December 2021

ON&T

40 YEARS 1981-2021

oceannews.com

OCEAN NEWS & TECHNOLOGY

// SPECIAL EDITION 2021 //

THE FUTURE OF OCEAN TECHNOLOGY


DEEPSEA
MBARI
Image Credit: © 2021 MBARI
MxD SeaCam®
A Unique Collaboration
The MxD SeaCam is a collaboration between the scientists and engineers at the Monterey Bay Aquarium Research Institute (MBARI) and DeepSea Power & Light, leveraging the world-class design and manufacturing expertise and first-hand field experience of both organizations. The result is a camera system that will be the next standard bearer in subsea imaging technology to serve the needs of the international subsea science, exploration, and film making communities for the next decade.
Scan or visit
DSPL.COM/MXD
to learn more
4K ULTRAHD
96° Horizontal F.O.V.
15x Optical Zoom
Optional 2x Teleconverter
3 CMOS 2/3" Sensors
Custom Corrector Optics


GENERAL DYNAMICS
Mission Systems
SUSTAINED INFLUENCE ACROSS THE MARITIME DOMAIN
VISIT GDMISSIONSYSTEMS.COM
PLATFORMS: SMARTER
MISSIONS: SMARTER
©2021 General Dynamics. All rights reserved

CONNECT WITH US:

linkedin.com/company/oceannews

twitter.com/oceannews

facebook.com/Ocean NewsandTechnology

FEATURES


Photo by Minderoo

Ocean News & Technology ISSN# 1082-6106 is published 11 times a year in print and digital by Technology Systems Corporation, 8502 SW Kansas Ave, Stuart, FL 34997, telephone 772-221-7720.

THE FUTURE OF OCEAN TECHNOLOGY STARTS HERE

BY ED FREEMAN, *Managing Editor, ON&T*
editor@oceannews.com

This decade, thus far, has been a tricky one to predict. The last 24 months, since the sun set on 2019, have not exactly tracked as many of us might have hoped. Indeed, 2020 held unprecedented promise; propelled by ever smarter systems and sophisticated equipment, we were to begin a new chapter of ocean discovery. The disruption we so craved on this voyage towards unchartered frontiers was supposed to be about pushing boundaries, not shutting borders.

Despite the day-to-day challenges, concerns, and frustrations that the COVID-19 pandemic has brought to the ocean industries, overall, the sector has weathered the proverbial storm—to date, at least—rather well. Especially when it comes to ocean tech. It's not so much that the tide has turned (you'll find no such long-range forecast here) but more a comment on the marketplace's leading protagonists, many of whom evidently subscribe to the age-old adage that the most reliable way to predict the future is to create it.

FULL THROTTLE ON INNOVATION

This defiant approach to our "not-so-new normal" has been reliably chronicled throughout 2021 by the unrelenting—and very welcome—tide of industry news and company announcements to hit ON&T's inbox: product launches; contract wins; groundbreaking scientific discoveries; public policy pledges; the "will-they-wont-they?" rollercoaster ride of conference scheduling; and, of course, a surge in projects relating to marine data analytics.

This has been one of busiest years on record for the editorial team at ON&T. This points to more than just an inspired ocean tech community; it infers that change is afoot. Even amid the virulent uncertainty of 2021, operators and technologists alike—both in the field and landlocked behind screens—have persisted on applying the latest technical, solutions-based thinking to the more pressing challenges associated with traditional coastal and offshore activities.

TECHNOLOGY FOR CHANGE

Some of these are matters of urgent necessity, such as the need to establish, monitor, and report on increasingly carbon conscious practices, while others, notwithstanding a commitment to curbing CO_2 emissions, are symptomatic of an industrious appetite for ocean exploration and enlightenment. But whether born of commercial endeavor or regulatory compliance, progress will be contingent on our collective ability to harness the accelerating capacity of our great enabler: ocean technology.

In other words, any constructive progress towards the goals of tomorrow will ultimately hinge on the steady adoption and integration of disruptive thinking, fresh approaches, and scalable innovation. In these pages, readers will find all the above, and more.

THE STEWARDS OF TOMORROW

The purpose of ON&T's end-of-year Special Edition, *The Future of Ocean Technology 2021*, is to showcase the market insights, engineering expertise, and applied ingenuity of a select group of contributors: the visionary minds and entrepreneurial organizations working to constantly advance how—and *why*—we need to continually adapt the way we work at sea.

This issue presents an exclusive mix of technical features and expert opinion pieces—thought leadership geared to fuel genuine progress and trigger meaningful action. From autonomous subsea assets to offshore renewable energy solutions, from remote offshore operations to high-resolution seabed mapping, the future of ocean technology starts here.


Looking for
more out there?
WE HEAR YOU
Electroacoustic System
Design & Manufacturing for
Virtually Any Application
Off-the-Shelf & Custom
Transducers and Systems
for Military Sonar and
Oceanographic Research
and Exploration . . .
Massa is Listening
781-749-4800
innovation@massa.com
MASSASONIC®
GENERATIONS AHEAD
MASSA
1945~2020
IN
SONAR & ULTRASONIC TECHNOLOGY
0°
V1A
V1A
V3B
60°
V3B
V2A
V2A
120°
V1B
180°
240°
V3A
V2B
300°
TR-1075
Profiling
TR-1055
Beacon
www.massa.com

| FEATURE |

THE FUTURE OF **OCEAN INTELLIGENCE FOR CLIMATE RESILIENCE**

By Shik Sundar
Global VP of Sales, Sofar Ocean

On ocean planets, solar radiation is exchanged between the atmosphere and the ocean in climatic cycles that drive global weather patterns. On Earth, we've watched our oceans warm, rise, and acidify in a climate heavily augmented by carbon emissions. Understanding as much as we can about our oceans will be critical to mitigating the effects of climate change equitably and effectively adapting to a new now.

ENABLING SCALABLE AND AFFORDABLE OCEAN INNOVATION

Most of the energy in the ocean can be found on its surface, trapped in swirling currents that sequester and spread heat, salt, and carbon poleward and to its depths. Changing atmospheric and ocean conditions affect sea surface temperature, salinity, and acidity as climate scientists have observed for decades.

With the future of our planet in mind and with the goal of enabling ocean intelligence at scale with massive amounts of ocean data, Sofar Ocean has deployed a global network of IoT sensors to deliver these ocean-powered climate insights. Our distributed Spotter network covers all five oceans and collects over 100K unique ocean data points a day. There are hundreds of Spotters, scaling to thousands, drifting in the world's oceans reporting spectral wave data in a distributed network united by high fidelity Swarm and Iridium satellites in the atmosphere.

» Bristlemouth connects sensors, processors, batteries by abstracting away power and data interfaces in harsh ocean conditions for streamlined marine sensing. (Photo credit: Sofar Ocean)

Trying to scale a network of electronics in the ocean is as hard as it sounds. Building systems to withstand extreme ocean conditions requires custom work to navigate a sea of disjointed platforms, connectors, and protocols. There has been no broad adoption of standards for interoperable marine hardware until now.

PLUG-AND-PLAY SYSTEMS TO FASTRACK OCEAN INNOVATION

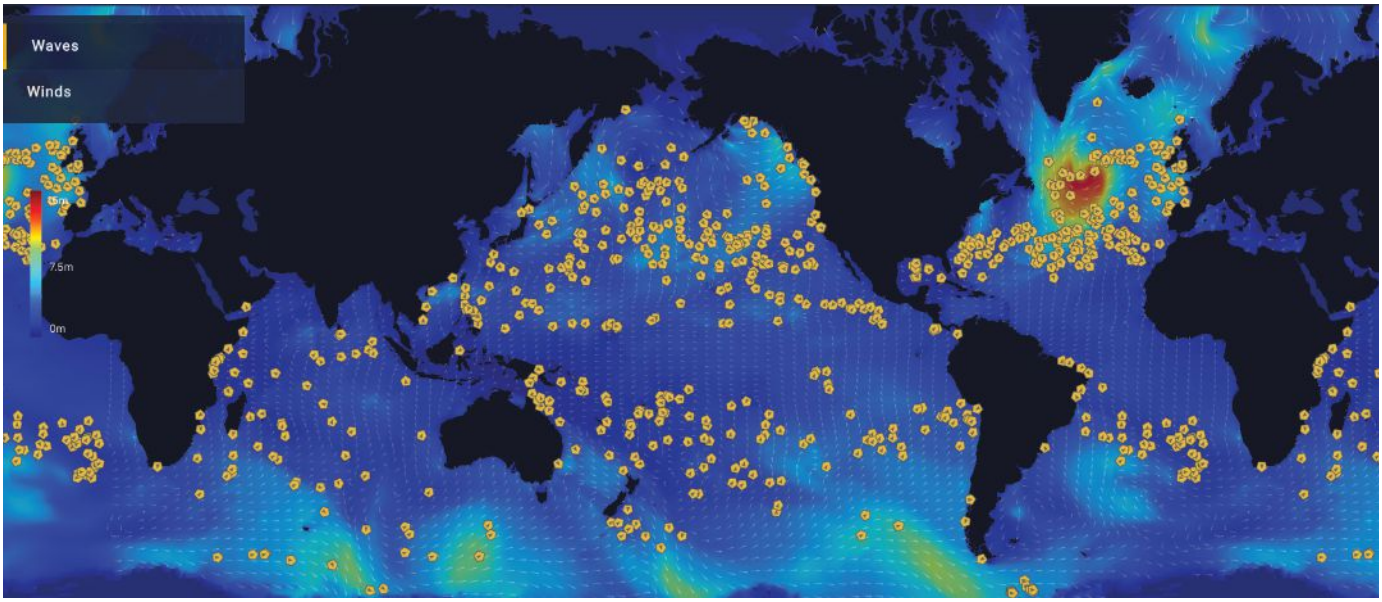
As one of the largest platform providers of marine sensing platforms, we saw an opportunity to build and scale a plug-and-play ecosystem to scale ocean sensing systems and fast-track ocean discoveries. The first-of-its-kind maritime open standard, Bristlemouth (*www.bristlemouth.org*) enables more collaboration, research, and innovation in ocean data collection. As part of this effort, we partnered with organizations that had a shared commitment, including The Office of Naval Research, DARPA, and Oceankind. With Bristlemouth, teams can easily overcome technological obstacles with interoperable and modular hardware and software systems.

Bristlemouth is built to be compatible with all devices, existing and new, as the goal is to make integration with all marine sensing devices seamless. This makes for frictionless and data-driven marine research.

RELIABLE & RUGGED HARDWARE, SUSTAINABLY DEVELOPED

Sofar's engineers debug our network's devices across some of the most remote regions of the ocean. With sustainability top of mind, our team employs energy-efficient computing strategies to test firmware remotely with limited bandwidth and resources. We're currently amending our Spotter hull design to naturally dissolve in the sea after its useful lifespan. We use GPS to pinpoint the exact location of each Spotter in our distributed array at all times. When any of the buoys go off grid, we're able to quickly retrieve them for maintenance with the help of marine stewards worldwide that take part in our buoy bounty program. We reward anyone who recovers a beached Spotter—frequently they are folks who want to redeploy them locally to serve their coastal community.

We drop Spotters and Smart Moorings along the U.S. Gulf and Atlantic Coasts to calibrate and validate hurricane forecasts for the United States Geological Survey (USGS). Normally, pressure sensors for measuring water level have to be moored offshore for several months before researchers can access



» Each yellow mark represents a Spotter buoy recording wave, wind, and temperature measurements in real time: publicly accessible at weather.sofarocean.com. (Image credit: Sofar Ocean)

any meaningful data. Anchored with a Smart Mooring, a Spotter can quickly improve coastal change forecasts with live ocean measurements in real time. In coastal areas, strong warning systems are crucial to provide residents with enough time to evacuate, shelter in place, or receive aid after a storm has made landfall. Insufficient ocean data prevents those at heightened risk of coastal storm surge from understanding holistic risks of coastal development, often discounting the risk of flooding.

With over 5 million hours of recorded ocean data in its repository, Sofar Ocean's weather model can make more informed predictions to reduce weather and climate uncertainty across sectors.

» Spotters are durable, weather-proof, and solar-powered. They can be deployed by plane, cargo ship, or paddle board. (Photo credit: Jim Thomson and E.J. Rainville)

Since our first grid deployment in late 2018, the network's grown in expanse and predictive capacity to enhance models of extreme weather around the world, trusted by governments, industry leaders, and forecasting service providers.

WIELDING OCEAN INTELLIGENCE FOR CLIMATE RESISTANCE

A solar-powered buoy may seem like a drop in the bucket, but a single Spotter can measure sea surface temperature and each wave's bidirectional period to derive wind measurements on the spot, from icy bays to the eyes of hurricanes. A single data sensor platform, no matter how accurate and complete it is, will not make measurable difference on a planetary scale. Thousands of noisier measurements are much more attractive than one 'exquisite' data point if you're interested in predicting the future. Within a distributed sensing system, maximizing data density at each node expands the capabilities of the larger network as a whole.

Each Spotter measures mesoscale displacement with GPS, which is continuously compared to past and forecasted values with spectral assimilation to yield more localized, accurate forecasts of global weather. Every hurricane, typhoon, Nor'easter, and polar low our network encounters validates accurate ground-truths with live real air-sea interactions for more predictive forecasts. Collectively, our global array holds incredible potential as the first planetary system of climate intelligence on Earth. We're grateful to our partners, who have helped us with features and deployments across the globe for immeasurable gains in marine sensing!

» NOAA's Ships of Opportunity Program unites an international community of seafarers and climatologists to deploy marine sensing equipment for more accurate ocean data and precise meteorological forecasts. (Photo credit: John Lund)

Provisioning ocean intelligence, powered by global sensor networks, is essential to reduce weather and climate uncertainty, help industries operate more efficiently, lower operational risk, and reduce emissions. With rising sea levels and intensification of storms, accurate and abundant ocean data is needed to keep vulnerable coastal communities safe and protect valuable infrastructure and maritime industries.

For more information, visit www.sofarocean.com

SOFAR

» *Reliable and consistent subsea navigation remains a critical challenge for AUV development. (Image credit: Voyis)*

| FEATURE |

THE FUTURE OF **OPTICAL SENSORS WILL ENHANCE NAVIGATION**

By Chris Gilson,
CEO, Voyis

The ocean sector has a clear emerging vision for underwater exploration—uncrewed surface vessels deploying autonomous subsea platforms, all controlled from ashore. The potential to disrupt the industry by drastically reducing the cost of deployment and access to remote regions is catalysing groups in all segments to pursue this dream, from survey companies to research institutes and global navies. Though the building blocks are starting to fall into place, with new commercial technologies enabling effective remote operations, and improved autonomous underwater vehicle (AUV) capabilities enabling remote deployment and recovery, there remains some core technical challenges that must be overcome to achieve this vision. One critical element is reliable and consistent subsea navigation.

VISION-BASED NAVIGATION

Subsea vehicles, particularly AUVs, have successfully relied on high accuracy dead-reckoned inertial navigation systems (INS) coupled with doppler velocity logs (DVLs) for their positioning during underwater surveys. Unfortunately, navigation using an INS-DVL without external aiding is a methodology that inherently drifts over time, meaning error continuously increases during a mission. Drift can be minimized by using surface-based USBL positioning, or localized LBL positioning, but these solutions have limitations in deep water, and across wide areas, respectively.

A truly autonomous framework will require complementary methods to deliver robust and long duration subsea positioning.

If we look to terrestrial applications for inspiration, driverless cars and aerial drones as an example, we see their solutions to comparable problems all leverage imaging sensors and computer vision to deliver accurate navigational solutions. By detecting environmental features, the platform's relative position can be tracked while simultaneously mapping the environment as it is perceived—technically referred to as simultaneous localization and mapping (SLAM). Not only does this

» 3D Laser Model of the shipwreck used for feature detection. (Image credit: Voyis)

improve reliability by aiding dead reckoning with through-the-sensor visual measurements, but it also provides a framework to reconnect with past perceptions by detecting loop closure events—an event where the autonomous vehicle recognizes a previously visited area, and is able to correct its position with this knowledge.

It is evident that these same methodologies could be applied to underwater navigation, utilizing imaging data of a subsea environment from sensors like digital stills cameras, laser scanners, or high-resolution sonar.

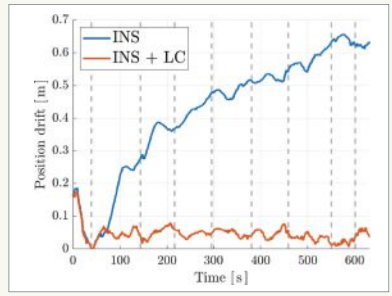
LASER LOOP CLOSURE

Voyis and its development partners, including the DECAR Systems Group at McGill University, have applied these terrestrial methodologies to the subsea environment by taking advantage of Voyis' high-resolution 3D laser data from its Insight laser scanners. Subsea laser scanners are uniquely suitable for this application since they generate rich quantitative data in real-time, enabling the identification of environmental features during an active mission, and then detecting loop closure events when a location has been previously visited.

Loop closure algorithms were tested on a local shipwreck survey which provides a quantifiable target to evaluate the methodology. The shipwreck was traversed on multiple survey passes to generate a sequence of loop closure events, with navigation data recorded with optional GPS aiding to provide a ground-truth trajectory. Real-time navigational data is used to identify possible loop closure regions, then the algorithms analyse the laser data to identify and match features. Once detected, these events can be input back into the navigational solution to eliminate the accumulated error. The identified loop closure events are shown in the trajectory map, matching features both on the shipwreck and in the surrounding seabed.

The improvement to navigational positioning is demonstrated in a trajectory error graph, where the baseline INS-DVL exhibits a continuously growing error, while the laser loop closure aided solution continually maintains an error of less than 0.1 m across the entire survey.

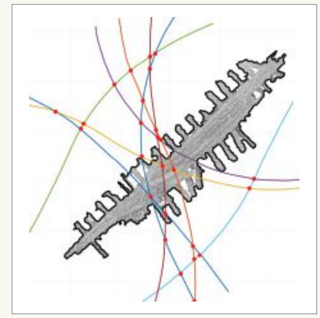
» Colour corrected image mosaic of the shipwreck target. (Image credit: Voyis)



» A trajectory error graph (left) shows where the baseline INS-DVL exhibits a continuously growing error, while the laser loop closure aided solution continually maintains an error of less than 0.1 m. (Image credit: Voyis)

FUTURE APPLICATIONS

The potential uses for this technology spans all ocean sector survey applications. At a high-level, when mapping large areas for marine research or generating digital twins of offshore windfarms and oil and gas installations, more globally consistent 3D models can be produced with improved localization of critical features. The automated data registration capability drastically improves the repeatability of accurate measurements within the dynamic laser scanning dataset and simplifies the process of overlaying subsequent survey results, facilitating automated change detection analysis.



» Detected loop closures. (Image credit: Voyis)

When using AUVs to search for specific targets, often first identified with side-scan sonar, an optical survey that needs to deliver complete coverage can achieve consistent positioning accuracy throughout the entire mission by linking together successive survey passes, ensuring targets identified at any point in the mission can be localized with high accuracy for the ensuing human intervention. This can be particularly useful for naval mine countermeasures applications, where operating covertly limits the ability to surface for GPS position updates, or when operating in in GPS restricted locations.

Looking further ahead, this capability could be incorporated more tightly into long duration navigation methodologies, utilizing prior maps or survey databases to achieve continuous landmark navigation. Features of known locations from past surveys or existing bathymetric maps can be continually referenced, so that when the vehicle enters an established area it can reinitialize its global position by identifying features in the area. Similarly, this capability could enhance vehicle autonomy in localized structure inspections where detected loops can support automated path planning to ensure complete inspection coverage is achieved

The challenge of fully uncrewed ocean operations is inspiring innovations across the ocean economy, and at both sensor and system levels, bringing us closer to a future where we can explore and understand our oceans more efficiently and with better data than ever before. The final step is pulling it all together on a commercial scale to attain this vision, but true autonomy will not be achieved in isolation, it will require surveyors, vehicle designers, and sensor manufacturers all working in collaboration to *Illuminate the Unknown*.

For more information, visit: www.voyis.com.

VOYIS

THE FUTURE OF **MARINE ROBOTICS' IMPACT ON MODERN SOCIETY**

BY KEN CHILDRESS,
Chief Revenue Officer, Terradepth

> We are focusing on advancement in persistence and autonomous behavior of marine robotic vehicles to provide highly reliable, high-resolution data…

Throughout history, accomplishments that impact society the most begin with some sort of technical innovation. Landing on the moon is one example. As a legacy of that, we now want to know more about water on Mars. How about what lies under our own oceans? Which of the two is likely to have more impact on our quest to benefit our planet's environment?

If we think about the advancements made possible by Lewis and Clark's mapping of a route to the Pacific Ocean, just knowing the way and what to expect opened up incredible opportunities that still affect us every day. The same holds for advancing marine robotics and big ocean data so that we can affordably map our ocean floors in reasonable time. Having a reliable map will help us know what is there. Knowing what is there will ultimately guide how we plan a sustainable future.

MAPPING A SUSTAINABLE APPROACH

A more refined topology of the ocean floor helps to understand the deep-current systems which distribute heat around the globe. Additionally, we will better understand both common and extreme weather events and have a more complete picture of fish, animals and organisms and their habitats.

From an economic perspective, how to more responsibly conduct important infrastructure activities like undersea cabling, responsible offshore energy development, planning Blue Economy activities including shipping, aquaculture, pharmaceutical research, dredging, mining and maritime history. The better the picture, the better we can responsibly determine how to manage this important part of our planet while holding all actors accountable for their actions.

Terradepth recently did a survey of ocean data professionals and the most cited issues were the difficulty of locating well documented mapping data and the proprietary nature of the tools used to process the data. Through this process we validated that it is time to bring access to ocean topology out of the "MapQuest" days and into the Digital Geospatial era that everyone can understand.

DEMOCRATICIZING DATA

At Terradepth, we believe that current methods of collecting, processing, analyzing, and distributing ocean mapping data is too human-centric and needs to be much more scalable and much less expensive. We are focusing on advancement in persistence and autonomous behavior of marine robotic vehicles to provide highly reliable, high-resolution data and the means to more efficiently process, distribute and visualize that data using common browsers and cloud-based efficiencies. Our approach is to improve on existing tech where we can and push fresh innovation where it is needed.

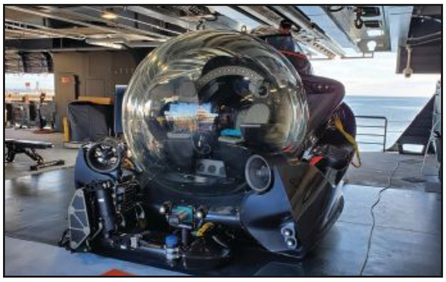
It is Terradepth's mission to use our technology to capture more data more affordably and provide easy access/easy use web-based tools for processing and displaying all types of seabed data sets. We are about making ways to collect and share ocean maps in a fashion similar to the Google Earth approach. We think that will have a lasting impact on how we collect and use ocean data helping to pave the way to a more sustainable future.

For more information, visit:
www.terradepth.com.

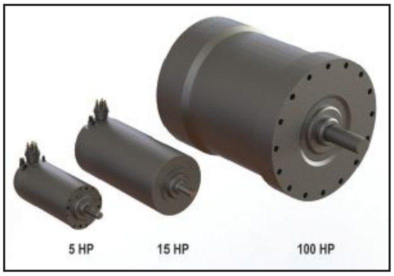
25 Years Heritage in Design and Fabrication - from Space to Deep Ocean Exploration

SPACE TOURISM INDUSTRY

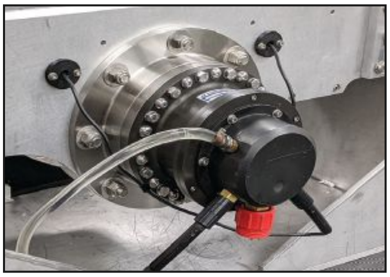
HYPERLOOP INDUSTRY



UW VEHICLES INDUSTRY



BDC ELECTRIC MOTORS



DC ROTARY ACTUATORS

BATTERY SYSTEMS

ASME PVHO WINDOWS

INSTALL CONFIDENCE

Experts in design, manufacture, test and certification of high reliability products, from pressure vessels to electromechanical systems to electric storage

HYDROSPACE
Group Incorporated

HydrospaceGroup.com

| FEATURE |

THE FUTURE OF **SCALABLE DIGITAL HYDROPHONE ARRAYS**

By Mark Wood, *Founder, Ocean Sonics*

Emma Carline *Algorithm Developer, Ocean Sonics*

If you have ever tried to locate a sound in a pitch-dark room, you're already familiar with acoustic arrays. Our ears are a small organic array on our heads, our right and left ear work together to help us localize sounds and sharpen noise in the soundscape.

Much like the array on our heads, Ocean Sonics is working towards digital-scalable-hydrophone-arrays enabling a profound fidelity, accuracy, and a refined focusing ability for ocean listening. Unlike other arrays, these arrays are high-bandwidth, digital, scalable, and easy to use.

While our array algorithms may not be as seamless and sophisticated as our brain's (for now), we do have much more sensitive instruments, capable of hearing far beyond what our ears can hear—from 1Hz to 200kHz.

A DECADE OF BUILDING ARRAYS (2012 – 2022)

Since 2012, the icListen product line has been giving our oceans a voice. The icListen hydrophone is the preferred hydrophone for researchers worldwide thanks to its accuracy, simplicity, and reliability. When we started, we knew we could help bring the ocean tech industry into the 21st century by creating high-resolution real-time digital hydrophone that are easy to use.

Today we're looking at breaking our own glass ceiling by creating fully scalable digital hydrophone arrays, which are equally easy to use.

Our latest hydrophone, the icListen Kayak has been designed to be exceptionally low power and built for scalability. With this instrument, we are developing hydrophone arrays that are more accurate, accessible, and reliable, with a resolution and bandwidth far beyond anything in the market. While the icListen hydrophone helped revolutionize the analog hydrophone market, the icListen Kayak is bringing new accessibility to hydrophone arrays.

44-CHANNEL DIGITAL ARRAY

Currently, we are testing a 44-channel digital array that has given us some exciting data sets. We are confident that, in the near future, a digital 100-channel hydrophone array will be a relatively simple deployment that can provide high-value data sets for a variety of use cases.

When we speak of hydrophone arrays there are many meanings, effectively an array is 2 or more hydrophones placed a few centimeters or kilometers apart which are used together to help get more information from a sound source. Arrays are nothing new, they have been around since hydrophones have been around. The military has used old-school analog versions for detecting things like submarines. There are highly sophisticated seismic

» *Testing Ocean Sonics' 44 channel array on our RR Borges, Ocean Sonic's moon-pool testing barge. (Photo credit: Ocean Sonics)*

» *The RB9 hydrophone is Ocean Sonics' most popular hydrophone. From 10Hz to 200kHz the RB9 is suitable for most field applications. (Photo credit: Ocean Sonics)*

» *Testing out an early version of a 34 channel array in Halifax harbour, NS. (Photo credit: Ocean Sonics)*

vessels that use low-frequency hydrophone cable-streamers paired with expensive computers for mapping the sub-bottom seafloor. There's even a worldwide array that has existed since the cold war, which spans the globe and keeps an ear out for nuclear bomb testing and seismic activity.

» *Using Ocean Sonics' Lucy Software to analyze acoustic data. (Photo credit: Ocean Sonics)*

In fact, we've made plenty of arrays using icListen's and our Lucy software, from subsea tripods used to localize whales and dolphins, or long-distance grids used for general environmental monitoring. In 2016 we made a large 36-channel vertical array using our legacy SB2-ETH hydrophones, which though successful, was undoubtedly a learning experience as to what we would need to do to create a highly scalable digital hydrophone. Hence, we designed the Kayak, a simple, accurate, and reliable hydrophone engineered for scaling, and usability. Ultimately simplifying the array process and opening up the use of localizing and beam steering for more specified use cases.

The array model we're currently testing is a 1.5-m baseline high-density 3D array with 44 kayaks placed in a grid-like pattern. This format allows for an extremely improved sound-to-noise ratio, meaning increased clarity in the listening, but it also allows for improved localization and beam steering. Beam steering is when we can offset the time of each hydrophone to focus its listening to a specific location. In some ways, it's like a flashlight pointed to where you want to listen, but it's also like a lens, clarifying sounds from one direction and ignoring other surrounding sounds. In practice, this means you could mathematically direct this array to listen to an open ocean vent, or any subsea infrastructure, and get extremely precise data on the acoustic activity.

In the process of developing every icListen hydrophone we've learned about processing high volumes of data, and how best to isolate important information. With our array we don't necessarily transmit 44 raw high-bandwidth acoustic data sets to the computer, instead we have it processed directly on the array creating a high-value spectrogram and waveform data streams without the need for elaborate external processing for each channel. Meaning that any field laptop is able to access and analyze high-quality array data.

FUTURE INVESTMENTS

In the future we envision our tools and software further refining edge computing in the industry and continuing to empower the environmental initiatives which are giving our oceans a voice.

Which, at the end of the day, is the whole reason we entered this industry. The global ocean ecosystem is still a hugely underestimated organ of planet Earth. We're only beginning to see the astronomical fallout of approaching the limits of our ocean in terms of a sink for carbon and heat. Today, we routinely see how environmental shifts, like changes in our ocean currents, have altered weather patterns worldwide.

Meanwhile, *sound is the most important tool we have for measuring health in the ocean.* Ocean acoustics can tell us information about ocean temperature through tomography; it can help us listen for seismic events; and, of course, it can tell us about the health of ocean life, and not just whales and dolphins—we're learning every year how important acoustics are to all sorts of marine life, from observing how the sounds of coral reefs can attract plankton to understanding how turtles function without ears. We are also beginning to grasp how the introduction of anthropogenic noise impacts marine life, and how to better regulate noise in the ocean. These are just some of the reasons why the team at Ocean Sonics is driven to innovate our products to be as sophisticated as possible, while still being accessible and usable to the average researcher.

For more information, visit:
www.oceansonics.com.

OCEAN SONICS

THE FUTURE OF **OCEAN TECHNOLOGY MAY BE SHAPED BY SILICON VALLEY**

By Atle Lohrmann,
President, General Oceans AS, and Founder of Nortek

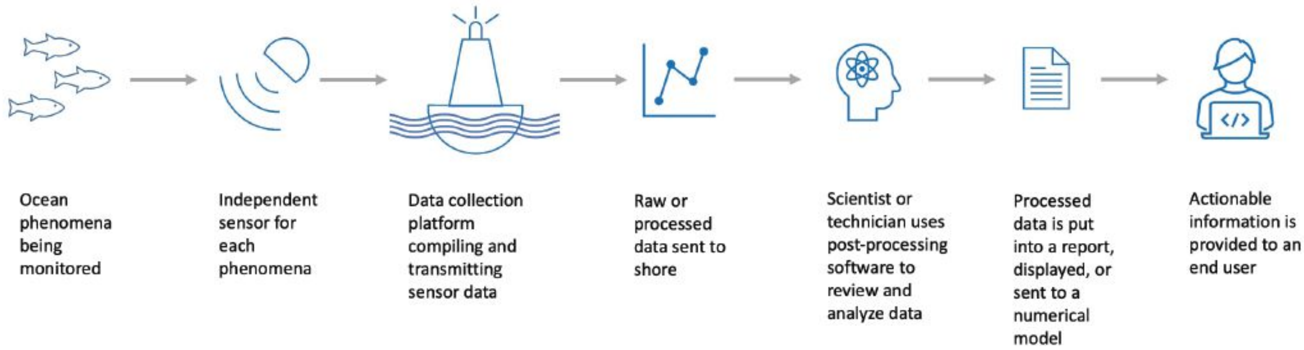
Looking at the landscape of oceanographic companies, one quickly sees something is afoot. The companies of the 1970s, '80s, and '90s, most of which started in the proverbial garage, have been mostly rolled up into larger conglomerate structures. In Europe, this was a corporate world from the beginning, as exemplified by Kongsberg's "Subsea and Marine Robotics" department. Over the last 20 years there has been a "reforestation" of small, modern companies, but the business model is the same as it was 30 years earlier—build brick-by-brick, stay small and nimble, fuel development based on customer needs, and live and reinvest based on the cash generated by the business.

Over the last 10 years we have seen two new trends emerge. One is the acquisition of anything "autonomous" by large military contractors. The valuation of these uncrewed vessel companies, to the rest of the community, seems influenced by a strong FOMO ("Fear Of Missing Out") component, but the acquisitions are not irrational when one looks at how large Navy programs like PMS406 are progressing.

The other trend is more confusing and began with Liquid Robotics, founded in 2007. Their USV, the "Waveglider," was an interesting and fun vehicle that saw strong interest both from scientists and the operational market, but the jaw-dropping $82 million in funding came as a surprise to everyone outside the company. We all sat there with our calculators trying to understand the case and more than one CEO could be seen snickering as we all wondered how investors could be duped into entering our little market space with the promise of favorable market-based returns. However, our sense of superiority disappeared in a hurry when Boeing in 2016 walked in and put $300 million on the table.

OCEAN TECH INVESTMENT

The Liquid Robotics acquisition is now recognized as the moment when Silicon Valley entered the world of ocean technology. And entered they have, bringing about the same post-dot-com transformation seen in the Valley. Technology is not something that the customer uses; rather, the customer is part of the ecosystem. Innovation no longer sits with the small and responsive, but rather with those with the largest data sets, which are themselves responsive. Almost $200 million has gone to Saildrone—a company developing and producing autonomous sailboats equipped with 3rd party environmental sensors, which send data to the cloud in near real time, often from remote locations or in challenging marine conditions. Sofar Oceans—a manufacturer of small buoys equipped with motion sensors and pursuing ambitions of creating a "data-abundant" ocean—have also secured



» *Classical data collection process in ocean science and engineering. (Image credit: Nortek)*

significant funding, to the tune of $46 million. Is this trend here to stay?

Generally, people rationalize these investments in three different ways: 1. "Silicon Valley is mad—they simply have too much money and it can never hurt to add sustainability to the portfolio"; 2. "Well, it worked for Liquid Robotics, so why not for others?"; 3. "Silicon Valley re-engineered the digital world. Is there a chance they could change our concept of ocean technology as well?" This begs the question: *Are we, the ocean tech industry, going to become part of the "Metaverse?"*

THE SILICON VALLEY APPROACH

Let us think about this a little closer. What is the method they use to gain dominance, whether they are Tesla, Uber, or AirBnB? It is not simply that people between San Jose and San Francisco are smarter or more motivated than everybody else.

The method:

1) Build for scale. If you cannot envisage becoming world dominant, do not even start.

2) Get something out there so people can see. Talk about it incessantly. The marketing department is not an intern that makes brochures; rather it is a group of professionals with the same status as your engineering department.

3) Build alliances. These include customers, suppliers, and stakeholders. Make sure they all have a vested interest in seeing you succeed.

4) Pivot. It will never be right the first time if the user is part of the development process, so be ready to come up with a new approach.

5) Have an almost infinite amount of money. You will not get a lot of attention from your vendor if you only buy one or two units—you need to show them that your successful future will bring them substantial reward. Further, you cannot plan to pivot if it is uncertain the money will be available. If you want to get your message across, that video you were able to place on CNN is not free.

This is how they work. Still, given the conservative nature of our business, the long lead times for testing, the horrors of corrosion, biofouling, and limits in communication and power, will it suffice to simply approach the market "the Silicon Valley Way?"

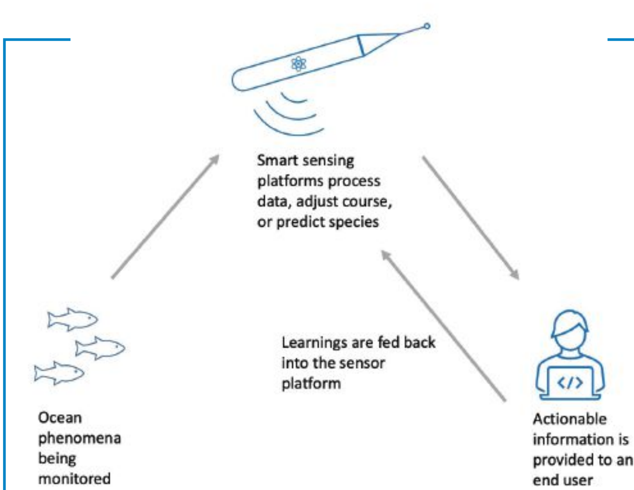
LOOPING IN AUTONOMY & AI

It is my hypothesis that the answer is "yes," if we can add intelligence and operational autonomy to our effort. In the classical approach to ocean technology activities, the process goes *deployment* (platform), *data collection* (sensors), *data download* (human), *data interpretation* (human), and *result* (action or knowledge). This is true for both science and most engineering problems. We sometimes add, at great cost, a human in the loop, for example for ROV operations, or we send a feeble amount of data home to make sure everything is working. Still, the basic paradigm holds true for a large section of ocean technology or ocean science projects.

If we modify to a loop which goes *data collection* (platform with integrated sensors), *intelligent automated data interpretation* (AI/ML), *actionable information* (cloud), things change. Costs would come down, the operational complexity and the need for human domain knowledge would be reduced, and the information could arrive in time to make a difference. All of this points to an expansion of the number of potential users for the same product, which is really what we mean when we say "scalable."

So, what happens under water or on the data collection platform will decide where this goes. And when Google takes ownership in an ocean technology company, there can be no doubt that the ambition is there. Let us hope it will not be driven by a "Winner-Takes-All" attitude, another aspect of Silicon Valley we should be acutely aware of.

For more information, visit: www.nortekgroup.com.



» *Modern, scalable data collection and optimization loop. (Image credit: Nortek)*

THE FUTURE OF **ATLANTIC CANADA, A GLOBAL OCEAN TECHNOLOGY LEADER**

BY MELANIE NADEAU, *CEO, Centre for Ocean Ventures & Entrepreneurship (COVE)*

COVE
centre for ocean ventures & entrepreneurship

> A surge in new Canadian Ocean Enterprise companies, that now has Canada exceeding the United States in total companies per capita, is no coincidence.

Canada's Blue Economy opportunities are as vast as our ocean shorelines, and a surge in high-tech ocean technology companies is propelling the growth and sustainable modernization of our national ocean sector.

The recently released Canadian Ocean Enterprise 2020 report by COVE, in partnership with the Marine Technology Society (MTS) and the Society for Underwater Technologies (SUT), is a benchmark study demonstrating the strength of the ocean enterprise cluster in the Atlantic region and the growth potential in Canada.

Other industry studies have grouped the entire value chain of fisheries, aquaculture, shipbuilding, energy, ocean science, and other disparate sectors. This study defines the term 'Ocean Enterprise,' which is often referred to as the 'New Blue Economy,' as platforms, technology, and information services that deliver ocean observations, measurements, analyses, and forecasts that enable the wider Blue or Ocean Economy.

A SURGE IN CANADIAN ENTERPRISE

Atlantic Canada, and Nova Scotia in particular, has cemented itself alongside other global ocean technology leaders. The cluster of companies in Atlantic Canada is massive compared to the rest of Canada with nearly 60% of all ocean enterprise businesses represented, and the Atlantic cluster is comparable in number of companies to the largest clusters in the United States such as Southern California or Massachusetts.

A surge in new Canadian Ocean Enterprise companies, that now has Canada exceeding the United States in total companies per capita, is no coincidence. For the most part, this surge has been propelled from the shores of the Halifax Harbour.

COVE was founded in 2016 to fill a long-standing commercialization gap in the ocean innovation ecosystem. Today, over sixty local and global ocean-based companies have set up shop at the Halifax-based facility. We are at the heart of Canada's ocean tech cluster. While we are excited by where we are today, the true excitement lies in the opportunities of tomorrow.

The Canadian Ocean Enterprise 2020 report found optimism amongst companies as they expect both an increase in employees and revenue. Furthermore, Canadian Ocean Enterprise companies tend to be export focused with a low failure rate. We found that 60% of these companies generate revenues in the range of $1 M – $20 M, which could imply a series of barriers that need to be better understood to unlock the growth potential of this industry.

PARTNERING FOR GROWTH

As COVE looks to continue driving the Canadian Ocean Enterprise surge and reach the true growth potential of the industry, our aim is to form strong global partnerships resulting in mutual benefit.

We recently signed a memorandum of understanding at the Digital Ocean Convention to work in partnership with companies in Norway and Germany to deepen global expertise and strengthen commercialization capabilities in the ocean technology sector.

We feel there is a natural opportunity to partner with our neighbors to the South as well. The proximity and shared coastline of Atlantic Canada and the Northeast of the United States provides a significant opportunity to collaborate, share expertise, and identify supply chain partners and commercial opportunities.

COVE and Atlantic Canada's ocean technology ecosystem are ready to elevate their role in creating prosperous and sustainable cross-border partnerships. We are just beginning to scratch the surface of our potential in the Ocean Enterprise industry. In taking the next step, the opportunity for global partnerships and its potential future benefit to local communities and regions, must be recognized.

For more information, visit: *www.coveocean.com.*

Seatronics' engineering team designed VALOR to give operators and edge in terms of bandwidth, thrust capability, and size. (Photo credit: Seatronics)

| FEATURE |

THE FUTURE OF **THE OBSERVATION ROV MARKET**

By Brett Laurenson,
Sales Director, Seatronics (part of Acteon)

The observation class remotely operated vehicle (ROV) market is forecast to grow by almost 10% annually between 2019 and 2026, and emerging market trends are providing exciting development opportunities.

In 2017, Seatronics, the lead brand within Acteon's electronics and tooling segment, performed extensive market research into observation class ROVs. What we discovered drove the development of VALOR (Versatile and Lightweight Observation ROV), a new generation of observation class ROV set to positively disrupt the market with survey and inspection capabilities beyond those of other vehicles in its class.

Today, the observation class market is dominated by one or two key players, and there are hundreds of these vehicles currently in use. Although these ROVs are popular, it is becoming clear that exponential advances in power- and data-hungry sensor technologies, driven largely by the mobile telecommunications and automotive industries, are outpacing the capabilities of these vehicles and other, similar market offerings.

More advanced sensor packages require more bandwidth and higher power, as seen in larger light work and work class ROVs. These vehicles have higher mobilisation and demobilisation costs and require larger operating teams. This comes at a time when many customers, particularly those working in renewable energy, are trying to reduce their operational footprints by using smaller vessels and smaller teams while spending less time offshore.

Our mission has been to positively disrupt the observation class ROV market by offering an innovative platform that gives our customers a competitive advantage.

We designed VALOR to meet the changing demands of the observation class ROV market. The vehicle provides customers with class-leading capabilities in three key areas: bandwidth, power (thrust capability) and size.

UNRIVALLED BANDWIDTH

VALOR supports bandwidth that is unrivalled in observation class ROVs: a 20-Gb/s Ethernet-based connection (expandable up to about 100 Gb/s) with throughput to five highly configurable sensor ports and three camera connectors. This level of connectivity is more synonymous with modern work class systems and is not typically found on an inspection class platform.

Therefore, VALOR can support the most advanced sensor packages available, unconstrained by bandwidth limitations. Of course, if clients just want a camera on a stick, VALOR can do that, too. But with options for a range of pipeline and dynamic laser scanning tools, and the ability to accommodate dual manipulators, customers can adapt the system however they want.

UNMATCHED POWER

VALOR boasts an unrivalled power and propulsion system, enabling the user to utilise the full thruster capacity without compromising payload operations. It has a dedicated 20-kW power supply that is available to the user via a dedicated auxiliary connector, enabling the use of more power-hungry tooling, such as cleaners and water-jetting tools, without the need for an additional umbilical. This not only reduces the risk of entanglement but also increases the vehicle's capabilities. VALOR achieves this advance without impacting its ability to provide full power to the thruster system, which also outputs more force than any other vehicle in this class.

Combining this power with an intelligent thruster control solution enables VALOR to hold station in currents of up to three knots, which means it can operate in significantly harsher conditions than those typically associated with vehicles of this class. This is a great advantage for our clients working in challenging environments such as the North Sea, who can operate both earlier and later in the season. Downtime is also reduced, so customers can get the job done quicker and spend less time offshore, which gives them a competitive advantage when bidding for jobs.

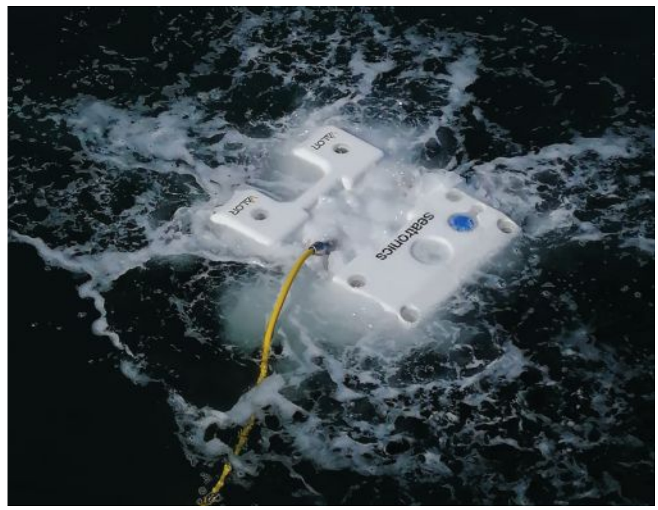
A word of caution on the statement above: having a lot of thrust is not a new phenomenon for ROV pilots, however, having too much thrust can be just as challenging as not having enough when it comes to effective vehicle control. As part of the core design, several pilot-aiding features were incorporated into the VALOR experience to aid operations and improve data quality.

VALOR's intelligent control software combines the pilot's input with real-time sensor data to calculate the optimal power needed to manoeuvre and hold station. This provides a smoother and more accurate level of control in even the harshest of environments.

COMPACT FOOTPRINT

VALOR was designed to be a small, yet versatile solution with a more compact footprint than its market competitors while still boasting an increased payload capacity. It can hold as much as 19 kg of tooling and sensor equipment in various configurations. At just 86 kg in air, its light weight is a big selling point to a market seeking smaller and lighter operational solutions that can be mobilised onto significantly smaller vessels.

» VALOR (Versatile and Lightweight Observation ROV) is a new generation of observation class ROV designed for survey and inspection. (Photo credit: Seatronics)



» Beyond oil and gas, VALOR is ideally suited to support a range of renewable energy projects, in particular offshore wind farm installation and maintenance. (Photo credit: Seatronics)

We are seeing a strong shift in the demand for small, yet powerful, observation class ROVs. Customers are sending a strong message that they are impressed with VALOR's performance and are seeing great value for their investment. With repeat orders and also having a very buoyant rental market for customers with lower capital resources, 2021 has been very positive.

The scope of applications is also diversifying. Beyond oil and gas, we now see VALOR being deployed across an increasing range of renewable energy projects, in particular those for offshore wind farm installation and maintenance. These projects are actively seeking to reduce vessel time and the carbon footprint of operations: VALOR is perfect for this. Additionally, VALOR's station-keeping abilities are excellent for underwater inspection in lieu of dry-docking (UWILD) projects.

In the future, we will likely start seeing ROVs launched from unmanned survey vessels and controlled from shore. VALOR has the capability for that, so it really does encompass everything that the observation ROV market is looking for at present, but on a very small and affordable platform.

For more information, visit: www.seatronics-group.com.

seatronics

THE FUTURE OF BUOYANCY MATERIALS FOR RESIDENT ROVs

By Trelleborg Applied Technologies

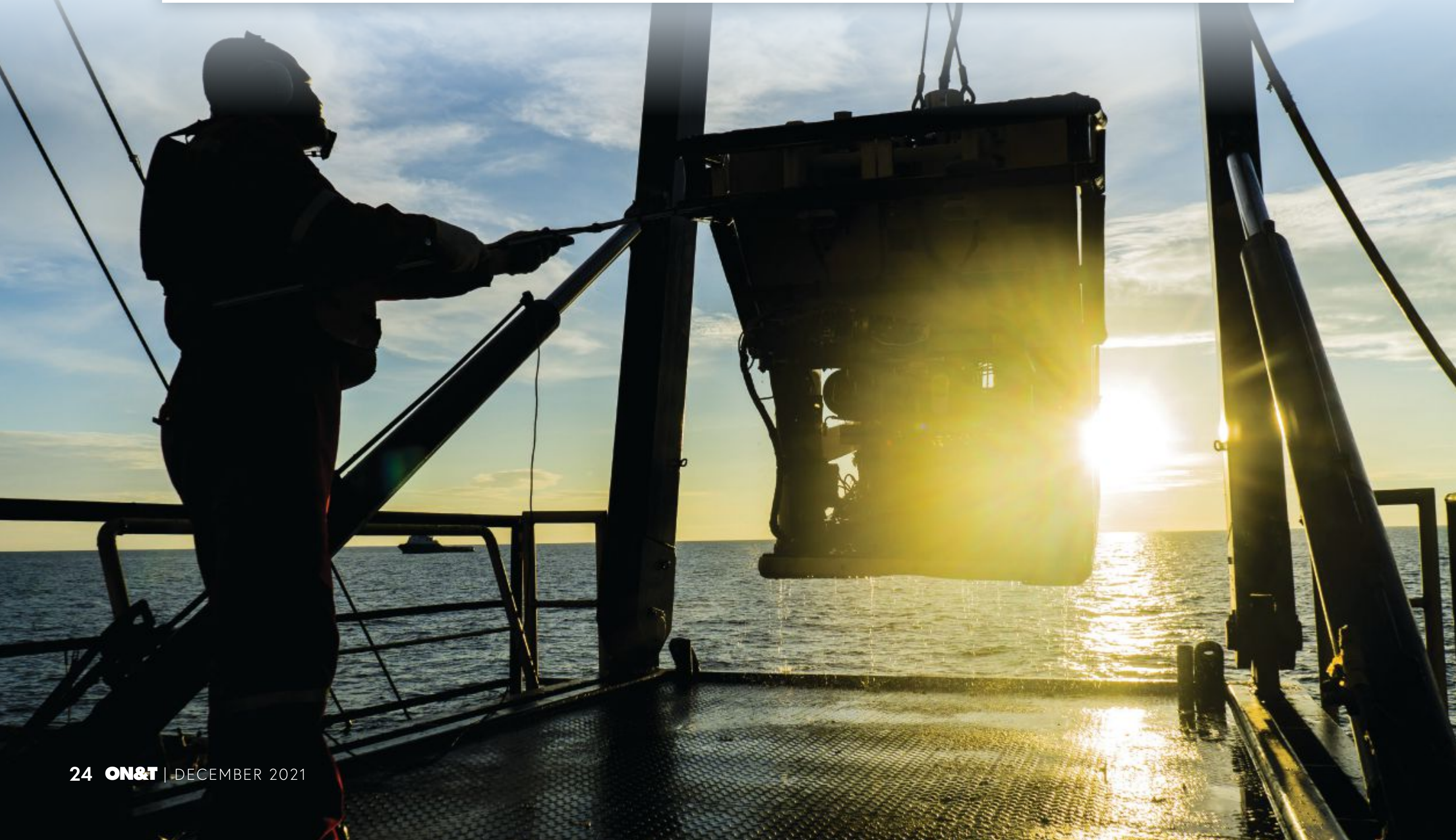
Empty space is often viewed as nothingness or a space that is waiting to be filled—but scientists and engineers know that space is intrinsically valuable. Voids can strengthen structures by design, without adding weight. The ability to utilize empty space brings new opportunities to many fields, especially in deep-sea exploration.

The issue of weight for Remotely Operated Vehicles (ROVs) used in deep-sea exploration can be overcome using empty space, or rather the use of high-tech hollow glass microspheres (HGMS) filled with air to create high-performance syntactic buoyancy materials—unique composite materials engineered to provide uplift from 1,000 meters subsea to full ocean depth.

Historically, syntactic buoyancy materials have satisfied the ROV industry requirements for density, water absorption, hydrostatic crush strength and bulk modulus. Typically, ROVs deploy on a cyclic operational mode, returning to the surface every 48 to 96 hours for maintenance. However, recent developments have seen several ROV manufacturers create a new class of ROV known as resident ROV or RROV. Specifically engineered for remote deployment between 1,000 and 6,000 meters subsea, long-term immersion of these vehicles is way beyond 96 hours.

The permanence of RROV deployment has changed the performance expectations of buoyancy materials, requiring resistance to elastic compression (reduced volume = reduced displacement and consequently reduced buoyancy). Manufacturers need to develop

» *Traditional ROVs deploy on a cyclic operational mode, returning to the surface every 48 to 96 hours for maintenance, but RROVs could change all that. (Image credit: Trelleborg)*



» *Trelleborg undertook a program of development, testing and qualification of syntactic materials for RROVs. (Image credit: Trelleborg)*

novel materials with a high bulk modulus, to offset the laws of physics.

RROVs require a much higher strength-to-weight ratio syntactic buoyancy material to withstand the unique conditions experienced at depth for extended periods; a challenge Trelleborg understands is crucial to solve. This new generation of RROV offers significant environmental and economic benefits, including negating the need for costly support vessels and labor; providing the ability to operate in adverse weather conditions and a smaller carbon footprint than traditional ROVs.

MAXIMUM DURABILITY

RROVs deployed at deep-sea and ultra-deep-sea depths demand maximum durability. The lack of higher strength syntactic materials capable of withstanding the extreme conditions, and constant hydrostatic pressure experienced at depth for extended periods, is one of the major barriers to the commercialization of RROV technology. This has fueled global research projects in the development of syntactic buoyancy materials specifically for residency applications.

Recognizing the need for superior buoyancy to meet the more demanding requirements for long term RROV submersion, Trelleborg's applied technologies operation undertook a program of development, testing and qualification of syntactic materials. By developing and validating simple predictive models, *Trelleborg has identified a range of syntactic materials capable of resident operation, which offer long-term immersion for up to two years permanently deployed subsea.* This timescale is unique within the materials buoyancy sector—previous typical service lifetime was closer to six-months.

Trelleborg's residency materials are fully qualified for long-term continuous use at water depths from 1,000 to 6,000 meters, at maximum operating pressure (based on accelerated ageing test data), with a maximum typical water absorption of 2% or less. These unique materials provide a reliable solution for the wide range of fast-emerging RROV applications.

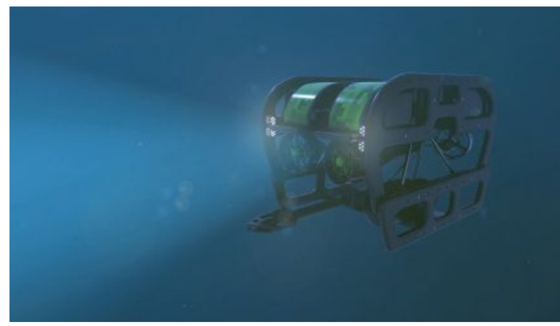
WHY IS RESIDENCY KEY?

RROVs that can be permanently housed on the seabed provide a major benefit to operators as they offer 24/7 availability throughout the year, no matter the weather conditions, greatly increasing the number of operational days and negating the need to bring the vessel back to the surface as frequently.

Historically, tethered from a ship with operators controlling the ROV from onboard, RROVs avoid the need for a secondary support vessel. This reduces carbon emissions as the RROVs can be operated remotely from onshore control centers. Running on battery power and re-charging on the seabed in specialist docking points, vehicles can be used for up to two years subsea, substantially extending vehicles' lifecycles and lowering the total cost of ownership for the operator.

FUTURE CONSIDERATIONS

When designing new RROVs, consideration should focus on the intended service requirements of the vehicle and its life expectancy. Buoyancy materials support specific applications and can incorporate additional requirements, such as threaded



» *Trelleborg's residency materials are fully qualified for long-term continuous use at water depths from 1,000 to 6,000 meters. (Image credit: Trelleborg)*

inserts and external anti-foul coatings to minimize marine growth.

Trelleborg's applied technologies operation can offer engineering resource to support RROV design and provide highly accurate predicted buoyancy performance values. This includes nominal, minimum, and maximum values for both buoyancy and weight in air, taking into consideration all aspects of the RROV design.

In addition to our ongoing investments in research and design, Trelleborg's applied technologies operation is a proud winner of the 2021 E&P Special Meritorious Award for Engineering Innovation for their Residency Buoyancy solution.

For more information, visit:
www.trelleborg.com/applied-technologies

TRELLEBORG

THE FUTURE OF **OFFSHORE IS KEY TO A NEW ENERGY ERA**

BY ERIK MILITO,
President, National Ocean Industries Association (NOIA)

> Part of the high-tech offshore revolution, offshore companies are electrifying operations and are finding ways to reduce the size, weight, and part count of their infrastructure.

The U.S. offshore energy industry has produced vital hydrocarbons in the Gulf of Mexico for decades. Today, the American offshore sector is not only transforming how we produce hydrocarbons, but how we tap entirely new streams of energy and deploy innovative energy solutions.

Whether we are filling up our car tanks or are using the hydrocarbons that are the building blocks of the staples of modern society—like smartphones, clothing, and medical equipment—the Gulf of Mexico is a low carbon basin that has unlocked modern life while still adhering to the highest safety and environmental standards.

In other words, the Gulf of Mexico has allowed us to have our energy cake and eat it, too.

The Gulf of Mexico oil and gas production has a carbon-intensity one-half of other oil producing regions. Deepwater production, which accounts for 92% of production in the Gulf of Mexico, provides the lowest carbon intensity out of any oil producing region.

NEW TECHNOLOGIES BRING NEW OPPORTUNITIES

Through continuous innovation, the already small U.S. Gulf of Mexico carbon footprint continues to shrink. Eighteen deepwater facilities—which equate to about the size of nine city blocks—produce about the same amount of oil as the entire state of North Dakota. New projects are coming online that will tap ultra-deepwater and high-pressure, high-temperature reservoirs and expand the frontier of low carbon Gulf of Mexico energy production.

Part of the high-tech offshore revolution, offshore companies are electrifying operations and are finding ways to reduce the size, weight, and part count of their infrastructure. Companies use AI to predict potential issues before they have a chance to become real problems and are deploying drones—in the air and below the sea—to constantly monitor production, enabling a level of real-time analysis seemingly pulled from a sci-fi blockbuster.

These innovations are simultaneously increasing the cost competitiveness of operations while reducing the carbon footprint.

OFFSHORE DIVERSIFICATION

Many of the same service and support companies that built up the Gulf of Mexico oil and gas industry are now helping to build the nascent American offshore wind industry. Billions of dollars in investment, thousands of jobs, and a pipeline of projects that will reduce our nation's carbon footprint are connecting the Gulf of Mexico to new wind areas along the Atlantic Coast.

Offshore innovation is occurring across other energy sectors.

TechnipFMC's Deep Purple pilot program is finding a path to integrate offshore green hydrogen production and renewable energy. Many aging platforms in the Gulf of Mexico may find future uses as hydrogen hubs.

Other companies, such as Talos and ExxonMobil, are working to advance carbon capture, use, and storage solutions. Thanks to its unique geology and robust infrastructure, the U.S. Gulf of Mexico may be the storage site for millions of tons of CO2 annually before the end of this decade.

We are entering a new energy era, but one that still will need safe and environmentally-responsible produced hydrocarbons as well as additional forms of low and zero carbon energy production. The U.S. Gulf of Mexico is in the lead in driving forward the innovation and technological advancement that is transforming the world.

For more information, visit: *www.noia.org.*

» SIDUS' product range includes underwater positioners, high-definition cameras, penetrating bright lights for subsea vehicles. (Photo credit: SIDUS Solutions)

| FEATURE |

THE FUTURE OF SITUATIONAL AWARENESS

By SIDUS Solutions

Worldwide, there is ongoing pressure placed on the safe extraction and operation in oil and gas exploration. The U.S. and other world governments have recently mandated "situational awareness" to the daily operations of large and small operators, and the new checks and balances help verify the safe operation of each asset. It's not exactly clear what the long-term effect is going to be on corporations, but it's certain now that the offshore drilling and oil and gas industry will be operating under a stricter regulatory environment than previous decades.

In recent years, the oil and gas industry has shifted toward comprehensive integrity management, with more emphasis being placed on the safe use of subsea systems and equipment. Future programs will be expected to provide even more robust monitoring systems.

A SOLUTION FOR SITUATIONAL AWARENESS

Situational Awareness (SA) is the perception of environmental elements with respect to time and/or space, the understanding of their meaning, and the projection of their status after some variable has changed. SA involves being aware of what is happening in the vicinity to understand how information, events, and one's own actions will impact goals and objectives, both immediately and in the near future. SA is especially important in work domains where the information flow can be quite high, and poor decisions may lead to serious consequences.

SIDUS Solutions, headquartered in San Diego, California, manufactures and produces integrated remote video surveillance systems, services, and equipment for subsea and top-side applications. With its products, services, and target businesses, *SIDUS has readily embraced situational awareness in support of global safety and security initiatives*. Having an extensive selection of video products to meet its clients' demands, SIDUS stands out through its comprehensive understanding of the diverse use of such equipment, as it relates to many industries and applications.

PROJECT ENGINEERING

Leonard Pool, SIDUS' managing director, stresses that the understanding of the different parts in the SA system, and how they are related, is key to applying SA hardware effectively and cost-efficiently. "This is why SIDUS has put its focus on individual project engineering and after sales support. Many people think of assets as only being materials or financial vehicles," he said. "At SIDUS, we feel the most important assets are our client's hard-working people who show up to the job site day in and day out. We want to make sure that they have the best tools to keep their people safe. Having the right hardware is a good start, but only when the hardware can be put to work in the most efficient way, will the video system truly show its value, allowing safety and security to be guaranteed."

"Tailoring systems to each individual applicant's demands enables our customers to apply SA in everyday business," Mr. Pool added. "Having a rich source of after-sales support to draw from, keeps the system and its operators on the right path as well as ensuring their safety and security for the future."

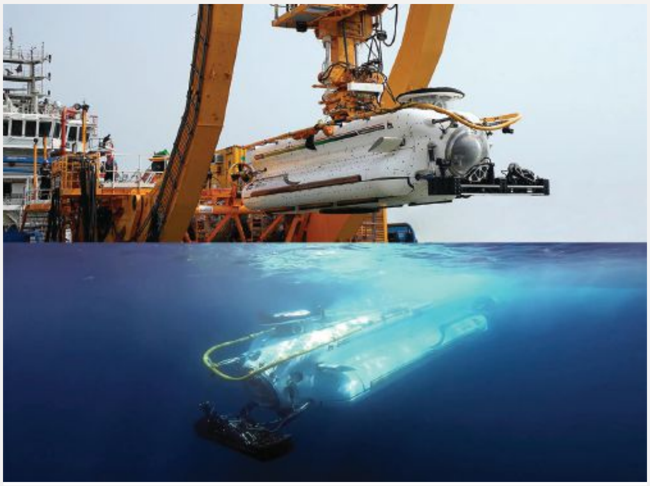
SIDUS has grown from designing primarily subsea pan and tilts and rotators to providing an extensive product line of underwater positioners, high-definition cameras, penetrating bright lights, projection lasers, and inspection systems, as well as an array of engineering services. While the SIDUS-designed and -manufactured product line focuses on subsea applications, their highly skilled engineering team provides topside design and installation for industrial and hazardous areas. Their world-class engineering staff provides seamless system integration, design, installation, and commissioning of all remote video surveillance systems.

From concept design to technical support, SIDUS has solutions for every need. To meet the demands of the customers, SIDUS offers over 80 models of cameras, lighting systems, pan & tilts, lasers, and control recording systems. In addition to many standard products, SIDUS offers application specific, customized solutions including specialized protocols, connectors, and power requirements

GOVERNMENTAL REGULATIONS

SIDUS' commitment to hardware, engineering, and support allows for corporations to comply with the growing governmental reporting regulations, thus reducing red tape. It also allows corporations to maintain or reduce their costs and the number of workers required to secure and monitor their assets and processes, while maintaining a company presence, meeting regulations, and protecting their employees' personal safety and security. In one example, SIDUS was able to provide a remotely controlled subsea deployed video

» *With increasing emphasis on integrity management and the safe use of subsea systems and equipment, oil and gas operators will rely on ever more robust monitoring systems. (Photo credit: SIDUS Solutions)*



» *SIDUS equipment is operational at depths of up to 6,500 meters and can be integrated with existing systems. (Photo credit: SIDUS Solutions)*

monitoring system to a major GOM operator for monitoring the Riser Pull-In operation. The client claims its investment in SIDUS' equipment has a projected saving of over $1 million annually. SIDUS' answer to the new governmental regulations, which it fully supports, is to focus on its core capabilities; designing mission critical video monitoring systems that consistently provide reliable and repeatable results. In 2021, SIDUS has become ISO 9001:2015 Certified in addition to following government regulations.

THE FUTURE

SIDUS introduces a new series of game changing HD-IP cameras. The SS400 Series and SS550 "Dark Crystal CAM" camera will allow you to have excellent video image quality under demanding lighting conditions and designed to fit where traditional cameras cannot go. Leveraging state of the art technology, SIDUS has significantly improved video quality and added numerous features never before available in such compact size and easy to use cameras. With depth ratings from 300 m or 4000 m with Delrin or aluminum housing and 11,000 m (optional) with the titanium housings, these cameras are designed for long- or short-term deployment applications. It is our mission to provide superior products, solutions, and service to our global customer base. We deliver products that improve safety, efficiency, and ease of operation in challenging environments. Making situational awareness our number one priority.

Specializing in environmental cameras, robotic-positioning, and lighting systems, SIDUS services and manufactures complete, integrated security and surveillance solutions for any marine, defense and subsea application. SIDUS equipment, operational in blue water and 6500-meter depths, is available alone or to integrate with existing systems. From concept design to technical support, SIDUS has solutions for every need. To meet the demands of the customers, we offer over 80 models of cameras, lighting systems, pan & tilts, lasers, and control recording systems. In addition to our many standard products, SIDUS offers application specific, customized solutions including specialized protocols, connectors, and power requirements. SIDUS is a field proven solution.

For more information, visit: www.sidus-solutions.com.

SIDUS

THE FUTURE OF **4K SUBSEA IMAGING IS A VISION OF COLLABORATION**

By Aaron Steiner,
General Manager – Oceanographic Products,
DeepSea Power & Light

In 2018, scientists and engineers at the Monterey Bay Aquarium Research Institute (MBARI) began researching upgrades to their high-definition camera systems on the 1,800-meter ROV *Ventana* and the 4,000-meter ROV *Doc Ricketts*. This search was inspired by the rapid adoption of 4K imaging and MBARI's experience that leaps in image resolution increase the quality of scientific observations, driving new insights and the pace of species discovery.

The imagery from MBARI's ROV systems is used by nearly all research groups at the institute and distributed to scientists and educators globally. *Images and video form a unique data record of the deep-ocean environment,* and are used for research applications as diverse as identifying new organisms to recording the behavior of liquid carbon dioxide at depth. Often, the visual record is the most important data collected from phenomena of interest, and MBARI frequently provides its underwater images and video for education and outreach. MBARI video has been featured in exhibitions at the Monterey Bay Aquarium and video productions by the BBC Nature unit.

The last great advance in MBARI's video imaging was more than 20 years ago, when MBARI transitioned to recording in high definition, resulting in an epochal improvement in MBARI's use of video. With video imaging worldwide now transitioning to the 4K formats for acquisition and dissemination, MBARI saw an exciting opportunity to develop a camera system that takes full advantage of the higher resolution, color rendition, dynamic range, and frame rates that this format offers.

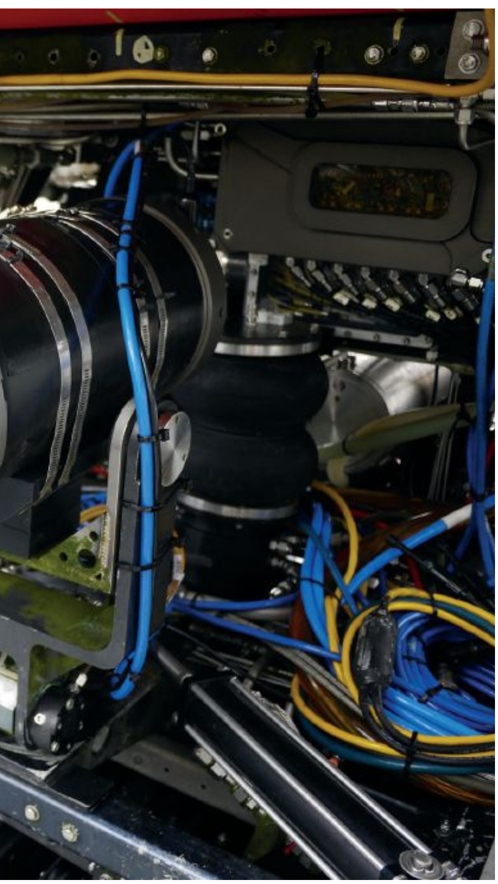
MBARI's mission is to advance marine science and technology to understand the changing ocean and disseminate this knowledge to the community at large. Partnering with a well-established commercial vendor who can serve the broader community helps accomplish this, so in October 2019, MBARI partnered with DeepSea Power & Light to develop the new camera. DeepSea also brought in Fathom Imaging to contribute the optical design, which was critical to realizing the full capabilities of the 4K format.

DESIGNING

Achieving the performance goals for the camera was going to require a large, precision optical dome port—larger than any commercial housing available for these depths at the time. Given the expected 10-year service life of the camera, this new housing also required unparalleled reliability. With two subsea 4K cameras already in

» 1) High pressure dome port housing developed by DeepSea, 2) optical corrector cell designed by Fathom Imaging, 3) camera chassis and telemetry system produced by MBARI. (Image credit: DSPL)

» MxD SeaCam 4K midwater frame capture of squid Gonatus onyx. (Photo credit: MBARI)



» MxD SeaCam installed on MBARI's ROV Ventana, capable of diving to 1,800 meters. (Photo credit: Mark Chaffey, MBARI)

production, DeepSea not only understood the system-level challenges, but had the combination of simulation, manufacturing, expertise in hydrostatic dome ports, and validation capabilities needed to successfully produce the housing.

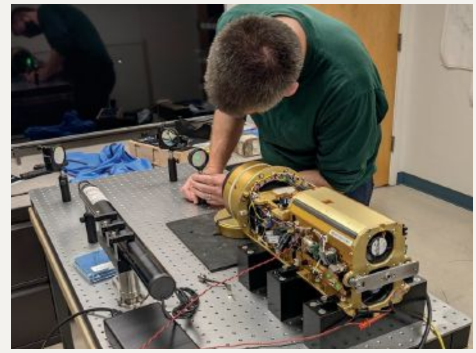
The camera required a bespoke optical adapter between the wide-angle zoom lens and the high-pressure dome port. Given the wide field-of-view and long telephoto range specifications, this optical adapter needed to balance many competing optimizations to achieve the high-resolution and low-distortion image targets across the telephoto and focal range of the system. This challenge was identified early on as the largest technical hurdle of the project. With decades of experience designing and producing best-in-class subsea optics used with Amphibico, Gates, and Light & Motion housings, Fathom Imaging was tasked with the optical adapter design to adapt the zoom lens with the dome port housing.

A key insight gained from MBARI's investigation into commercial 4K cameras was the lack of professional-grade video camera operator and painting controls needed to get the most out of an imaging system. With decades of combined fieldwork and the perspectives from scientists and videographers alike, MBARI was in a unique position to understand what the camera operators needed and had the engineering capabilities to design and manufacture the chassis, camera control, and telemetry system. The chief challenges in the chassis were modifying the stock camera module to achieve the smallest housing possible, the thermal design, accommodating the precision optical alignment requirements, and the integration of smooth and responsive lens controls.

BUILDING

The team was assembled, and over the course of the last two years the camera's ambitious design took shape. The result of this collaboration is the MxD SeaCam—a first-of-its-kind "Blue Chip" 4K subsea imaging system. DeepSea wrapped up design of the housing in March 2021 after completing more than 10,000 pressure cycles to 7,000 meters, assessment of thermal shock performance, and in situ validation of the finite element model used to optimize the mechanical design.

The optical design process is an iterative exercise, and more than a dozen designs were evaluated before the team chose the final prescription. Fathom completed the adapter cell in April 2021 following extensive inspection of the individual elements and spacers. As a final verification step, Fathom used interferometry to measure the corrector assembly wavefront and validated the results against simulated interferogram.



» The MxD SeaCam chassis optical block and lens are precision aligned with the adapter cell using laser reflections from each lens surface. An MBARI engineer sets up the alignment test on an optical bench. (Photo credit: Mark Chaffey © 2021 MBARI)

It fell on the team at MBARI to do the final assembly and calibration of the optical components. The optical design sensitivity analysis allowed the team to focus on the tightest tolerance parameters and come up with a process that would ensure all of the elements of the optical path came into perfect alignment. The MBARI team used a combination of techniques, including aligning optical surfaces by the concentric reflections produced by a laser to calibrate each part of the optical path.

DEPLOYING

The first camera deployed on ROV *Ventana* in the fall of 2021 and is now in active use for science operations on ROV *Doc Ricketts* at MBARI.

The complete MxD SeaCam system is made up of the camera, a top-side unit, and the lap controller. More complete details are available online at www.deepsea.com/mxd. DeepSea is producing a commercial version of the system for both 4,000-meter and 7,000-meter operating depths for availability within 2022 and taking inquiries for interested parties as of publication.

The MxD SeaCam camera provides an exciting new level of visibility into the deep sea, advancing research and education through more detailed observations. Visual images are a powerful way to communicate the beauty and importance of the deep sea and share the scientific knowledge and discoveries made there with the public. The MxD SeaCam produces an image library of the highest quality "Tier 1" 4K recordings suitable for major media distribution channels, such as BBC Nature, Discovery, and Netflix.

For more information, visit:
www.deepsea.com.

DEEPSEA Power & Light

THE FUTURE OF **OFFSHORE WIND IS NOW**

BY JOHN MANOCK,
Editor, SubCableWorld

SubCableWorld

> The US offshore wind market could easily become one of the Top 5, and possibly Top 3, markets in the world by 2030.

The US offshore wind market has been a long time coming. While there have been plans for commercial-scale offshore wind farms for more than two decades, only seven turbines in two demonstration-scale farms are installed. But the entire environment surrounding the US offshore wind market changed in 2021 with numerous groundbreaking announcements that have generated a level of enthusiasm that has never been seen before.

One reason for this enthusiasm is the market's potential size. The US offshore wind market could easily become one of the Top 5, and possibly Top 3, markets in the world by 2030, with some sources estimating a total investment of well over $50 billion by 2030.

CABLES IN DEMAND

A significant part of this investment will be in the submarine cabling required for the operations of future wind farms in the US. ON&T's sister publication, SubCableWorld, has been following this market closely and has created a model for US offshore wind cable demand. In its latest report, SubCableWorld is forecasting a level of demand that could reach nearly $10 billion during the decade from 2021-2030, if the current, stable regulatory situation continues.

SuSubCableWorld's forecast looks at three scenarios predicting paths that the US offshore wind cable market could take by 2030. All three scenarios call for significant growth in demand for cable during this decade—as much as 12,000 kilometers of cable contracted for cumulatively over the course of the decade. But even the most conservative makes the US a major player in the global offshore wind market.

2021 TAKES OFF

The forecast defines demand as the amount of submarine cable represented in awarded supply contracts or other supply agreements. Back in 2019, we saw hopes of a growing offshore wind cable market, with the first contract awards for commercial-scale wind farms. 2020, however, with the pandemic and regulatory uncertainty due to the upcoming presidential election, was basically a "lost year" for the market, but in 2021, the market truly took off. Prior to 2021, demand only totaled approximately 1,000 kilometers of cable in four contract awards. Meanwhile, in 2021 alone, nearly 1,200 kilometers of cable were awarded in five contract awards. This included the biggest contract ever awarded for a US offshore wind farm, with more than 500 kilometers of export and array cable for the 2.6 GW Coastal Virginia Offshore Wind (CVOW) project.

INWARD INVESTMENT

But the growth of the US offshore wind cable market in 2021 can be seen in other ways as well. In November, Nexans held a ceremony for its new cable factory in South Carolina. This is the first factory in the US that has the capability to manufacture HVDC cables for offshore wind applications. But this was not the only development. As part of a proposal for a new offshore wind development in Maryland, Ørsted and Hellenic Cables will build another cable plant in that state if their proposal is accepted.

The advances made by the US offshore wind market in 2021 began with a goal set in the first days of the new Biden Administration in January to bring 30 GW of offshore wind energy into production in the US by 2030. This has been followed by action on numerous fronts; including by federal regulators, individual states, and developers to create a sustainable market environment and fully develop the domestic supply chain. If this momentum can continue, the US offshore wind market in general and the cable market will truly flourish.

For more information, visit: *www.subcableworld.com*.

THE FUTURE OF **POWER & CONTROL IN THE DEEP OCEAN**

By William Kohnen,
President, Hydrospace Group Inc.

Electricity is the magic power behind the vast spectrum of our ocean projects. Jules Verne understood this more than 150 years ago when he wrote about the Nautilus, a vessel that circled the globe underwater using a new form of energy he simply called "electricity." He does not explain where this energy comes from or how it is stored. The suspension of disbelief was enough for his audience.

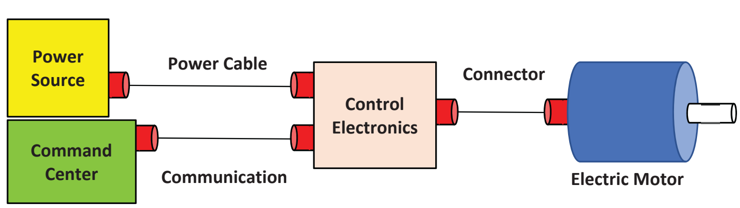
Electric motors are no longer a novelty; they are almost a commodity and have a central place in the future of subsea applications. Their simplicity and heritage of reliability are a matter of record. Today, they are often treated like a Lego block, easily snapped into a larger design. Just pick the right color and size and continue with the high-tech aspects of the system. The reality is that the electric motors are often critical elements in a new system and its specifications can benefit immensely from early design evaluation to ensure it is practical and cost effective. This is true for any subsea motor but especially so when larger horsepower units are specified.

One advantage in subsea systems design is that we can borrow from aerospace, land, and defense industries. The major challenge in subsea, however, is the low volumes and controlling cost while in many cases these also require additional customization. The problems with fully custom solutions are not only cost and lead times but also the issue of qualification testing for new systems. The first instinct is to use existing off-the-shelf components and make the solution subsea compatible, by enclosing components in a pressure vessel. This can prove to be a lot harder than it looks, particularly for high power electric systems, which involve a lot more than just the motor.

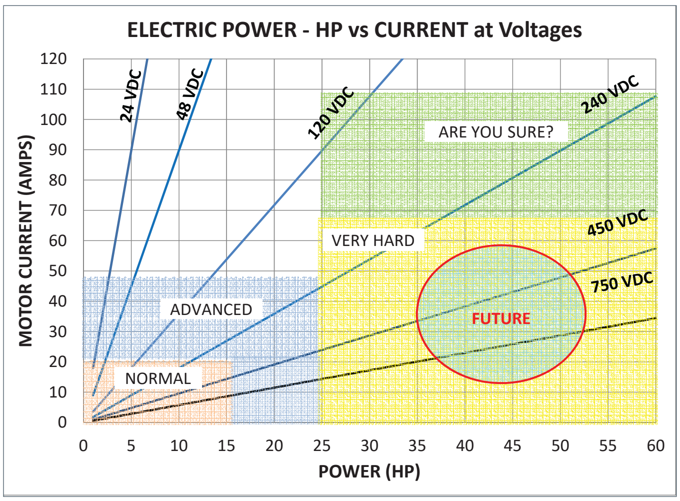
HIGH POWER ELECTRICAL SYSTEMS

Subsea electric control systems consist of four primary elements: 1) Power Source; 2) Control Electronics; 3) Electric motor; and 4) Connectors. Selecting the power source specifications is an important step that can affect the cost and complexity of all four elements. The fifth element, the communication between the motor controls and the command center, is less affected by the power level but equally critical in the ability to interface with various control platforms.

Electric motors can be fabricated in any size, weight and dimension. Size and space constraints are often the primary



» *Electric Motor Power & Control Systems. (Image credit: Hydrospace)* driver, followed by the HP specification. High torques require either large motor dimensions (length, diameter, or both) or high motor currents, or both. High currents affect the motor size but also cost and complexity of the electronics and the connectors. After torque, considerations turn to speed requirements. In general, higher speeds also require more voltage to keep current levels in the "reasonable" range. This is a bit of an over-simplification, but it provides a helpful guideline. These combinations can make it difficult to evaluate a design. We can, however, map the current levels required for specific shaft HP levels according to specific system voltages (as pictured). High voltage systems are more sophisticated and expensive, but low voltages also have practical limits and can present serious cost and reliability impacts.



» *Electric Motor HP vs Electric Current and Voltage. (Image credit: Hydrospace)*

DESIGN FOR HI-RELIABILITY

Designing for high reliability requires additional consideration of the parts that wear or degrade. For electric motors, the bearings and seals are central to long life and designing for lower speeds improves life. An additional degradation element is current. Ratings of connectors, cable and electronics will typically have more problems dealing with high current levels than high voltage. All these considerations impact a design when reliability is a requirement.

It is helpful to divide system currents in four categories, by complexity and cost. The table below shows how controllers and connectors up to 25 amps are a well proven technology. Systems delivering 25-50 amps are more advanced and can serve power levels up to 25 HP but will require higher voltages. Designs that can accommodate 50-100 amps become a more difficult but new developments in high voltage electronics offer excellent form factors for future electric motors in the 40-50 HP range.

System designs with motor currents > 100 amps are extremely demanding, become expensive, and should lead the designer to question whether this is necessary. In addition, qualification testing a custom connector to 150A at depth can be an expensive enterprise. While not a hard and fast rule, the table below provides a useful arms-length guide to the level of complexity of connectors and electronic controllers.

LEVEL OF DIFFICULTY	Current Levels
EASY	0-15 amps
MODERATE	< 30 - 40 amps
HARD	50 – 100 amps
VERY EXPENSIVE	100+ amps

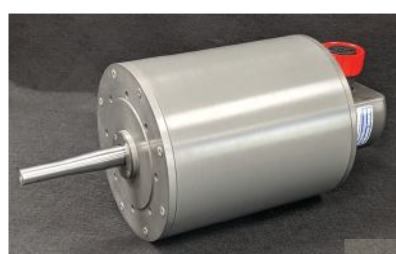
Current Levels vs. Component Complexity

Of course, there are more parameters in a design tradeoff, but it is good to keep these in mind at the system design level. The finer details and optimizations can be discussed with technical experts. There are many more conditions and details that affect a design but too complex to address here.

FUTURE HI-RELIABILITY SYSTEMS

The subsea industry has access to high power levels through umbilical cables as well as high energy batteries. *New technology developments in electronic controls make new high power design options available*. Some electronics are pressure tolerant, many more are not. Leveraging on commercial land-based solutions in this power range is smart but not always a simple process. Generally, the form factor of industrial controllers is square or rectangular and not volume efficient to fit inside a cylindrical pressure vessel. Thermal management is also a critical difference, especially for electronics. While the sea provides an infinite heat sink, getting the heat out requires careful analysis.

There are more challenges in these future systems beyond power. New systems demand more control options and can benefit from remote diagnostics. Systems that are operated remotely and managing data rates of long communication lines is challenging. This encourages designs to prioritize local control processing to reduce data transmission. Smart actuators, for example, with resident intelligence and an integrated uninterrupted power supply can provide local control to achieve a safe mode in case of emergency. There is also the need for some form of communication interface standardization. With the demand for more sophisticated control, digital interfaces are very useful but servicing too many communication protocols gets expensive and difficult to manage. Consideration for TCP-IP standard, CAN Bus, Ethernet are all ideas that are used on land. Agreeing to standard in subsea would be helpful. Industry associations and classification societies can play a part. Above all, it is about providing more cost-effective solutions through better reliability, to be solved with imagination and sound engineering.



» *Hydrospace 600V x 35HP BDC Motor. (Photo credit: Hydrospace)*

» *48V Winch Drum rotary Actuator with integrated control electronics. (Photo credit: Hydrospace)*

For more information, visit: *www.hydrospacegroup.com*.

HYDROSPACE
Group Incorporated

THE FUTURE OF **OFFSHORE WIND**

BY LIZ BURDOCK,
President & CEO, The Business Network for Offshore Wind

BUSINESS NETWORK for OFFSHORE WIND

"Unlocking the full potential of offshore wind requires new technologies and ensuring policies are in place to support them."

A year ago, the offshore wind industry in the United States was eager with anticipation. We knew we sat at the precipice of substantial global growth, but continued federal inaction jeopardized our projects and investments were sidelined. We looked keenly to the future.

What a difference a year makes. The federal government has finally matched the vigor of state governments and its actions have jumpstarted the industry into high gear. President Biden's administration set an ambitious 30 GW by 2030 goal and finally approved the first commercial scale project in the U.S., while also advancing a dozen more projects and areas. Project developers and manufacturers have announced several new investments in the domestic supply chain and Congress has turned its focus to supporting the industry.

In part, the future of offshore wind is today, and now the hard work begins.

SCALING A SUPPLY CHAIN

Our focus now turns to accelerating industry development to reach federal and state development goals. Of paramount importance is developing a domestic supply chain capable of supporting our own projects. The Network estimates global goals total over 250 GW by 2030, which means the industry will needs to quadruple annual installation rates overnight. With the current global supply chain unable to meet those demands, the ensuing intense competition that could crowd out U.S. projects in favor of mature markets. A national industrial strategy must target support to manufacturers, shipbuilders, and lower-level suppliers. New partnerships between established and emergent suppliers must be forged. And our antiquated energy grid needs urgent, coordinated upgrades.

We must plan for the next future, too.

FIELDING NEW TECHNOLOGIES

Unlocking the full potential of offshore wind requires new technologies and ensuring policies are in place to support them. Floating turbine technology, already coming into use in Europe and Asia, is essential to development off the West Coast and into deeper East Coast waters. Even though construction has barely begun on the first commercial-scale project, policymakers and industry must plan for this next industry by reviewing regulations, port developments, and supply chain needs.

Advancing development in the Gulf of Mexico allows the offshore wind industry to tap into a robust existing infrastructure and explore more opportunities to couple wind with green hydrogen, a zero-emissions energy source that can help transition manufacturing and transportation to a clean future.

Offshore wind can partner with future forms of marine-based renewable energy generation, like tidal power, or other resource management technologies. Just as offshore wind existed only on paper a decade ago, these emergent technologies deserve forethought and serious policy preparation to ensure the acceleration of renewable energy future continues unabated.

For more information, visit: *www.offshorewindus.org.*

Advances in UUV technology have led to improvements in information processing and the speed at which data is delivered to decision makers. (Photo credit: General Dynamics Mission Systems)

| FEATURE |

THE FUTURE OF **OCEAN CONNECTIVITY DEMANDS A NEW NETWORK FOR UNDERSEA AUTONOMOUS PLATFORMS AND SENSORS**

By Paul Dalton,
Vice President – Undersea Systems, General Dynamics Mission Systems

New technologies have long driven the need to improve the networks that carry data between them. You need look no further than the growth and expansion of commercial Internet and 5G wireless cellular data to find a quintessential example of the network backbone advancing to meet new information demands. We are reaching a level of maturity for unmanned and autonomous systems that their success and effectiveness in military operations is increasingly dependent on the U.S. and its allied nations ability to connect their disparate autonomous systems to achieve the desired mission effects. This requires a fully integrated and interoperable network that works seamlessly between the various command echelons, from dispersed and disadvantaged tactical units to theater-level combatant commanders.

The sophistication of modern autonomous platforms and payloads is dazzling. Steady improvements in processing and moving data to decision makers has become the norm in air, ground and surface operational environments. These improvements have been striving to create seamless and as close to real-time as possible transmission to impact mission plans and ensure mission success. Steady improvements in processing and moving data to decision makers has become the norm in air, ground, and surface operational environments striving to be seamless and as close to real-time as possible to impact mission plans and ensure mission success.

Unmanned Underwater Vehicles and other subsea capabilities must move in a similar direction. The next level of maturity in these systems will be the completion of a robust, flexible, and secure subsea network that ties in afloat and ashore operations centers, enabling migration of mission data generated by the sensors off these platforms, and back to mission partners in a timely manner. A modern seabed network that connects unmanned systems is not only feasible, it is necessary to achieve the full potential of unmanned systems below the water.

SEABED NETWORK EFFICIENCIES

Today, most underwater vehicles are recovered, and their data recorders removed to retrieve the data for analysis. Exchanging data recorders and batteries takes time and removes the vehicles from the operational environment resulting in a loss of on-station mission execution time. If data is desired to be transmitted prior to recovery, then the data is generally transmitted to a platform by means of acoustic modems. Current acoustic modem data rates are low, and the acoustic information must be received and relayed from a surface gateway buoy or other means to a manned or unmanned aircraft, or via space to a satellite and back to Earth.

Over-reliance on satellites has long been recognized as a potential point-of-failure in military communications. In the heat of a conflict, satellites are likely destroyed or severely degraded by opposing forces. Subsea infrastructure maintains a distinct advantage in this space, acting as a resilient method of connecting a variety of assets back to commanders. The scientific and oil and gas industries have long utilized cabled networks to communicate from deployed platforms to shore. Consisting of shore-based trunks, hard-wired cables, and subsea nodes, such networks have been vital to these enterprises. Undersea networks for military applications exist today that can provide power and large data throughput capabilities. The challenges and opportunities are in the ability for these networks to be integrated with various unmanned systems.

INFRASTRUCTURE-AS-A-SERVICE

A future network must include increased use of near-field communications or high-endurance physical connections that provide higher throughput than traditional subsea communications techniques like acoustics. To provide truly resilient and robust mission capabilities, we must expand our undersea infrastructure to provide power and data capabilities that are required to exploit the full potential of our maturing manned and unmanned systems. This infrastructure-as-a-service approach would give undersea assets new-found flexibility and time-to-action for data exfiltration. It would provide the ability to extend missions without the cumbersome and conspicuous operations required to recharge today. And it would realize the benefit of the edge processing improvements being implemented on-board unmanned platforms today, enabling a streamlined offload and subsequent transmittal of only relevant and necessary information.

» *The capability of UUVs to carry out over-the-horizon missions increases their reach and versatility for military operations. (Photo credit: General Dynamics Mission Systems)*

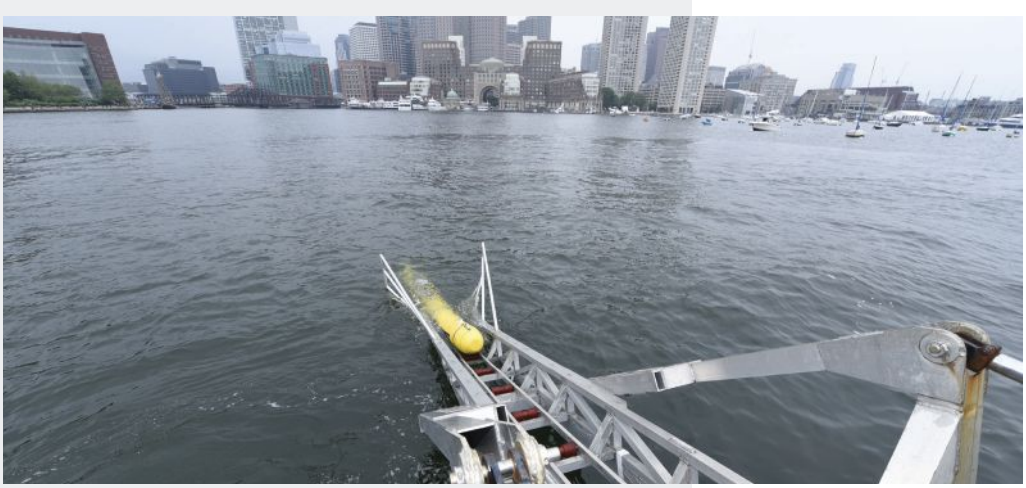
ONGOING INVESTMENT

If we are not as equally focused today on maturing the network that will ultimately connect our undersea systems together, we will never be able to realize the full potential of these rapidly advancing platforms and systems. While there are still many obstacles to overcome as we field a growing fleet of unmanned undersea vehicles, there can be no doubt that they represent the future of undersea warfare and the *technology is maturing faster than our ability to adapt our operations to maximize their value.*

A very important first step to address this is to deploy a network that will allow for these assets to maximize their availability and utility and reduce the time it takes to access their mission data. Many of these network capabilities exist today, but we must accelerate their adoption into the undersea domain and improve our ability to transmit data to and from this network if we are to realize the full potential of our expanding undersea systems.

For more information, visit: *www.gdmissionsystems.com*.

GENERAL DYNAMICS
Mission Systems



» *The General Dynamics Mission Systems Bluefin®-12 is a lightweight medium class UUV designed to deliver mission critical capability and data over long-duration operations. (Photo credit: General Dynamics Mission Systems)*

THE FUTURE OF **OCEAN INNOVATION IS WIDE OPEN**

By Dawn D'Angelillo,
Marketing Director, Greensea Systems, Inc.

Looking back through recent history, a pattern emerges when focusing on major leaps in knowledge or technology advancements. Major challenges are overcome by bringing together groups of people with diverse technical backgrounds and a strong collaborative ethos. You can see it in the race to the moon in the 1960's or, more recently, in the push to create a COVID-19 vaccine. Putting someone on the moon or creating a vaccine in under a year required the best minds working together, making sure they had the best tools available, and the removal of as many blockages as possible between them and their goal.

Any substantial advancement of marine technology over the next decade will only happen with large-scale collaboration, something that we have not yet seen in the industry. Communication advancements have removed geographical barriers and brought together a more diverse pool of scientists and engineers.

COLLABORATION CULTURE NEEDED

But diversity and human communication alone won't drive technological advancement, the marine industry must also make their systems open to collaboration. To drive advancement, products and technologies must be able to easily talk to each other. Ben Kinnaman, Greensea CEO, addressed other marine industry CEOs in a blog post earlier this year about the need for systems to integrate: "What you need to understand is that in the future of the ocean industry, your IP will be worthless if it doesn't integrate with other systems."[1] We're long past the time when a single human operator could fuse disparate systems together themselves, integrations need to be facilitated at the systems level.

» *Collaboration among companies—including competitors—will be needed to fuel ocean tech advancement. (Photo credit: Greensea Systems)*

» *Naomi Harrison, a Greensea engineer, recently used a webinar to demonstrate how she solved the issue of data stream management using Safe2C. (Photo credit: Greensea Systems)*

No single company is going to pull the marine industry into the future on their own. What will drive the next advancement and break through major technological barriers is collaboration among companies; including between those who might be considered competitors. This is going to require the abandonment of corporate ego, to acknowledge that someone does something better than you, and that together you can be more than the sum of your parts. Customer goals, such as time to a minimum viable product, will require multiple companies to collaborate and integrate their systems. This can be made easier if all parts of the system are built on a foundation of an open architecture platform.

OPEN ARCHITECTURE

Greensea is involved in several government and commercial projects that combine and unite the work of several marine companies into an integrated system using Greensea's open architecture platform OPENSEA. Ocean Infinity's Armada fleet is one such project. Using the OPENSEA API and OPENSEA SDK interfaces, Greensea, Ocean Infinity, and any other partner is able to easily add a capability into the Armada DPC to expand the capabilities of the fleet.

Just as crowdfunding has created a distributed way to secure project financing, crowd thinking will drive advancing technology. To harness the power of crowd thinking, Greensea has invested in the creation of a community for marine developers and technology enthusiasts to share ideas and solutions in a public forum. Launched in early 2022, the Greensea community—greensea.com/community—provides ways for systems integrators who have access to the OPENSEA API to find solutions within the community.

There are two ways to reach a technological goal. One way is to go it alone, to add more people or power to solve your specific problem. The other, more efficient way is to create a solution that removes friction or barriers to allow for wider collaboration and integration.

ELIMINATING TECHNOLOGICAL FRICTION

There are several likely advances that will radically change the marine industry over the next few years: tetherless ROVs, resident subsea systems, and over the horizon supervision of systems. Each of these advances has their own 'technological friction' that will need to be removed, such as handling of the data stream between the operator and vehicle. Greensea was awarded a Small Business Innovation Research (SBIR) Phase II grant to advance a long-range standoff command and control system for ROVs. The commercial product coming out of this is SafeC2. SafeC2 removes the technological friction of data transfer by transmitting the least amount of data necessary and synchronizing data so that, even with reduced bandwidth; sonar, video, and vehicle response will remain in sync when the operator sees them. In a recent webinar, Greensea engineer Naomi Harrison, demonstrated how she solved the issue of data stream management.[2]

SEEING IS BELIEVING

Tetherless ROVs, resident subsea systems, and over the horizon supervision will all contribute to the larger shift in the future of marine technology; the end of the one ship, one ROV, one operator model. ROVs can and will be deployed by any means convenient while being supervised by personnel throughout the world without needing to be present onsite. This will be accomplished by removing technological friction but will also require changing the mindset of owners and operators. This may be a larger barrier than the technology friction. To change minds, there needs to be solid proof, this might be accomplished by showing financial or commercial gains, but more likely people may be convinced by seeing that the technology actually works. Much of what we see in the marine industry are promises backed by well animated videos or 3D renderings, but what we come up short is there's very little proof of new technology working in a real-life marine environment.

There will be dramatic advances in marine technology over the next few years, but advances will happen faster and be more reliable IF we can integrate, collaborate, and remove barriers that currently exist between both systems, companies, and people. We believe that this can and will happen through the use of open architecture platforms like OPENSEA and a barrier removing, corporate ethos like the one shown by Greensea.

For more information, visit: www.greensea.com.

[1] Unfiltered #7 – Dearest CEO… posted on Jan 8, 2021. https://greensea.com/unfiltered-7-dearest-ceo/
[2] Mixtape Session #5: Introducing SafeC2 - recorded July 28, 2021. Pete Kerson, Greg Horton, and Naomi Harrison present on SafeC2.

THE FUTURE OF **SEABED 2030**

BY JAMIE MCMICHAEL-PHILLIPS,
Project Director, The Nippon Foundation-GEBCO Seabed 2030 Project

> The project will also continue to seek and establish new partnerships, and collaborate with academia, research organizations, government, and industry to develop leading edge technology.

With 2021 coming to an end, The Nippon Foundation-GEBCO Seabed 2030 Project will have just eight years left to achieve its ambitious goal of the complete map of the entire world ocean floor by 2030. When Seabed 2030 was launched in 2017, only six percent of the seabed had been mapped to a modern standard—a figure which in the project's first four years has increased to 20.1 percent.

The world's ocean plays a vital role for humanity and has aptly been described by the UN as 'our planet's life support,' and yet we still know so little about it. There are many benefits to having a complete bathymetric map of the ocean—knowing the shape of the seabed is critical to understanding the circulation of ocean currents and associated effects on climate change, weather systems, and tsunami wave propagation. The lack of bathymetric data also challenges our ability to sustainably manage marine resources and protect coastal communities, and prevents us from making informed policy, regulatory and management decisions which will have long-lasting effects.

FULL STEAM AHEADPROGRESS

Despite the challenges brought by the pandemic, the past year has been significant for Seabed 2030. The project was one of the first to be endorsed by the UN's Decade of Ocean Science for Sustainable Development (2021 to 2030) and was an invited participant in two milestone events: the UN Climate Change conference (COP26) and the fourth edition of the Paris Peace Forum. Seabed 2030's participation in these key conferences highlighted the importance of the ocean and the integral part it has to play in the fight against climate change—a reality which is often overlooked.

With around 80 percent of the seafloor left to map, Seabed 2030 is aware of the monumental task ahead. But realizing this goal is dependent on collaboration on an international scale—by humanity for humanity. It will also require advancements in technology, which will enable us to map the deepest and most remote parts of the planet. Indeed, the past few decades have seen constant improvements in the accuracy, resolution, and seafloor coverage offered by echo-sounding methods, and Seabed 2030's strategy will continue to evolve to make use of new technologies as they become available. The project will also continue to seek and establish new partnerships, and collaborate with academia, research organizations, government, and industry to develop leading edge technology.

COLLABORATING TO FILL THE GAPS

The project has made commendable progress since its launch, but the race is now on to map the remainder of earth's final frontier. With collaboration on a global scale, a complete map of the ocean floor by the end of the decade is achievable. Every time a research vessel adds bathymetric data gathering to its mission, every time a ship takes a slightly altered course while in transit to survey an uncharted area, they are helping to fill the gaps. Assembling the definitive map of the seabed is certainly deserving of a global effort—not least because it will help safeguard the future of our planet.

For more information, visit: *www.seabed2030.org.*

THE FUTURE OF **OCEAN ELECTROACOUSTICS**

By Dawn F. Massa Stancavish, *President & CEO, Massa Products Corporation*

Underwater. The vastness of our oceans and our understanding of their fathoms are vastly unfathomable! To date, only 20% of our oceans have been thoroughly explored. There are many things that contribute to this lack of exploration, but technological capability is not one of them. Massa Products Corporation (Massa) is a 3rd generation family business located in Hingham, MA which, after 76 years in business, continues to pioneer this effort and challenge what's possible with our sophisticated and enduring products and technology.

Massa is a woman-run, certified small business, and an ideal partner for industry, oceanographers, and the military thanks to our rapid design process and reliable products. Presently, Massa manufacturers transducers that outfit over 60% of the sonar systems utilized on US nuclear submarines. Massa is sought after for our technological expertise and ability to expeditiously transition from concept to new product development and for improvements to existing designs.

» *SEA Expedition Students Collecting Data with Help from MassaSonic® Technology & Products. (Photo credit: Sea Education Association)*

APPLYING THE FUNDAMENTALS

Massa is the only existing company in the field of Electroacoustics, Sonar and Ultrasonics, that was started by a founder of the field and continues to nurture an in-depth training of its staff with respect to both the scientific and philosophical fundamentals of the field and of the technology. Why is this important? Because it is through having a profound understanding of all the "whys" and "hows" presented in an applied science such as Electroacoustics that one can truly harness the full potential of adapting it for practical use. The future innovation and the advancement of this type of technology is dependent on having sound fundamental understanding and, most definitely, a fervent sense of creativity and curiosity.

At Massa we have a common belief that just because something doesn't exist, doesn't mean it can't exist. We know this because of our experience and success with the advancement of the field, and the advancement and longevity of our products. This philosophy originating with my grandfather, Frank Massa, founder of Massa and of Electroacoustics; and the teachings of my father Don Massa, CTO. Technological progression truly knows no bounds, and its potential resides in the hearts and passions of creative thinkers. This is especially the case with electroacoustics. *We believe that the more people get familiar with using ultrasonics and sonar, the greater uses they will discover they have.* Massa's business model advances the field whether it is in creating new to the world technology or advancing the awareness of where sonar can be used. Massa does this for the military, for industry, and for the education sector.

TRANDUCERS IN ACTION

Ironically, sometimes technological advancement can occur even with using older products! Recently, Massa was contacted by a wonderful organization in Woods Hole, MA called Sea Education Association (SEA). They contacted Massa looking to refurbish some sub bottom profiling sonars. As Massa investigated the request, it became evident that the transducers they were using in their systems, were over 40 years old! In fact, they purchased them used in 1987 and had been using them reliably ever since. They had gone through 3 generations of sonar electronics, but the original Massa 8-transducer arrays would keep getting reused in each new

» *SEA's Students Processing Data from Massa Sub-bottom Transducer Array. (Photo credit: Sea Education Association)*

system! The sub bottom profiling transducers used by SEA is also used by many in the oceanographic community; however, for a smaller organization such as SEA, they are a necessity that is not as easily replaced due to cost and other logistics. It's also a capability that they describe as central to the operations of the ship that they use on numerous student voyages, and they're a tool that allows students to better research and understand a range of topics from coral atoll formation and stability to tracking shifts in equatorial oceanic production from sediment deposition on the sea floor.

» *SEA's Refurbished Massa Sub-bottom Transducer Array in 30% Propylene Glycol. (Photo credit: Sea Education Association)*

SEA's mission and vision are closely anchored towards bringing educational experiences to students around the world with respect to better understanding oceans and marine life. This extends to also educating students in how to use technology in that research. Massa Transducers are integral to SEA's purpose of educating students about the ocean. For programs such as in the SEA's Pacific voyages, students are looking at seamount and island-induced upwelling where there are steep slopes, SEA depends on the reliability and accuracy in performance that Massa Transducers provide.

Other programs that utilize the Massa transducers are collaborations between SEA and WHOI such as their research program regarding cyclone frequencies in the tropical Pacific, and other collaborative programs where SEA has sent ships to be used as scout sites for sediment cores in both the Atlantic and Pacific. In SEA's words: "Well over half of SEA's 9000+ alumni have in one way, or another benefited from the use of Massa's transducers, many of whom have gone on to careers in marine sciences. SEA and Massa have been working together to train the future workforce in ocean sciences."

GOING WHERE OTHER TRANDUCERS HAVE NOT

As Massa approaches its 8th decade, our focus, programs, and products encapsulate the past, transform the present, and define the future of electroacoustics, in terms of design, development, and application. By partnering with customers and scientists alike, Massa utilizes our expertise to create value added products that directly benefit the oceans be it on earth or elsewhere. Existing programs and products are focused on enhancing the design of sonar transducers and systems to outlast and outperform in the oceans be it for military, commercial, or scientific use.

Present products are used at extreme depths, in intense pressures, and in fluctuating temperatures. They are used in applications that study and protect marine life, and marine conditions, habitat, and environment. There are several new products that are under development for new spaces. If you want to know what's out there, Massa hears you. The future of MassaSonic® technology is in our ability to go where no other electroacoustic products have gone before.

For more information, visit: *www.massa.com/industrial/oceanographic* and *www.sea.edu/about_sea/history*.

THE FUTURE OF **LOWERING CARBON EMISSIONS AND INCREASING WORKER SAFETY THROUGH REMOTE OPERATIONS**

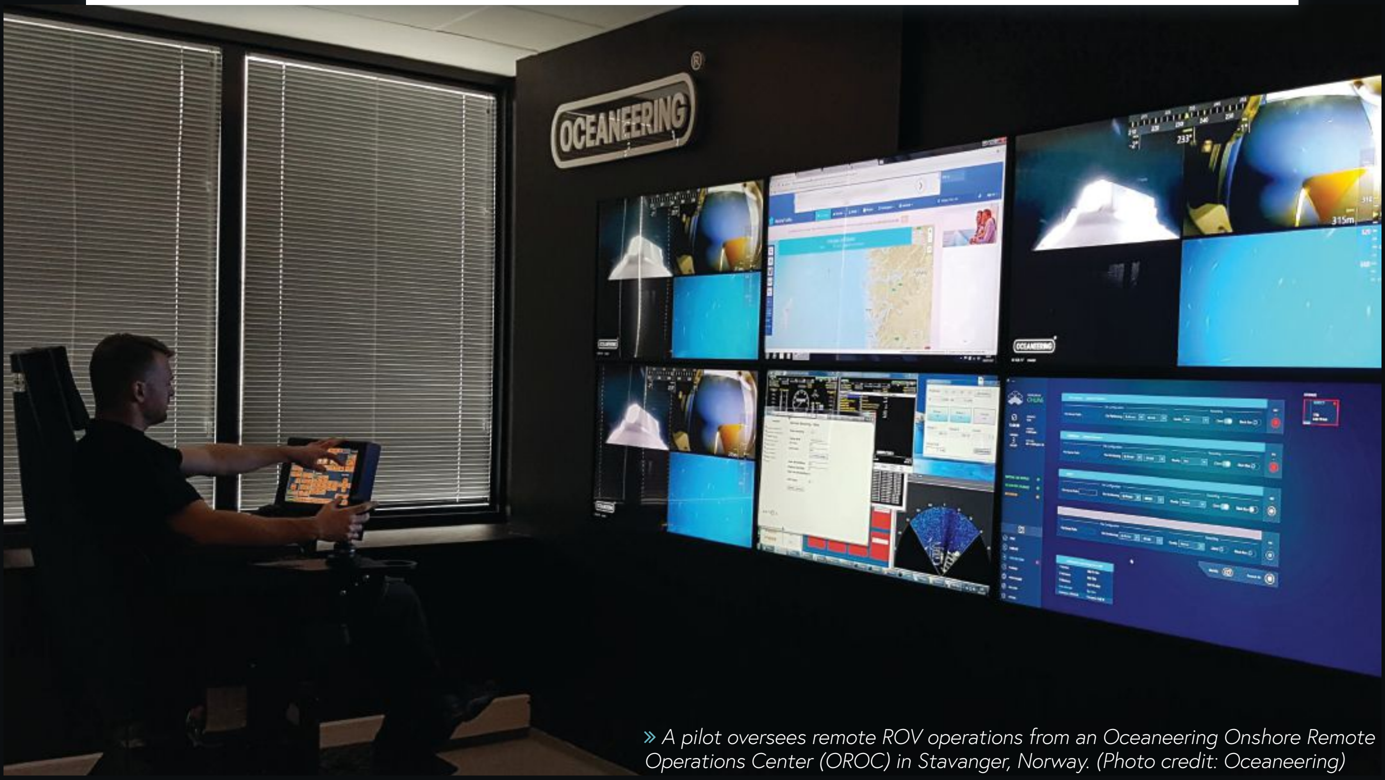
By Simao Silva,
Director, Oceaneering

Advances in technology are making remote operations more commonplace, and the range of functions being carried out remotely continues to expand. Remote operations can double operating windows, expanding the traditional 12-hour operational day to 24 hours, without the need for helicopter flights to transport the additional crew members to the rig.

Oceaneering achieved proof of concept in 2004 with activities successfully executed from shore on multiple assets in the North Sea. In 2021, Oceaneering achieved a milestone 50,000 hours (equivalent to over five years) of remote ROV operations; the COVID-19 pandemic significantly accelerated adoption of remote operations, lowering the number of personnel needed offshore while maintaining operational standards.

REMOTE CONNECTIVITY

In simplified terms, the operation of subsea robots and ROVs have always been remote; the operator controls the machine from the topside of the asset where all commands flow through a cable. Operating these robots from shore adds one chain to the communication link as the information now flows through the internet before it arrives to the machine. Remote piloting and automated control technology



» *A pilot oversees remote ROV operations from an Oceaneering Onshore Remote Operations Center (OROC) in Stavanger, Norway. (Photo credit: Oceaneering)* enable full ROV piloting via virtual connection technologies such as vessel-to-vessel radio frequency, satellite/internet, and subsea optical link. This capability allows for increased operational support from onshore or from another vessel during complex or long-duration activities, providing access to a broader team of subject matter experts (SMEs) and specialists.

Launched in 2015, *Oceaneering's onshore remote operations centers (OROC) enables effective execution of offshore operations from a remote base, where client representatives could interact with ROV pilots and SMEs.* Working from an OROC eliminates offshore safety risks for the shore-based team. It increases efficiencies by decreasing the number of workers mobilized offshore, reducing operational wait time, simplifying interaction between the customer representative and ROV pilots and operations. It also enables teams to manage multiple operations that require specialist oversight from a unique location.

REMOTE PILOTING IN THE GULF OF MEXICO

Remote piloting of ROVs was first adopted in the North Sea due to the availability of high-speed communications infrastructure offshore. Previous trials of remote piloting have been performed in the Gulf of Mexico (GoM) on the Ocean Evolution vessel using high latency satellite communications. In 2020, Oceaneering carried out the first commercial remote piloting of an ROV in the GoM using the operator's existing infrastructure, which included high-speed communications connected to a tension leg platform (TLP).

The biggest challenge in moving ROV control to an onshore facility is managing the communications path. In the GoM, most offshore facilities are not in range of 4G communication like they are in Europe. This is due to the location of the assets and their distance from the beach. Offshore data communications links are narrow, which diminishes the ability to transfer data in real time. Because communications from the operating TLP were already available, remote ROV piloting was a prime candidate for this project.

Special equipment is needed to manage remote ROV operations, and all of it relies on the data being transferred from the offshore asset to the onshore facility. The ROV pilot needs to see and respond in near-real time to what is happening subsea for this solution to be effective. This is especially true for precise work programs where it is vital to transmit the data from glass to glass (i.e., camera to monitor) in the least amount of time to minimize the effect of latency on piloting.

To ensure cybersecurity, the data stream passed through a data transport system using secure, encrypted tunnels to transmit data between the offshore asset and onshore facility. The ROV control software has the flexibility to allow full control of the ROV and manipulators by either offshore or onshore pilots, or a collaborative approach whereby the pilot at one end controls flight and the pilot at the other end controls manipulators. Cybersecurity is one of the areas that receives the most attention, including the use of a specialized company to test the system by trying to hack into it.

A proprietary remote piloting system was used to transmit video, audio, and control data for this project. The Oceaneering Media Vault system, based on the Microsoft Azure platform, is typically used to safely and securely control and store data. The system was shipped to the offshore asset and installed in a couple of days by the ROV crew already onboard. On projects where existing communications infrastructure is insufficient, a fully redundant satellite agnostic intelligent link (SAIL) can be installed to ensure 99.9% uptime on the communication while the

» A pilot and other personnel oversee remote ROV operations from an Oceaneering Onshore Remote Operations Center (OROC) in Stavanger, Norway. (Photo credit: Oceaneering)

offshore crew provide the redundancy needed by taking control of the robot, if needed.

TRAINING PILOTS

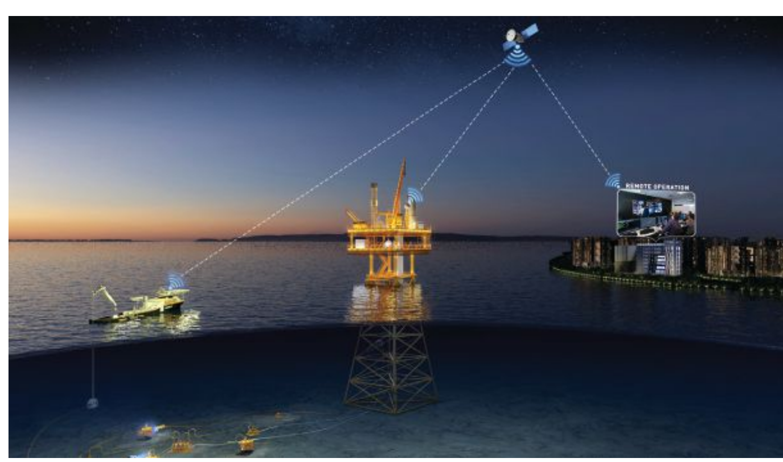
Training is an important portion of remote operations projects. The pilots train on simulators onshore to learn how to adjust the way they maneuver the ROV to account for signal latency to effectively execute work subsea. The training program also includes a portion designed to be asset-specific and allows team members to become familiar with the subsea field layout.

One of the main departures from the standard mode of operations is in the way the pilots talk with each other. For remote operations, they communicate via a Voice Over Internet Protocol (VOIP) communication link, instead of face-to-face. In this project, the training and familiarization process had a duration of approximately four weeks before responsibility for the controls were transferred to the shore-based remote pilot for the execution of the work scopes.

The ROV control software and data communication hardware ensured a safe and robust sharing of piloting duties by the pilots at both end of the link. Control is handed over in a structured manner that involves a series of invite and acknowledge commands sent via the software. This methodology, along with visual and audible indicators, ensures that each pilot is fully aware of who has control of the ROV at any given time. The pilots are at all time in direct voice communication with each other via a VOIP communication link.

With the positive results of the inaugural GoM project, this technology is gaining a foothold in the United States. As communication networks in the GoM improve, such as the implementation of 4G LTE in the region, remote operations will become increasingly easier to implement.

For more information, visit: *www.oceaneering.com*.



» An Illustration of Remote Operations. (Image credit: Oceaneering)

THE FUTURE OF **OCEAN TECH CONFERENCES**

BY TOBIAS STAPLETON,
Co-Founder & Managing Director,
Blue Innovation Symposium

> Let's face it, in-person conferences offer benefits that are hard, if not impossible, to replicate virtually."

Over the last two years, the blue tech community, like everyone else, has had to cope with the shift away from face-to-face meetings and events to all-virtual programming. As we emerge from the pandemic, the industry is eager to get back to face-to-face ocean tech conferences because they have traditionally been the primary tool for the industry to engage with customers and prospects, demonstrate new technologies, and identify industry trends.

This year, we conducted a survey of our blue technology community and we learned that more than 87% of respondents were planning to attend a face-to-face ocean tech conference in 2022. So, as we contemplate a return to face-to-face industry gatherings, attendance at ocean tech conferences is surely set to surge.

VIRTUALLY NO COMPARISON

Let's face it, in-person conferences offer benefits that are hard, if not impossible, to replicate virtually. Serendipity, for one, is a real factor. We all have a story about running into someone by chance, be it at a booth, reception, or on the exhibition show floor, who ended up having a positive impact on our business. This is someone whom you might never have met but for the fact that we were both at the same show. Virtual environments seldom cater for such chance encounters.

Conferences also offer the opportunity to get caught up with colleagues, new product innovations, and industry gossip. The blue tech industry is a close-knit community, and camaraderie is a hallmark of it. So, ocean tech conferences are important for industry stakeholders to build and keep relationships. But these post-pandemic ocean tech conference will look different.

THE NEW NORMAL

Safety will be prioritized. No matter where the show takes place, show organizers will implement and enforce a host of safety protocols. Our survey indicated that more than 70% of respondents would participate in a face-to-face conference only if protocols, like evidence of vaccination, mask mandates, social distancing, and limits to attendance, were in place.

More virtual programming will be in place, to augment the trade show experience. Over the last two years, we've all gotten a lot more comfortable with using technology. This provides conference and trade show organizers with the opportunity to introduce digital tools that will provide exhibitors and attendees better ways to engage with customers before, during, and after events. One thing that we have learned about virtual programming is that it offers us the ability to reach a larger audience more cost effectively.

Regional shows will remain important. More than half (50%+) of respondents were planning to attend a conference that required air travel. But 90% of respondents were planning to attend events that were within driving distance. This is partly due to concerns about safety, but it is also due to the uncertainty surrounding air travel, which limits our ability to participate in international shows. It remains to be seen how perceptions about travel safety and enforcement of travel restrictions will continue to impact global travel, so shows that cater to local eco-system(s) will remain important.

This is a resilient industry, and the future of ocean tech conferences is bright—I am looking forward to seeing you at one soon.

For more information, visit: *www.blueinnovationsymposium.com.*

The SR-Surveyor M1.8 is rapidly deployable and ideally suited for surveying coastal and hard-to-access waters. (Photo credit: SeaRobotics)

| FEATURE |

THE FUTURE OF **AUTONOMOUS SURFACE VEHICLES (ASVs)**

By Don Darling, *President, SeaRobotics*

Advances in ocean technology continue to revolutionize the way we explore marine environments, safely and efficiently. Autonomous Surface Vehicles (ASVs) represent one of the fastest growing markets in this space, and are increasingly deployed for hydrographic survey, inspection and maintenance, and search, recovery, and reconnaissance operations. Accordingly, ASVs vary in size, weight, and capacity, and can be custom engineered to perform an expanding range of tasks and support an array of sensors and payloads.

The advent of ASVs is symptomatic of an undeniable paradigm shift. The use of specialized marine survey equipment, such tethered sensors, towed bodies, and sampling systems, has traditionally relied on vessel support, as well as an onboard team of seasoned professionals coordinating deck operations and executing mission objectives. However, ASVs allow operators to curb in-field resources and run surveys remotely. Less time and personnel running repetitive survey lines frees up crews to focus on interpreting decision-critical data, on dry land, hence maximizing operational efficiency while minimalizing HSSE exposure.

The challenge for ASV developers, therefore, is to match the most suitable ASV capabilities with real-world customer demands (applications) and bundle these features into one intuitive platform. In essence, this means striking the right balance between data quality, operating efficiency, and ancillary functions. In recent years, aided by sophisticated control systems and software packages, ASV companies have launched a series of multi-purpose vehicles, each defined by proprietary hull forms, dimensions, and payload options.

FROM CONCEPT TO PORTFOLIO

SeaRobotics has been building ASVs for commercial, government, and defense clients around the world for over twenty years now—more than 75 since we opened our doors in Florida, back in 1999. Over the last two decades we have seen uncrewed systems evolve from novel prototypes into highly sophisticated platforms designed to drastically enhance hydrographic survey and marine operations and significantly reducing the carbon footprint. However, the acquisition of an ASV represents a significant financial investment and so customers need to better understand which type might be right for their specific need. Application has always driven our thinking at SeaRobotics and has been instrumental in framing our comprehensive portfolio of ASVs over time. Today, our product line is categorized by vehicle class and application to help empower interested parties with the tools and knowledge to make a lasting impact on their own operations.

INTEGRATED AND PORTABLE

Our SR Surveyor Class ASVs have proven increasingly popular among "on the go" hydrographers given that these highly portable, plug-and-play systems are designed for rapid set up and deployment. Dimensions are paramount, so one of the key design parameters at conception stage was making these ASVs SUV-compatible. Our flagship model is the SR-Surveyor M1.8, a tightly integrated unit configured to simplify logistics and optimize data collection in shallow and hard-to-access waters.

As well as an MBES, the SR-Surveyor M1.8 also features a Velodyne Puck LiDAR for terrestrial mapping, ideal for inspecting coastal infrastructure, such as near-shore pipelines, bridges, piers, and underwater rigs.

VERSATILITY IN THE FIELD

Certain field operations call for greater versatility than is generally available with more compact, fully integrated ASVs. There is a need for broader application, extended reach, and flexible payload capacity. These criteria form the three pillars of SeaRobotics' Utility Class. There are a number of different models, including the SR-Utility 2.5, SR-Utility 3.0 and SR-Utility 3.6, all of which support large multibeam sonar systems, a water quality sonde, and custom handling equipment. A large payload deck and onboard computer allow operators to interchange various hydrographic sensors. SeaRobotics' ASV driver for HYPACK and QINSy provides streamlined interfacing, making the vehicles intuitive, safe, and efficient to operate. This class of ASV offers a full suite of autonomous survey planning features, fail safes, health monitoring and redundancy, and can operate for a full day in sea states 2/3—ideal for working in coastal waters.

RUGGED AND ENDURING

For longer, more arduous missions further offshore, SeaRobotics also offers a series of electric hybrid propulsion (allowing for a quieter operating mode needed for acoustic research) Work Class ASVs. Our SR Endurance Class ASVs feature an exclusive hydrographic winch coupled with a simple A-Frame with an instrumented over boarding sheave capable of launching and recovering additional ride-on assets, such as towed payloads or ROVs. The system is equipped to deploy towed instruments, or various 100-kilogram payloads.

Our latest model in this class, the SR-Endurance 8.0 features a self-righting aluminum monohull and are fully operational in seas

» SR-Endurance 7.0 offers operators ride on/off options. (Photo credit: SeaRobotics)

generated by Beaufort Wind Scale 7 (waves up to 4 meters). The direct drive electric propulsion system that can achieve speeds of 10+ knots, with an efficient multiday cruise speed of 5 knots, providing smooth speed control throughout the entire speed range. MBESs, DVLs, ADCPs, USBLs and acoustic modems can all be deployed through the moon pool, while HD, full color video cameras provide a 360-degree field of view in daylight and low light operations.

» SeaRobotics' latest addition to the fleet, the SR-Endurance 8.0 for offshore survey missions. (Image credit: SeaRobotics)

CUSTOMIZING THE FUTURE

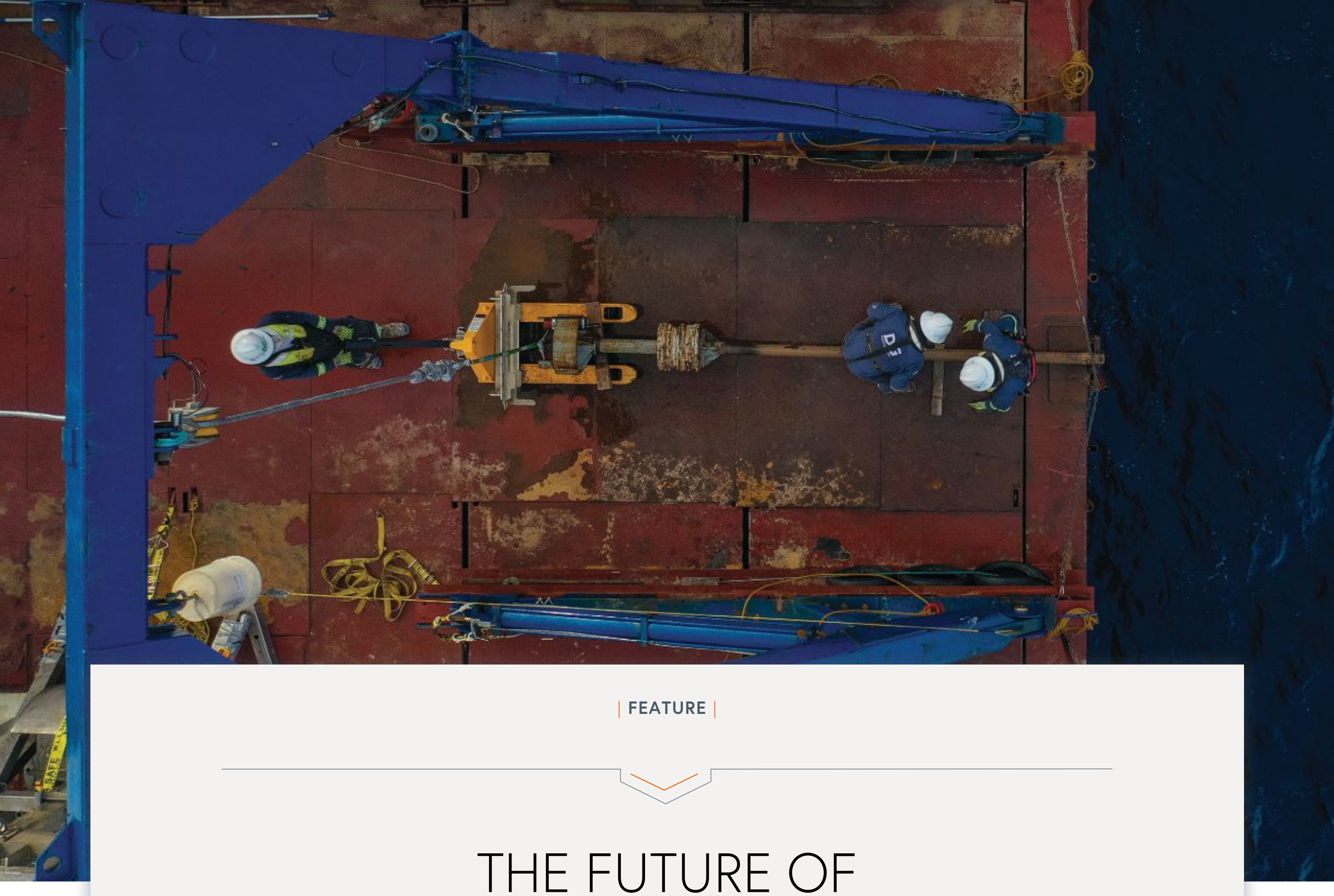
The future of ASVs has already begun. While the SeaRobotics team has distilled our industry experience and expertise into a relatively tight product line, we know that as technology continues to push the boundaries of what's possible, custom requirements are inevitable.

When opting for our SR CyberHelm option, which allows customers to either retrofit an existing marine asset with one of our payload/sensor packages or completely custom design an ASV from concept, our service offers on-staff engineering expertise and fabrication resources to ensure seamless integration and interfacing.

But custom designing ASVs demands proven experience, and the engineers at SeaRobotics boast over 300 years of combined experience in developing electric, diesel-electric hybrid, diesel/gas, and catamaran/monohull ASVs. This makes SeaRobotics uniquely positioned to partner with customers to design, develop, field test, and ultimately deliver the future of ASVs.

For more information, visit: www.searobotics.com.

SeaRobotics



| FEATURE |

THE FUTURE OF SUBSEA GEOTECHNOLOGY

By Jim Edmunds,
Managing Director, Bluefield Geoservices UK

Recent geopolitical pledges towards an increasingly green energy mix bode well for the world of subsea geotechnical service providers. The phased planning, build-out, and operation of safe and sustainable offshore infrastructure, including anchored assets that tower hundreds of meters above the waterline, is fundamentally reliant on the robust geotechnical analysis of seafloor conditions and a clear understanding of location-specific loadings and geohazards.

The thorough in situ site investigation and modelling of these often-hazardous marine environments, especially as developers venture into deeper waters, hinges not only on seasoned geotechnical expertise but the ongoing development of modern geotechnologies. Notable in recent years, there has been a significant uptick in the rate of subsea geotechnical innovation, triggered by a growing appetite among developers for new technologies and positively disruptive approaches to the long-established order of offshore geotechnical practices.

TOOLING THE FUTURE

This was the pretext to the founding of Bluefield Geoservices in 2018 by a select group of geoengineers that, above all else, share an unwavering commitment to high-quality data and decision-critical analysis. In less than three years, the team has fielded several proprietary custom geotechnologies, including our ROVcone and BOXcone systems.

When it comes to offshore planning, be it for cable routing, subsea intervention tasks, drill cuttings pile surveys, or decommissioning studies, the ability to conduct precise CPT (Cone Penetration Test) and seabed sampling within a tightly defined area is paramount. The ROVcone system allows operators to deploy a lightweight unit but still deliver in excess of 1,000 kg push force for soil testing. While the ROVcone can be paired with any work class ROV or trencher, the system features the unique benefit of wire-free (acoustic) real-time communications between the penetrometer and the ROV, which ultimately eliminates cabling, reduces snag hazards, and expedites deployment time.

The BOXcone system is a specialized in situ testing tool designed to interface with a box core sample box and deliver precision-controlled push force. The system is designed for in situ testing including CPT, T-bar, ball cone penetrometer, lab vane, and plate load testing, as well as push-in sub-sampling. Other probes can also be integrated, such as thermal conductivity.

Both the ROVcone and the BOXcone are field-proven examples of how the Bluefield team is leveraging its extensive hands-on experience of performing in situ testing and site investigation around the world—including in the Pacific Ocean, the Gulf of Mexico, the North Sea, and in offshore regions of Australasia—to devise and deliver innovative solutions to the most persistent problems associated with modern offshore developments.

REMOTE OPERATIONS

However, as history attests, new technologies do not always cancel out existing ones, and CPT has played a pivotal role in offshore soil investigations, notably when it comes to oil and gas E&P. Recent projects seeking to establish operations at new depths, have shifted focus from piled jacket structures or jack-up platforms to new structures such as large diameter monopiles, gravity base platforms, floating structures and seabed structures anchored by suction piles. With this shift comes an order of magnitude or greater increase in the quantity of seabed structures required over the coming decades compared with the preceding decades.

This puts increased emphasis on in situ seabed testing and, increasingly, geohazard assessment in ever deeper water and extending the traditional working season into the autumn and winter. This has given rise to an increasing demand for remotely operable CPT platforms—capable of "over the horizon" operations—from offshore developers.

One such tool custom designed to perform such operations is Bluefield's remotely operated CPT platform, depth rated to 3,000 meters and with a 6,000 meter rated system under development. While the device still requires personnel onsite for system mobilization, deployment, and the collection of physical samples, the system is operable by shore-based technicians, who can also ensure quality control of acquired data. The growing incorporation of automated hardware like this not only facilitates a significant down-manning of at-sea personnel but it, subsequently, guarantees a significant reduction of a projects carbon footprint.

Much of this demand can be attributed to the burgeoning offshore renewable market, especially the offshore wind sector in the United States, where the Biden administration's pledge to deliver 30 GW by

» *Bluefield's ROVcone can be paired with any work class ROV or trencher. (Photo credit: Bluefield Geoservices)*

» *Bluefield's BOXcone system is an in situ testing tool designed to interface with a box core sample box and deliver precision-controlled push force. (Photo credit: Bluefield Geoservices)*

2030 has finally kickstarted a flurry of subsea geotechnical survey work. The scale of turbines required in the US to make good on this policy—be them monopile, jacket, twisted jacket, tension-leg floating platform, semi-submersible platform, or spar-buoy—remains to be seen, but infrastructure investment on this scale walks hand in hand with the need to comprehensively investigate seafloor conditions up and down the continental shelf in the timeliest and the most carbon-conscious manner possible.

FUTURE OPPORTUNITIES

The future of offshore geotechnics requires balancing what's possible with what's practical, and it is Bluefield's multi-disciplinary experience that gives the team a distinct advantage when seeking to conceptualize, procure, or upgrade subsea survey capabilities. The Bluefield approach tends to be project specific, which helps recalibrate R&D efforts towards challenging the status quo when and where we can make a difference. But it is also about collaborating with the right industry partners to develop fit-for-purpose resources and solutions.

Through key strategic partnerships, Bluefield has also broadened its range of services to incorporate geophysical and environmental survey—including physical sampling; geophysical and hydrographic surveys; offshore environmental baseline surveys and monitoring; habitat mapping; and Environmental Impact Studies—to serve the international offshore energy community, especially in the US, with a complementary suite of specialist services.

This diversification has also given the team the opportunity to work on several next-generation foundation and anchoring concepts for the offshore structures of tomorrow. Current projects include robotically installed foundations for offshore floating wind anchors and pipeline stabilization, combining micropiling principles and the use of subsea robotics to provide tensile capacity and lateral restraint.

However, the future of subsea geotechnics will be defined as much by the past as it will the offshore infrastructure of tomorrow. As unprecedented numbers of assets require decommissioning over the coming decades, site investigation services that prioritize the safe, cost-effective, and low impact survey techniques needed to acquire the robust and reliable data are sure to come out on top. As with most things offshore, our people and technological capabilities will be a key differentiator.

For more information, visit: www.bluefieldgeo.com.

Bluefield Geoservices

THE FUTURE OF OCEAN INFRASTRUCTURE IS BUILDING BACK BLUER

BY DR. ALAN LEONARDI,
CEO, Consortium of Ocean Leadership (COL)

> "Continuous, sustained ocean observations are the bare minimum needed to keep up with the scientific demands of a changing climate."

We are in a race against time when it comes to demands of the changing planet, from how to mitigate change to how we will adapt as ecosystems—which provide food, habitat, oxygen, and more while storing carbon dioxide—are impacted in turn. As the scientific community defines requirements for our core and essential biogeochemical ocean variables, which are key to understanding changes already taking place as well as forecasting future scenarios, ocean observing systems themselves cannot also be a variable. Continuous, sustained ocean observations are the bare minimum needed to keep up with the scientific demands of a changing climate: objective, reliable time series on ocean conditions are the baseline from which all ocean science is built.

What more could our community do if we did not have to worry about just sustaining existing observation platforms? When we first deployed moorings for the Tropical Atmosphere Ocean (TAO) array in the Pacific to learn about El Niño and the Southern Oscillation, some were wary of what the investment would yield, but TAO quickly proved the value of sustained observations in the Pacific and expanded from a few moorings to 70, with sibling arrays later deployed in the tropical Atlantic and Indian oceans. Similarly, the international Argo program, supported by more than 30 countries, sustains an array of nearly 4,000 floating instruments that have improved our understanding of global ocean circulation patterns and global rainfall patterns and have reduced uncertainty in sea level rise projections.

HARNESSING NEW TECHNOLOGY

Looking forward, the survival of our planet depends on knowing our ocean, and knowing our ocean depends on making the most of our capabilities by integrating modern technologies into existing systems, growing them to a planet-wide scale, and ensuring observations adhere to common data standards. Whether or not we could gather ocean data on this scale is not the question; ocean observing technology, shoreside analysis, and storage methods are improving every day. Sensors are becoming smaller; onboard computational power continues to grow; battery technologies allow sensors to be deployed for longer; communications technologies allow for real-time monitoring; and neural networks and machine learning are identifying patterns and trends faster, improving ocean and ecosystem predictions.

Leveraging the data we already have can also lead to new insights. For example, coupling global subsurface biogeochemistry measurements, such as primary production and how plankton migrate over time, with data gathered through satellites like those of the Plankton, Aerosol, Cloud, and ocean Ecosystem (PACE) mission could provide a complete view on how the planet "breathes" from the water column through the atmosphere.

THE FUTURE DEMANDS COLLABORATION

No, the question today is whether we are going to harness the power of human ingenuity and bring modern day ocean observing systems to the scale needed to solve some of the world's most pressing challenges, convening stakeholders to solve these challenges while simultaneously supporting sustainable development of the blue economy. Technology is already here today to achieve this goal; we just need to commit the resources to this challenge and work across sectors to make it a reality.

For more information, visit: *www.oceanleadership.org.*

| FEATURE |

THE FUTURE OF **UNDERWATER WINCHES**

By Okeanus Science & Technology

If there is one word likely to define the future of the offshore industries, it is automation. Ongoing investment in smart ocean technology, including complex subsea systems and intelligent oceanographic instrumentation, continues to push us toward a new reality, one that legitimately grants us the ability to significantly scale back in-field human resources in the name of optimized efficiency and safety.

In years to come, this orchestra of automated assets will mostly rely on shore-based conductors. While there will always be some requirement for intermittent topside support and intervention, offshore developers, marine survey companies, and ocean researchers are increasingly motivated by the growing capacity of at-sea autonomy and, increasingly, subsea residency. That is, the ability to deploy, monitor and control marine assets, be them vehicles, sensors, or critical infrastructure—on, below and above the surface—for sustained periods, remotely.

However, operating such sophisticated hardware in often harsh and remote marine environments—especially in deeper waters—comes with inherent risks so the evolving role, form, and function of failsafe handing systems is of equal importance and concern. Put another way, the adoption rate and successful integration of these autonomous systems is intrinsically linked to the capabilities of the support infrastructure engineered to serve them. This is perhaps best exemplified by a recent spike in interest for one specific product line at Okeanus: underwater winches.

UNDERWATER WINCHES OF TOMORROW

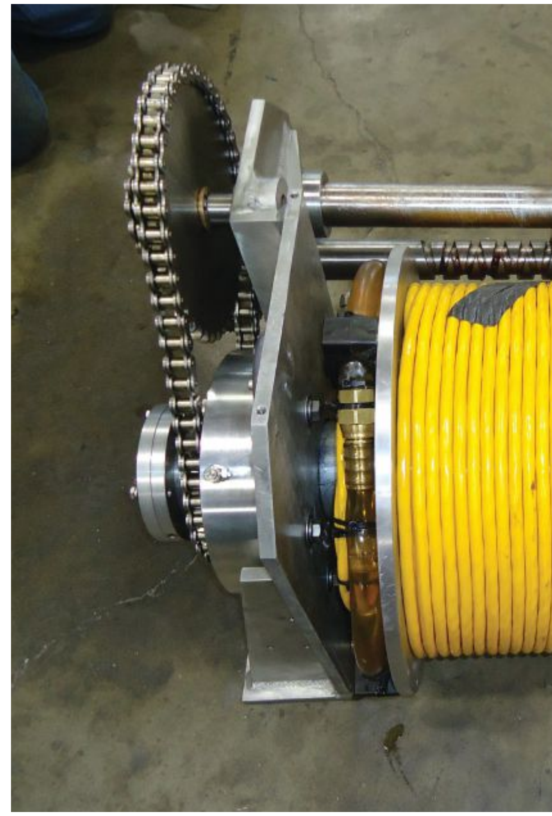
Underwater winches are used to perform a range of critical undersea tasks. Common applications include anchoring an unmanned asset, managing an ROV's tether system, or deploying marine scientific equipment. Underwater winches can be deployed on the seafloor or within the water column, mounted on a subsurface platform. While their use in the field is nothing new, in the age of autonomy they will prove instrumental to modern-day remote projects in ocean exploration, homeland security and defense, and offshore infrastructure development.

They can carry out their missions under a pre-programmed profiling schedule (autonomously), periodic commands/data download via surface penetrating buoy and antenna or passing AUV, or remotely from a permanent comms cable installed on a seafloor, which ultimately reduces the need for the ongoing support of a topside vessel to operate long-term missions. This paradigm shift is the key to unlocking game-changing operational efficiencies and increasing operation windows while also keeping more humans out of harm's way.

Underwater winches of tomorrow will transform the mechanical workings of this emerging network of remotely supervised offshore equipment and interconnected seabed infrastructure. These seafloor installations are particularly relevant to long-term defense missions or marine surveys that call for periodic data sampling over a sustained period. *As we continue to explore subsea autonomy, our reliance on underwater winches to serve additional subsea applications will undoubtedly grow.*

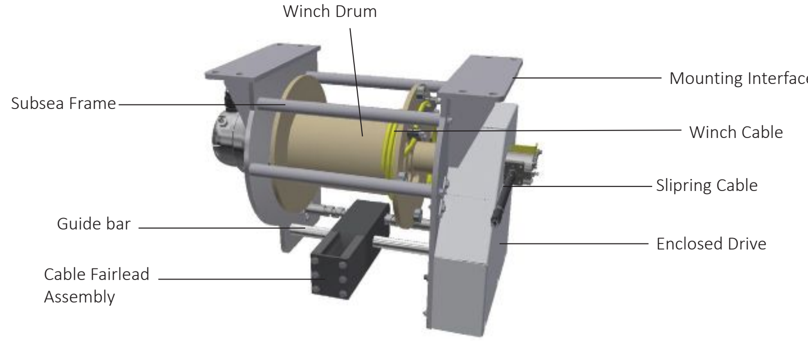
DESIGN DELIBERATIONS

However, a winch is never *just* a winch, especially when handling critical—and challenging to recover—subsea assets. Some design considerations, as one might expect, mirror general deck-based oceanographic winch design parameters, such as line pull, line speed, minimum bend radius of cable,



» *Bottom image - The successful integration of progressively autonomous systems, such as USVs/UUVs, is reliant on failproof handling systems, above and below the waterline. (Image credit: Okeanus)*

Underwater Winch



» *Underwater winches are engineered to function without constant supervision and so product development often hinges on input from customer requirements. (Image credit: Okeanus)*

» *Top image - Underwater winches can be deployed on the seafloor or within the water column, mounted on a subsurface platform. (Photo credit: Okeanus)*

cable diameter, and cable length. Others relate more directly to the exacting in-field requirements, such as water depth, mounting (UUV vs. seafloor mounted), duration of deployment, and controls and comms (autonomously commanded by host or remotely controlled by shoreside operator). Power budgeting and optimization is also critical, especially if the system is to be operated using battery power.

For longer deployments, material selection—and corrosion—is imperative. The need for special materials, cathodic protection, and coatings may be essential depending on the specific tasks or subaquatic environments. Further, it is not just the corrosive nature of seawater that poses a threat to failproof operations; biofouling—the undesirable accumulation of microorganisms, plants, algae, and animals on submerged surfaces—can severely compromise the moving parts of an underwater winch.

Finally, underwater winches, for the most part, are designed to function without the need for constant supervision. Therefore, there must be confidence that the winch will perform to specification. This stage of product development involves complex analysis that often requires inputs from customer developed systems, or third-party systems, to ensure that the winch can monitor its health/status and report as needed.

STAGE GATE PRODUCT DEVELOPMENT

Suffice to say, there is no "one size fits all" when it comes to underwater winches or understanding how they will shape the future of offshore activities. As such, they tend to be custom designed or variants of existing blueprints. The process of engineering a fit-for-purpose, field-ready unit always begins with a set of requirements or statement of work, usually drawn up in partnership between client and manufacturer. In our case, the Okeanus team follows an established and well-defined product development process:

1. **Preliminary design phase:** the application of general design guidelines to the requirement set, which results in a preliminary design that meets the requirement/statement of work.

2. **Detailed design phase:** the selection of components to meet the design requirements and analysis of the structure/material chosen. At this stage, design refinements are made as required, amid the creation of detailed production and interface drawings

3. **Prototyping and testing phase:** depending on the systems complexity, this phase will result in a fully functional unit being available for ongoing testing. Any future requirements are logged centrally to ensure that the next generation of winch addresses concerns that were not within the initial scope of work.

4. **Final build phase:** this is the green light for production.

Naturally, the design of the winch is directly related to the duration of mission deployment because maintenance is nearly impossible while in the field. Our underwater winch designs must be simple and robust, yet guarantee the operation as required. Okeanus uses a variety of materials in construction to extend the lifespan of our winches, including stainless steel, anodized aluminum, and titanium. Okeanus also offers expert marine winch maintenance services at our facilities in Houston, TX, Houma, LA, and East Greenwich, RI.

For more information, visit:
www.okeanus.com.

THE FUTURE OF ON&T

By Your ON&T Team

> Our collective ability to document applied technology in the field has never been greater.

2021 was ON&T's 40th year. A lot has happened over the past four decades, so as we embark on our fifth in print, the future of ON&T is nothing short of irresistible for our dedicated editorial and production team. Keeping our readership informed of the latest news and industry insights is more than a labor of love—it is our shared passion. But none of this would be possible without the ongoing support and collaboration of our industry partners and loyal advertisers. So, first and foremost, thank you.

Now, amid all the expert forecasting in this edition of *The Future of Ocean Technology*, you might ask: what does 2022 hold for ON&T?

STAYING ON COURSE

As always, ON&T will continue to diligently report on the latest technologies and groundbreaking developments from the offshore energy, defense, and scientific industries, but our editorial coordinates are continually recalculated by the expanding capacity and application of ocean technology. Our plotted course for 2022—our new editorial calendar, which also details our planned show distribution—is available for download at *www.oceannews.com/2022-media-card*, but we see a number of dominant themes for the coming year, mostly fueling the drive for increased efficiency of at-sea operations, optimized HSSE, and, of course, a ever more carbon conscious approach to offshore activities. The ongoing adoption and scalability of autonomous systems will likely prove instrumental to all three. Should there be additional topics you would like to see covered in the future, don't hesitate to contact us.

A QUICK SNAPSHOT

Pick up an early edition of ON&T and you might graciously concede that the magazine has, over time, shed its 1980s stylings in favor of a look more befitting 2021. Such is the world of fashion. And like any trendsetter, 2022 will see ON&T introduce a few minor aesthetic tweaks, here and there. But one of the more impactful ways we enjoy bringing the wonderment of the ocean industries to the armchair is through strong photography. Our collective ability to document applied technology in the field has never been greater. Today, our magazine is flooded with your hi-res images of ocean tech in action. And we are always looking for fresh impetus. Get clicking.

AND YOUR OPINION?

If this Special Edition is anything to go by, this is a sector with plenty to say. Our ultimate goal here at ON&T is to celebrate creative thinking and profile thought leadership. Each edition features an exclusive "OpEd" alongside our Table of Contents, but we would like to expand this opportunity further in 2022. If you have an opinion, we want to hear from you.

BE HEARD

Launched in 2020, ON&T's podcast, SeaState, has proven a huge hit with guests and listeners alike. Details of our scheduling for 2022, which kicks off in January with an episode about deep-sea biology, can be found here: *www.oceannews.com/seastate*. There are 11 editions planned for the year, one each month plus an end-of-year special in December. If you want to be heard, let us know.

So, in short, the future of ON&T centers around you, the reader. We believe ON&T—the magazine, newsletter, or website—is the ocean tech community's premier media platform and we are here to make your content count.

So, what now? Let's talk about the future: *editor@oceannews.com*.

MONTH & DEADLINES	EDITORIAL FOCUS & SHOW DISTRIBUTION	CONTENT FOCUS & PRODUCT/SERVICE
JANUARY Editorial: Dec. 17 Ad: Jan. 13	» **Uncrewed Surface Vehicles** Floating Wind Solutions / March 1-3 US Offshore Wind / March 16-17 Oceanology International / March 15-17	**Content Focus:** Remote Marine Operations, Force Multiplication, Ocean Research, Search & Rescue, Tooling **Product/Service:** A/USV manufacturers, multibeam echosounders, side scan sonars, control systems, thrusters, positioning systems, thermal cameras, communication systems
FEBRUARY Editorial: Jan. 24 Ad: Feb. 10	» **Naval Defense & Security** CUCE / March 27-29	**Content Focus:** Intelligence, Surveillance & Reconnaissance (ISR), Mine Countermeasures (MCM), Harbor Security, Anti-Submarine Warfare (ASW) **Product/Service:** AUVs, USVs, marine robotics, search and rescue technologies, underwater tracking & communications
MARCH Editorial: Feb. 21 Ad: Mar. 10	» **21st Century Marine Survey** AUVSI XPONENTIAL / April 25-28 H2O Conference / June 14-16	**Content Focus:** Hydrographic Survey, Sensor Innovation, Research Vessels **Product/Service:** Sensor manufacturers, UAVs, multibeam echosounders, sonars, software & analytics, deck handling equipment, survey companies, research vessels
APRIL Editorial: Mar. 21 Ad: Apr. 07	» **Green Energy**	**Content Focus:** Renewable Offshore Energy (Wind, Solar, Tidal & Wave), Green Hydrogen, Power Storage Supply Chain **Product/Service:** Offshore wind supply chain, alternative offshore energy technologies, subsea batteries, hydrogen powered vessels
MAY Editorial: Apr. 18 Ad: May 05	» **Subsea IMR Technology**	**Content Focus:** Shore-based Command Systems, Subsea Residency, Digital Twins **Product/Service:** AUVs, ROVs, robotic tooling, buoyancy materials, cameras & lighting, pressure sensors, propellers, tethers, simulation software
JUNE Editorial: June 06 Ad: June 23	» **Oceanography**	**Content Focus:** Data Collection, Transmission & Communication, Data Analytics & Software Platforms **Product/Service:** Buoys, drifters, acoustic modems, releases & transponders, magnetometers, subsea cables, connectors, weather stations
JULY Spotlights: June 14 Ad: July 11	» **Uncrewed Vehicles Buyers' Guide** 💻	**Content Focus:** Special Edition
AUGUST Editorial: July 25 Ad: Aug. 11	» **Submersibles & The Deep Sea**	**Content Focus:** Deep-sea Exploration, Seafloor Archaeology, Deep-sea Science, Ocean Mining **Product/Service:** Crewed submersibles, support vessels, mining machines, geotechnical technologies
SEPTEMBER Editorial: Aug. 22 Ad: Sep. 08	» **Artificial Intelligence & Remote Marine Operations**	**Content Focus:** Swarm Technology, Control Systems, Automation, Ocean Health, Maritime Efficiency **Product/Service:** Uncrewed vehicles, simulation & modelling platforms, cloud-based data analytics
OCTOBER Editorial: Sep. 19 Ad: Oct. 06	» **Offshore Energy**	**Content Focus:** Sector Diversification, Seabed IMR, Sensor Innovation, HSSE, Decommissioning, Oil Spill Response, Renewables **Product/Service:** Marine survey, oil spill response, renewable energy technologies, geotechnical services
NOVEMBER Editorial: Oct. 17 Ad: Nov. 03	» **Underwater Imaging**	**Content Focus:** Bathymetric Mapping, IMR, Habitat Characterization, Acoustic Sensing **Product/Service:** Observation ROVs, AUVs, cameras, lights, diving innovation, tracking & positioning systems, optical and acoustic sensors
DECEMBER Editorial: Nov. 14 Ad: Nov. 18	» **The Future of Ocean Technology**	**Content Focus:** Special Edition

💻 Digital Issue


From shallow to deep-water
sites, our experienced engineering team develops and deploys innovative in situ seabed investigation methods and custom technologies that guarantee best-quality geotechnical, geophysical, and environmental data and analysis.
With an established track record of partnering with the offshore energy, marine mining and trenching industries, we're helping redefine geoscientific exploration.
Find out how at bluefieldgeo.com
Bluefield Geoservices
Geoservices | Engineering | Technology


OCEANEERING®
Connecting What's Needed with What's Next™
READY TO (REMOTE) WORK
The future of remote operations is already here. Oceaneering offers proven, integrated remote services from shore to carry out offshore survey, rig positioning, inspections, UWILDs, commissioning and monitoring activities, and more.
Connect with what's next at oceaneering.com/remote-services
Copyright © 2021 Oceaneering International, Inc. All rights reserved.


GREENSEA
OPEN
ARCHITECTURE
ROBOTICS FOR MILITARY AND MARINE APPLICATIONS
Greensea develops OPENSEA® for the most demanding applications in the world.
OPENSEA, an open architecture software platform, integrates across vehicles, sensors, and payloads regardless of manufacturer. Systems built on OPENSEA core are ready for tomorrow as developing technologies can be added and dispensable technologies can be removed.
The future demands open architecture. OPENSEA provides the solution.
Call 802.434.6080 or visit: Greensea.com/technology
Visit Greensea.com/events for access to webinars on open architecture, robotics, and more.
©2021 Greensea Systems, Inc. | Greensea®, OPENSEA® are registered trademarks of Greensea Systems, Inc.