, an international team of researchers used one of WHOI's underwater robots, Nereid Under Ice (NUI), to explore Kolumbo volcano, an active submarine volcano off Greece's Santorini island.

"For a vehicle to take a sample without a pilot driving it was a huge step forward," says Rich Camilli, an associate scientist at WHOI leading the development of automation technology as part of NASA's Planetary Science and Technology from Analog Research (PSTAR) interdisciplinary research program. "One of our goals was to toss out the joystick, and we were able to do just that."

As with self-driving cars, handing the wheel over to a computer algorithm can be unsettling. Camilli was part of an international team of researchers on an expedition aimed at learning about life in the harsh, chemical-laden environment of Kolumbo, and also exploring the extent to which scientists can hand over the controls to ocean robots and allow them to explore without human intervention.

"One of our goals was to toss out the joystick, and we were able to do just that."

Slightly smaller than a Smart Car, NUI was equipped with Artificial Intelligence (AI)-based automated planning software — including a planner named 'Spock' — that enabled the ROV to decide which sites to visit in the volcano and take samples autonomously. Gideon Billings, a guest student whose thesis research focuses on automated technologies, had the honors of using his code to collect the very first automated sample, which was of a patch of sediment from Kolumbo's mineral-rich seafloor. He issued a command to the autonomous manipulator and, moments later, a slurp-sample hose attached to the robotic arm extended down to the precise sample location and sucked up the dirt.

Moving forward, Camilli will continue working with Billings and colleagues, as well as researchers from the Australian Center for Field Robotics, Massachusetts Institute of Technology, and the Toyota Technological Institute at Chicago to push the automation technology forward. The work will include training ocean robots to see like ROV pilots using "gaze tracking" technology, and building a robust human-language interface so scientists can talk directly to robots without a pilot go-between.

Source: WHOI

NUI is lowered into the Aegean Sea before plunging to a depth of 500 meters to explore Kolumbo volcano.

Photo by Evan Lubofsky, © Woods Hole Oceanographic Institution

“Marine Litter Hunter” Autonomous Plastic Collector

DEME Environmental Contractors (DEC) is installing a plastic collector on the river Scheldt on behalf of the Vlaamse Waterweg (the Flemish authority responsible for waterways in Flanders). A combination of a fixed and mobile installation will be tested for a year to collect waste from the water. To tackle the increasing problem of river pollution, the Vlaamse Waterweg is joining forces with the business world to test the concept of waste collectors on the river Scheldt. After a call from the Vlaamse Waterweg to companies to submit an innovative proposal, DEME proposed a project for collecting waste by the Temse-Bornem Scheldt bridges.

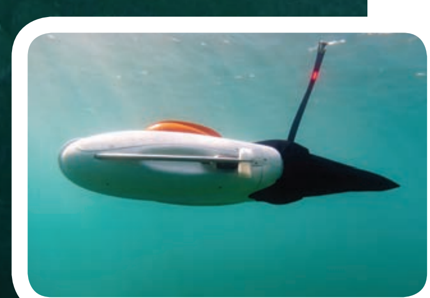
The DEME test set-up consists of a fixed installation that passively collects floating and suspended waste from the water and a mobile system that actively collects bigger pieces of waste. The test phase, that will start in February 2020, is being carried out in cooperation with the University of Antwerp and the Institute for Nature and Forestry Management (Instituut voor Natuur- en Bosbeheer). The mobile installation consists of a smart detection system, a work boat that can navigate autonomously and a charging point. Floating waste is detected using artificial intelligence by smart cameras that are installed on the old Temse bridge. An autonomously navigating work boat, the “Marine Litter Hunter” intercepts waste and pushes it to a collection pontoon. The waste is collected in the collection pontoon, where a crane equipped with a grab transfers the waste into a container.

The fixed crane is operated remotely by an operator using virtual reality and 3D vision technology. When the container is full, the work boat takes this autonomously to the docking station, where it is unloaded by a transfer crane on the quay. The “Marine Litter Hunter” is fully CO2-neutral and moors autonomously at the docking station to charge.

www.deme-group.com

Meet Seamount "Poggy": A Bionic AUV

EvoLogics GmbH introduces Poggy, a novel bionic autonomous underwater vehicle that uses Fin-Ray technology. The vehicle is being developed as part of Bonus Seamount collaborative R&D project and made its first dives at Breaking The Surface 2019 workshop in early October 2019.



Evologics

Nicknamed Poggy, the AUV is a one of a kind, novel bionic design with two propulsion thrusters and two independent flexible “tails” that give the robot unique mobility features.

Its dual-tail construction is an original idea that stemmed from previous work on EvoLogics’ Manta Ray AUV and its lifelike “flapping wing” propulsion system. The design was simplified and optimized - the robot lost the wings, and its tail was divided in two.

Together with the rigid part of the body, the progressively bendable tails perform as two adjustable hydroplanes that in every steering position have an overall streamlined shape. The new concept facilitates outstanding roll and depth control combined with low drag performance. Both parts of the dual-tail use independent bionic Fin-Ray drives and allow for precise heave, pitch and roll adjustments, enabling dynamic climbs and dives, leveled gliding and bottom following. Due to the small size of its basic AUV components, Poggy has an excellent payload capacity and can carry multiple sensors and instruments at the same time.

In addition, the dual-tails facilitate unique maneuvers that could open new opportunities for sensing and monitoring: the vehicle was designed to keep any desired roll angle and maintain a steady glide, even at very low speeds.

At Breaking The Surface 2019 in Biograd na Moru, Croatia, EvoLogics team performed the first sea trials of the Poggy prototype as part of a workshop on underwater communication and networking for UUVs. The goal of BONUS SEAMOUNT is to develop innovative autonomous vehicles and integrated sensor systems for complex real-time sea surveying, analysis and monitoring, and then to apply these in the study of submarine groundwater discharge (SGD) in the Baltic Sea. SEAMOUNT UUVs would locate and monitor SGD and associated nutrients and/or pollutants in coastal waters. Coordinated by EvoLogics, SEAMOUNT project is funded within the framework of “BONUS - Science for a better future of the Baltic Sea region”, the joint Baltic Sea research and development program. Project partners are EvoLogics GmbH (Germany), Christian-Albrechts-University Kiel, Institute of Geosciences (Germany), Leibniz Institute for Baltic Sea Research (Germany), Geological Survey of Denmark and Greenland (Denmark), Geologian tutkimuskeskus - Geological Survey of Finland (Finland), Maritime Institute in Gdansk (Poland), NOA (Poland).

Ocean Energy Systems

Expecting a surge in wave and tidal energy activity in 2020

By Henry Jeffrey

Ocean Energy Systems (OES) was launched in 2001 as a technology collaboration program of the International Energy Agency (IEA). It was created in response to increased ocean wave and tidal current energy activity primarily in Denmark, Portugal and the United Kingdom. The organization today consists of 25 members including specialists from government departments, national energy agencies, and research and scientific bodies. OES Chair Henry Jeffrey explains why the outlook for ocean energy advances looks particularly positive for 2020.

In recent months OES has recorded major progress across the ocean energy sector with global tidal projects achieving extensive operating hours and wave technology advancing in large-scale laboratory and offshore test sites. A growing range of devices are now being tested in open water through an increase of cross-border R&D projects supported by the European Commission.

These developments are documented in the OES 2019 Annual Report, which also reveals significant public and private sector investment earmarked for 2020. Marquee projects include $25m pledged by the US Department of Energy to support 12 'next-generation' marine energy pilots and Wave Energy Scotland committing £7.7 million to two wave energy machines using the Stage Gate selection process. The European Commission is further investing in a broad set of initiatives and deployments.

OES is expecting to see many more positive advances in 2020 as governments around the world look to harness the power from the ocean.

A key function of OES is to provide a comprehensive overview of ocean energy policy, research and technology being implemented by member countries. One notable trend we are observing is a growing number of 'cross-border' R&D projects supported by European Union funding. These projects are increasing knowledge and understanding of device developments. The strengthened communication is also helping tackle pressing issues surrounding design and efficiency improvements, array configurations, environmental impacts and cost reduction.

Strong progress is also being recorded across a number of OES collaborative strategic tasks. The OES 'Task on Cost of Energy' is being successfully used alongside the 'Stage Gate Metrics Task' to analyze historical trends, future developments and various nuances between technologies and countries. This work allows us to chart and monitor the evolution of ocean energy costs and assess the impact of different drivers.

It is widely recognized that a rigorous technical review approach is required across the ocean energy sector, making use of improved evaluation methods and metrics. OES has been working closely with US Department of Energy, Wave Energy Scotland and the European Commission to achieve an internationally accepted approach of performance metrics for ocean energy development. This will be of high value to technology developers, investors and funders.

Meanwhile, the OES 'Environmental Task' is playing an important role continuing to collect, synthesize, and disseminate information. This provides access to knowledge and information related to research, monitoring, and evaluation of the environmental effects of ocean energy helping advance the industry. This task is supported by the publicly accessible online knowledge management system Tethys, developed by Pacific Northwest National Laboratory. Greater attention is however still required to assess potential job creation stimulated by the sector and to update projections for 2030 and 2050.

In recent years commercial interest in ocean energy has grown significantly at a global level. However, there are considerable investment costs and bottlenecks that need to be overcome. Globally, we are still waiting for clear market signals for ocean energy projects, which are vital for the industry to progress from demonstration to commercial projects.

The ocean energy sector is at a crucial point where it must make best use of public funds, to deliver the right research, development and demonstration activity to build the confidence of the private investment community.

A great benefit of the OES network is that it enables nations to pool talent and resources to address global ocean energy challenges that no country can tackle alone. As an organization OES is firmly focused on uniting forces to advance research, development and demonstration of conversion technologies. Our underlying mission is to make ocean power a cost-effective, reliable and low-carbon source of energy generation for the whole world.

@ Schmidt Marine Technology Partners

The Future is Now

By Carlie Wiener

On an unseasonably warm October day in San Francisco, hundreds gather in the Dogpatch district to hear about the latest innovations in ocean conservation and science. Bubble barriers to trap plastic in river mouths and portable DNA scanners preventing illegal wildlife trafficking are just a few of the ground-breaking tools and technologies that are transitioning from dream to reality. And the unifying factor amongst these groups is support from Schmidt Marine Technology Partners (SMTP).

SMTP is a relatively new program of the Schmidt Family Foundation, established in 2015, that is making significant impact in marine technology development for ocean conservation and research. It provides funding and business support to help groups develop technologies that solve ocean problems in hopes of transforming the way society uses ocean resources and protects them for the future.

SMTP's goal at the demonstration was to get the word out about some of the most creative groups tackling ocean issues, and to get new investors and others excited about the potential of the field. SMTP is proving this can be done in the four short years that they have been operating.

SMTP Director Mark Schrope provides welcome remarks at SMTP's first demonstration event.

Credit: Erika Montaue/SMTP

Credit: Megan Bayley

SMTP awardees pose together with SMTP staff at the San Francisco demonstration event.

Dan of SafetyNet Technologies discusses his plans while getting input from the local fishing community in Indonesia.

Credit: Mark Schrope.

Ethan Edson of Ocean Diagnostics demonstrates some of his microplastic sensors.

Credit: Ocean Diagnostics

"We know the good ideas are out there, the resources to develop them have just been too limited," says the program's director, Mark Schrope. "We created this "venture philanthropy" model to fill an often-fatal gap in support available for the development of ocean technologies, which typically require something beyond traditional grants in order to achieve full potential and availability."

The organization focuses on technologies working toward sustaining fisheries, enabling ocean research, promoting habitat health, and preventing marine plastic pollution, supporting more than 40 groups in accomplishing the development, dissemination, and possible commercialization of ocean technologies. The work of the SMTP group is allowing for new companies to expand ocean observing capabilities at an accelerating pace.

From Lab to Ocean

One success story begins with Ethan Edson, an undergraduate engineering student at Northeastern University, who saw how scientists collected microplastics—essentially using techniques from a century ago involving net tows and physical counting. Edson thought there had to be a better way, so with funding from SMTP, Ocean Diagnostics began doing just that.

The company is building a suite of products that range from portable tools that can be lowered over the side of a kayak, or deployed while SCUBA diving, to completely autonomous sensors that hook into a ship to passively collect data. "Sampling microplastics is really tricky because the ocean has so many other things in it," says Edson. "If you are in Massachusetts, Bermuda, the Mediterranean, or Southeast Asia, it all looks different. Designing one sensor that can go into any water body and detect microplastics has been a great challenge. But really fun to work on."

The SMTP program is doing exactly what it set out to do, helping Ocean Diagnostics to get products from a small lab to the commercial stage. Edson acknowledges the difficulties in going commercial, "I can understand why so many products fail before they ever make it to a commercial stage. It's really hard to get out of the lab and into a commercial stage, especially in a niche market. It's not like an app that you can just sort of serve out."

A Beacon of Light

Another example of SMTP's successful support has been SafetyNet Technologies. Currently, one in every five fish caught is the wrong species leading to more than 27 million tons of wasted fish and depleting economic and ecological sources for communities all over the globe. Dan Watson, founder of SafetyNet, and his team developed a light emitting device that helps fishermen and women identify the right fish. This device has the ability to lower bycatch by 90% and increase revenue by 25%—saving more fish, helping people, and protecting a vital food source.

In order to offer experimental flexibility their devices span different geometries and sizes and can be fitted to any kind of fish capture equipment. Most of the devices that they produce also have a degree of programmability, in order to allow specifications such as emitted wavelength, flash-rate and intensity of light to be set by scientists. By producing tools that are simple, standardized, and flexible, Dan and his team hope to rapidly increase the understanding of how light can alter the species and size selectivity of different types of fishing bear.

A New Kind of Ocean Robot

Tools that are adaptable and flexible are really the successful ingredients in today's ocean start-ups. Sunfish Inc., a new subsidiary of Stone Aerospace, and another SMTP grantee, has designed and built a new type of hovering autonomous underwater vehicle (HAUV). Unlike other AUVs, the "Sunfish" is capable of mapping and monitoring its environment to create its own mission plan. This dramatically refines what can be accomplished autonomously, exploring diverse systems from coral reefs to the undersides of glaciers. The Sunfish may also prove to be an enabling technology for scaling aquaculture and wind power by simplifying inspections and maintenance.

In just the past two years, SMTP has aided a wide breadth of ocean technology and conservation companies to reach their potential, creating both a virtual and a physical hub for the ocean community.

All together, the impressive group of grantees presented their latest at the SMTP showcase, sharing their aspirations to a group of investors looking to fund ways to make a difference. "One of the most encouraging things we heard from people after the event was that they left with a bit more hope about our ability to solve ocean challenges," says Schrope, "And that's exactly what we were aiming for."

SMTP awardees.

Credit: SMTP

Photo: SAMS

Science + Autonomy = Answers

Few sea and ocean-related research projects today do not involve some form of underwater robotic or marine autonomous system. Elaine Maslin reports on how they're being used by the Scottish Association of Marine Science.

By Elaine Maslin

Whether it's large autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), gliders, landers, small man-portable AUV systems and even air-borne vehicles, unmanned systems have become a day-to-day tool. And, while ready built systems are now readily available, easy access to components is enabling researchers to assemble bespoke platforms to meet specific research needs.

The result is that the reach and resolution of the data marine science research is able to gather is being extended. The work done by the Scottish Association of Marine Science (SAMS) is a case in point. It's a charitable organization, with its roots in the 1800s, that does a lot more than its remote location on the wet and crinkly west coast of Scotland might suggest. It's involved in projects on a global stage and there are few areas of the seas and oceans that it's not been at least some studies in; from looking at the survivability of prawn catch discards to the behaviour of the Atlantic Meridional Overturning Circulation (AMOC) and its influence global climate patterns.

SAMS has a fleet of vehicles to aid its work. In fact, 2019 marked 10 years since it first used a glider, a Seaglider named Talisker, which was most recently deployed off the Western Isles of Scotland to listen for whales. To date (or up to when I visited in October 2019), SAMS had deployed 19 different gliders, completing – in total – 38 missions over 4201 days, covering 68,238 km. Talisker itself has logged more than 12,000 km and is joined by two other Seagliders: Ardbed and Corryvreckan.

SAMS' fleet includes ROVs, AUVs and gliders, as well as unmanned aerial vehicles (UAV/drones) and even vehicles it's built itself.

Monitoring Arctic Ecosystems

These platforms are enabling data gathering previously too expensive or difficult to do before. For example, Professor Finlo Cottier and Dr. Marie Porter from SAMS have been leading the Arctic PRIZE project. It's not actually a prize. PRIZE stands for "productivity in the ice zone". Specifically, it's the productivity of phytoplankton.

Dr. Phil Anderson and his kayak.

Photo: SAMS

SAMS' Gavia's are used on a wide range of missions.

These creatures tend to bloom every spring – kick-starting the eco-system after winter. But, what sparks the bloom, when, its extent and how this is impacted by changes in shrinking seasonal sea ice coverage isn't that well understood.

That's because monitoring arctic areas during cold dark winters isn't easy, so data is sparse and usually only obtained in summer. In 2018, SAMS was part of a group that looked to change that. It went into the Norwegian arctic Barents Sea in January (24-hour darkness), April and July (24-hour daylight) - something no one had done in that area in a single year - to gather data on cruises using research vessels (the University of Tromsø's Helmer Hanssen and British Antarctic Survey's RRS James Clark Ross). To fill multi-month-long gaps between the cruises and overlapping with the cruises, G2 Slocum gliders were deployed. The Slocum used is part of the UK's Marine Autonomous & Robotics Systems (MARS) pool and can dive to 200m deep.

With support from modelling, the scientists were able to place the Slocum in the right place at the right time when the algal bloom started. The vehicle's sensors detect chlorophyll proxies (sending out light and detecting the change in wavelength of the return to detect what's there/fluorometer). These went from "just above background level to almost off the chart about three days and saw how it moved," says Dr Porter. As well as the phytoplankton detections, the vehicle also measures other parameters: temperature, salinity, dissolved oxygen, depth, average current, and ambient light so scientists can try to understand the wider picture.

"That's where robotics are really good," says Prof Cottier. "They're limited by batteries but are very useful, so there's desire to use them more in these areas, especially in difficult (seasonal) windows."

But, there're trade-offs. How much instrumentation you take limits mission length due to battery capacity. What's more, in arctic waters, the freezing temperatures also drain batteries faster than in warmer waters, points out Dr. Porter. With few recovery options in the area – the nearest port being 24 vessel steaming hours away – the project had to balance risk too. And, working in ice-strewn areas, there had to be close attention to the possibility of fresh water, from melting ice, which would impact the buoyancy driven vehicle's performance, and the potential for the vehicle to get stuck under ice, which can move quicker, driven by ice, on the sea surface than the vehicle itself. There are also underwater currents, driven by the bathymetry, to be wary of.

The result is a better understanding of the algal blooms. With these data, the team can now work with data gathered over 20 years by Norwegian organisations to inform models and predictions of what could happen in future years. Another project, the Nansen project, now started in Norway, will also look to pick up the monitoring mantle.

The listening project

Another SAMS project is COMPASS (Collaborative Oceanography & Monitoring for Protected Areas and Species). Under COMPASS, Dr. Andy Dale and Dr. Denise Risch have been looking at the way life moves around sea area between the Republic of Ireland, Ireland and Scotland. It's perhaps not a huge area, relative to the open ocean, but, it's a complex one. The area is very influenced by slow currents from the continental edge and it follows a slope to the north. Some goes down on to the shelf. There's a current around the top of the Republic of Ireland, one comes up from the Irish Sea. Atlantic water comes into this region and loops around and heads north. These currents drive ecology in the area, bringing in nutrients and organisms. Understanding these will help support models and input into Marine Protected Areas.

Part of the project is creating a network of buoys to track, model and monitor aquatic life and oceanographic processes in these areas. The scientists also annually send a Seaglider out on a planned mission in a triangle-shaped track, gathering data as it goes. This means the scientists can see changes each year and update their flow models. In 2018, a glider was sent out from August to mid-September, covering about six weeks, and again in 2019.

The glider is being used to collect profiles of water properties – temperature, salinity, chlorophyll, oxygen, turbidity, etc. – as it travels. With this information, water density can be calculated and that's used to understand where flows are coming from. Using a glider has some significant benefits to help do this, but also challenges, says Dr. Dale.

"It's not trivial to put a glider in the water but it saves money and time," he says. "It goes out there and gets on with it. There's no risk of being weathered off. It provides a lot more data because the glider is constantly going up and down. The resolution of the data along the track is vastly greater than if we were sampling from a boat." But, he says, there's a trade-off. "It's difficult to get a straight line because it can be buffeted by the wind and waves. When it dives, there's a more complex profile than we would get from a vessel. We have to have complex models to adjust (the data) for that. Marine growth can also make the way it flies change. We try to correct that as best we can." Another challenge is flying in the shallow euphotic zone (where light gets through) – where there's less room for its sea-saw buoyancy driven path. Tides are also stronger on the shelf.

As part of the project, marine mammal monitoring is being done using 10 static passive acoustic recorders (Soundtrap, Ocean Instruments, Ltd.) across the area to record ambient noise levels, says Dr. Risch. Before putting in the recorders, there was little information about marine mammals and their movements in this area, but it is known as a hot spot for some species, such as harbor porpoise and fin whale, so it's a marine protected area and a special area of conservation. But, more knowledge is needed to about how many of these species there are and where they go to make sure protected areas cover the right areas. To supplement the static sensors, which only pick up mammal sounds out to 500m, the team started using gliders.

"Acoustic recorders are getting smaller and smaller, some even small enough to attach to animals themselves," says Dr. Risch. "This makes them useful for attaching to gliders, some of which already have hydrophones." For the moment, it's all about trial and error, testing different systems to "figure out the bugs and which instruments are best to

Photo: SAMS

Gliders have become a regularly used platform for ocean monitoring.

Photo: Photo by Michael O. Snyder

Work in the snowy, 24-hour night of the Norwegian arctic.

use. We can then attach them to all the missions we're doing," she says. This includes glider voyages along the Ellett line, an annual survey between Scotland and Iceland, which began in 1948 (on a more limited scale). It's done with a ship but could be done with gliders, due to their long endurance.

"The value will be long-term data where we can work out what they (the marine mammals) are doing in the water," says Dr. Risch, "species distribution and what's happening offshore and any impacts of climate change."

Glacial Gavias

Another area where small underwater vehicles help scientists get closer to things that they want to study is at glacier edges. Survey work close to the edge of glaciers can be too dangerous for a survey ship because of the falling, or calving, ice.

Using a Teledyne Gavia, the ship doesn't have to go close. In 2016-2017, SAMS used a Gavia, called Freya, to do just this in Svalbard. There, it was able to survey seabed previously hidden by the now retreating glacier. Photographs, sonar images and crucial oceanographic information were gathered to help scientists to understand how the increasing rate of melting caused by climate change is affecting the seabed below the glaciers. This data was then combined with satellite data to calculate glacial ice retreat rates for the past 10 years and recently published in Marine Geology journal. Then, in summer 2019, the team went further, using an ecoSUB AUV (pictured below), Freya and an aerial drone, data from which can be geolocated, giving scientists a way to better look at sub-glacial discharge – or how the mixing of Atlantic and arctic waters affect glacial calving. The ecoSUB drone – a recent addition to the SAMS fleet – is less than a meter long and weighs under 4kg and went down to 100m deep to collect data including temperature and salinity, while Freya will once again collected bathymetric data.

Going unmanned on the waves

Not all marine research has to be under the waves. Dr. Phil Anderson is a physicist, but he's also found himself building and adapting robotics – sea and airborne. A recent acquisition is a specially designed Tetra Drones UAV that can safely land on water to suck up and filter water, collecting algae samples. This is to detect blooms of harmful algae before they read fish farms where they could cause issues with stock. The knowledge of how these harmful blooms move and interact with the environment, especially the "crinkly coastline" of the west coast of Scotland and other areas suited to fish farms, isn't very well understood, so this type of sample gathering would help. Currently, fish farm operators go out and just scoop up a bucket of water.

While the UAV adds great capability, it's got limited endurance, so, Dr. Anderson has been converting a Pyranha

Photo: SAMS

PHD student James Coogan deployed an ecoSUB during a mission to understand the extent of melting from glaciers.

kayak that will be able to go on longer sample gathering missions. Unlike the UAV, it'll also be able to collect unfiltered samples where the algae will be undamaged for analysis. The sampling rates are yet to be fully formulated; being another trade off, between coverage area and resolution.

It's all being built from standard hobbyist aircraft components – with different software – and some small thrusters that will enable it to be programmed to go on automated routes, all at a cost of under $400, says Dr. Anderson. It'll also have a glass dome with a spectrometer to detect algal blooms and light. "It's an affordable way of getting 1km from shore to pick up samples and come back," he says. "That could be around Mull or it could go to Ireland, it just needs enough batteries."

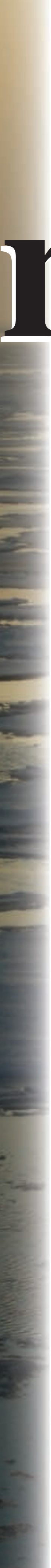
The ability to create systems like this – in a gap between toy drones and military grade vehicles – is being driven by accessibility to miniaturized components made cheap enough by the mass mobile phone manufacturing industry, he says. This ability means scientists can design systems around a question they want answering, instead of trying to make a system fit. It's only going to get easier, he says, as systems learn to talk to each other, even if on different protocols.

There's plenty more going on at SAMS. For example, under a NEXUSS - Next Generation Unmanned Systems Science - project, Jason Salt is using a Seaglider to gather data about phytoplankton blooms in the Atlantic. Detecting microplastics in the marine environment is the focus of another project, using a novel, hyperspectral infrared camera on a UAV. We look forward to learning more and telling you about it.

SAMS' fleet

- Three Seagliders 1K (Talisker, Ardbeg and Corryvreckan) – owned by SAMS.
- SAMS also use other gliders owned by the Marine Autonomous and Robotic Systems (MARS) ~30 in the national pool)
- 1 Remus 600 AUV – owned by SAMS
- 1 Gavia Offshore Surveyor AUV – owned by MARS
- 2 EcoSub AUVs – owned by SAMS
- 1 Mojave ROV – owned by MARS
- 1 Deep Trekker ROV (SAMS owned)

Exploring U



nder the Ice

& keeping your AUV in one piece

By Luke Alden & Alex Johnson,
International Submarine Engineering Ltd.

December 2019 marked the one-year anniversary since University of Tasmania sent ISE built AUV nupiri muka to Antarctica as part of the Antarctica Gateway Partnership. While there it successfully completed many survey missions under the Sørsdal glacier. What better way to celebrate this accomplishment than to send it back for a victory lap this year! Under ice missions can be notoriously difficult, and ISE has built up a wealth of experience in the 25+ years since it began sending vehicles to the polar regions. In addition to the most recent Antarctica mission, ISE's AUVs have been to the Arctic multiple times. Notably, two of ISE's AUVs created for Canada's Project Cornerstone completed 1000km of under ice survey in 2010, and for Project Spinnaker ISE-built Theseus laid 100s of kilometers of fiber optic cable. A multitude of factors led to these successful operations, and in this article we'll discuss some of the inherent dangers of working under polar ice and how they were mitigated.

Why are under AUV missions challenging?

Every time an AUV descends to explore unknown regions, there is a chance it can be lost. Even for AUVs the ocean is not a friendly place. The terrain it navigates is only partially mapped at high resolution.

This said, there are ways to minimize the risks. There is always safety at the surface for example. If an AUV is designed to be slightly buoyant with emergency drop weights to make it even more so, then it can simply float to the surface in case of emergency. The AUV also has a suite of sensors to help avoid obstacles and the ocean floor itself so that it can react to the terrain below and in front of it.

The position of the AUV is almost always known with USBL tracking and can be communicated with via acoustic communication during the whole operation. This allows the pilot to make critical decisions to help keep the AUV safe.

Why are under under-ice missions challenging?

Being under polar ice makes the consequence of failure so much higher. You do not have the safety net of the surface to return to anymore, there is less known about the terrain and there is limited to no communication with the AUV. Any time it encounters difficulty it must have systems that allow it to recover on its own, with no human intervention.

On top of this, USBL tracking does not work well. If something goes wrong, you don't know where the AUV is and it is likely not recoverable. Not only do you lose a multi-million-dollar asset, but you can't find out what went wrong in order to improve it for next time.

Even after a successful mission, recovery is not a sure thing as the nupiri muka found out in on its travels in Antarctica. Each day it had to transit back to Davis station through waters full of floating icebergs the size of cars.

Sometimes the only access to the survey location will be via a small hole in the ice that moves multiple kilometers per day, as experienced on the Cornerstone missions.

This puts a lot of pressure on ensuring that the mission plan is correct and the AUV can react to all situations appropriately.

How do we mitigate the extra risks?

• ***Advanced Autonomy:*** Without the relative safety of the surface, this is the main tool ISE uses to keep its AUVs safe. It gives the AUV the ability to

All photos courtesy ISE

All photos courtesy ISE

make contextual decisions at different stages of the mission plan. There are many scenarios that can interrupt the mission and change the AUV's objective, for example if an emergency arises and it needs to abort mission via the safest route. Based on set parameters the AUV can determine where the most suited one is. Early on in the operation this could be simple as there might be minimal obstructions, however in an unknown area under ice the safest option might be to return the way it came rather than other, possibly shorter options. While under the Sørsdal glacier this is precisely the kind of autonomy nupiri muka was outfitted with. As the glacier is coastal there are many locations where the shallow waters could restrict its movement so being able to change its behavior based the depth of the water is essential. Additionally, if one of the AUV's sensors malfunction it can react in several ways depending on how critical the malfunction is: it can switch to a backup sensor or return home. Other important autonomous features include monitoring of energy levels and ensuring the AUV returns home before its batteries run out. In addition, having geographical bounding and timers for

each section of the mission ensures that the AUV can react if it's taking too long to complete segments or heading out of mission territory.

• ***Robust Hardware:*** having the right hardware is another important way to mitigate risks. For example, nupiri muka was outfitted with a multibeam obstacle avoidance sonar that allowed it to see not only what was in front of it but what was below and above it as well. Its avoidance algorithm was designed to react appropriately depending on where the obstacle was, as simply rising and turning starboard is not always a safe option. To improve navigational accuracy nupiri muka was also equipped with a DVL for following the ice in addition to one following the ocean floor. Without this it would very quickly lose positional accuracy and may not be able to make its way home. The vehicle also had an extra acoustic modem pointing downwards to help improve communication for situations where the AUV was close to the surface ice. The more the pilot can help the AUV the higher the chance of success.

For Project Cornerstone the AUVs were deployed through an ice hole that moved multiple kilometers per day. The vehicles were outfitted with a homing system that could help them find their way home even from 100km away. They were also outfitted with a variable ballast system to give them the ability to park under ice and wait for an ROV to transport them the final distance to the ice hole. To minimise risks of launch and recovery, these AUVs were also outfitted with underwater connectors for charging and data download.

All of this hardware needs to be tried and true - mature designs, used for years to ensure their reliability. Even one failed system can make or break a mission.

On to success

As we can see, there were many contributors to successful under ice missions. Most discussed were in the vehicles themselves but it is important to remember the planning and experience needed too. Every time the vehicle is sent out, its mission plan it should be carefully reviewed by individuals with polar experience. With this in mind – plus some blood, sweat, tears and maybe a little luck - there is no reason why there won't be many more successful polar missions in the future.

Going Remote

Images: L3 Harris UK

L3 Harris UK's C-Worker 7 working with an ROV off the UK's south coast.
Inset Above: The C-Worker 7 payload

Marine autonomous systems and combinations of such systems are being increasingly put to the test in the offshore space. MTR looks at how hybrid remote and autonomous systems are being tested.

By Elaine Maslin

Concepts like resident subsea vehicles, for inspection, repair and maintenance, are attractive options, but not the only ones being tried. Deploying remotely operated vehicles (ROVs) from unmanned surface vessels (USVs) are also being tested and put to use. It's another way to take operators out of harm's way, centralize operations and cut costs and environmental footprints. But, there's a way to go until these systems can face the harsh conditions of the likes of the North Sea.

Early adopters

French firm Marine Tech has been combining USV and ROV capabilities, with commercial success since 2017. Those behind the firm, which was founded in 2014, have been providing what they call remote surface vessels (RSVs) into the oil and gas industry since 2012, in marine survey operations in the Middle East.

Marine Tech started investigating the possibility of adding ROV capabilities to its RSVs in 2016, through a project with Abu Dhabi's National Petroleum Construction Company (NPCC) Survey & Diving team. NPCC wanted a solution for survey and monitoring missions, including in hazardous or restricted areas, that could launch and recover an ROV.

Magali Mouries, a co-founder of Marine Tech and also its Commercial Manager, says, "They wanted to save cost and improve the security of personnel and divers and to reduce the technical means that they have to deploy to carry out these missions. An RSV replaces divers and vessels and all the teams required to carry out these conventional missions."

The result was using their 4.2m-long, 2.1m-wide RSV Sea Observer with multibeam echosounder and a Teledyne Seabotix vLBV300 ROV on board, for visual inspection. The battery powered RSV, which has 24-hour endurance and can travel at 10 kts, was fitted with a winch, tensioning system and an articulated platform for ROV deployment, down to 100m water depth. Command and control is via UHF, using the same systems deployed on all Marine Tech's RSV fleet, with Wi-Fi to recover data recorded by the onboard sensors. Communication between the ROV and RSV was part of the development, as well as the autopiloting with position keeping of the RSV and the ROV tether management.

Following demonstrations in 2017, the RSV, which can currently operate in up to 1.8m seas, became the first RSV (or ASV/USV) to be used offshore, says Mouries. It was put to use in the Zakum field, 16km off Abu Dhabi, inspecting pipeline, doing bathymetric surveys and deploying the ROV for a detailed inspection if something was discovered. It's been working for NPCC ever since, says Mouries, an oceanographer by training, with 12 years' experience in the marine environment and marine pollution.

While the vehicle is able to operate for 24 hours, including power drain from the ROV, it's often not actually used for this long says Mouries, because survey/hydrographic works do not need to be carried out continuously, during all this time. "This is the first and I think still the only one, with a young brother RSV Sea Observer Compact, operating," Mouries adds. Indeed, following the work with NPCC, in 2018, Marine Tech has also delivered an RSV Sea Observer Compact, at 3.2m-long, with a BlueROV2 onboard to IMODCO (an offshore loading terminal technology firm owned by floating production technology company SBM Offshore). For IMODCO, it's being used as part of the maintenance of offshore loading/offloading buoys, including single mooring line surveys. Again, it's still being used since going into work two years' ago. "We've been working nearly 10 years in this field," says Mouries. "We've produced more than 10 platforms into Europe, the Middle East and Asia, which is why we're able to develop these kinds of platforms." For more companies to adopt these technologies mindsets need to change, she says. "Industry has to be ready to change their process of work and it takes time to do that. The market is developing now, however. Minds are changing."

Increasing autonomy in harsher environments

Indeed, BP has been looking at this technology. The company, which speaks of a goal to have 100% of its subsea inspection activities with unmanned systems by 2025, has been supporting UK-based USV manufacturer L3Harris UK on project called ARISE. It stands for Autonomous Robotic Intervention System for Extreme Maritime Environments, an Innovate UK part-funded project which involved the University of Exeter as an academic partner.

James Cowles, Commercial Technical Sales Manager from L3Harris UK, says doing autonomous subsea inspection takes the "dull, dirty and dangerous" work off humans. Instead of having a 24m-long vessel with people on, "bouncing around", a 7m-long unmanned boat can be used. It's also not just applicable to oil and gas, he says, but also offshore wind, where thousands of structures need inspecting, as well as the cables between them. It also reduces cost and increases repeatability, Cowles says. Phase 1 of the ARISE project was a feasibility study, part funded by Innovate UK. This saw a Saab Seaeye inspection class Falcon ROV deployed from a C-Worker 7 ASV with a 2.5 x 1m moonpool. The ROV was kept in a hanger with a winch to pay out up to 50m of tether and a powered sheath wheel to maintain tension. All the electronics were in an electronic enclosure and kept separate from main control system. ROV control was treated it similar to other payloads, with a remote desk top connection via radio link, providing robust control of the ROV. The ROV was tracked using an

Main photo: Photo from IMODCO. Inset: Copyright MARINE TECH

Marine Tech has supplied RSV-ROV systems to IMODCO for CALM buoy inspection operations.
Inset Above: MARINE TECH-RSV SO Compact in operation.

Ultra-Short BaseLine (USBL) system.

This set-up was trialled in Cawsand Bay, Plymouth, early in 2019. There was also nothing to actually inspect in Cawsand Bay. So, L3Harris UK recruited Portuguese visualisation and simulation firm Aybssal Systems to build a synthetic environment so there were things to "look at" on the seabed. The vessel pilots were able to oversee what was going on and BP staff from Sunbury, UK, or Houston, US, were also able to log-in and see what was happening. Ten dives were done in a fairy friendly sea-state 3 (slight). The dives included testing vertical inspection, getting to a site and hovering, flying the ROV by hand (from shore), putting the ASV on a heading hold and flying the ROV underneath, and testing a docking algorithm.

"One of the major challenges was the winch," says Cowles. "An early learning was that if you don't synchronize these, it does wrong quickly." Also, there will not always be 10mb bandwidth offshore, says Cowles, and there can be times when the vessel is straight above the ROV making it hard to track. But, these are learnings, he adds.

"At this stage, we just wanted to see it work, the next stage collaborative autonomy between vehicle and the subsurface vehicle," he says. "So, the next step is to look at increasing automation and machine learning to generate paths to get back into its enclosure, way points, etc." The ability to work in sea states above three will also be needed, as well as a larger ROV, with a Tiger, also from Saab Seaeye, being eyed for the next trials, as part of Phase 2 of the project, scheduled for this year (2020), which is hoped will include a real inspection scope delivering data. L3Harris UK will also be looking to increase the ROV tether length to 275m, in order to operate in 150m water depth, which would cover 70-75% of the North Sea. Future systems will also incorporate line-cutting, in case the ROV tether gets caught and potentially becomes an anchor.

"The goal is a more robust launch and recovery system. We need to work in higher sea states to get the work window we need in North Sea and elsewhere around the world. And we need more autonomy," says Cowles. The future could see an 18-24m vessel with a light work class ROV or larger AUVs.

The potential is there, says Cowles, citing an ability to have 20-day endurance with a USV-ROV combination. "You can leave Aberdeen or Peterhead, transit, do 10 days work and still have a significant reserve," he says. "Even if the vessel needs a while to transit, that offers scope." Questions remaining include who would pilot the ROV – the same person as the USV pilot, or not? Marine regulations also remain a question but L3Harris UK is working with the Maritime Autonomy Sustainability Regulatory Working Group (MASRWG). Cowles says that it appears that current collision regulations (Colregs) are probably fit for purpose for the current size ASVs. As vessels get bigger, however, we will need changes, he says.

Others see the potential too. XOCEAN, an Irish company, based in County Louth, Ireland, is also working on a solution to deploy underwater robotics from an unmanned surface platform. James Ives, the firm's CEO, says, "Multiple clients have expressed an interest in extending the solution to deeper water to cover more of their assets. This inevitably means positioning sensors lower in the water column. XOCEAN is working on this next generation of technology to achieve this.

"The system is based around the integration of a subsea inspection vehicle with a larger XO-900 (9m) USV. The inspection vehicle will be fitted with an array of sensors including cameras and laser scanners allowing detailed inspection of subsea assets. The system is currently in development and XOCEAN plan to have a system in operation in 2021."

Others have been working on similar capabilities. Last year [2019], ECA GROUP, which mostly provides USVs with mine counter measures capabilities (to detect then destroy mine-like objects) demonstrated the capability of performing a subsea inspection using its USV (Unmanned Surface Vehicle) INSPECTOR deploying a H300V type ROV within a Research and Development program led by Total and TechnipFMC.

BP speaks of a goal to have 100% of its subsea inspection activities with unmanned systems by 2025, (and) has been supporting L3Harris UK on project called ARISE.

Vehicles

Good undersea vehicles come in small packages

By Justin Manley

The Riptide AUV.

Credit: BAE Systems

The holiday season has just passed, and many may have heard the phrase, "good things come in small packages." Does this hold true for today's undersea vehicles? Indeed it does. One of the most striking recent trends in the field is the proliferation of compact and affordable, yet highly effective, undersea vehicles. The past decade has seen new remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs) produced that are easily carried and deployed by one person. Capitalizing on developments in circuitry, sensors, and batteries inspired by the consumer electronics sector, these small vehicles punch above their weight class in practical applications.

There are many examples of both ROV and AUV one could consider, but a selection of four are worth reviewing as exemplars of the category. They also offer contrasting perspectives on some key technical and operational choices. For ROVs the Sofar Ocean Trident represents perhaps the pinnacle of compact performance and design optimization. While the Blue Robotics aptly named BlueROV presents a more flexible option. In AUVs the highly engineered "classic" approach is demonstrated by BAE Systems Riptide micro vehicle, albeit with a very flexible software outlook. A new entrant from Queensland University of Technology, the RangerBot, presents a novel paradigm change to keep costs down for specific use cases.

Starting with the ROVs, the BlueROV from Blue Robotics presents a typical ROV form factor. Designed just as a larger work or research ROV would be, the vehicle has an open frame carrying the electronics and battery enclosures, thrusters, buoyancy foam, and ballast weights. This simple design is robust, expandable, and entirely familiar to the field. The system offers six- and eight-thruster configurations, many optional accessories, and significant performance and flexibility. But the novel approach to cost reduction and management of complexity make this a game changer.

To keep costs down the BlueROV is shipped partially assembled, requiring an estimated six to 12 hours of user assembly to complete. While this is a cost savings for the buyer it also provides customers the chance to understand the components and the system architecture. This supports a tool intended for end user modifications and upgrades. The vehicle leverages common drone technologies and employs the open-source ArduSub control firmware, this offers both useful features and an extensive user community. The operator controls the ROV with a laptop computer and game controller. The open-source QGround-Control application provides the user interface. This potent combination of technology is offered at a remarkably low entry price of $3,500. This brings a truly capable ROV to a significant new audience.

Also expanding the audience for ROVs is the Trident from Sofar Ocean, formerly OpenROV. This compact ROV is a case study in engineering optimization. Its form factor and architecture are a significant evolution from other battery powered ROVs. Trident has a unique design that combines the versatility and control of an ROV (Remotely Operated Vehicle) and the efficiency of an AUV (Autonomous Underwater Vehicle). It can perform extended linear transects and complex maneuvers in tight spaces. Using only three thrusters, in a unique offset configuration, the ROV can move forward efficiently but maneuver very delicately. The off-center vertical thruster of the ROV can cause it to pitch at high speeds but also hover or change

A BlueROV.

Credit Blue Robotics, Jeff Milisen

depth without pitching while operating at low speeds—similar to the way a traditional ROV works.

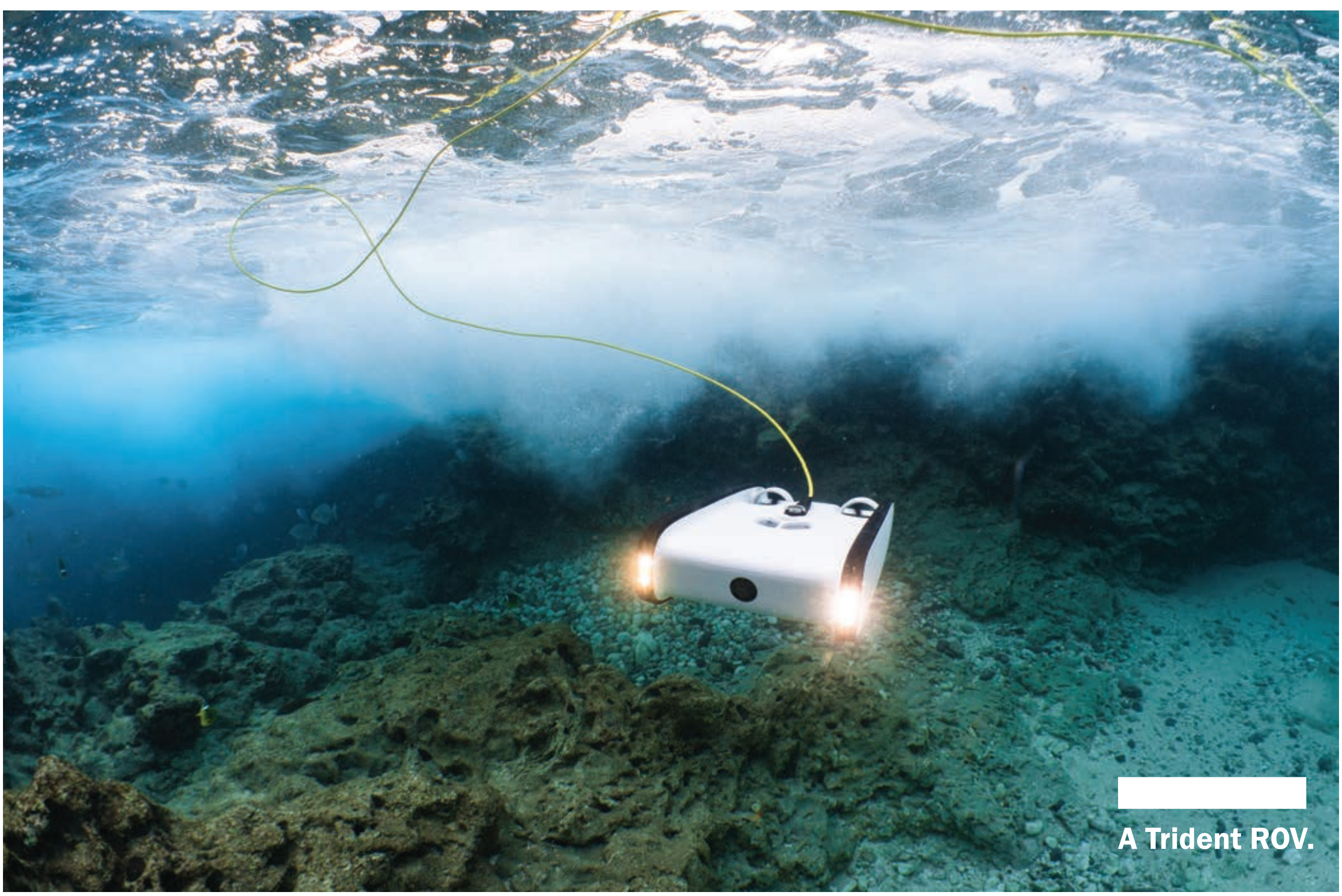
In addition to an elegant hydrodynamic design Trident was designed to be highly portable and quite durable. The ROV is small enough to fit in a backpack while its side panels are molded with a rubber coating giving it a form of bumpers. The user interface is based on internet standards such as HTML5 and WebGL to enable piloting through just a browser that runs on laptops, tablets, and mobile devices. The embrace of modern software open source approaches ensures that the code base can be continually updated by both the community and the company. This allows user driven software changes such as new user interfaces to shape the operating experience and delivery of improved ROV capabilities to the global Trident community.

This easy to use, high performance package is available on Amazon staring at $1,700. It is truly a new era for accessible, and useful, ocean robots. Those looking for a tethered experience can select a highly optimized system or a modular approach with more end-user configurability. In either case, for the cost of a modern laptop or PC one can be fully equipped to engage meaningful missions in water depths up to 100 meters. Those willing to "cut the cord" have additional options.

Effective AUVs have become smaller, and more affordable, in recent years. As with their ROV cousins there are multiple examples to consider. The modern "micro" AUV is perhaps best associated with the products of BAE Systems, formerly Riptide Autonomous Solutions. Riptide is a story of small vehicles and rapid growth. Founded in 2015 Riptide quickly delivered a compact AUV offering.

Riptide's first product was the micro-UUV, a highly flexible, open source autonomous undersea vehicle that provided a state-of-the-art, low cost solution well suited for developers of autonomy and behaviors, subsea sensors, and other new payloads. The micro-UUV featured open hardware and software interfaces giving users a reliable and robust platform to advance technology development. The vehicle design was optimized for high efficiency with the best hydrodynamic signature in its class. The base micro-UUV is 4 7/8 inches in diameter, 40 inches in length, and weighs 22 lbs. The standard system is rated to a depth of 300 meters.

While this vehicle may look like a "typical" industry offering it is differentiated by more than its small size. The focus on end-user needs was most prevalent in the software design. In contrast to typical proprietary architectures, the micro-UUV featured a flexible architecture leveraging a large amount of open source software. In the initial release of micro-UUV software, Riptide offered code for the Arduino and Beaglebone Black development platforms, as well as support for the MOOS-IvP robot control engine. This was a powerful feature set for any AUV. At a starting price around



Credit SOFAR Ocean

A Trident ROV.

$15,000 there was significant market interest.

By 2019 the success of this product was noted by BAE Systems. The BAE Systems FAST Labs organization acquired Riptide and is now maturing the platform technology and scaling manufacturing. FAST Labs is the R&D arm of BAE Systems, Inc. and is unique in the defense industry as an in-house, customer-funded R&D business designed to collaborate across the company's global enterprise to develop and transition advanced technologies. The micro AUV originally launched by Riptide is benefitting from this process.

Another small AUV that has recently come on scene is the RangerBot. This vehicle takes a different approach to de-

RangerBot over a reef.

Photo Credits: Matthew Dunbabin

livering an affordable solution for end users. The RangerBot was designed by engineers at Queensland University of Technology (QUT) in Brisbane, Australia. The team at QUT work in a robotics center focused on machine vision. They also work to support environmental assessments on the Great Barrier Reef. A key paradigm shift was enabled when the team, recognizing that water conditions in their target environment were very clear, chose to employ exclusively vision-based sensing.

This perhaps sounds obvious but abandoning the size, power and, most notably, cost penalties of acoustic instruments, RangerBot became smaller, easier to use, and more affordable than typical alternatives. Using a series of cameras, the RangerBot can manage its horizontal course over the bottom as well as its depth. Using the latest photo mosaic tools, the vehicle can also produce useful data products over a survey site. The visual systems also allow for complex environmental management applications.

RangerBot, and its predecessor prototypes, has proved able to identify crown of thorns starfish (COTS), a predator that can ravage coral reefs. The AUVs have also demonstrated the ability to carry a payload that can eliminate the COTS through precise injection of a solution that only harms the invasive organism. The payload interface that supports this mission is also helping with reef restoration. A bladder of up to 8 liters of coral larvae can be installed on the RangerBot. Using its automated vision capabilities, the AUV can identify proper bare spaces on a degraded reef and deposit the appropriate concentration of larvae. Thus, a fully loaded RangerBot can seed approximately 250 square meters of reef. This is more efficient than previous diver-based techniques.

Inspired by these successful research efforts the team at QUT have optimized the RangerBot design for production and are preparing to support a commercialization effort. When this product variant comes to market it will offer a powerful solution combining AUV free-swimming efficiency with ROV levels of maneuverability as well as advanced survey and inspection capabilities. The caveat here is that water clarity must be sufficiently high for the visual technology to work. But there are many such operating environments in the global ocean.

The examples presented here are offered to validate the statement that “good undersea vehicles come in small packages.” ROV and AUV users can find many choices, including beyond the systems discussed here. The trends underlying these developments include a greater adoption of open source software, modern production tools, and cost benefits from other fields, notably consumer electronics. The impact of innovative thinking and clean sheet design is also notable. The vehicles profiled here, and many other compact offerings in the field, benefit from the thinking of individuals, or organizations, that are new to the sector. Breaking free of older technologies, or design concepts, appears to be a big idea enabling the smaller undersea vehicle community.

Measuring the Hostile Ocean Beneath Hurricanes

Unmanned Vehicles Collect Data for Improving Storm Forecasts

By Peter Spain and Clayton Jones, Teledyne Marine

The influences of ocean conditions and currents on living environments are now more widely appreciated—from the Earth's climate and severe weather conditions to fisheries and biodiversity. Sustained and widespread measurements are needed to provide essential clues for understanding the oceans, for effective monitoring of environmental changes, and for helping to clarify the long-term effects of global warming.

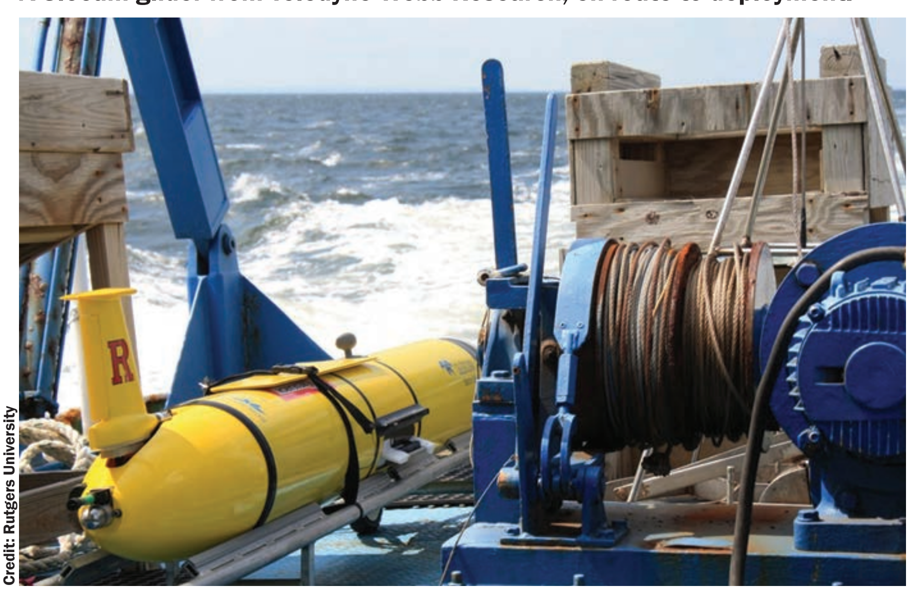
To meet this challenge, ocean researchers have invented various types of unmanned observing platforms. Two variants developed and supplied by Teledyne Webb Research are gliders for measuring upper-ocean waters and profiling floats for observing global circulation. These platforms, which support a growing range of applications, have been especially valuable for measuring the challenging waters beneath severe storms.

Measuring Ocean Conditions in Storm Tracks

Global concern about Earth's changing climate has thrust warming trends in the atmosphere and ocean into public attention. Storms have been in the spotlight, especially hurricanes and typhoons. Accurately predicting a storm's landfall and strength saves lives and reduces unnecessary defensive expenses.

The energy that feeds tropical storms comes from heat in the upper 50 m of the ocean, specifically waters warmer than 79° F. Researchers have identified that significantly improved forecasting of a tropical storm's intensity, the indicator of its devastating impact, comes from accurately knowing about subsurface water temperatures along the storm's path. The underlying water temperature is not static. Rather the storm's action on the ocean entrains deeper water into the surface layers thereby changing the available energy supply. This mixing can act to either intensify or diminish the storm depending on the temperature of the upwelled water. Thus, knowing subsea temperatures is crucial information for storm forecasting. Additionally, knowing the currents and their shear at different phases of a storm gives greater insight into the dynamics of air/sea interactions.

Fig.1
A Slocum glider from Teledyne Webb Research, en route to deployment.



Credit: Rutgers University

Credit: Teledyne Marine

Slocum Gliders

Teledyne Webb Research were pioneers of unmanned undersea glider technology. Slocum gliders advanced rapidly from experimental prototypes to reliable mobile platforms that have operated worldwide in diverse upper-ocean activities.

Slocum gliders change their volume to sink or rise; attached wings produce lift when fluid passes over their surfaces. The net effect is to convert some of glider's vertical motion into horizontal travel. Slocum gliders move at 35 cm/s and can operate from 4 m to 1000 m depth; an optional hybrid thruster provides speeds to 100 cm/s.

Slocum gliders fly in an undulating sawtooth pattern, following a programmed transect, sometimes for extended periods. For example, Slocum gliders have made continuous crossings of major ocean basins that have required more than four hundred days at sea.

Over time, Slocum gliders have been equipped with an increasing variety of oceanographic sensors, including an integrated current profiler. Physical properties such as water temperature and salinity are routinely measured. Gliders have also observed ocean acidity, chlorophyll, suspended sediments, and harmful algal blooms, as well as internal waves.

Over 45 sensor suites have been integrated on Slocum gliders allowing them to serve a broad range of applications. During the Macondo oil spill in 2010 in the Gulf of Mexico, Slocum gliders collected subsurface data to support response work. Recent payloads have included turbulence sensors for measuring ocean mixing, bio-acoustic sensors for assessing zooplankton stocks off Antarctica, and hydrophones for near

Fig.2
Teledyne Slocum glider in tropical waters.

Fig.3

Teledyne Slocum glider for storm monitoring.

Credit: Teledyne Marine

real-time monitoring of North Atlantic right whales off the east coasts of U.S. and Canada. Slocum gliders are serving new roles at Antarctic research sites as well, especially at the edge of ice sheets.

Storm Monitoring Gliders

For the last decade, Slocum gliders from Teledyne Webb Research have monitored the challenging waters associated with severe storms, sending reports even while encountering waves exceeding 10 m in height. These unmanned vehicles provide a cost-effective way to take sustained ocean measurements with high-spatial resolution. Equally important for storm monitoring, the gliders have both the control authority and endurance to intercept the storm track. For storm monitoring, Slocum gliders continually patrol a designated transect. The gliders measure temperature, salinity, and other properties while they descend and rise through the upper ocean. The gliders surface periodically to send their measurements to storm-forecasting centers. This subsea data is input to computer models that output predictions about a storm's intensity and trajectory. The accuracy of these computer predictions has improved due to the data from gliders.

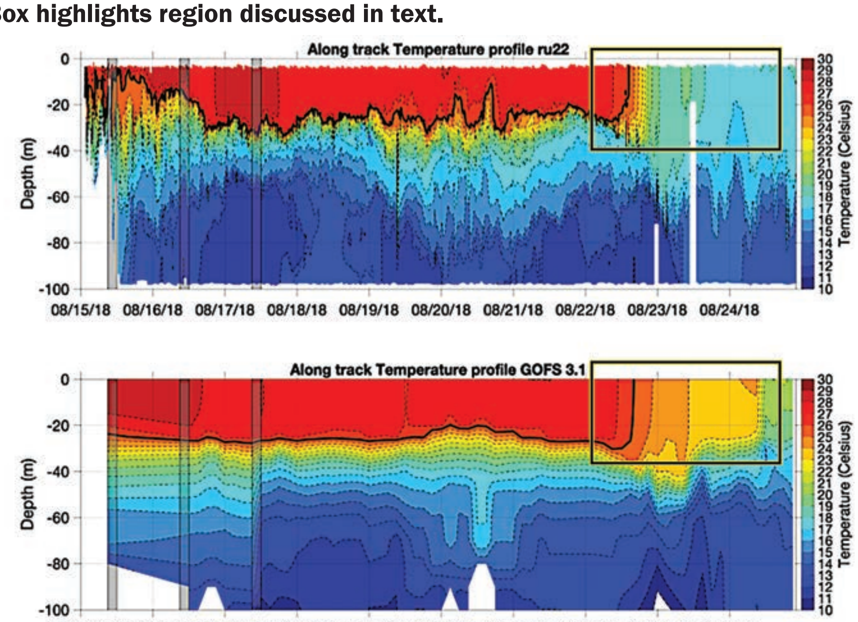
In fact, the U.S. Navy often has 50 gliders deployed worldwide that send data for ocean weather forecasting. Ten years ago, Teledyne was awarded the Navy's Program of Record contract for the operational use of gliders.

An impressive example of the benefit of using storm monitoring gliders comes from data collected during Typhoon Soulik in the Western North Pacific in 2018. A Slocum glider from Rutgers University had been deployed in advance of the storm. The in-situ data showed an extremely rapid change in upper ocean water temperature upon the arrival of the storm. In comparison, a computer-based forecasting model showed a much slower transition in response to the storm, leading to a discrepancy of 6˚ C for the change in water temperature, between the model and the collected data. Updating the model with near-real time data allows for a better storm forecast.

During a recent hurricane season in the U.S., a dozen organizations deployed storm gliders. Slocum gliders from Teledyne Webb Research were preva-

Fig. 4

Comparison of water temperature data from the upper ocean in the Western North Pacific during Typhoon Soulik in 2018. Upper pane in-situ data observed with a Slocum glider. Lower panel: Output from a computer model. Box highlights region discussed in text.



Credit: Rutgers University

lent due to their proven performance. Taking weather forecasts into account, researchers directed the gliders towards a storm's anticipated path several days in advance. Glider transects were coordinated and oriented to run across the path of the storm, covering the mid to outer continental shelf, along much of the U.S. east coast.

In the mid-Atlantic Bight, which extends from Cape Cod, MA to Cape Hatteras, NC, the continental shelf is shallow. Its deep waters are well documented to be much colder than surface waters during summer time. Considering the oceanic upwelling below the eye of a storm, the surfacing of these cold waters might be expected to weaken a passing hurricane.

Two Slocum gliders, deployed ahead of Hurricane Sandy, helped tell a different story in that case. Using computer models and data from the gliders, researchers from Rutgers University determined that strong winds on the leading edge of the hurricane set up a downwelling circulation that caused the cold bottom water to be carried offshore. Thus, there was no available cold water to mix to the surface and thereby diminish the storm's intensity when its eye passed over the same region; the storm intensity was, in fact, significantly stronger than would have been conventionally predicted.

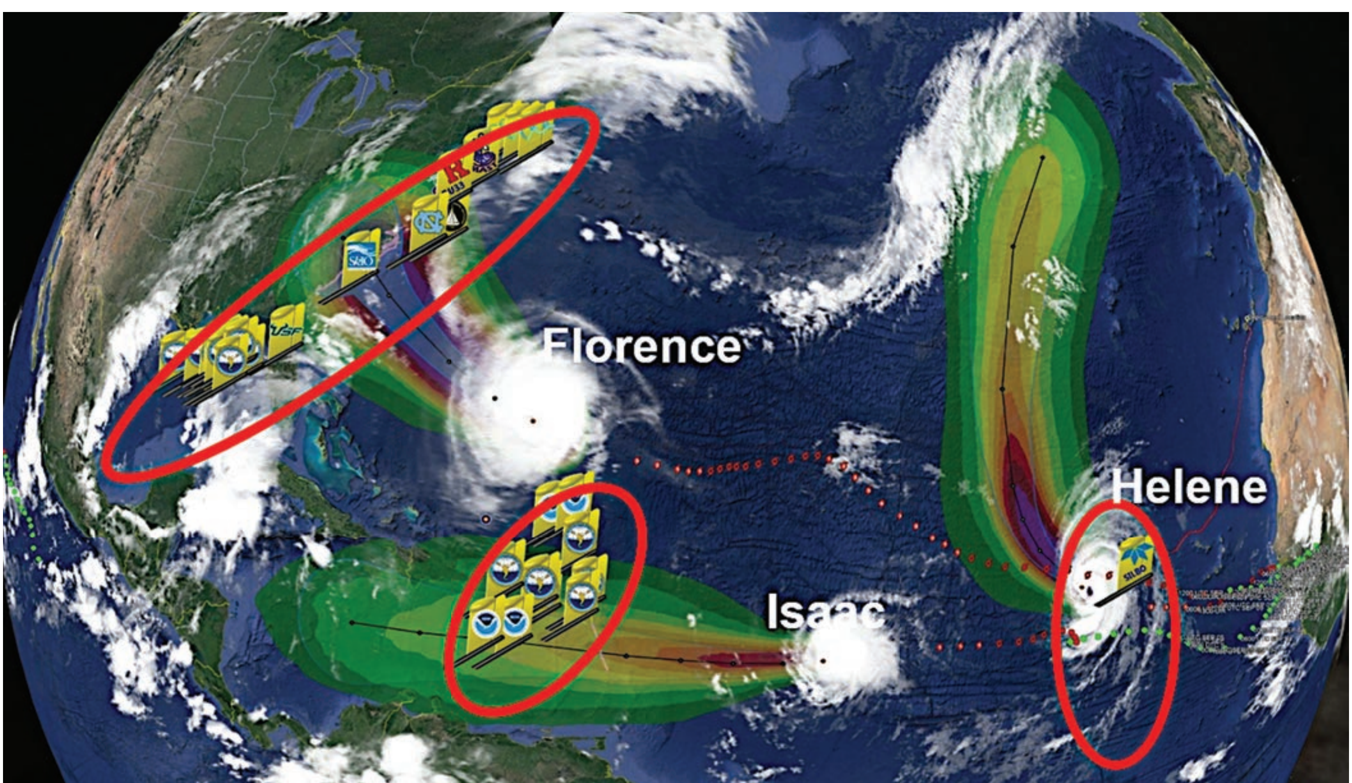
The success of using Slocum gliders for storm monitoring is apparent from the growing size of the fleet. In 2018, more than thirty gliders were on duty for observing hurricanes Florence, Isaac, and Helene. Participating glider organizations came together from government, academia, and industry in a team effort to use technology to better protect coastal communities.

Measuring the Changing Ocean Beneath Hurricane Michael

Profiling float technology has transformed how the ocean is observed. This method was pioneered by scientists and engineers at Teledyne Webb Research and Scripps Institution of Oceanography. The international Argo program has deployed fleets of these devices for sustained and widespread exploration of the global ocean. The resulting data sets form a rich resource for studying climate and ocean processes.

Many of these devices are the Autonomous Profiling Explorer (APEX) floats supplied by Teledyne Webb Research, which has delivered over 10,000 profiling floats to the Argo program—the largest quantity from one supplier. APEX floats make periodic vertical cy-

Fig. 5
Three picket lines of Hurricane Sentinel gliders were at work on the same day in 2018.



Credit: U.S. IOOS Glider Data Assembly Center

Credit: Teledyne Marine

Fig.6
Teledyne Webb Research EM-APEX float.

cles, typically every 10 days, by changing their volume (and therefore buoyancy) to rise and sink. As they ascend through the water column, they measure temperature and salinity.

Efforts to improve understanding and prediction of major hurricanes require gathering ocean and atmospheric data in hostile and challenging places. Oceanic properties such as water current velocity, temperature, and salinity must be measured not only throughout the water column but before, during, and after the storm's passage.

A variant of the APEX float—the Electromagnetic Profiling float, EM-APEX, developed with the Applied Physics Laboratory, University of Washington—is well suited for collecting this essential information. Besides measuring water properties, this device records profiles of water current velocity. The EM-APEX measurements exploit motionally-induced electric fields that arise when sea water moves through the Earth's magnetic field.

For exploring ocean conditions beneath hurricanes, the EM-APEX floats must be deployed at short notice ahead of moving storms; thus, they are air-dropped by parachute from aircraft. When hurricane Michael entered the Gulf of Mexico in October 2018, three EM-APEX floats were launched into its path by a research team led by Professor Nick Shay (University of Miami). Air deployment was from a USAF WC-130J Hercules aircraft operating from

Fig. 7
Airborne deployment of an EM-APEX float.

the Keesler Air Force base; these planes are modified for collecting weather information in hurricanes. Several US government agencies that monitor and predict hurricanes helped with the air deployment. Teledyne Marine provided hosting services for all data transmitted from the deployed floats, as well as other technical support.

The profiling patterns of the EM-APEX floats varied during the deployment. For 12 hours before the hurricane's arrival, the floats continually cycle between the surface and 800 m depth. Once the hurricane arrived, the floats switched to cycling between 30 m and 300 m depth thereby avoiding the hazardous, highly energized surface region while still acquiring upper-ocean data.

After the hurricane had passed, the floats cycled between the surface and 500 m depth. This pattern resolved near-inertial waves, which are the most energetic feature in a storm's wake. Near-inertial motions have enhanced velocity shear, making them a key driver for vertical mixing processes.

The EM-APEX floats were deployed about 12 hours before the hurricane arrived at their location. During the campaign, the desired profiling cycles in all three phases were executed correctly, ensuring that none of the EM-APEX floats were damaged by the storm's fury. While a float was at the surface, its data transmissions were received by the Teledyne dataserver. The EM-APEX floats recorded more than 600 profiles over six days. This data stream helped researchers to understand and predict the characteristics of a major hurricane, as well as to see, in near real-time, how the ocean responded to energetic atmospheric forcing.

Protecting Coastal Communities

The preceding accounts exemplify the remarkable advances in ocean observing capabilities that have come from unmanned observing platforms. These portable, mobile devices have been used to take extended measurements in waters that are too challenging for ships and too hazardous for humans. Gliders and profiling floats permit assessing and reporting in near real-time the hostile ocean conditions beneath hurricanes and typhoons. In addition to the value of these data for ocean research, their informational content delivers important societal benefit. They have contributed to more accurate predictions of storms' landfall and strength, thereby protecting coastal communities, reducing unnecessary defensive expenses, and even saving lives.

Credit: U.S. Air Force Staff Sgt. Julianne M. Showalter, DVIDS. The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement

Robots in the Splash Zone

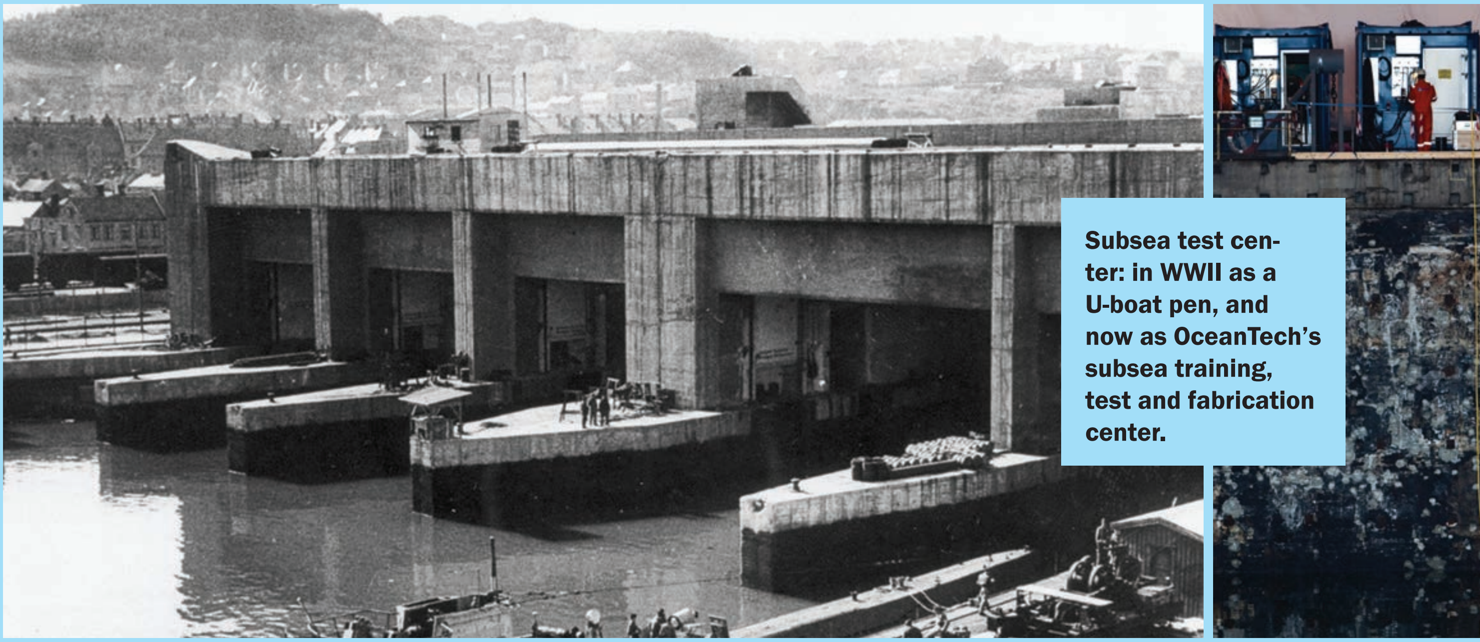
From their base deep within a former World War II U-boat pen, Norwegian outfit, OceanTech, is developing a set of robot tools that cling to offshore structures in order to effect inspection, maintenance and repair, or IMR. Old submarine anchorages are now subsea testing and training sites, but the North Sea is still the target. Hundreds of aging platforms and subsea structures require IMR that's too costly, complex or hazardous for divers or remotely operated vehicles, or ROVs.

By William Stoichevski

As he walks us through Dora II, the original name of the U-boat pen, OceanTech CEO, Berndt Schjetne, points to corners of the building stashed with rental tools custom-built for a range of past clients: a lift palette for the serpentine ROV, Eelume; a large splash-zone tool with its own crane for immersing probes into a platform jacket's wave-lashed splashzone. "We use it as a kind of subsea workshop," Schjetne says among the mostly dank recesses.

The former anchorages, from four to eight meters deep, are crammed with training platforms and testing equipment. IMR tools are in increasing demand, as offshore operators and their contractors look to extend field life and increase oil recovery. This is where OceanTech's prototype, all-electric iCon inspection robot was tested for its ability to lower itself and its probes below the splashzone to effect subsea inspections of … you name it: pipe, riser, concrete or jacket. The iCon is the latest in a series of about five OceanTech access tools that are either joystick controlled or semi-autonomous.

Crucially, OceanTech's splash zone



Subsea test center: in WWII as a U-boat pen, and now as OceanTech's subsea training, test and fabrication center.

tools may be key, for some operators, to securing inspections and then certifications of platform integrity.

Splash zone climber

Judging by a DNV GL study, the surf is a neglected area of safety: “In areas with harsh environments, such as in the North Sea, it is common to assume that structural details located below or in the splash zone are not accessible for inspection and repair.” The splash zone is defined in DNVGL standard, ST-0126.

“Inspection of structures in the splash zone and below water focuses in addition on the corrosion protection systems (steel wall thickness, anodes, coating, etc.), marine growth and scour protection.” Yet, OceanTech’s tools do that hazardous work. The iCon robot addresses these and subsea structures as well, starting with risers that could lose buoyancy if fouled by marine life: they can also develop tiny leaks, as can infield pipelines accessible via an iCon-equipped ROV.

“Climbing down” a platform and into those difficult areas is sort of natural for OceanTech. The company’s origins lie in putting up the transmission lines that crisscross Norway’s fjords. In 2009, they began bringing the tech and techniques offshore. Masts and platforms are structurally similar.

“We made climbing our trade,” Schjetne says. “We saw that there was a need for working just below the surface. Divers couldn’t work there. No one could work in the splash zone.” Work between 2007 to 2019 created a line of ready-to-go access tools, with five or six concepts sent recently on missions to Azerbaijan, the North Sea and the Gulf of Mexico.

The VAT, or vertical access tool, is at the core of the robotized line. This climber can travel all the way from the splash zone to the bottom along risers and production lines using its robotic arm or arms. Tools attached at its back are accessed by a second robotic arm. Operators in a control cabin topside uses screens and joysticks to manipulate and gain all-round awareness. When developed in 2012, the system quickly won work in the Dutch sector and now forms the basis for future deployments of the iCon.

No support

Development hasn’t been all straightforward. “Perfection”, OceanTech learned, can be a setback. An access tolo that was 20 meters long and cost EUR 2 million to develop epitomized the company’s early eagerness to create the perfect IMR Swiss Army Knife. “We’ve never used it. It was too good. Too big. Too perfect. Too heavy to install. We learned a lot. We made smaller tools.”

So, a two-meter-long arm for inspection and cleaning was devised. It can inspect grout work on wind installations or clear marine fouling on aquaculture pens. “We believe it can be transferred to other industries, but right now it’s done 99 percent (of its work) for oil and gas.” Industry pilots paid for its development, and now it does expert cutting, inspection, cleaning, “Whatever you need to do underwater. We do everything from the platform on down. We don’t need any support vessels that use a lot of fuel. The important thing is we don’t need any divers in the water. That’s the HSE aspect and the cost aspect.”

The smaller robot splashzone tool won work from the start. Jobs were unusual for being in areas that looked easily accessible but were, in fact, death traps. After the bends and being dragged around on the ocean floor in their habitat, North Sea saturation divers’ No. 1 fear was getting tangled up around jacket legs or zapping themselves by touching their electric wands to a structure before they were ready, something could help ensure happened.

A recent Australian work order to

Photo Credits: The author/OceanTech

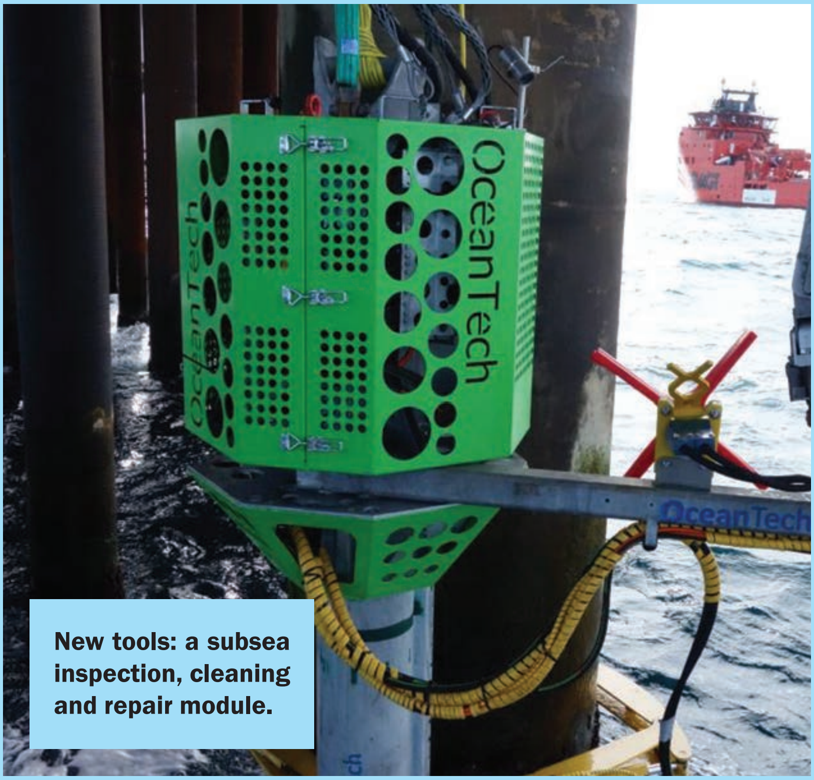


Photo Credit: OceanTech

New tools: a subsea inspection, cleaning and repair module.

Photo Credit: the iCon

IMR range: OceanTech's own range of access tools.

place giant clamps in 16 m of water illustrated how a robot clinging to a structure was superior to exposing a diver to pummeling waves. "We were supposed to work in behind (a massive structure). So, we made an access tool for the subsea clamp installation that went down to 23 m with these robotic arms to install subsea clamps on (a stretch of pipe)," Schjetne recalls.

The Aussie customer had planned to do the work with divers but called a stop after seeing the risks. "They didn't do the work. Work in those zones was difficult but needed to be done."

More IMR

OceanTech was able to engineer an automated solution and redesigned the repair clamps for robotic arms rather than for divers. "It was a minor cost in the overall picture," he recalls, adding, "We also rigged up pipe behind hard-to-access (I and J tubes). It would have been an extremely dangerous place for divers to operate," Schjetne says. At most, divers have a day or two in which to work. The robot arms' weather windows can last 30 days or a whole season.

The industry seems to agree. As platforms age, Schjetne is getting more calls. While North Sea jobs have always been at-hand, OceanTech is also active in the Gulf of Mexico and has been lined-up for jobs in the sprawling UKCS decommissioning market. In contrast, much decommissioning in Norway has been put on hold by a wave of life-extension projects, where platforms and subsea structures are given new life — another niche market for the robot arms. "The equipment and the techniques can be used in many different ways," says Schjetne. Meanwhile, ConocoPhillips, BP, Aker BP have all called in to inquire ahead of necessary inspections.

VAT vs ROV

It isn't just steel these splash zone robots can repair. They can lock on by magnet or suction. They can bolt on to concrete, as in Russian and Norway. "We haven't had any projects where we have had to say, "We cannot do this"."

Watching the VAT lowered into place with the platform's own crane before lowering the robot into the sea is like imagining a gremlin grip onto a structure.

"That's what it's all about. We attach to the structures. They're fixed. They don't flail around. That's the main difference between our system and ROV operations (of this type)." The subsea unit with its tools launches from the VAT down into the water on a vertical access beam that can be 23 m long. An affixed robotic arm — with lights and cameras and tools needed for the work — seems a most efficient worker. "The tools are hung around like a tool belt. We don't have to go back up for a new tool."

Subsea robot

The robotic arms can also install subsea assemblies in waves 6 m high while doing "very detailed work".

"We can start in April and continue until September," says OceanTech CFO, Geir Ingar Bjornsen. Schjetnes adds that with the normal diver window of a few days, 30 days of work "would take seven years". So, major splash zone IMR has simply not been done. Now, inspecting nodes or changing out anodes can be part of a service package that includes yearly inspections or pre-project sur-

The VAT, or vertical access tool, is at the core of the robotized line. This climber can travel all the way from the splash zone to the bottom along risers and production lines using its robotic arm or arms. Tools attached at its back are accessed by a second robotic arm.

Photo Credit: OceanTech

New tool: The iCon inspection robot searches for cracks.

veys.

"We do the planning. We can take care of all the installation planning and modifications and then do the installation."

Class's DNV GL says there is in fact much to do at or just below the splash zone: apart from clearing marine growth and checking for leakage or corrosion, there are the effects of collisions and even earthquakes that warrant a closer look or, sometimes, a surface wrap.

iCon inspections

The new iCon, with its sensor package, could be decisive in an operator's bid to get a life-extension project approved. With new tools just out of development, it can inspect for fatigue cracks using alternating current field measurement, or ACFM.

A year ago, for the first time, a degree of autonomous movement turned the iCon Deepwater Inspection Tool into a splash zone tool able to effect repairs below the waterline. It's crack-finding sensor — originally a handheld tool for divers — is affixed a probe carried by the robot and allowing it to trace subsea structures. It's delivered by VAT. Using machine vision and automated thrusts in six directions, the tool follows a weld right around a structure, staying just millimetres form item being studied.

When a crack is detected, its length and the depth are seen topsides and another splash zone tool can be deployed. For deeper water, an ROV will be able to deploy the robot probe "in the future": so, from 5 m to 12 m into the splash-zone. Below that, you might prefer an ROV for the iCon.

OceanTech's strength is an ability to create a unique access tool from which to deploy inspection robots in days or weeks. "If the tool fits, then we can go right out to the job." The right clamp size for the pipe is all that's needed to get an inspection robot fixed in place ahead of monitoring, reinforcing, grinding down or drilling the crack to an end point.

The iCon tool also creates "a digital twin", and that has raised eyebrows among operators, including tech-savvy Equinor.

The Norwegian operator is understood to be already piloting its use, precursor to coming contracts.

New Products

Innovative new products, technologies and concepts

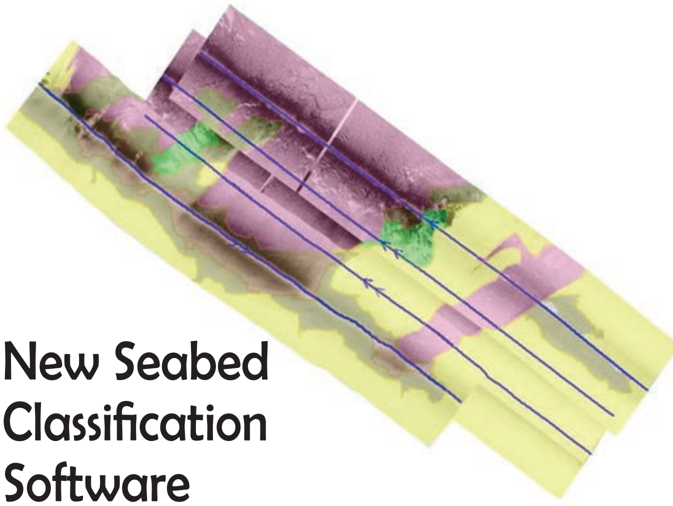


Photo: Coda Octopus

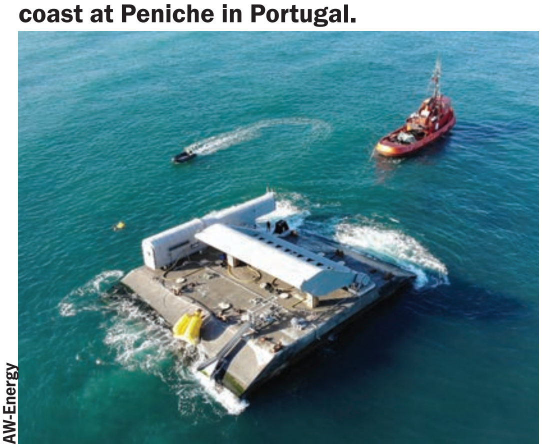
New Seabed Classification Software

Coda Octopus released the beta version of its software package for automated seabed classification. Integrated within the Survey Engine range, the software automatically interprets users' sidescan sonar data to detect and classify different seabed types. The seabed classification module uses AI-based methods to detect and classify seabeds in both type and geopgraphical extent from sidescan sonar data. The extent boundaries are instantly visible to the user for validation and QC and can then be exported for use in chart and map generation, direct import to the users chosen GIS platform, or for further processing. Within Survey Engine, the seabed type boundaries are stored using the GeoKit feature set allowing them to be manually edited, reported or supplemented if required. The boundary generation process automatically creates nodes in a way that avoids any gaps between adjacent seabed types which is vital for contiguous segmentation and reporting. The software also displays closed boundary areas as colored polygons helping to identify and distinguish these seabed types, particularly useful to visualize those areas completely surrounded by other seabed types. Currently, Seabed Classification Beta is programmed to recognize six different types of seabed compositions. This Seabed Classification package is fully extensible and specific types can be added on request.

Renewable Energy
WaveRoller Tested

A first-of-a-kind commercially-ready offshore wave power generation device is soon to be completed thanks to the experts from Finnish-based wave energy technology developer AW-Energy. The team has deployed its WaveRoller device offshore at Peniche, a seaside municipality and a city in Portugal. Extended sea trials are being used to fine-tune the WaveRoller's control system to maximize its performance and yield. Engineers are also monitoring the device's performance using the company's next generation monitoring software which can be used to remotely access the device by any of the engineers from anywhere in the world and at any time, to help assess and manage the performance of WaveRoller.

WaveRoller towed in to position off the coast at Peniche in Portugal.



AW-Energy

BlueROV

BlueROV2 Surface Power

Torrance-based Blue Robotics announced its newest product, the Outland Technology Power Supply for the BlueROV2, which was developed and manufactured by Outland Technology of Slidell, Louisiana. The Outland Technology Power Supply (OTPS) provides a solution to power the BlueROV2 through the tether cable, eliminating the need for batteries and allowing it to be operated indefinitely. The OTPS is available immediately from Blue Robotics, starting at $11,300 for a complete system.

Arctic Rays

Mako 4K mini camera

Arctic Rays released Mako for use on multiple platforms, including ROVs, HOVs, ASVs, landers and fixed platforms.

In addition to recording 4K (3840 x 2160P) UHD video, the camera can capture 8MP still images at 3840x2160 resolution.

It measures 70mm diameter by 140mm long. Housed in a 6061-T6 AHC aluminum housing, it is available in depth ratings of 2,000 or 6,000m.

Henriksen Puts New LARS to the Test

The smooth launch and recovery of a Hugin Autonomous Underwater Vehicle (AUV) has been demonstrated using a new system from H. Henriksen AS. Capable of being used by a wide range of small manned or un-manned auxiliary craft, the Henriksen Launch and Recovery System introduces a versatile new option for the operators of AUVs and UUVs.

The Henriksen launch system can be deployed by any craft capable of supporting its weight and that of the AUV. The Hugin AUV used to test the system was 5.5 -meters long and weighed 780 kg yet with the Henriksen launch system, it was well within the capabilities of the RIB (Rigid Inflatable Boat) chosen to carry it.

The initial test was performed with a modified launch and recovery system designed for bigger ships. H Henriksen is now designing the first-generation system dedicated for use on smaller boats such as an unmanned surface vehicle (USV). The new system will optimize weight, have a lower center of gravity and reduce hydrodynamic drag when extended into the water. By using the smallest boat capable of carrying the AUV and its launch system the user benefits from lower operating costs combined with the increased maneuverability that smaller boats provide.

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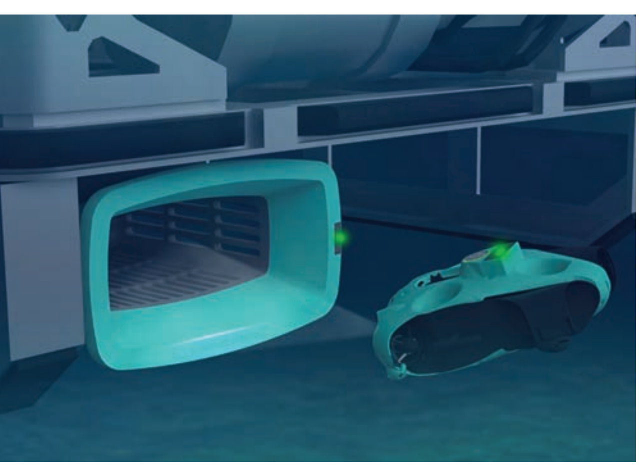
Transmark

Transmark Subsea

Transmark Subsea, a Norwegian firm which bought Bergen based has developed Halo, a “suspended” docking station for smaller vehicles that would be cable-deployed from USVs, to provide power to a small untethered vehicle and communications gateway to shore for remote control. Halo is being promoted with its Maelstrom pinless power and communications connector, Swiss firm Hydromea’s Luma optical modem and Trondheim-based Waterlinked’s acoustic modem for wireless control. It’s also got a garage dock concept (pictured), again with optical and acoustic wireless communications, as well as pinless power and communication connectors, for temporary and “long stay” drones. It’s small enough to be integrated into work class ROVs or offshore infrastructure to house small fly-out drones

Get a Grip

Manipulators for flexibility & efficiency working underwater

While much focus on resident subsea vehicles has been about the vehicles, there's also been a lot of focus behind the scenes on creating electric tooling. The industry has relied on hydraulic tooling since tooling has been used, with the benefits and drawbacks that come with it. Leading the field has been Schilling Robotics, now a part of the TechnipFMC group. But, for electric vehicles to really make to most of being all-electric, they really need to be free of the burdens of hydraulic systems. Suppliers are coming up with solutions.

Electric manipulation

Saab Seaeye is already well versed with all-electric technology, having the broadest fleet of fully electric vehicles. It's now also adding an electric manipulator to its toolbox.

It's a seven-function electric manipulator that offers advanced control capabilities to "enhance the operator experience and increase operational efficiency", says Matt Bates, Sales Director at Saab Seaeye. Saab Seaeye's manipulator has a maximum reach of 1.9 metres with a lift capacity between 125kg fully extended and 455kg at minimum extension.

It has an advanced intelligent control system, combined with a perception system, makes it possible to deliver supervised automatic manipulation. This includes end point control, collision prediction, detection and prevention.

"Greater manipulator control has come from designing a system with braked, electric rotary joints and an intelligent, distributed, control architecture offering position and power feedback," says Bates. "The result is a manipulator with the capability of existing hydraulic work class manipulators that is more precise, more dexterous and more capable of adopting advanced AI control techniques.

Bates says the development is well advanced with testing all the core joints and building blocks. A first prototype arm will be tested in March, with a first deployment mid-year and then first production deliveries expected end of the year.

Whilst the manipulator will be generally available to the market, a pair will be installed as standard on Saab Seaeye's new electric work class vehicle. More on that another time.

Saab Seaeye's electric manipulator.

Credit: Saab Seaeye

The Freedom ROV with tooling package: Gator clamp, pinless generator, torque tool, multipurpose cleaning tool, drone, and interface.

tooling, including the motors, are on the vehicle so that the interchangeable tools (suites of which can be kept, ready to use, subsea) can be as simple and robust as possible.

Getting a Grip

Grip Offshore is also working on a fully electric manipulator, called eManip7. Bjarte Nedrehagen, the company's CEO, points out that most electric ROVs today still use hydraulic manipulators. In 2018, the company, signed a LOOP agreement with Equinor Technology Ventures, to develop a seven-function electric manipulator similar in design and physical capability to a Schilling Titan 4, using Grip Offshore's standardized smart actuators as robotic joints and motion control capabilities better than a hydraulic system.

Core to the project is developing motion control software that will enable the use of a Titan 4 control joystick. Another Norwegian firm, IKM Technology, is a partner on the project.

Nedrehagen told OE at Tau, "It is a conservative market," with an 'if it's not broken, don't fix it' attitude and contracting models that inhibit new technology adoption." But, change is happening and he's keen to see an industry standard interface for subsea tooling so that it's easier for alternative suppliers to provide equipment.

A new concept

Oceaneering has developed a completely new concept for its Freedom vehicle. It has designed a tooling interface that can either work inline of the vehicle, e.g. facing forward, or pointing down, by rotating it 90 degrees. The neat thing, Torleif Carlsen, research and design engineer, Oceaneering, told OE at the Tau event, is that all the "smarts" for operating the tooling, including the motors, are on the vehicle so that the interchangeable tools (suites of which can be kept, ready to use, subsea) can be as simple and robust as possible.

"It's a mechanical interface with all the smarts inside the AUV," he says. These "smarts" are comprised of two motors, each independently controllable, that can drive multiple functions within the individual tools, including a gripper, cleaning brush, CP probe, and softline cutter in one with an output of up to 2700nm. It's not just handy for tooling; when docking, one motor drives a locking mechanism to hold the vehicle onto its docking system. The innovative interface also provides pinless power and communications connectivity.

"When we looked at this approach, we saw we could do much more," says Carlsen. "We can even put a propeller on (to the interface), for long range operations. This is just the tip of the iceberg." Another idea is to use it to fly out a small drone from this interface on Freedom, when perhaps an alternative viewing angle is needed. Furthermore, because it's electric, when applying torque, it's able to sense the rotational torque being applied (something that isn't measured with existing hydraulic driven systems).

While designed for the Freedom, the idea is for the interface to be compatible with the entire Oceaneering fleet of ROVs, says Carlsen. This roll out will include a handheld version of the interface for traditional work class ROVs and enable the entire fleet to make use of the subsea tooling suite.

– Elaine Maslin

Oceaneering's electric work class eNovus ROV with handheld tooling interface.

Credit: Oceaneering

Photo: UKHO

UKHO Appoints RADM Sparkes
The UK Hydrographic Office (UKHO) appointed **Rear Admiral Peter Sparkes** to the position of National Hydrographer and Deputy Chief Executive. Sparkes joins the UKHO as a Rear Admiral in the Royal Navy. He has served previously in a wide variety of appointments, both at sea and ashore. Notably, he commanded the frigate HMS Cumberland on counter-piracy patrol off Somalia and the UK's Ice Patrol Ship, HMS Protector, in Antarctica.

Hanlon to Retire from COVE
Jim Hanlon announces his plans to retire as Chief Executive Officer of the Center for Ocean Ventures and Entrepreneurship (COVE) in 2020. Hanlon, with the late **Colin MacLean** (CEO of Waterfront Development, now Develop Nova Scotia), and **Gordon Gale**, President of OTCNS, were the early visionaries behind COVE. COVE's Board of Directors is finalizing a recruitment strategy for the next CEO.

Greensea Opens Second Office
Greensea Systems (Richmond, VT) is opening a second office in Plymouth, Mass., at 10 Cordage Park Circle, Suite 222. It will be the company's first office outside of Vermont and will become home to a growing team of software developers and robotics engineers. "Greensea is actively recruiting navigation and controls engineers, project managers, and program managers to support our expanding business," said Marybeth Gilliam, COO. "Adding a second location in a major market with a well-known maritime community will help us to secure exceptional talent."

MTS Welcomes Two New Board Members
The Marine Technology Society (MTS) has elected two new Board members: **Josh Kohut** & **Jerry Miller**. Dr. Miller, President of Science for Decisions, will serve as the VP of Government and Public Affairs. Dr. Kohut, a professor at Rutgers University at the Center for Ocean Observing Leadership, will serve on its Board of Directors as the Vice President of Education. The positions for both will run from January 1, 2020, to December 31, 2022.

Mitcham Names New Tech Positions
Mitcham Industries, Inc. has made two additions to its technology development team. **Andy Meecham** has joined Mitcham in the newly-created position of Vice President and Chief Technology Officer. Additionally, **Dr. Peter Ramsay** has joined the company as Director – Strategic Hydrographic Programs.

Sonardyne's Rescue for Korean Sub
Sonardyne will supply underwater positioning and tracking technology for the Republic of Korea Navy's (RoKN's) new auxiliary submarine rescue ship (ASR-II), a ship scheduled for delivery at the end of 2022. Through a contract with GE's Power Conversion business, the ASR-II will be fitted with Sonardyne's Ranger 2 Ultra-Short BaseLine (USBL) system. This will interface onboard the vessel with GE's Seastream Dynamic Position (DP) control system.

Peel Ports invests in Multibeam
NORBIT announced the recent supply of iWBMSh Integrated Multibeam Survey Systems to Peel Ports Group. NORBIT iWBMSh now commissioned on the Royal Charter has replaced the vessels previously installed multibeam system. With the vessel now delivering high quality bathymetric and backscatter hydrographic data, Peel Ports have additionally installed a NORBIT iLiDAR laser scanner to provide further survey capability in their often interesting and challenging survey environments.

First Subsea Lifting Tools for Allseas
First Subsea won a contract to supply three Ballgrab Internal Lifting Tools (ILT) to Allseas. The tools are designed for lifting loads up to 900mT and will be used by Allseas for offshore decommissioning projects. The first planned offshore operation will be the Tyra Redevelopment Project, when the ILT tools will be used to lift the top jacket structures for Tyra East D Flare Jacket and Tyra West D Flare Jacket.

Photo Credit: Oceanology International

Oi 2020 "Happy 50th"

Oceanology International preps to mark its half-century in style

Oi London 2020 event builds upon a wealth of previous events to herald a new chapter in ocean science and technology

Much has (and hasn't) changed in the half-century since Oceanology International staged its first, comparatively low-key event in the UK city of Brighton. The inaugural Oi expo attracted a small but dedicated band of 600 exhibitors and visitors, and merited a brief, typically upbeat mention in a Pathé newsreel of the day. However, if the optimistic reportage of the 1960s feels a world away from the grave environmental and economic portents of today, it should be borne in mind that Oi is not only still with us, but now has more influence than ever as an industry-supporting champion of beneficial ocean science and technology innovations – and that in itself should be cause for celebration.

Oi 2020, a special 50th anniversary presentation, will be held in the long-running exhibition and conference's habitual UK venue, ExCel London, on March 17-19, 2020. Indicative of the franchise's still snowballing global profile, Oi has now made strong inroads into new international markets with the introduction of sister expos in China and the Americas (since 2013 and 2017 respectively), plus a forthcoming series with a Middle Eastern and Indian Ocean focus, due for launch in Abu Dhabi in September 2020. This impressive expansion is reflected by the way the numbers are already stacking up for the London 2020 event: more than 8,000 visitors are expected, making this landmark show the largest undertaking in Oi's history.

Accordingly, organisers Reed Exhibitions have commandeered 17,000+m2 of floorspace in ExCel London to make room for over 500 exhibiting companies and organisations from 70 countries. USV supplier OceanAlpha Group Ltd (stand G450) is just one example of companies well placed to take advantage of the ExCel's proximity to the

Photo Credits: Oceanology International

Royal Victoria Dock for the staging of on-water product demonstrations. OceanAlpha will be displaying its M40 and M80 hydrographic survey boats and ME40 bathymetric survey boat, having developed more than 25 USV models in the decade since the company's launch in 2010.

In comparison to the last Oi London event in 2018, twice as many companies will be using the waterside location in 2020 for product demonstrations. Other exhibitors with watercraft to publicise include Bibby HydroMap (stand E301), which will be extolling the capabilities of its Bibby Athena and Bibby Tetra semi-SWATH coastal survey vessels as well as its d'ROP bathymetric survey and inspection system, and Ocean Aero (stand A160), whose Submaran is the first hybrid wind and solar-powered surface and subsurface vessel specifically designed for long-term ocean observation and data collection.

Meanwhile, Oi London 2020's conference itinerary is also taking shape with the inclusion of dedicated content programmes such as the Spotlight Theatre, providing exhibitors with an outlet to discuss their new products and technologies, and Near and Far Markets, in which company representatives can receive advice on reinforcing trade arrangements with overseas partners and optimising the commercial value of their export strategies.

The expo will also see the return of the popular Catch The Next Wave feature (Thursday, March 19, 2020), wherein speakers will celebrate the many ways in which the mutually supportive disciplines of science and exploration have benefited the world's oceans since Oi's inception half a century ago, while focusing on trends and concepts which illustrate how responsible, sustainable ocean industries may be evolving over the next 50 years.

Catch The Next Wave follows on from another of Oi's keenly-anticipated one-day content and networking events, the Ocean Futures Forum (Tuesday, March 17, 2020), which will touch upon topics such as autonomous shipping and regional perspectives in the course of presentations committed to strengthening the development of a tenable Blue Economy. Confirmed speakers at the time of writing include Martin Visbeck, President of The Oceanographic Society, and Mark Spalding, President of The Ocean Foundation.

Additionally, all three days of the event will be filled as always with free-to-attend technical conferences covering all maritime sectors: a mine of concentrated information and insights bringing delegates up to speed with the latest advancements in critical areas of technology. For 2020, conference threads will include Hydrography, Geophysics & Geotechnics, examining cutting-edge data collection, processing and analysis techniques in offshore site studies; Unmanned Vehicles & Vessels, looking at the most recent (and forthcoming) advances in robotics, AUVs. ASVs and ROVs; and Ocean Observation & Sensing, through which attendees will learn about the ever-more accurate and sophisticated instruments and techniques which are now being used for monitoring ocean and atmospheric physics, chemistry, biology, and genomics.

"Perhaps the most defining attribute of this highly-anticipated 50th anniversary Oi event is the fact that the celebratory aspect doesn't merely involve the ocean technology community congratulating itself on its collective achievements over the last 50 years, but is woven into planning positively for the planet's future as the expo's exhibitors and speakers have always done," says David Ince, Event Director, Reed Exhibitions. "We are witnessing a major cultural shift in the way the ocean environment is perceived in the wider world, at the same time as digitalisation is transforming working practices across the entire maritime sector. The collaborative commercial and conceptual networks that Oceanology International has helped to forge have been significant drivers for change for five decades now, and it's genuinely heartening to see a broader recognition of the efforts which are being made to secure the sustainability of our oceans. It has never been more urgently important for technologists, corporate bodies and governments to work together in this regard, and at Oi London 2020 visitors will see first-hand how inspirational new synergies continue to bring about practical solutions."

www.oceanologyinternational.com

THE #1 MARINE TECH

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Marine Technology Reporter is the industry's largest circulating magazine dedicated to the underwater technology and ocean science markets. From the surface to the sub-seafloor, *MTR* provides unbiased news and information on equipment, systems and platforms for use in everything from hydrographic and oceanographic research to defense and renewable energy.

Marine Technology Reporter is proud to maintain a 100% BPA Audited Circulation, and is currently the only audited underwater technology magazine serving the subsea market.

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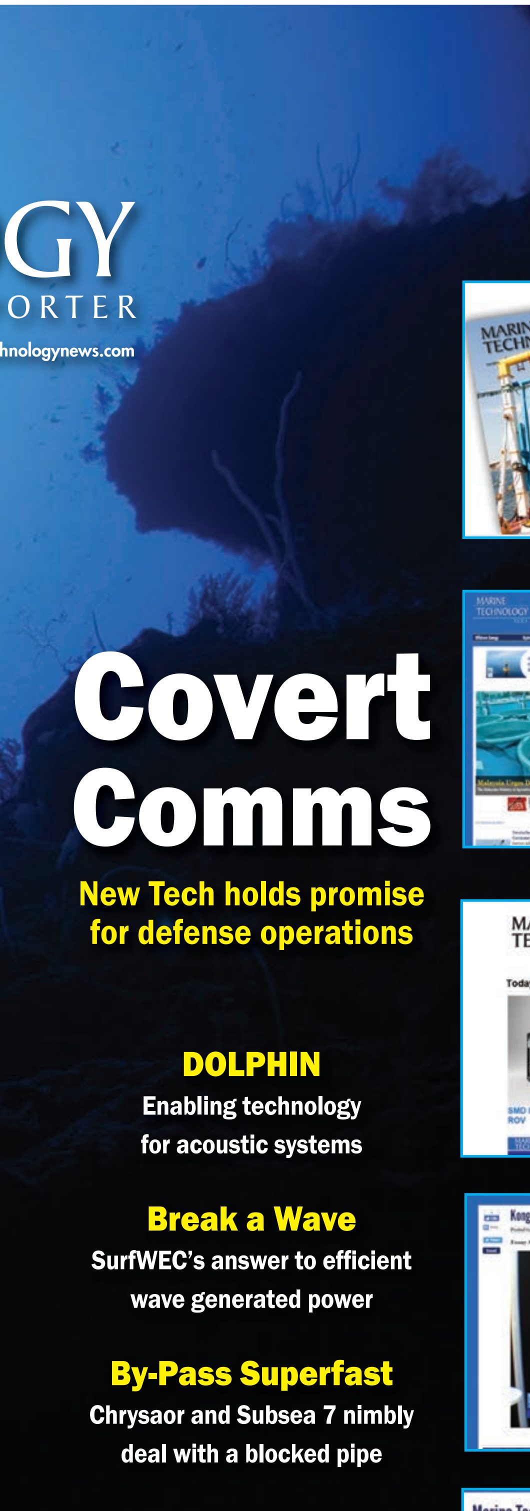

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The Industry's Leading Publication

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Marine Technology Whitepapers

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Three exclusive electronic-only editions of Marine Technology Reporter featuring papers from three industry sectors including: Oceanographic, Hydrographic, and Unmanned Marine & Subsea Vehicles.

2020 Editorial Calendar

JAN/FEB

Ad Close: Dec 21

Underwater Vehicle Annual

Subsea Defense Tech

Manipulator Arms and Tools

Autonomous Navigation GNSS MEMS

Unmanned Vehicle Propulsion

Event Distribution

Subsea Expo 2020- Feb 11- 13, Aberdeen
Underwater Defense & Security - Mar 3-5, Southampton
Canadian Hydrograpic Conference- Feb 24-27, Quebec City
Oceans 2020 Singapore - Apr 6-9 Singapore

FEBRUARY

Ad Close: Jan 22

MTR White Papers: Oceanographic

White Paper Electronic Edition Publication Date: February 2020

MARCH

Ad Close: Feb 21

Oceanographic Instrumentation: Measurement, Process & Analysis

Oceanology International New Tech Gallery

Fiber Optic Cables, Connectors & Slip Rings

Marine Drones

Hydrographic Sonar & Software

Event Distribution

Oceanology International - Mar 17-19, London
Sea-Air-Space- Apr 6-8, Baltimore, MD

APRIL

Ad Close: Mar 21

Offshore Energy: Oil & Gas, Wind & Tide

Subsea Electrification

Lights, Cameras, Lasers, Multibeam Sonar

Buoyancy Technology

Scientific Deck Machinery / LARS

Event Distribution

Offshore Technology Conference- May 4-7, Houston, TX
AUVSI XPONENTIAL- May 4-7, Boston, MA

MAY

Ad Close: Apr 21

Underwater Defense Technology

Comms, Telemetry & Data Processing

Hydrophones

Magnetometers & Streamers

Beacons, Flashers & Tracking Systems

Event Distribution

UDT- May 12-14, Rotterdam
Underwater Technology Conference- Jun 16-18, Bergen

JUNE

Ad Close: May 21

Hydrographic Survey: Single & Multibeam Sonar

Research Institutions

USV Platforms

GPS, Gyro Compasses & MEMS Motion Tracking

Interconnect: Underwater Cables and Connectors

JULY

Ad Close: Jun 22

MTR White Papers: Hydrographic

White Paper Electronic Edition Publication Date: July 2020

JULY/AUGUST

Ad Close: Jul 21

MTR 100 - Edition

The 15th Annual Listing of 100 Leading Subsea Companies

MTR looks at 100 leading companies and executives in all subsea disciplines, defense, offshore energy and science.

Event Distribution

Offshore Northern Seas- Aug 31-Sep 1, Stavanger

SEPTEMBER

Ad Close: Aug 21

Autonomous Vehicle Operations

Subsea Residency

ROV Technology: Work Class to Micro Systems

Thruster Tech: Underwater Propulsion

Underwater Tools & Manipulators

Event Distribution

SNAME Sep 29- Oct 3,Houston, TX
Offshore Energy Europe- Oct 7- 10, Amsterdam

OCTOBER

Ad Close: Sep 21

Ocean Observation: Gliders, Buoys & Sub-Surface Networks

Instrumentation: Profilers, Samplers & Sediment Corers

Seafloor Mapping

Harsh Environment Systems for Arctic Ops

Geospatial Software Systems for Hydrography

Event Distribution

Oceans 2020- Oct 19- 22, Biloxi, MS
Blue Tech Week, San Diego, CA
MAST Japan Defense- Nov 2-4, Tokyo

NOVEMBER

Ad Close: Oct 22

MTR White Papers: Subsea Vehicles

White Paper Electronic Edition Publication Date: November 2020

NOVEMBER/DECEMBER

Ad Close: Nov 21

Acoustic Doppler Sonar Technologies ADCPs and DVLs

Fresh Water Monitoring & Sensors

Offshore Inspection, Maintenance & Repair (IMR)

Underwater Imaging: Lights, Cameras, Lasers & Multibeam Sonars

The 2021 Subsea Market Planner

Event Distribution

Underwater Intervention 2021

information may be subject to change

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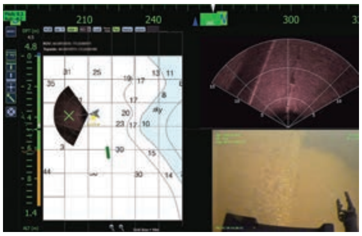

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