MARINE TECHNOLOGY REPORTER

May 2019

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Covert Comms

New Tech holds promise for defense operations

DOLPHIN
Enabling technology for acoustic systems

Break a Wave
SurfWEC's answer to efficient wave generated power

By-Pass Superfast
Chrysaor and Subsea 7 nimbly deal with a blocked pipe

Volume 62 Number 4

Marie Fleetwood

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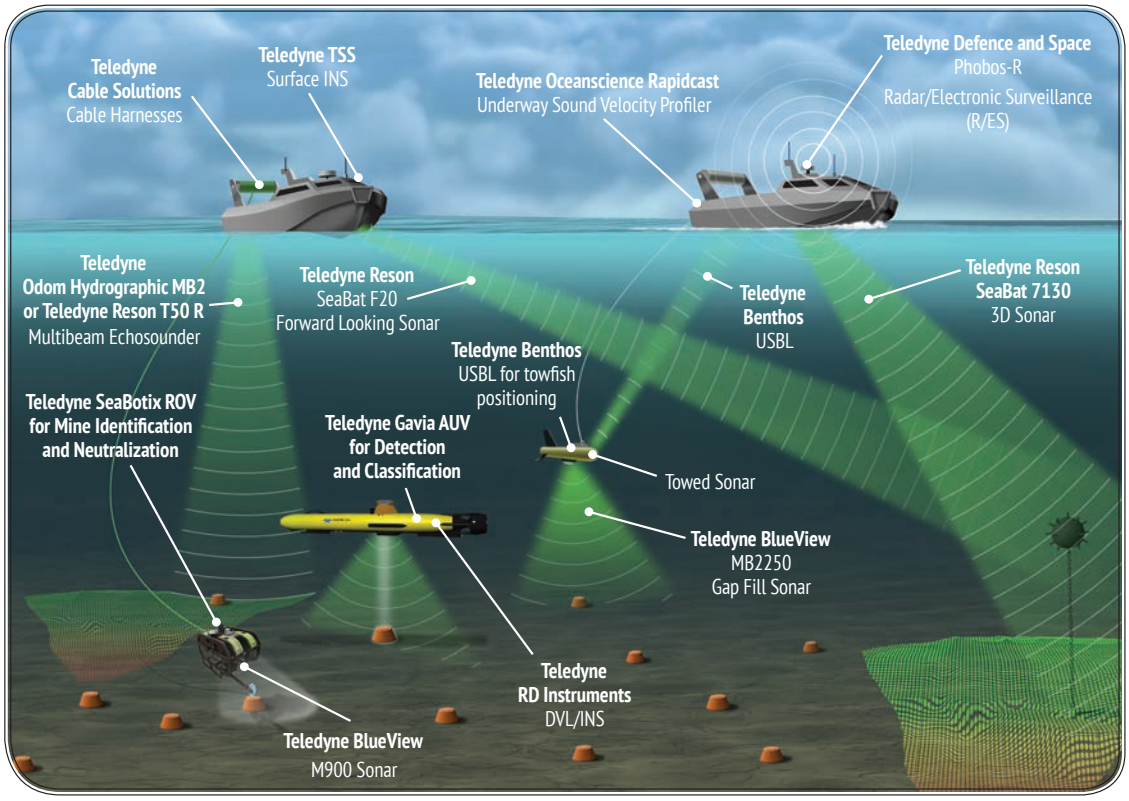

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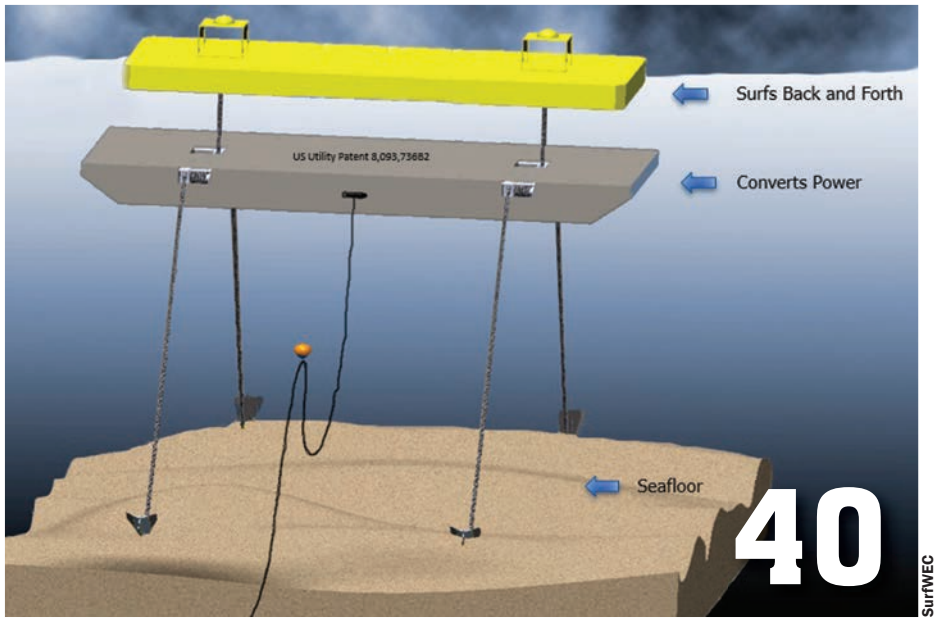

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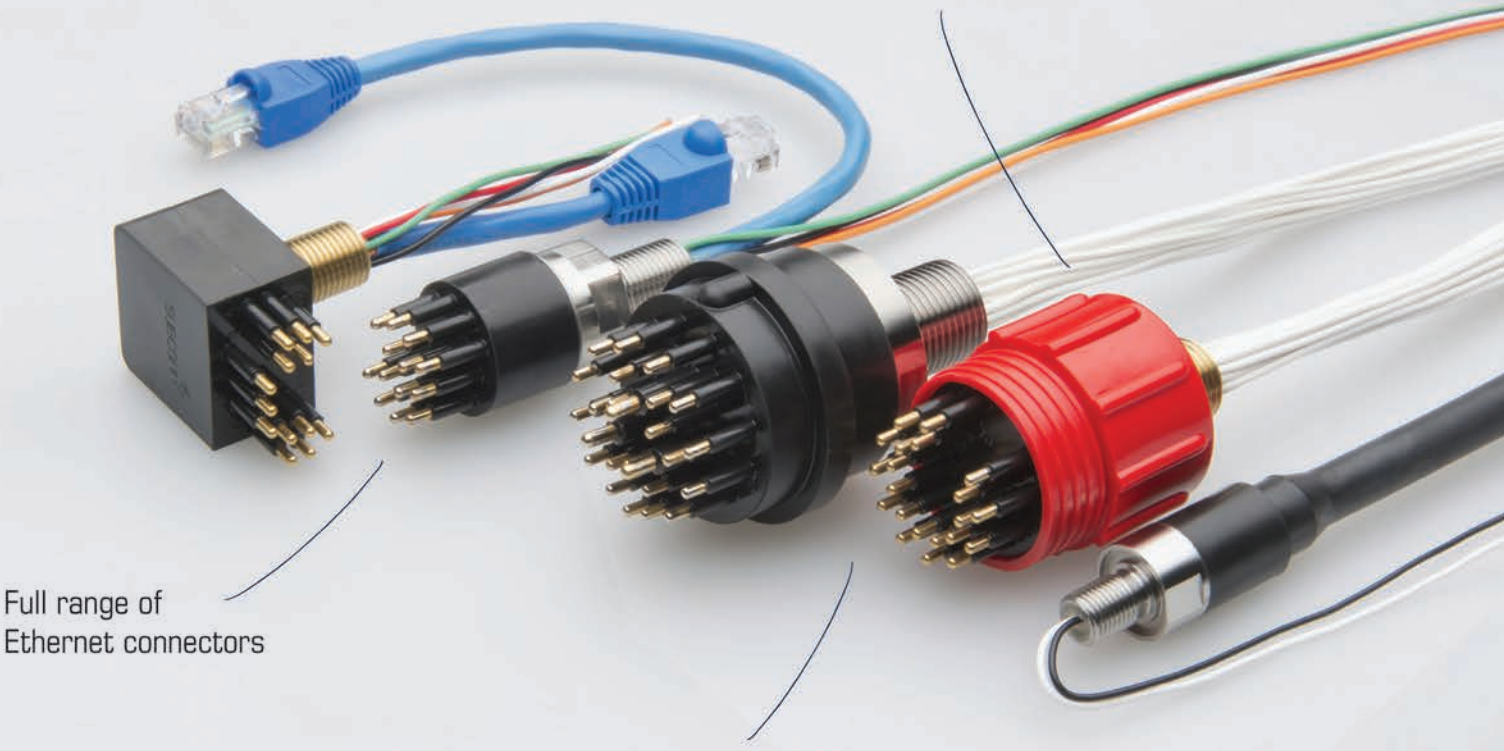

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Editor's Note

Making Waves

As the saying goes, "if you can't beat 'em, join 'em", which is exactly the attitude that **Michael Raftery**, CTO, SurfWEC had when he envisioned the Wave Energy Harnessing Device. Generating power from waves, at least generating power at the utility scale, has proved to be an elusive engineering task, and the advent of wave energy is still in its infancy. But with the world turning decidely 'green', there could be political will, and more importantly funding and subsidies, to help the wave energy industry evolve into adolescence and keep pace with developments on other green energy technologies, namely solar and wind. In the case of SurfWEC, the reference to "join 'em" was not speaking to competition from other devices, rather to the waves and the ocean themselves. One of the big challenges with many wave energy devices is the matter of positioning it in the surf itself, guaranteeing a steady stream of power-producing waves while keeping the unit intact in this rough water environment. Raftery believes he has found the solution with the patented Wave Energy Harnesing Device because the unit effectively creates its own surf. In principle the SurfWEC system can be placed anywhere where there are ocean waves and water depths are from 135 to 1000 ft., and it is, in fact, a major design feather in SurfWEC's cap that the system need not be placed directly in the surf zone to work. It is designed to be a 'one size fits all' solution, and it leans on a neural network to keep the variable-depth platform at the optimal depth at all times. The complete story on this innovative new solution starts on page 40.

Gregory R. Trauthwein
Associate Publisher & Editor

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Valeport: New Enviro Range

Valeport has launched a new Enviromental range of optical sensors.

Hyperion Turbidity – A standalone turbidity sensor with a small footprint to combine Nephelometer and OBS readings in the same instrument. Created for inshore, coastal and oceanographic monitoring, it delivers a minimum detection level of just 0.03 NTU (nephelometer) and can measure turbidity up to 6,000 NTU (OBS). Features titanium housing, data output up to 16Hz and low power requirements.

SWiFTplus Fluorometer – This range of probes combine the power of the SWiFT technology and a fluorometer for the high performance measurement of Chlorophyll a, Fluorescein, Rhodamine or Phycocyanin. The suite of instruments are ideal for shallow water bathymetric and environmental survey, where observations can be monitored and recorded for surveys for up to three days continuous operation.

www.valeport.co.uk

Turner Design's C-FLUOR

C-FLUOR Submersible Probes are sensitive, low-power single wavelength in-situ fluorescence and turbidity sensors available in several optical configurations. Requiring a maximum of 12mA current at 12VDC input, according to their manufacturer C-FLUOR probes can be integrated and deployed for much longer intervals than previously possible with submersible probes. And, with a very fast response time of less than 0.6 seconds, they require even less power, outputting data soon after power is applied. Factory-calibrated, each C-FLUOR ships with a calibration certificate used to convert the analog output signal to a specific concentration estimate. The Titanium construction allows for a depth rating of 2,000 meters as well as superior resistance to corrosion.

www.turnerdesigns.com

Hydramec Electric AHC LARS

Hydramec Offshore completed the supply, integration and operational testing of a fully Active Heave compensated Launch and Recovery System for a Saab Seaeye Cougar XT ROV to the New Zealand Navy.

The New Zealand Navy having acquired Ostensjo's EDDA FONN multipurpose vessel for conversion to a diving support vessel required an ROV to assist with diving support and other operations.

The Supply Brief for the LARS system was very specific, the winch system had to be electric driven and have AHC capability for operations in up to sea state 6. The A-Frame needed to be designed so that it would dip 1.2m below the deck level of the launch hanger to reduce the air gap between the launch point and splashzone. It was also specified that the A-frame must have an outreach of 5m from the vessels side. Scantrol AS is Hydramec's supplier of AHC control systems.

Deep Trekker launches DTG3

Deep Trekker, a manufacturer of remotely operated vehicles (ROV), recently launched the DTG3 ROV and introduced BRIDGE technology. BRIDGE technology is comprised of custom hardware, software and integration. BRIDGE is a platform that will become the base for future products, new and advanced features and third-party integrations by Deep Trekker. The new DTG3 ROV can work to depths of 305 meters (1000 ft). An enhanced viewing and recording experience provide smarter inspections with its live, 4K video and waterproof handheld controller. Coupled with BRIDGE, DTG3 is designed to provide advanced stability even in rough underwater environments; the freedom to move with direct sonar integration, and an automated station holding capable of rotating 270 degrees.

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The Navigator, a second generation Sonar Imaging and Navigation system, designed by Shark Marine primarily for MCM and SAR use.

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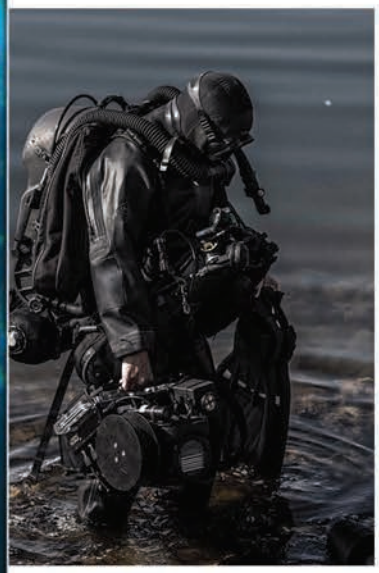
Tested and proven, the Navigator is the trusted choice of 17 Navies, as well as Law Enforcement, Search and Rescue Teams and Scientific Researchers spanning the globe. The Navigator has become a critical part of the Standard Kit and has reshaped SOPs. The modularity of the system and numerous advanced sensors available allow the Navigator be to become a force multiplier, enabling smaller groups to cover more ground efficiently with increased safety.

Mission Ready

The Navigator is the most modular system of its kind, enabling it to be quickly configured for any application.

Intuitive

Shark Marine's DiveLog software controls all operations of the navigator and its accessories, operators need only learn one software to master all their equipment.



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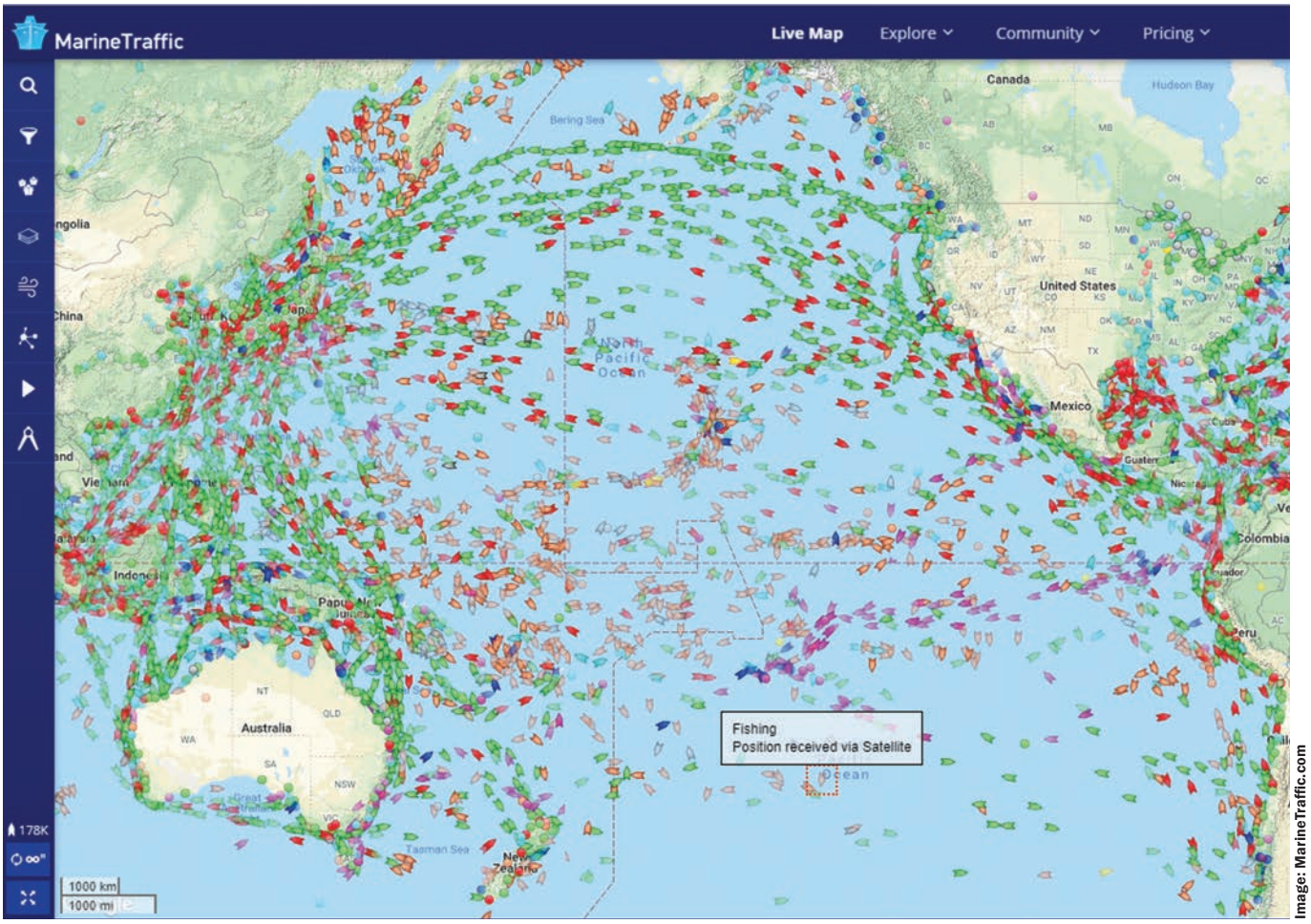
AIS DATA

Governments are now using AIS in an innovative manner by creating virtual aids-to-navigation that provide an AIS signal to mark hazards to navigation in locations where a physical aid-to-navigation does not exist.

By Dennis Bryant

The Automatic Identification System (AIS) was developed with the sole goal of improving maritime safety by allowing ships in proximity to one another to automatically exchange information regarding their name, course, speed, type, cargo, etc. The exchange of this information would allow conning officers on each ship to make better decisions regarding the possibility of close encounters and the need to change course and/or speed. It would also make it easier for one ship to contact the other by radio-telephone to hopefully remove any doubt. To that extent, AIS has largely worked as intended, although collisions continue to occur.

It did not take long, though, for governments to get involved.



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Teledyne's proven proton exchange membrane (PEM) fuel cell technology provides excellent efficiency and long life (>10,000 hrs.). The stack design is specifically tailored for operation with pure oxygen and includes design aspects generated through years of experience with this technology. The fuel cell system features an integrated balance-of-plant (BoP) with ejector driven reactant (EDR) technology for reactant recirculation. The BoP allows the fuel cell stack to be fed reactants in a "dead-ended" configuration maximizing energy delivery.

Reactant Storage

The fuel cell system is reactant storage agnostic. Reactants can be suppplied via compressed gas, cryogenic, or solid-state reactant storage systems. The Subsea Power Node is equipped with a compressed-gas reactant storage system. This storage system is at a technology readiness level (TRL) of 9 and is commercially refillable.

High TRL

Teledyne has a proven history of supplying high reliability fuel cells to NASA and other customers.

For more information:

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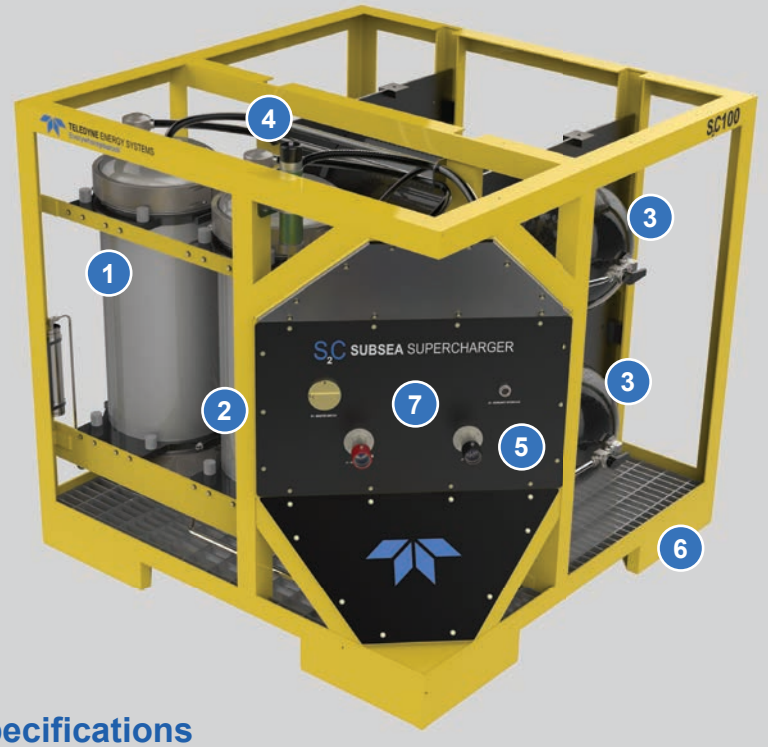
S_2C100 Series



Specifications

1 EDR Fuel Cell System Module
- Minimal components for maximum reliability
- 8 kW power output (per module)
- Module capable of processing > 30 MWh of energy
- Operation at full ocean depth

2 Hybridization / Power Conditioning Module

3 Reactant Storage (H_2/O_2)
- Modular to meet energy and reactant storage system requirements

4 Teledyne Benthos Acoustic Modem

5 Subsea Tested Components
- Teledyne ODI wet mate connectors
- Electrical power and data transfer

6 Skid Details
- 1.6m X 1.6m X 1.5m
- 1300 kg mass in air (500 kg wet)
- Marine recovery system available

7 Electrical Output
- Voltage range: as specified
- Power: 1-8 kW continuous output

They started installing shore-based receivers to monitor AIS transmissions from approaching ships, out to a point just beyond the horizon. Those governments could also monitor ships in harbors and transiting off the coast or on inland waterways. The United States incorporated this data into its maritime security or maritime domain awareness programs. Governments also utilize the data to analyze marine casualties and to determine waterway usage. A large amount of AIS data is collected by governments around the world, which share much of that data amongst themselves. There are also commercial companies that collect AIS data, including several that utilize satellites to collect this data from ships on the high seas outside the range of land-based AIS receivers.

Governments are now using AIS in an innovative manner by creating virtual aids-to-navigation that provide an AIS signal to mark hazards to navigation in locations where a physical aid-to-navigation does not exist. The virtual aid appears on the electronic chart display and information system (ECDIS) of ships within range and they know (or should know) to avoid the location. By combining AIS data with other information, such as photos from surveillance aircraft or satellites, correlations can be made between individual vessels and pollution incidents. Use of AIS data from commercial services can allow traders and others to track vessels (and their cargoes) worldwide, making it difficult for vessels to arrive unexpectedly and influence a market.

As we learned in a recent report of the U.S. Committee on the Marine Transportation System (CMTS), three federal agencies generate terrestrial AIS-derived information. The U.S. Coast Guard focuses primarily on coastal areas, ports, and harbors. The U.S. Army Corps of Engineers (USACE) focuses on AIS products for inland waterways. The Saint Lawrence Seaway Development Corporation (SLSDC) focuses on the St. Lawrence Seaway and associated waters.

Numerous other federal agencies utilize AIS data in furtherance of their missions. The National Oceanic and Atmospheric Administration (NOAA) utilizes AIS data to monitor and analyze fishing activity; improve marine mammal protec-

tion; and prioritize charting and surveying based on measured traffic volumes. The Bureau of Ocean Energy Management (BOEM) uses AIS data to support its marine planning needs associated with offshore energy development.

The Maritime Safety and Security Information System (MSSIS) is a government-to-government data sharing network operated by the Department of Transportation. It combines AIS data from 74 participating nations into a single raw-AIS data stream that collects over 150 million vessel position reports per day from approximately 60,000 vessels. The combined data is available in several different formats to participating governments and federal agencies.

NOAA and BOEM jointly manage MarineCadestre.gov, a Geographic Information System (GIS)-based marine data viewer and repository that provides decision support tools for siting of offshore energy development, aquaculture, and other activities.

Because AIS data is stored on the Electronic Chart Display and Information System (ECIS) devices carried on most vessels engaged in international commerce, it has become the go-to location for marine casualty investigators and, in the event of litigation, for legal counsel. Almost every marine casualty report published by flag state or port state includes AIS data and an analysis of the movements of all vessels involved in the casualty based on that data. Interviews of crew members are still important, but actual ship movements as recorded in the AIS data tends to be the dominating factor in the analysis – and always prevails in the event of conflicts between different sources of information. The AIS data does not reveal why particular actions were taken, but it is almost always given full weight in determining what actions were.

AIS has expanded far beyond its original purpose and it is hard to imagine maritime operations in today's complex environment without it. It is not, though, a panacea. The Automatic Identification System is clearly an important tool, but must continue to be used with caution, recognizing its inherent limits, as well as future possibilities, including the increased prevalence of automated ships.

New View of the Ocean Floor

Otherworldly Mirror Pools, New Lifeforms, and Mesmerizing Landscapes Discovered on Ocean Floor

Scientists aboard Schmidt Ocean Institute's research vessel Falkor discovered and explored a hydrothermal field at 2,000m depth in the Gulf of California where towering mineral structures serve as biological hotspots for life. These newly discovered geological formations feature upside down 'mirror-like flanges' that act as pooling sites for discharged fluids.

While exploring hydrothermal vent and cold seep environments, Dr. Mandy Joye (University of Georgia), and her interdisciplinary research team discovered large venting mineral towers that reach up to 23 meters in height and 10 meters across. These towers featured numerous volcanic flanges that create the illusion of looking at a mirror when observing the superheated (366ºC) hydrothermal fluids beneath them. The minerals across the features were laden with metals and the fluids were highly sulfidic, yet these sites were teeming with biodiversity and potentially novel fauna.

"We discovered remarkable towers where every surface was occupied by some type of life. The vibrant colors found on the 'living rocks' was striking, and reflects a diversity in bi-

The Oil Chimney Landscape.

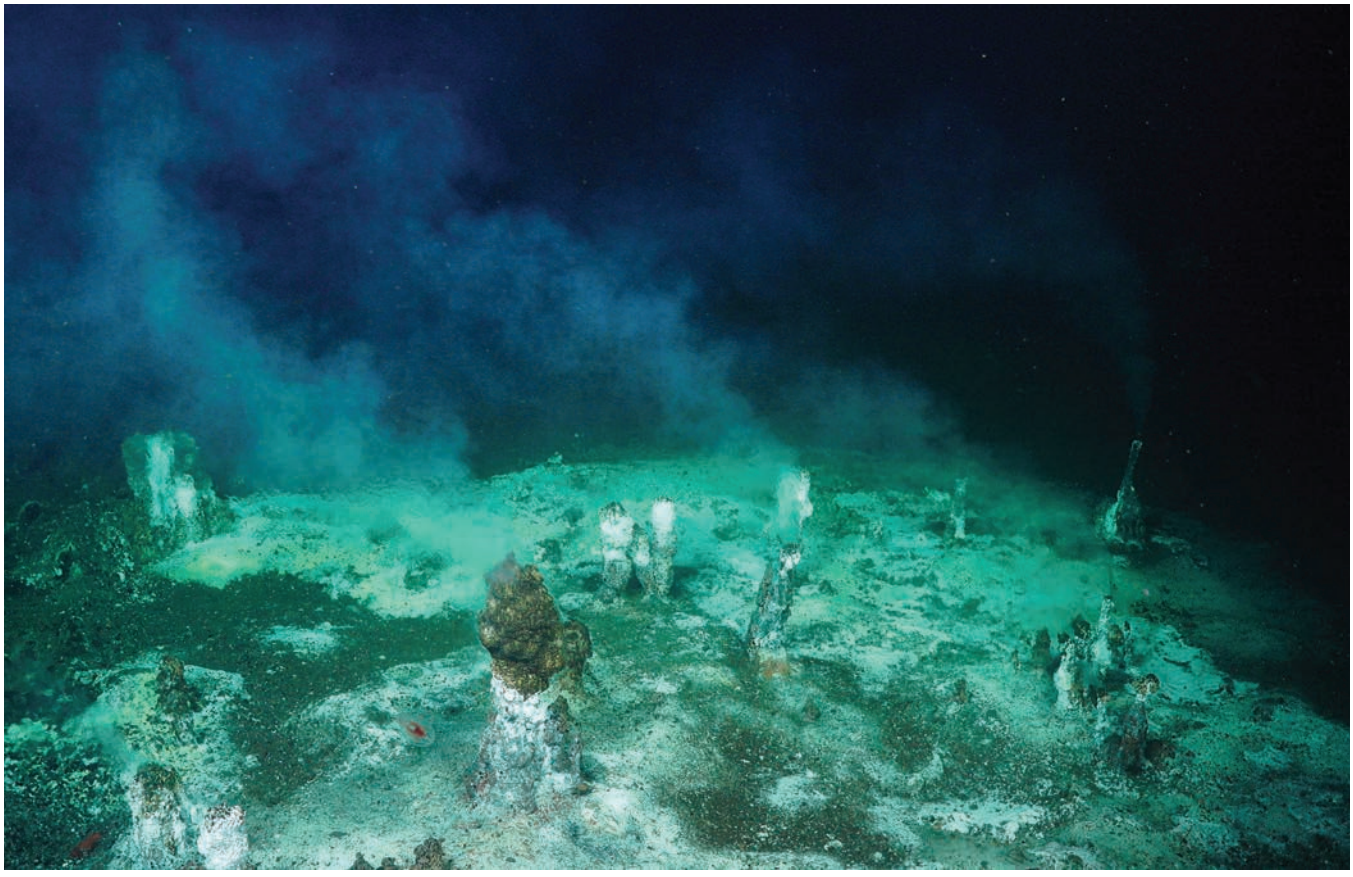


Image: Schmidt Ocean Institute

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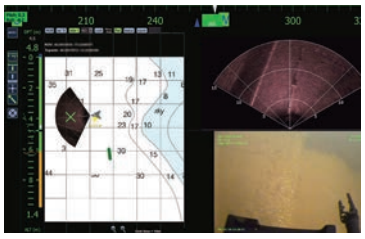

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Above:
You can see the reflection of the ROV SuBastian in the eye of this octopus.

Inset:
In the Control Room

Below:
SuBastian measuring the temperature of the Hydro-thermal vent

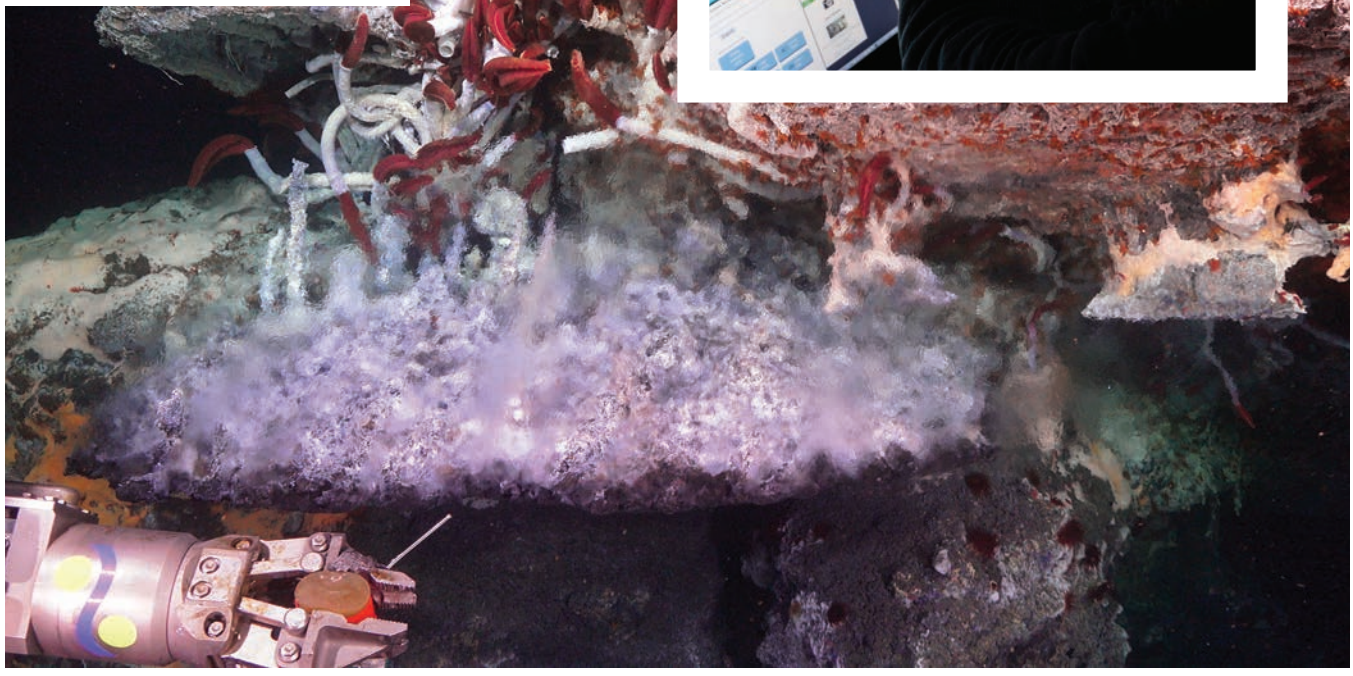

Image: Schmidt Ocean Institute

Image: Schmidt Ocean Institute

ological composition as well as mineral distributions," said Dr. Joye. "This is an amazing natural laboratory to document incredible organisms and better understand how they survive in extremely challenging environments. Unfortunately, even in these remote and beautiful environments we saw copious amounts of trash including fishing nets, deflated Mylar balloons, and even a discarded Christmas trees. This provided a stark juxtaposition next to the spectacular mineral structures and biodiversity."

The expedition was an unprecedented study of hydrothermal and gas plumes, with researchers using 4K deep-sea underwater cameras and radiation tracking devices, as well as sediment and fluid samplers working via a remotely operated vehicle, ROV SuBastian. To get a true measure of methane and other volatile substances existing in the deep sea, scientists need to capture the samples at the source. The scientists were able to do this with a unique osmo sampler, a device that draws hydrothermal fluids into small capillary-like tubing, mounted onto the ROV. Several other in-situ experiments were performed, including a high throughput water filtration for viruses that allowed the team to reduce processing bias.

From super-hot hydrothermal vents to slowly discharging cold seeps, the common thread of the sample collections involved studies of methane cycling. Hydrothermal fluids and gas plume samples all contained highly elevated concentrations of methane and surface-breaching methane hydrate mounds. Methane is a potent atmospheric greenhouse gas, 30 times the strength of carbon dioxide, and this study will advance the knowledge of the biological storage for methane in water column and sediment systems.

"It is a different world down there. Each dive feels like floating into a science fiction film," said Schmidt Ocean Institute Cofounder Wendy Schmidt. "The complex layers of data we've collected aboard Falkor during this expedition will help tell the story of this remote place and bring it to public attention. Witnessing these remarkable oceanscapes, we are reminded that although they are out of our everyday sight, they are hardly immune from human impact. Our hope is to inspire people to learn more and care more about our ocean."

The team will now spend the next few months analyzing samples and plans to publicly share the results. As the different data sets are synthesized, scientists will generate a more complete understanding of the Gulf of California system. This understanding will be applicable to oceanic environments around the globe, as well as allow scientists to identify and frame exciting new questions.

Above:
The science team.

Inset:
Setting the CTD @ sunset.

Below:
An ROV water sample.

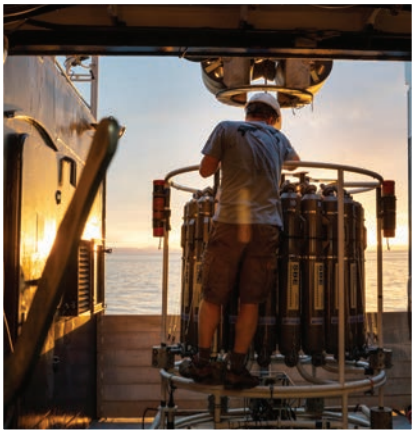

Image: Schmidt Ocean Institute

Image: Schmidt Ocean Institute

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DOLPHIN

Enabling Technology for Acoustic Systems

Justin Manley, Just Innovation
Michael Murphree, QinetiQ North America
Greg Folts, QinetiQ North America

Figure 1: The basic concept of DOLPHIN

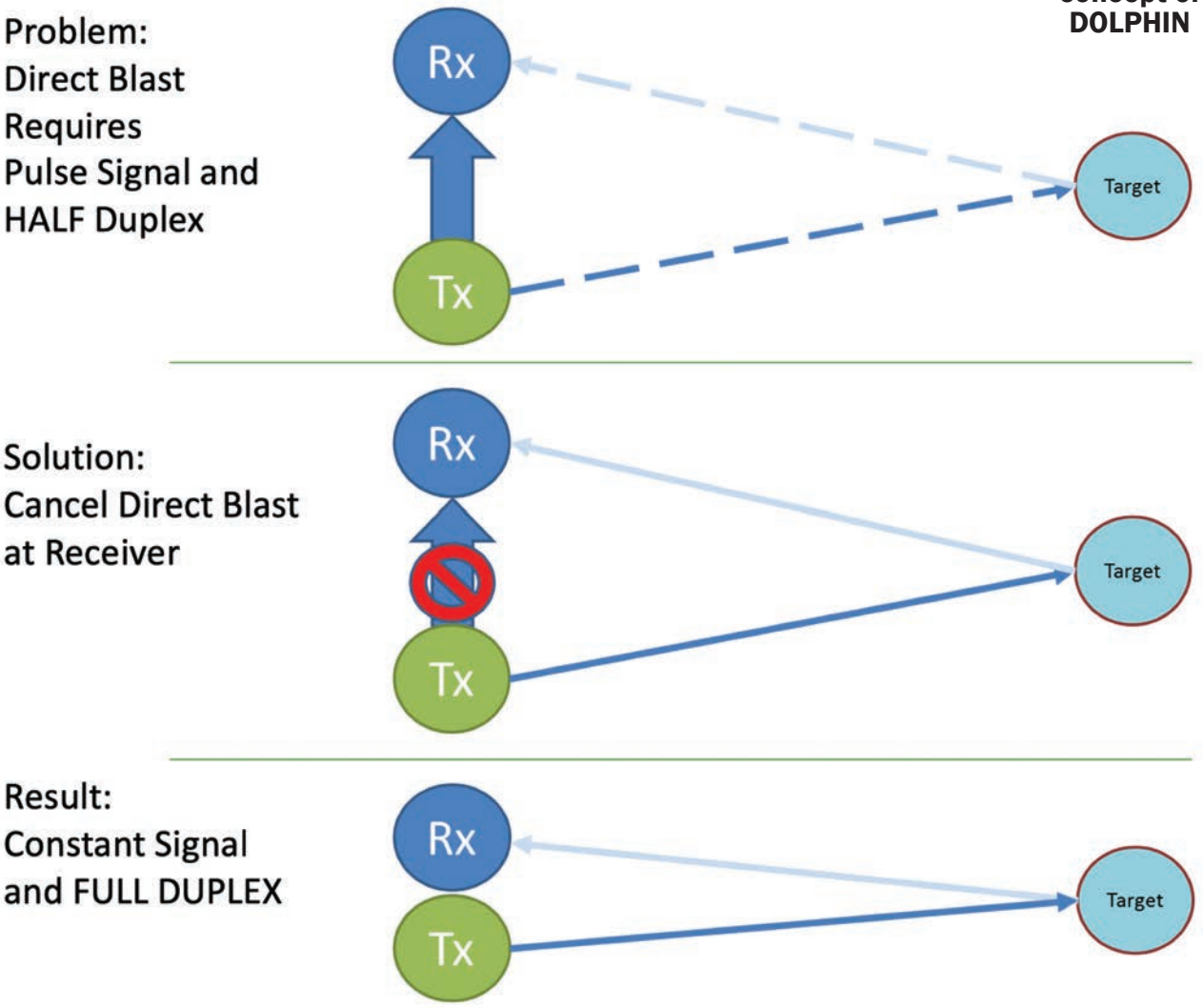

Image: QinetiQ North America

DOLPHIN Signal Processing Technology

Acoustics enable many core undersea capabilities. Where radio waves do not propagate well, and light is absorbed quickly, acoustic signals help us map, see, locate and communicate. The many products and technologies that employ acoustics all depend upon signal processing, thus new processing approaches can impact many applications. QinetiQ North America (QNA) and its partner Optimal Systems Laboratory (OSL) have developed DOLPHIN - a patented method using analog cancellation that eliminates receiver saturation and enables simultaneous transmit and receive. Figure 1 (to the left) describes this concept.

Application to Underwater Telemetry

Since the beginning of acoustic communications, the state-of-the-art technology has been limited to half-duplex signals: transmit with the receiver off and then turn the transmitter off and receiver on and wait to receive, because the direct transmission at the source saturates the receiver electronics if they are enabled simultaneously.

Ocean physics are fixed, but DOLPHIN technology enables true full-duplex acoustic telemetry. It cancels the transmit signal at the receiver in real-time. This eliminates receiver self-signal saturation and enables simultaneous transmitting and receiving on the same frequency, with collocated transducers. The DOLPHIN technology is frequency and range independent – thus yielding flexible new approaches to underwater communications and sensors.

In practice, the impact of full duplex comms vs standard half duplex comms can be viewed in terms of the change in data throughput (speed of receipt of meaningful information). This can be generically viewed in terms of data rate vs range. Figure 2 (on the next page) shows a generalization of the benefits of DOLPHIN Comms vs traditional approaches.

The positive benefits are particularly clear as the number of nodes in a half-duplex (mobile or static) network increase. While increasing nodes degrades the overall throughput of conventional, half-duplex networks, modeling and testing show that DOLPHIN Comms networks will maintain consistent performance. This is even more evident in networks of moving nodes where half-duplex networks generally cease to function with more than two nodes. But full-duplex networks of more than two moving nodes are possible and maintain high data throughput. This demonstrates the value of the DOLPHIN Comms technology in enabling networks of moving nodes, like swarms of UUVs.

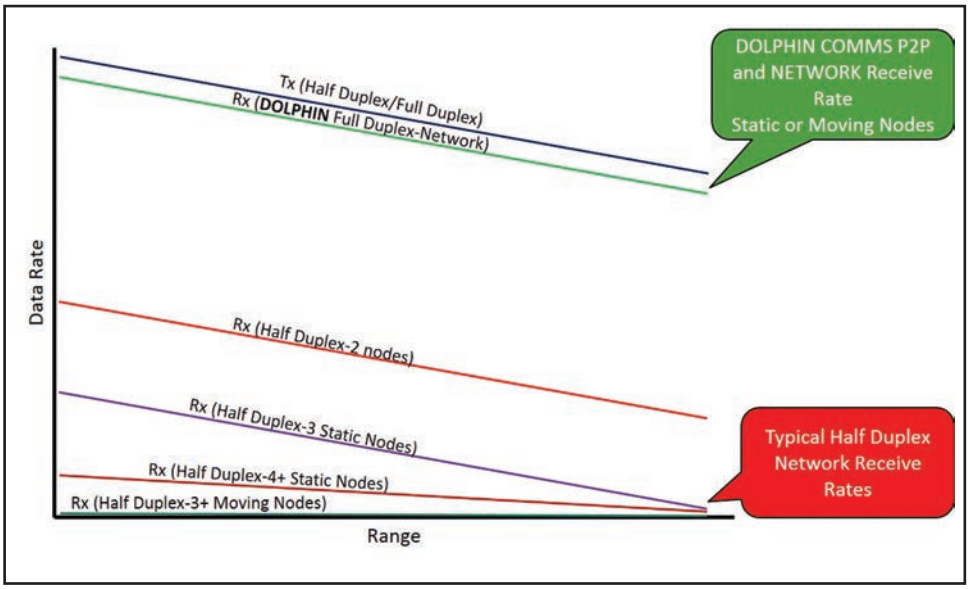

Image: QinetiQ North America

Figure 2:
DOLPHIN Receive Rate vs. Conventional Receive Rates

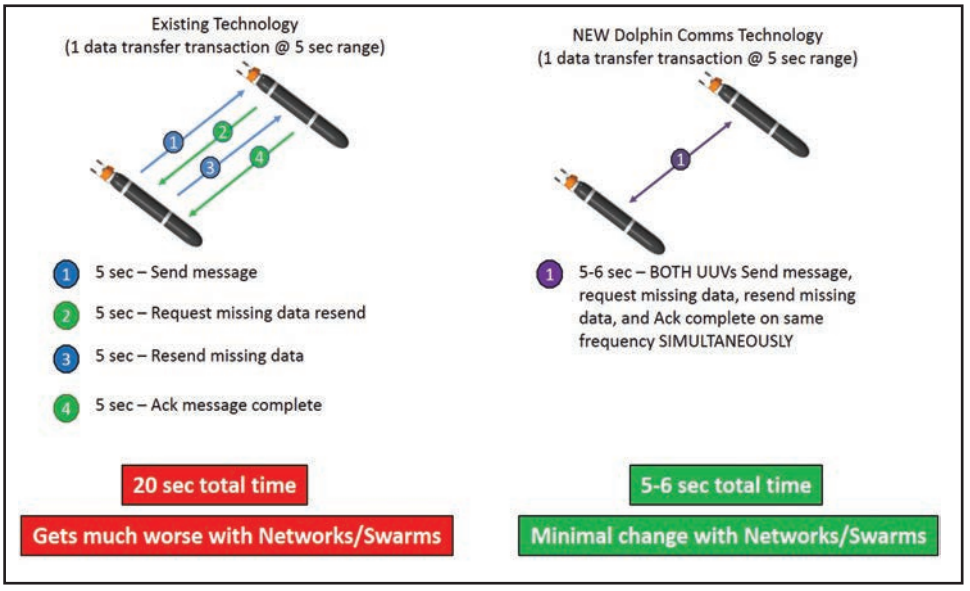

Image: QinetiQ North America

Figure 3:
Data Throughput Improvements for UUV Case Study

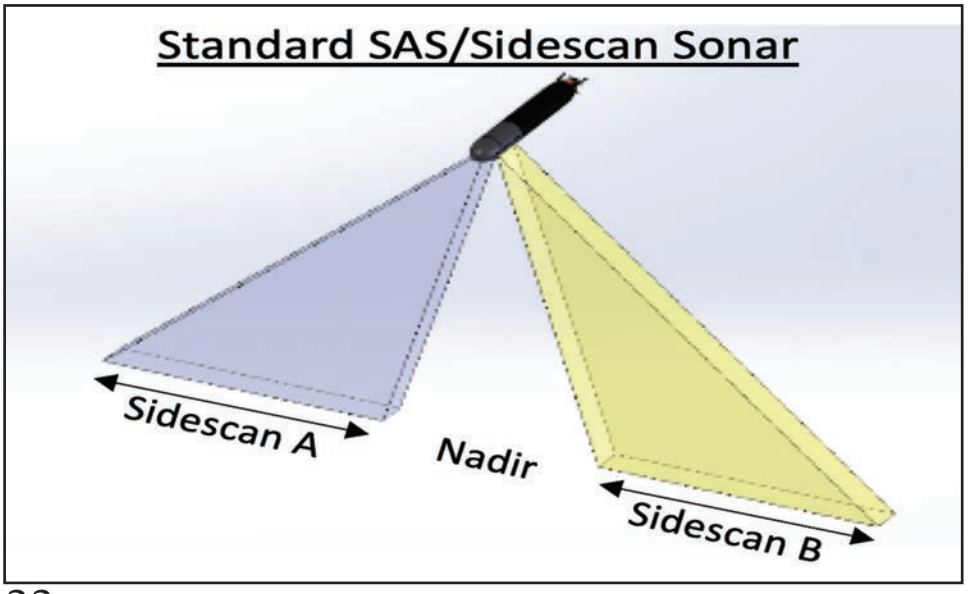

Image: QinetiQ North America

Figure 4:
Typical Side-scan displays a gap in coverage.

A more concrete example of the benefits can be seen by considering the case of two UUVs attempting to communicate using Assured Data Communications. This is depicted in Figure 3 (to the left). Traditional half-duplex approaches require an acknowledgement from the receiving node for each packet that is sent and take 20 seconds, in this example, to deliver a data message between UUVs. But using a DOLPHIN full-duplex approach can deliver up to a 400% improvement of throughput. To be clear, this improvement is entirely due to the signal processing approach, the overall limitations of acoustic transmission remain. Or to put it a bit casually, while the laws of physics have not changed, DOLPHIN Comms provides better lawyers.

Application to Mapping Sonar

This same technology can be applied to side-scan sonar (SSS), a very common tool for seafloor mapping and survey, and synthetic aperture sonar (SAS) an emerging technology. Typically, SSS presents a "gap" in the coverage it offers, as in Figure 4 (to the left). This gap, or "Nadir" separates the left side sonar from the right to avoid interference.

Because DOLPHIN enables transmission and reception of many signals in the water column simultaneously it allows for coverage to overlap. As shown in Figure 5, one set of signals, Sidescan A, is ensonifying a portion the same area as Sidescan B. In traditional sonar applications this would result in interference and lost data. But with DOLPHIN processing it is possible to interpret both signals and thus fill the nadir gap as in Figure 5 (on the next page). This provides full swath coverage of a SSS or SAS with no gap. In fact, the forward scatter from either sidescan (A or B) can be used by the other sidescan (B or A) to improve the resolution in the area that both sides overlap.

In addition to the obvious benefit of improved coverage, DOLPHIN processing can provide other advantages to sonar systems including increased resolution and adaptability to environmental concerns such as marine mammal safety.

Lab and Field Testing

DOLPHIN Comms and Sonar proof-of-concept (POC) demonstrations have been successfully completed. In tank and harbor trials, previously reported upon, DOLPHIN Comms delivered successful results. The system was able to demonstrate 65+ dB of analog cancellation in a highly reverberant, laboratory tank. Following tank trials, the development program moved to open water. This test included omni directional transducers, realistic frequencies and bandwidths, useful range distances, in highly reverberant conditions. The

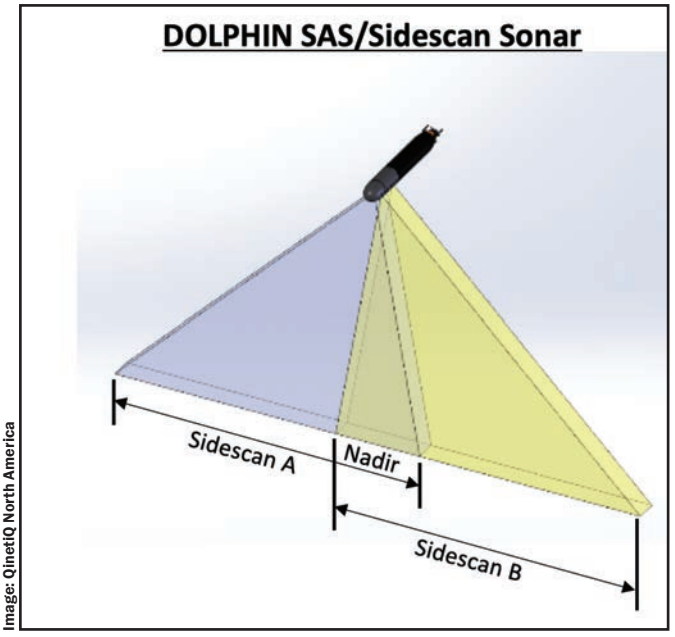

Image: QinetiQ North America

Figure 5:
Two sonar swaths overlapping with DOLPHIN processing fill the typical nadir gap

Figure 6:
A DOLPHIN Sonar trial result, SAS at three times Nyquist speed.

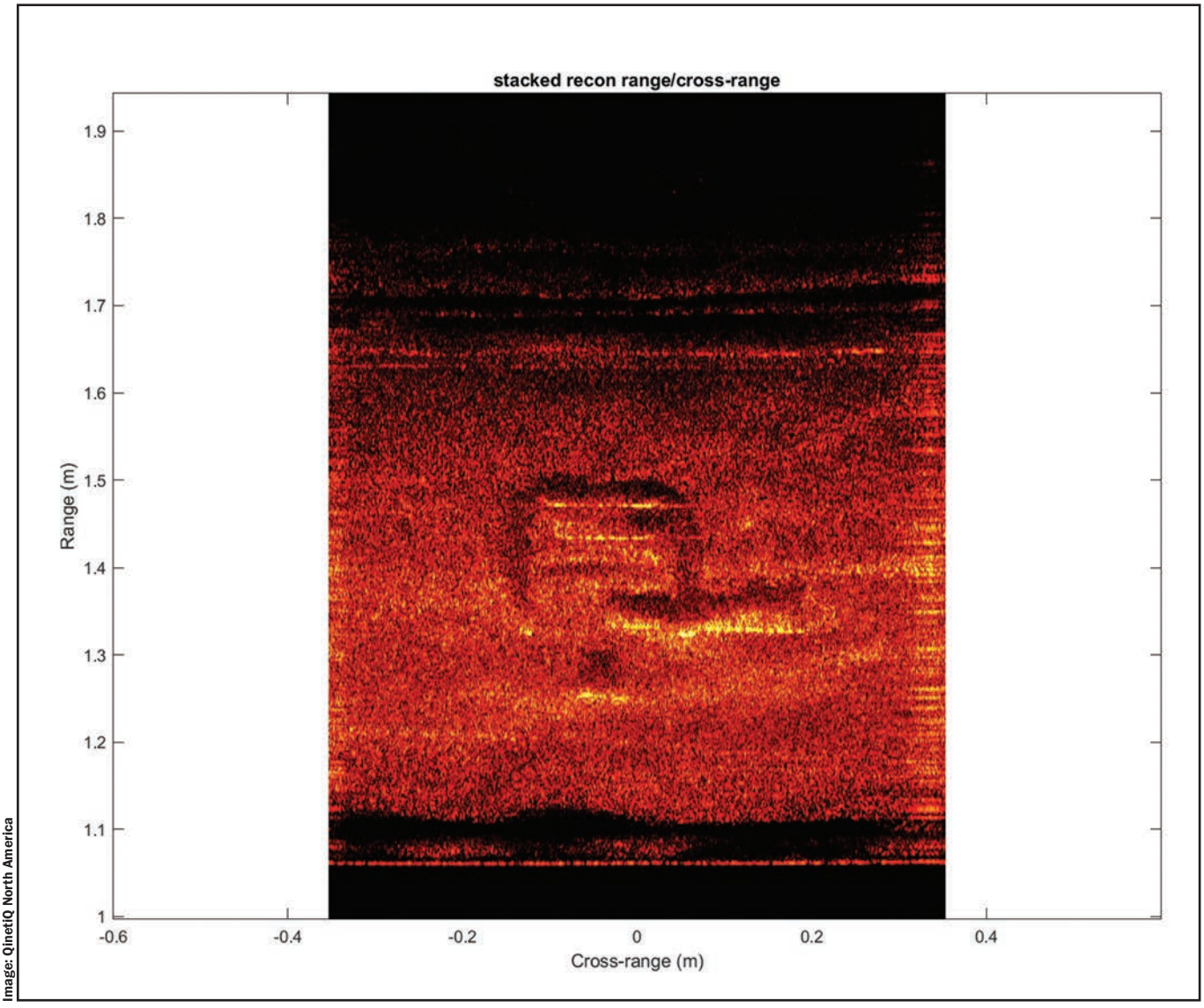

Image: QinetiQ North America

test demonstrated 80 dB of analog cancellation in a difficult and dynamic environment and the ability to scale to useful distances using commercial equipment, while maintaining robust, reliable full-duplex communications. The test was performed at 6% power (60 mW or 160 dB) and demonstrated its expected 1.6 Kbits/sec data rate, full-duplex telemetry.

In sonar testing DOLPHIN has also shown promise. To date work has modelled 100% reconstruction of an image (nadir filling) and demonstrated DOLPHIN SSS and SAS in a laboratory environment. It has also demonstrated DOLPHIN SONAR operation in a laboratory environment with prototype equipment. The test case to date has used a 3 meter tank at 1 meter range with a 2 MHz frequency.

In addition, QNA has demonstrated the ability of the DOLPHIN SAS to be able to exceed the typical SAS Nyquist speed limitations. Conventional SAS can only advance as fast as the Nyquist speed, based on the specifications of the SAS. If one exceeds the Nyquist speed, the conventional SAS image fails completely. With a DOLPHIN SAS, one can exceed the Nyquist speed without losing signal. As a result, the image will gracefully degrade (blur) the more the sonar exceeds 2x the Nyquist speed. In other words, DOLPHIN SAS can at least double the standard SAS speed. It can even increase the speed, albeit with an increasing blurry image. Figure 6 was created in a test tank with a simple DOLPHIN SAS operating at 3x the Nyquist speed. In 2018 QNA was awarded a contract from the Naval Surface Warfare Center, Panama City Division, (NSWC PCD), Panama City, FL to demonstrate advanced, low power, sidescan sonar technology. Phase 1 is complete and results will be presented in future publications.

Practical Applications

The DOLPHIN processing technology can be applied to communications, sonar, and telemetry systems. In practice this will yield benefits to many markets and applications. Military operations will benefit from networking, clandestine communications, improved throughput, and increased tolerance for difficult acoustic conditions. One could envision DOLPHIN enabled networks of unmanned systems more quickly and reliably finding and neutralizing mines in deep waters and in the surf zone. Commercially the oil and gas, and to a lesser extent offshore renewables, are looking to seafloor resident systems for both installation and inspection, maintenance and repair (IMR). These underwater applications will benefit immensely from the utility, position navigation and timing (PNT) and data connectivity, taken for granted by mobile devices connected to conventional satellite and radio networks.

These markets will also benefit from improved sonar. Mine hunting coverage rates will increase with faster sonar advance speed and the systems will not have to survey twice to fill the SSS/SAS "gaps." Energy infrastructure will be quickly mapped to support operations and maintenance needs. Ocean science and exploration will benefit from increased mapping coverage rate. DOLPHIN will improve upon limited ocean mapping coverage to date.

DOLPHIN Comms is a transformational technology that enables full duplex acoustic underwater communication and improved sonar systems. The technology has been validated in field trials. There are ongoing applications and development projects planned in defense applications. Commercial and scientific applications and trials are of great interest. While the core technology is ready, the many layers of product and "system of systems" developments will evolve over time. A robust ecosystem of hardware manufacturers, software developers and end users must mature around the underlying, enabling technology. With appropriate, collaborative effort, it is reasonable to assume that many products and applications will become DOLPHIN enabled.

Unheard Underwater *Covert Comms*

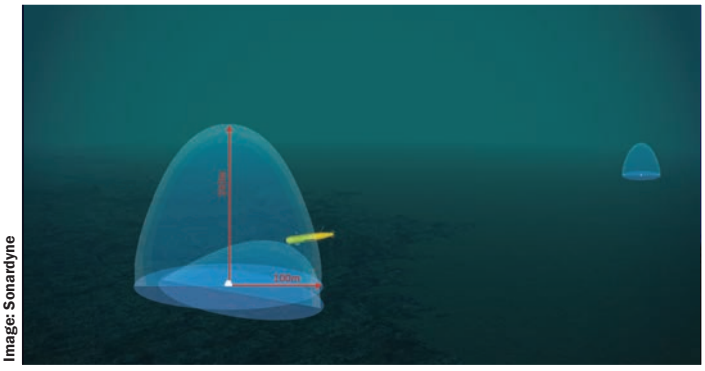

Image: Sonardyne

BlueComm 200 UV could be used to support covert AUV communications at relevant outposts along the seabed.

Sonarydne's Blue-Comm depressor in the water at Aldabra, during the Nekton First Descent mission.

Image: Nekton Oxford Deep Ocean Research Institute

Technology that has helped to achieve world firsts in ocean exploration broadcasting could also provide **the answer for covert operations in the defense realm**, *where communications need to go unheard.*

By Ioseba Tena, Global Business Mgr. - Defense & Robotics, Sonardyne

Traditionally, wireless subsea communications use acoustic signals. Sound is practical, because it travels further through water than electromagnetic waves. Using sound, information can be shared over many km. Unfortunately, it is also relatively easy to hear those sounds and target the source using passive sensors; including when beyond the actual range at which the signals are effective. For several years, a new technology has been developed which enables significant data rates of up to 10Mbps over distances spanning up to 150m, using free space optics to modulate signals. As the effective communication range is shorter, the effective detection rate is shorter too – listening in isn't so easy.

Acoustics communications

The use of acoustics is prevalent when communicating wirelessly underwater and it is likely to remain so. The physics of how sound propagates in water are well understood. Instruments to both communicate with and track other acoustic beacons are common. In fact, low and medium frequency acoustic systems can be used to communicate effectively subsea over vast ranges. Sonardyne recently demonstrated data rates of up to 3000bps over an 11km range. However, the same reasons which make sound such an effective means for carrying data through the water also make it susceptible to interference and detection. Sound signals can be interfered with by simply sending other sound signals at the same frequency at the same time. Simply increase the amplitude of your interference and it becomes difficult for the receiver to make out the signal of interest. Targeting the source of the sound is simple trigonometry. To listen into the

Image: Nekton Oxford Deep Ocean Research Institute

One of Sonarydne's BlueComm units attached to one of the Nekton mission submersibles.

messages is not so simple, as the way the data is modulated, and perhaps compressed, needs to be understood. Still, the use of sound can put the user in a compromising position. The result has been that, when covertness is a prime requirement for a subsea mission, communications have not been an option.

Free space optical modems

Electromagnetic waves have not been successful subsea as they attenuate rapidly and their effective communication ranges are, in relative terms, very short. This situation has been changing as new free space optical modems have been pushing the ranges and how much data can be transmitted further.

Sonardyne's BlueComm 200 is a good example. It uses visible blue light because at that wavelength (450nm) light travels furthest through water. Most blue light can travel as far as 150m and it is not uncommon to detect small amounts of blue light emitted by the sun even as deep as 300 to even 1,000m depth, beyond the euphotic zone! Using blue light, we can transfer a lot more data than it is possible by using acoustics. BlueComm 200 can sustain data rates of up to 10Mpbs. That is enough to transfer HD video in real time. BlueComm 200 modems have been of real interest in support of resident subsea autonomous underwater vehicle (AUV) programmes in deep waters – where we can manoeuvre an AUV around a hemispherical shape with a 150m maximum range! That's a lot of distance.

Image: Sonardyne

An L3ASV C-Worker unmanned surface vehicle and the National Oceanography Center's ALR working together in recent trials demonstrating acoustic and optical communications.

In shallow waters, their use is limited by interference from sunlight (which as we have seen can make its way down to even 1,000m depth). Interference from other light sources limits the modem's effective range. Free space optical modems are also not that covert, they operate in the visible light spectrum and are therefore visible to the naked eye.

Ultraviolet

We set out to address the challenge of interference first. If we were to operate outside the visible light spectrum, to avoid interference from artificial lights, which wavelength would be the best choice? A center wavelength of 405nm was a good compromise containing ultraviolet (UV) and some visible violet light, the BlueComm 200 UV was born. The concession we had to make was range. It has been effectively halved, to up to 75m. In exchange we gained two benefits. First, we wouldn't suffer from artificial light contamination. This means we could operate concurrently while filming video or in the presence of other light sources. Second, we would be able to operate closer to the surface and suffer less interference from sunlight.

This is because UV light emitted by the sun is not as effective as blue light when travelling through water. Meanwhile, we maintained an update rate of up to 10Mpbs. And, when you take a step back, a shape almost resembling a hemisphere

Images: Sonardyne

One of Sonarydne's BlueComm units attached to one of the Nekton mission submersibles.

with 75m maximum range in which you can operate and sustain up to 10Mbps is significant in size and able to support a wide number of concepts of operations. One of which is covert communications.

Covert communications

As a BlueComm 200 UV can propagate up to 75m, this means that, when operating in depths below just 75m, we can communicate and remain unseen by anyone observing from the sea's surface. In fact, for someone to be within 75m range of our BlueComm 200 UV in the first place, it would be highly likely that they would be acting on intelligence, i.e. that someone would only be within range because it knows where to find us in the first place. Even when operating closer to the surface, the limited range of the BlueComm 200 UV, when seen from space, is very much like a needle in a haystack. This means we can now communicate subsea and remain covert. This is great news for a new generation of submariners and new unmanned underwater vehicle (UUV) concepts.

Unmanned vehicles as a force multiplier for submarines are not a new idea. In 1997, the National Research Council published Volume 6 of the "Technology for the United States Navy and Marine Corps, 2000-2035". In this document, the authors detail how AUV/UUV systems will be used in support of operations and cite secure communication links as a requirement to make this vision happen. BlueComm 200 UV can provide this link, securely and covertly.

With BlueComm 200 UV, extra-large unmanned underwater vehicle (XLUUV) platforms will be able to operate and communicate with other vehicles or with ground stations at choke points, helping to monitor, detect and prevent incursions from foreign agents, all while remaining covert.

Practical examples

It's not all about covertness, recently we achieved quite the opposite. The technology was out in the field, being used to achieve a world first. Working with the Nekton Foundation: Associated Press and then Sky News achieved live transmission from a manned submersible wirelessly to a vessel and then on to millions of homes using our free space optical modem. Nekton Foundation was set up to help change our knowledge and understanding of the world's oceans and to speed up the protection and governance of this last great wilderness, the deep ocean. Their First Descent initiative involved a series of expeditions, using two manned submersibles, in the Indian Ocean to help explore and conserve one of our least protected spaces.

In this mission, they set up a depressor (a cabled receiver from a surface vessel) with a BlueComm 200 UV on one submersible and, on other, a BlueComm 200 that was working with a prototype green light wavelength in order to keep

During the Nekton mission, two manned submersibles were fitted with BlueComms to transmit live video to the surface, then on to worldwide audiences. Image still from Sky News live broadcast.

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Image: Sonardyne

Anna Botting from Sky News shown while live on television using BlueComm 200 UV to communicate wirelessly subsea.

sufficient separation in the wavelengths to limit interference between each unit and the depressor. The depressor was submerged to 90m depth and was used to communicate wirelessly with the two manned submersibles using the BlueComms. With this arrangement, Sky News presenter Anna Botting was able to film herself inside one of the manned submersibles, using high definition video, and transmit that data live to millions of homes around the planet with little, or no interference from the sun. The building blocks to support covert operations are ready and proven.

Riachuelo submarine during launching.

Image Marinha do Brasil

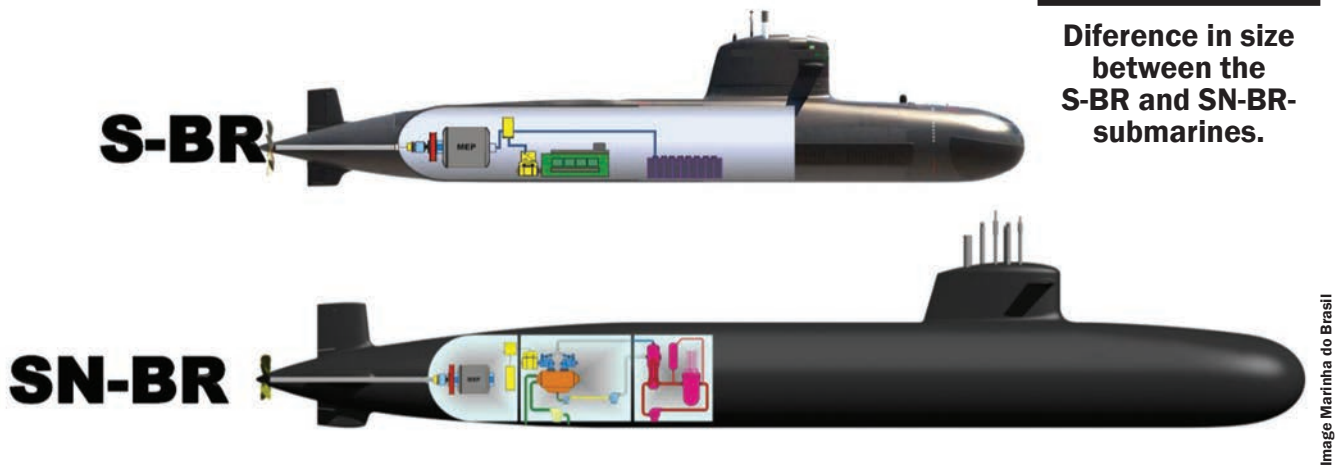
Brazil´s Riachuelo Submarine – S 40

By Claudio Paschoa

Brazil is a country with a coastline over 7,000 km long, bathed to the east by the Atlantic Ocean. Along this coastline and offshore is where the country develops its fisheries activities, maritime trade and the exploitation of a variety of biological and mineral resources. The incredible environmental and financial wealth found in these waters, and under the seabed gave way to the term - Blue Amazon – relating to the Amazon Jungle. The Blue Amazon officially covers an area of 3.5 million square kilometers. However, Brazil is calling on the United Nations to expand its borders to the limits of the continental shelf, which should raise the sea area to about 4.5 million square kilometers - equivalent to half of Brazil's land area.

To protect this natural heritage and guarantee Brazilian sovereignty at sea, the Brazilian Navy (BN) invests in the expansion of its naval force and in the development of a viable defense industry. An essential part of this investment is the Submarine Development Program (PROSUB). The National Defense Strategy, launched in 2008, established that Brazil needed to have a major naval force, including a submarine with nuclear propulsion. In that same year, a technology transfer agreement was signed between Brazil and France in the area of submarine construction. The program is enabling the production of four conventional submarines (S-BRs), which will be added to the fleet of five ageing and obsolete conventional submarines, and the building of the first Brazilian submarine with nuclear propulsion (SN-BR), all made in Brazil at a purpose build state-of-the-art Navy shipyard on the south coast of the state of Rio de Janeiro.

Of the four conventional submarines already being built, the first to be launched was the Riachuelo (S40). Now going through a fitting out phase before beginning ocean trials,



Diference in size between the S-BR and SN-BR-submarines.

Image Marinha do Brasil

the S40 was launched on December 14, 2018. The last of the modern conventional submarines is scheduled be launched by the end of 2022. The Humaitá (S41) should be launched in 2020, followed by the Tonelero (S42) in 2021 and the Angostura (S43) in 2022. The name of the first submarine, Riachuelo alludes to the Riachuelo Naval Battle, considered decisive in the Paraguayan War (1864 to 1870), and an outstanding victory for the Brazilian Navy.

Submarine S 40

The Riachuelo class submarines are based on the Scorpène class, measuring 71.62 meters long with a displacement of 2,200 tons in immersion. It has a capacity for 35 crew, is able to spend 70 days at sea and can submerge up to 300 meters.

"It is a great satisfaction to lead a crew that is very well prepared and will operate a very modern, technologically upgraded submarine and will certainly increase greatly our ability to defend the Blue Amazon," said S 40s skipper, Corvette Captain Edson do Vale.

The four S-BR submarines will be larger than the Scorpène class acquired by the Chilean, Malaysian and Indian Navies. "A review of the entire project was carried out and, thus, the need to incorporate an intermediate section was identified, in order to allow the expansion of berths, fuel oil tanks and storage spaces, thus increasing the original capacity of our submarines at sea on patrol," said Fleet Admiral Eduardo Bacellar Leal Ferreira. Admiral Ferreira was the Commander in Chief of the BN up to the end of 2018.

Specifications of the S-BRs

Displacement:	1,870 tons (surfaced) 2,200 tons (submerged)
Length:	71.6 m
Width:	6.2 m
Draft:	5.5 m
Propulsion:	Diesel motors 4 x MTU 16V 396 SE84 (2990cv/hp) 1 x Motor elétrico Jeumont Schneider (2.8MW)
Speed:	20 knots (max)
Autonomy:	70 days at sea, 13,000 miles at 8 knots; can navigate 400 miles at 4 knots without use of snorkel
Depth:	300m (max)
Weapons:	18 - 533 mm torpedoes; 6 torpedo tubes 8 - Exocet missiles - SM 39
Crew:	35

They will be armed with six 21-inch torpedo tubes for up to 18 F21 torpedoes and/or SM39 Sub Exocet missiles and underwater mines. It will also be equipped with two periscopes, one traditional and the other optronic, capable of sending images directly to the MF-CCs (Multifunction Common Console). S-BRs will also have two Contralto-S countermeasure launchers for CANTO torpedo decoys.

When asked about the delay of nearly one year for the S 40 to be launched, Fleet Admiral Leal Ferreira explained that "The construction schedule for the first conventional submarine (S-BR1) was modified to include the time necessary to adapt to the French construction techniques and the design changes required to meet the operational requirements established by the Brazilian Navy".

The Scorpène has a hydrodynamic hull built with HLES 80 steel, derived from what is used currently in French nuclear submarines. Some technologies used in the "Amethyste" and "Le Triomphant" (nuclear) classes, such as the SUBTICS system, are also used in Scorpène.

Transfer of Technology

The agreement between Brazil and France for the Subsea Development Program (PROSUB) has three basic premises: technology transfer, nationalization of equipment and systems, and training of personnel. The technological transfer takes place in the areas of submarine design and construction and industrial infrastructure.

The ToT for the construction of the conventional submarines or S-BRs has been taking place since 2010 in the city of Cherbourg, France, where more than 250 engineers and technicians from the BN, NUCLEP (Nuclebrás Heavy Equipment) and Itaguaí Construções Navais (Navy shipyard) have already been qualified. The technology transfer process continues in Brazil, with the technical consulting activities during the project detailing the modified parts of the conventional submarine.

"PROSUB has as one of its main goals the ToT, through personnel training and the search for a high index of nationalization. This generates benefits for Brazil, of a technological and industrial nature, including not only the naval market, but also other segments that supply goods and services in the country," said Fleet Admiral Ferreira. The program has a total cost forecast at R$35.5 billion (US$9,36 billion) by 2029 when the nuclear submarine should be ready. So far, the Brazilian Navy has spent half of this budget.

Image Gaúcha Zero Hora

Control room of the S 40, Brazil's most modern submarine.

Image Courtesy French Navy/RTSYS

Improving French Navy Detection Capacities on Older Gen Frigate Sonars

Since the summer of 2017, four vessels equipped with analog sonars have been upgraded using RTsys AS3i technology (Analog Surface Ship Sonar Improvement), which digitalized and improved the processing of signals rendered by sensors.

Brittany-based company RTSYS does not only deals with AUV, subsea recorders and buoys, but can also display a full range of sonar systems such as handheld devices for divers or sonar retrofit. The latter of which led the French SME to lately offer in summer 2017 its services to the French Navy by upgrading analogue sonars on four frigates.

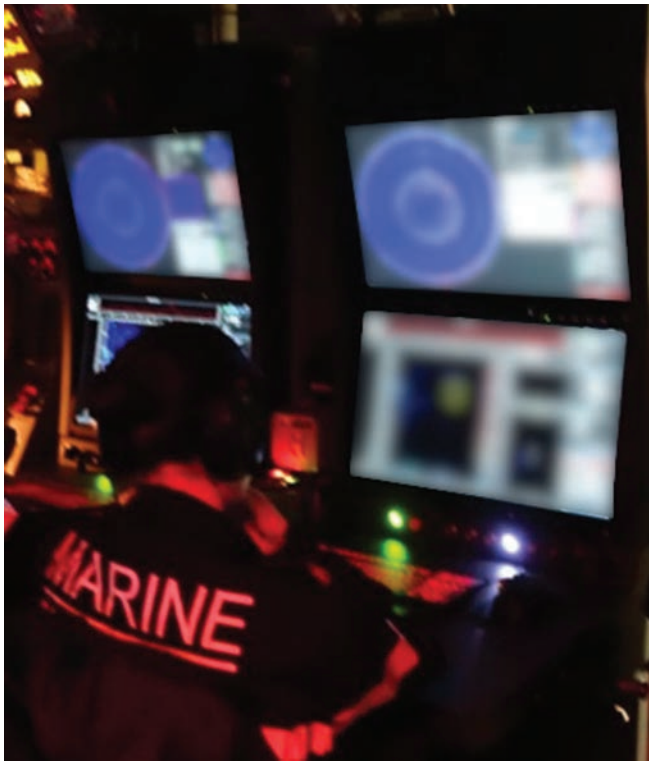
In accordance with the ACORES public procurement program (a French acronym standing for Frigate Sonar Capacity Upgrade), RTSYS featured a reliable solution based on its SDA (Synchronous Data Acquisition) technological core to digitalize and process the signals received, without any modification on the existing transmitters and transducers.

This system has been installed on three Anti-Submarine Warfare Frigates FASM in Brest (Brittany, France) and on one Anti-Aircraft Frigate FAA based in Toulon by the Mediterranean French coast, thereby providing them with effective digital tools in order to avoid the costly replacement of the entire sonar system. Improved signal processing significantly enhances reception especially thanks to the SDA motherboard running on all RTSYS products and providing very neat acoustic rendering. Thanks to signal digitalization, new User Interface is also to be displayed through HD color screens aiming to replace old analog ones. This intuitive Man-Machine Interface allows several screen configurations such as active or passive mode, torpedo mode, or PPI picture (Plan Position Indicator) and can accept multiples codes (Continuous Waves, Hyperbolic Frequency Modulation or Combo Mode). It is also to be noted that this upgrade increases bandwidth along with the duration of the pulse which gives crystal-clear signal at the reception and more specifically in the reverberation.

RTSYS project manager and ex-French Navy Commander Christian Nicolas said: “This is a smart system we developed

“This system is really easy and convenient to use and we provide constant technical support along with all necessary training to the crew so this technological upgrade goes really smoothly.”

Christian Nicolas is a former French Navy Commander. He now offers his expertise at RTSYS.



Images Courtesy RTSYS/French Navy

ABOVE: Old analog sonar on the left versus new console.

LEFT: New console working.

as it works on various sides. First of all, it allows tremendous gain of time for Navies as the upgrade does not run for too long so the crew can quickly be back onboard. Secondly, the overall solution is cost-effective as we do not replace the HMS and VDS transducers; only receivers, processors, computers, monitors and operating consoles are. Finally, crews gain skills while training: data from previous missions are logged into the AS3i and can be set to replay mode. Thanks to the mission simulator, users can generate acoustic training simulations to meet requirements such as submarine or torpedo detection in either active or passive modes".

In addition to signal improvement this upgrade means that the frigates sonars have new aptitudes such as the ability to extract objects and pursue them. Besides, an automatic torpedo detection system running as a background process emits warning signals based on simple detection criteria to attract the operator's attention. The operator nonetheless still decides whether or not to confirm an alert. Implementing the RTSYS solution will make these frigate sonars compatible with other digital measuring devices, so this will definitely enhance Navies' onboard crew skills by letting them train more efficiently to Anti-Submarine Warfare and gain reactivity in case of troubles.

"This system is really easy and convenient to use and we provide constant technical support along with all necessary training to the crew so this technological upgrade goes really smoothly. After all this is what RTSYS partly does: improving training capacities such as we already do with our SEMA Training Target for Anti-Submarine Warfare," Nicolas concludes.

SurfWEC & the quest for efficient wave-generated power

Wave-generated power could be considered the Rodney Dangerfield of offshore renewable energy sources; it gets no respect. *There have been a number of high-profile, expensive failures that have conspired to give the sector a poor reputation despite a number of engineering advances. A new entrant is SurfWEC offering a patented "surf-making" Wave Energy Converter which has been in development since 2007. Its developers promise it will stand out from the field and perform where others have failed. How? The SurfWEC design improves upon a generation of 'lessons learned,' and more importantly it makes its own surf.*

By Greg Trauthwein

Renewable energy production is officially 'hot', as a number of engineering advances and government subsidies have conspired to help deploy, test, and prove in real-world conditions the viability of various systems. While solar and wind power have jumped out as early leaders, there is a renewed push to turn ocean wave power into a viable, renewable source of power and stored energy. A new entrant is SurfWEC LLC, which is aiming to become the 'go to' in the wave energy category, both as a stand-alone system and as added power source, energy storage, and wave damping units co-located with existing or future offshore wind farms.

SurfWEC @ a Glance

The Company
SurfWEC LLC

The Technology
Wave Energy Harnessing Device

The Start of Design
2007

The Patent Issued
2012

The Patent Owner
Stevens Institute of Technology

The Exclusive License Holder
SurfWEC LLC

The Website
www.surfwec.com

Meet the "Old New" Company

A driving force behind the new performance projections for Wave Energy Converters (WECs) is Martin & Ottaway, a New Jersey-based marine engineering firm that has been in continuous operation since 1875 which incubated SurfWEC LLC in December of 2018. SurfWEC, with university and industry partners – Stevens Institute of Technology, ABB, Airline Hydraulics, Bosch-Rexroth, Deeptek, HYDAC, ISCO Pipe, Wire Co./Lankhorst Ropes, and others – is working to develop WECs using patented features that are expected to increase energy recovery rates by an order of magnitude as stand-alone units or integrated with legacy WEC systems.

The SurfWEC system is also designed to avoid wave damage associated with hurricanes, equipment located in surf zones, and stationary mooring systems offshore via technology that conquers the challenge of highly variable wave sizes. To put it simply, it does this with a patented variable-depth shoaling feature, invented by Michael Raftery, SurfWEC Chief Technology Officer (CTO) while performing research at Stevens Institute of Technology from 2004 to 2012. The technology essentially allows offshore waves to be converted to surging surf waves, allowing much more effective wave energy recovery.

Meeting with Raftery in Martin & Ottaway's Tinton Falls,

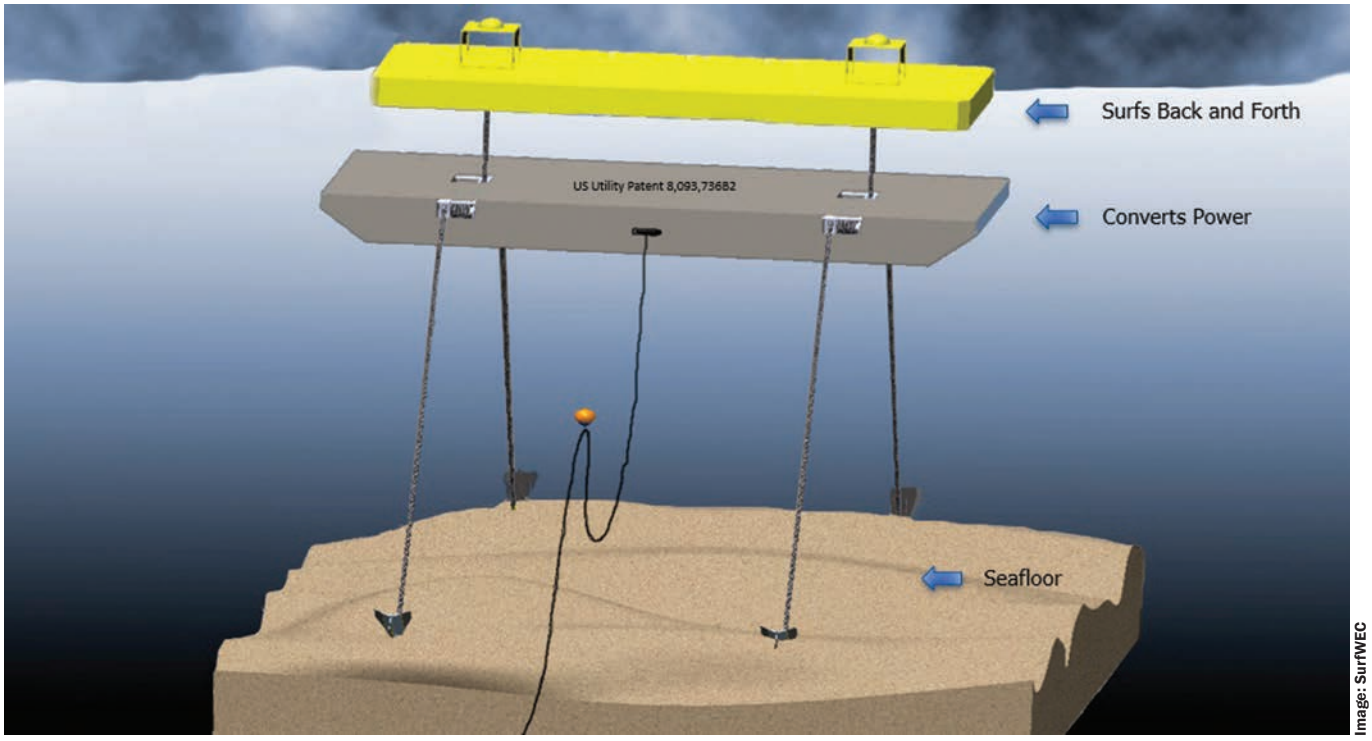


Image: SurfWEC

"There have been four major failures in the industry that really put investors off. The sinking of the Advanced Research Technologies/Wavegen "Osprey" in 1995, the sinking of the Finavera "Aquabuoy" in 2007, the sinking of the Trident "DECM" in 2009, and the recent sinking of the Wello OY "Penguin" in 2019."

Michael Raftery, CTO, SurfWEC

New Jersey office, it becomes immediately clear that this system and its development are a labor of love for the inventor who's long-term goal is to end human dependence on fossil fuels. The patent was submitted in 2007 and issued in 2012. It is was created while Raftery worked at Stevens Institute of Technology, the renowned engineering school, which paid for and owns the patent rights to the system, while SurfWEC has an exclusive license option agreement in place to use this technology.

"I think the biggest perceptions to overcome are the perceptions that wave energy conversion is inefficient, and that WEC units cannot be designed and fabricated with buoyant integrity similar to Boston Whaler boats, these are the design

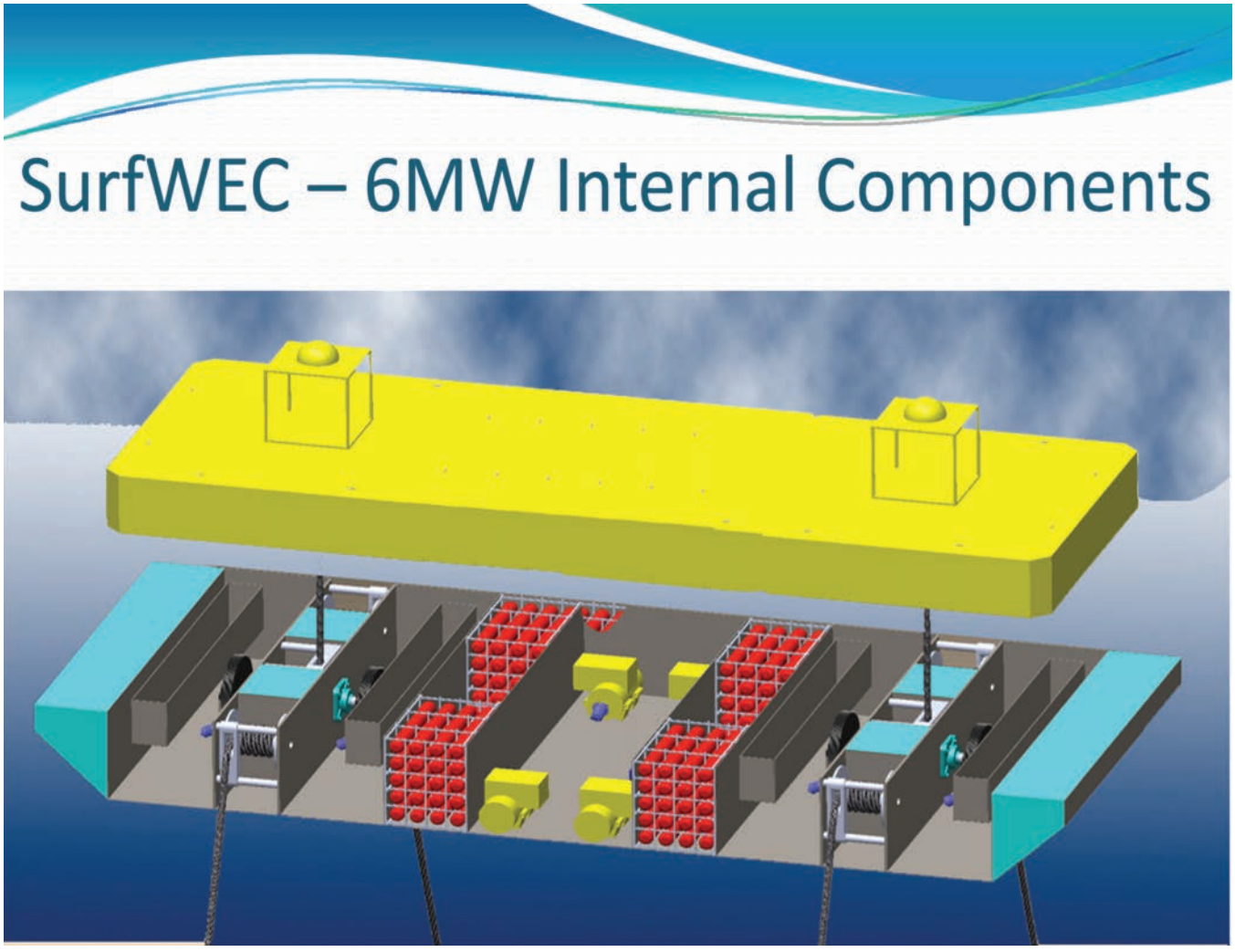


Image: SurfWEC

> "I'm convinced that we can get it to work, but this is the **one technical challenge that give me the cold sweat of the engineer. Rope technology** has advanced tremendously, but that is the point where a lot of energy will go in. Fortunately the rope issue is not and end-all as flapper/surge type devices mounted to the top deck of the variable-depth platform may be commercially viable as well."
>
> **Rik von Hemmen, Owner, Martin & Ottaway**

criteria specifically required to bring wave energy conversion to the utility level," said Raftery. "There have been four major failures in the industry that really put investors off. The sinking of the Advanced Research Technologies/Wavegen "Osprey" in 1995, the sinking of the Finavera "Aquabuoy" in 2007, the sinking of the Trident "DECM" in 2009, and the recent sinking of the Wello OY "Penguin" in 2019."

Raftery said that those failures collectively cost many millions of dollars while earning the WEC industry a bad reputation. He said early investor reactions to SurfWEC have been "you're probably just like those other systems."

But Raftery contends that SurfWEC has learned from past incidents, and he said that creating a system with "buoyant integrity" was number one on his list. To this end the wave energy system features foam-filled compartments making it virtually unsinkable. "We've addressed all of the failures in the industry with this one design."

Also, creating a system that is 'smart', a system able to adjust itself continually to maximize and efficiently convert the ocean's motion into power, was central to success. For this, the SurfWEC

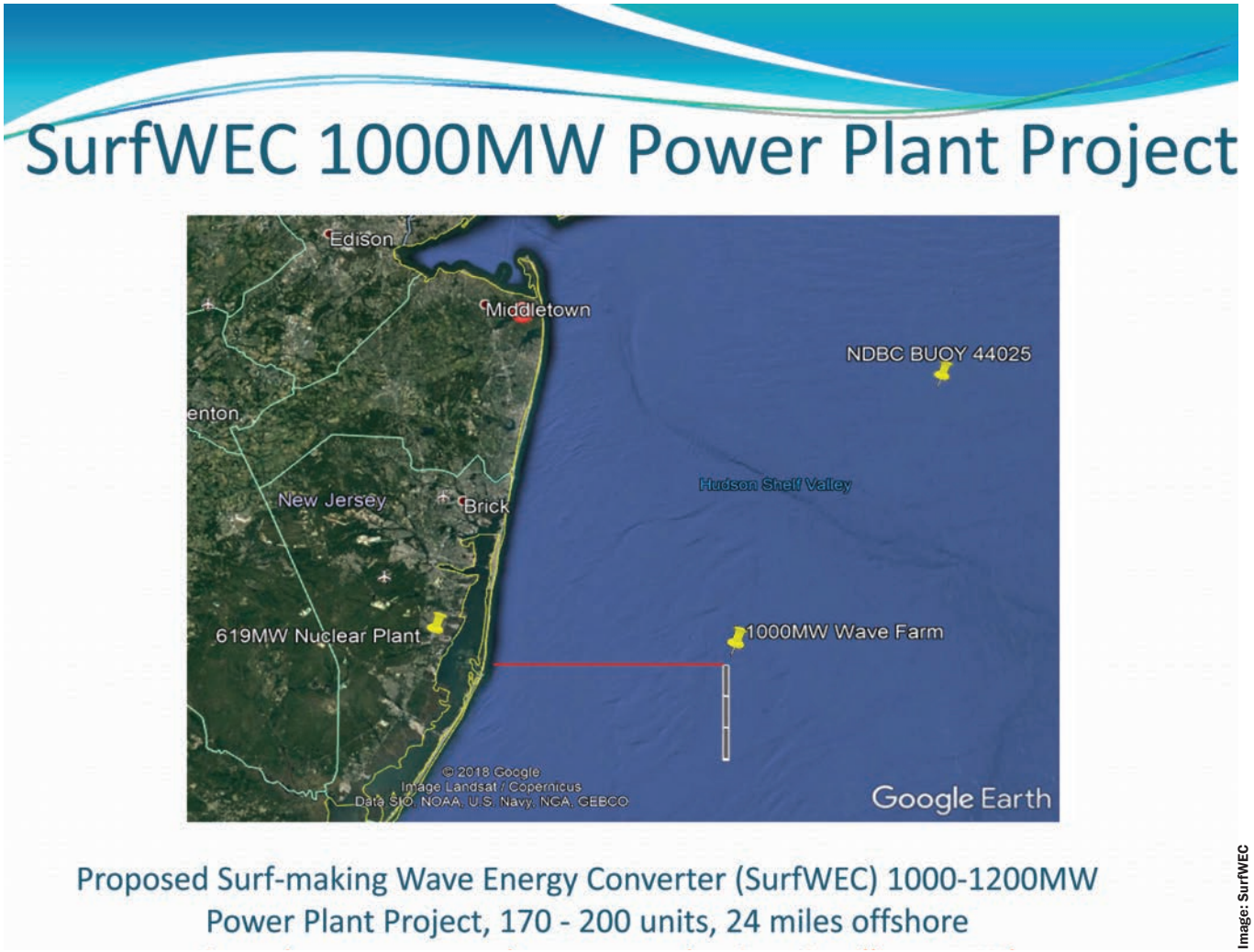


Image: SurfWEC

team relies on a neural network.

"Neural networks are a way to respond to things that are not clearly, easily defined," said van Hemmen. "If I have a perfect sine wave, I can calculate and design something that will respond to this perfect sine wave as the wave length and wave height changes. But ocean waves are messy. Neural networks take input from different sensors that go together helps the system 'learn'. It is simply a response mechanism."

The system is designed to be flexible too, and in principle the SurfWEC system can be placed anywhere where there are ocean waves and water depths are from 135 to 1000 ft. It is, in fact, a major design feather in SurfWEC's cap that the system need not be placed directly in the surf zone to work. "You don't have to design different devices for different locations. We can put them anywhere, and it's a one-size-fits all solution, and the neural network will keep the variable-depth platform at the optimal depth at all times." said van Hemmen.

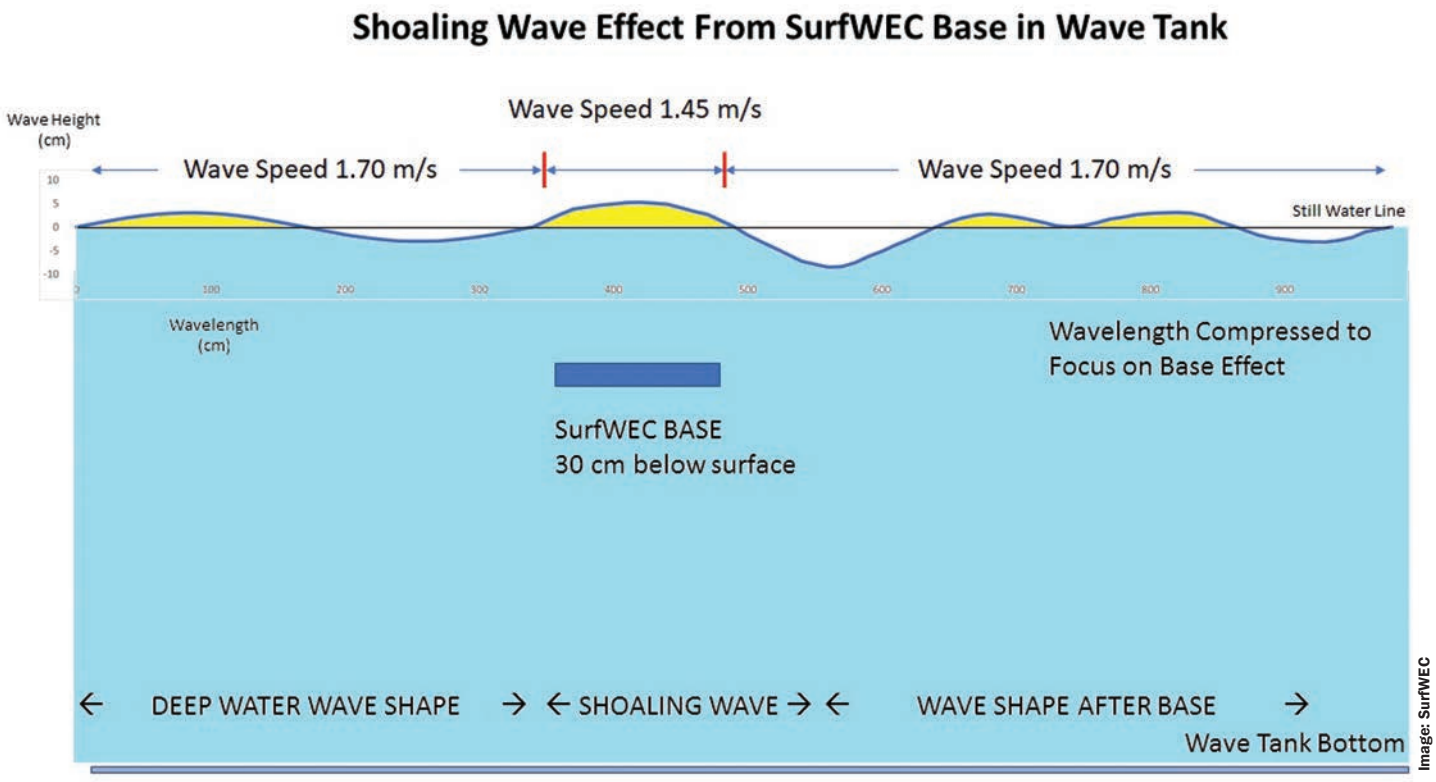
The Path Ahead

Anyone who has worked in the field of renewable energy knows that the path from inventor's workbench to utility level performance is neither straight, short or cheap. The SurfWEC platform has already been under development for a dozen years, and Raftery reckons it will be another four to five years to bring it through sea trials.

"The next step is to get a scale model tested at the Ohmsett facility in Leonardo, New Jersey, at approximately 15:1 scale," said Raftery. "We'll take those performance numbers, then we'll build a skid platform for the power take-off system, and we will bench test. After that we'll make adjustments to the designs based on those two datasets, to be followed by a full-scale prototype and sea trials."

While time is one element, money is another, and Rik F. van Hemmen, P.E., owner of Martin & Ottaway has put the price tag today at $20 million to bring the system through sea trials, with (approximately) $2m for bench testing, $1m for computer modeling, $1m for a scale model, about $12m for the final prototype unit, and $4m for two-year sea trials.

"I've just submitted a White Paper to the Office of Naval Research for that full budget," said van Hemmen. "On the



Model basin result for change in wave shape over submerged platform. Steeper wave allows more efficient wave energy conversion.

commercial side we will approach venture capital sources for funding, too. Then we have DOE applications in for subsystem development."

Think Global, Act (NJ) Local

"Certain projects are so big that they need a national or a global view and presence. This particular technology does not require that huge amount of investment," said van Hemmen. "This makes it inherently more efficient to build and run a local project, and if you can do that your chance of success inherently goes up."

According to van Hemmen the stars are seemingly aligned for this project, as New Jersey offers "this weird hotbed for technological innovation. New Jersey has the waterfront, it has the transportation capacity, it has the education … the project size is right for it to be developed in New Jersey."

One of the key players is Ohmsett in Leonardo, New Jersey, situated on Raritan Bay. This is a world-class tank testing facility situated directly in an area that could prove ideal for real-world testing, as van Hemmen reasons that the waves in the protected portions of Raritan bay are right on scale with the 15:1 model as the ocean waves would be for the full-scale model.

While political (to get the permitting to moor the system for real-world trials) and funding issues are rarely easy to navigate, van Hemmen, who went to Harvard Business School, said that he would be shocked if the organization can't build support among the utilities and the politicians. "The numbers (cost per kWh) are there, and they are convincing." (See chart on next page)

In fact van Hemmen, always the engineer first, sees the biggest challenge of delivering the system to utility scale as quite simple: Rope. "If the money exists, the biggest challenge will be the reliability of the rope yanking system. That is the challenge that my mind will be around day and night," he said. "I'm convinced that we can get it to work, but this is the one technical challenge that give me the cold sweat of the engineer. Rope technology has advanced tremendously, but that is the point where a lot of energy will go in. Fortunately the rope issue is not and end-all as flapper/surge type devices mounted to the top deck of the variable-depth platform may be commercially viable as well."

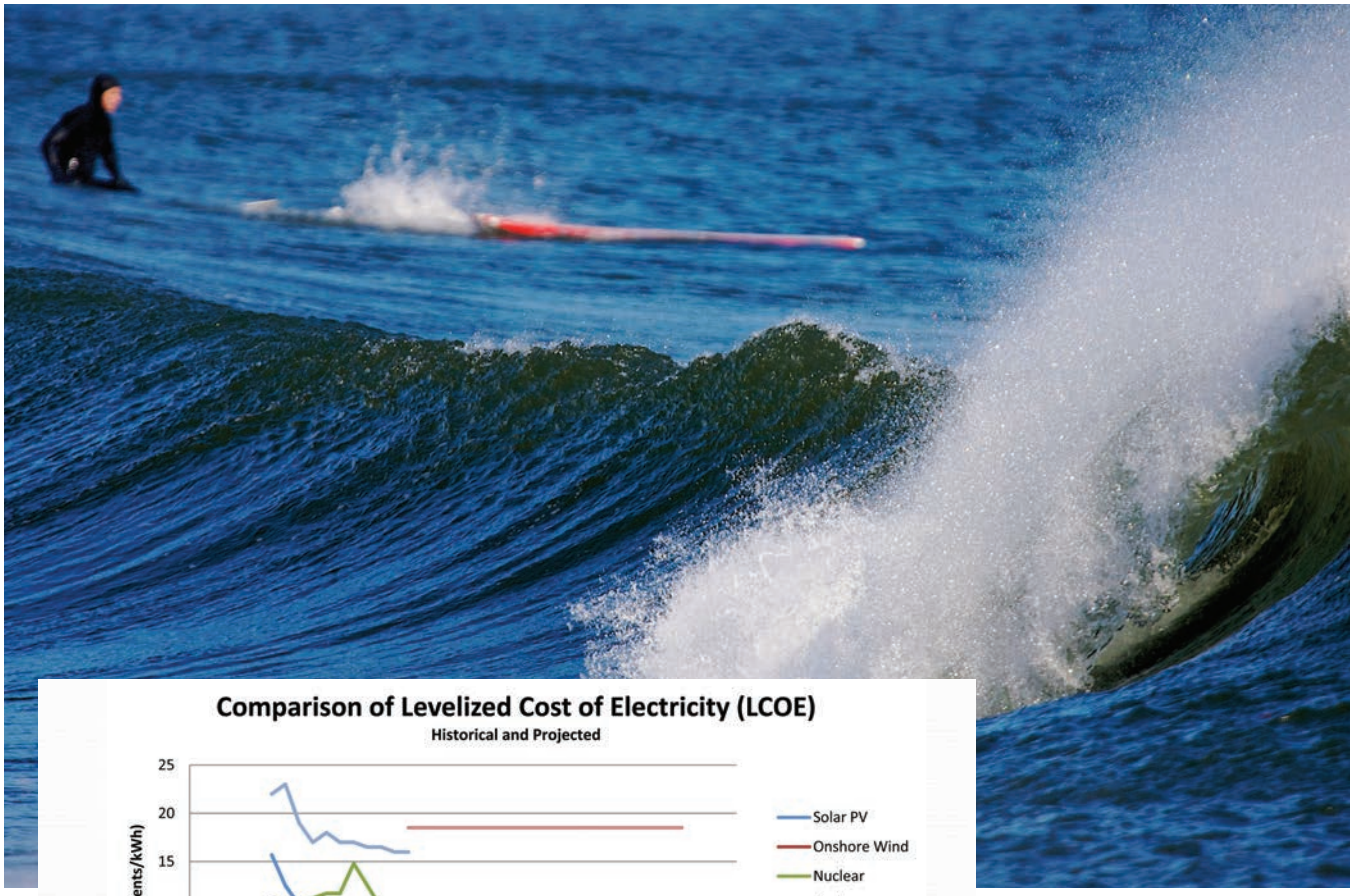
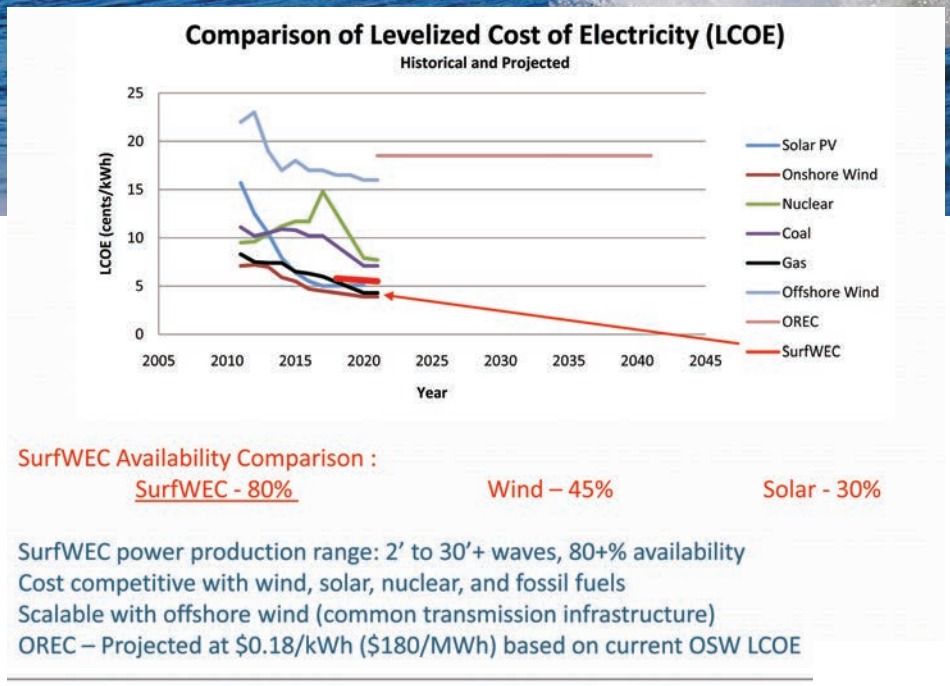


Photo credit Pim van Hemmen



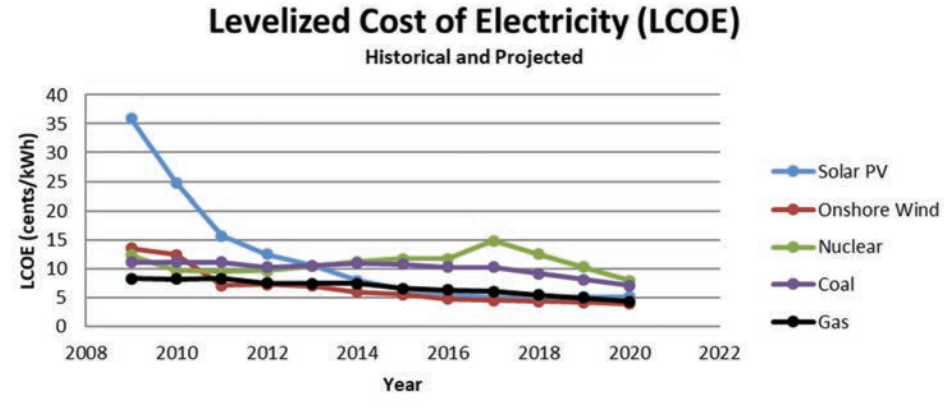


Image: SurfWEC

Michael Raftery (top), CTO, SurfWEC & Rik von Hemmen, owner, Martin & Ottaway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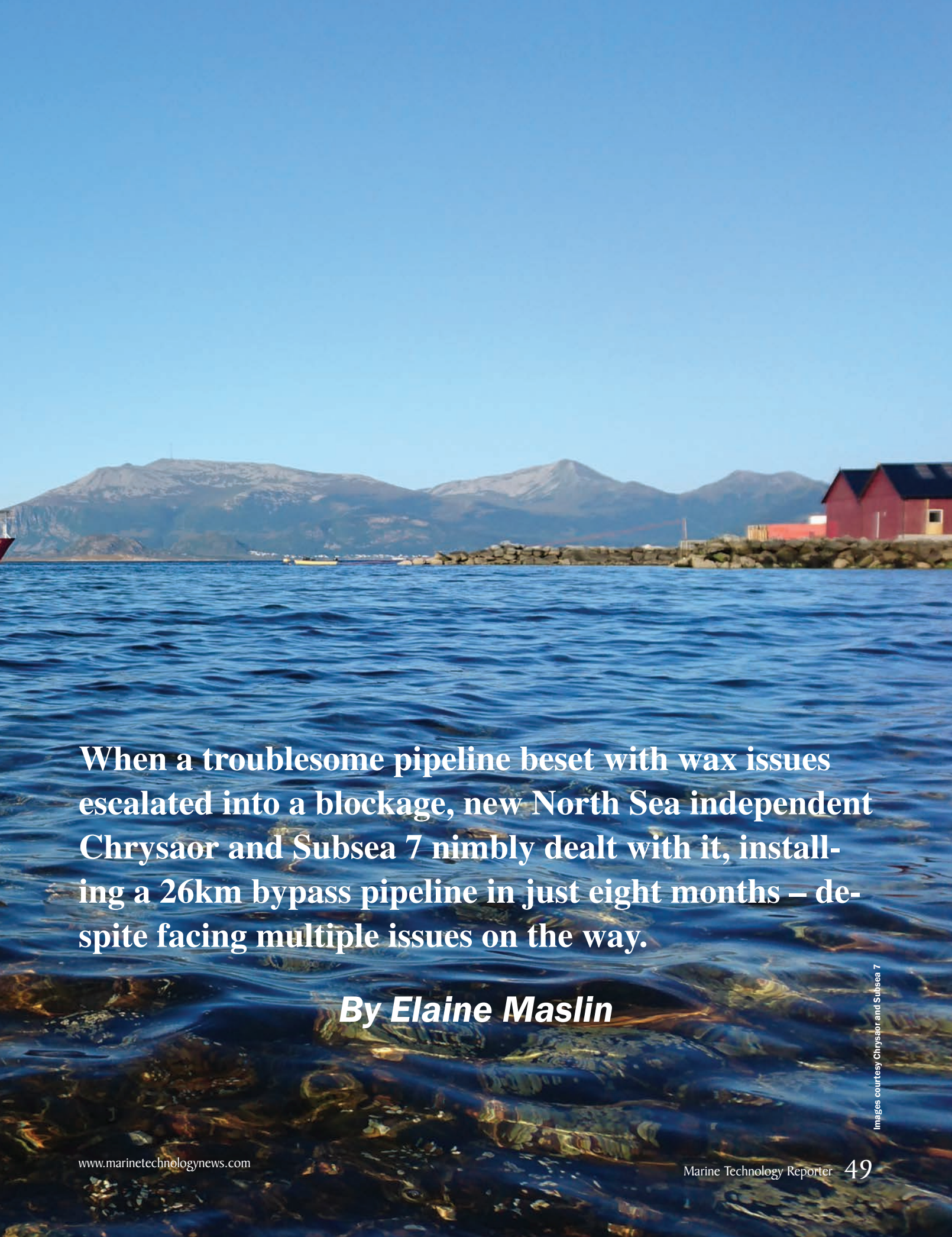


When a troublesome pipeline beset with wax issues escalated into a blockage, new North Sea independent Chrysaor and Subsea 7 nimbly dealt with it, installing a 26km bypass pipeline in just eight months – despite facing multiple issues on the way.

By Elaine Maslin

Images courtesy Chrysaor and Subsea 7

Chrysaor is a new operator on the UK Continental Shelf. Only about 18 months old, it's got growth ambitions, after first acquiring a package of assets from Shell in 2017 in a $3.8 billion deal.

But, acquiring existing producing assets can come with issues, including that they're older, complex, interconnected and have been through multiple owners and therefore might not come with complete records – including exactly where and what diameter pipelines are.

The Lomond platform (initially operated by Amoco, BP, BG Group and then Shell) sits 145m east of Aberdeen in 83.8m water depth and started producing in 1993. Gas condensate from the Erskine facility, operated by Chevron, is exported to the Lomond platform and then 57.8km on to the Everest platform for onward export via the CATS system into the Forties Pipeline System to shore.

When Chrysaor took on Lomond as part of its acquisition of (ex-BG Group) assets from Shell in 2017, it knew there was a history of blockages in the Lomond to Everest condensate line, due to wax dropping out of the condensate flow as it cooled. While condensate from Erskine is transported through an insulated pipeline from Erskine to Lomond - stopping it falling to temperatures where wax forms - the Lomond to Everest pipeline isn't insulated.

"As it leaves Lomond, where the line is not insulated, as soon as it falls below 48°C the wax falls out," says Emily Eadington, Wells & Subsea Projects Manager, at Chrysaor. "When the line was installed in 1992, there were only Lomond fluids to transport, so wax was not an issue, thus no insulation." In 1997, Erskine condensate was added, and in order to mitigate potential wax-build up, a strategy to pig the pipeline every two weeks was developed. "But, it was last pigged in 2009. When we took it over, you couldn't put a PIG in because the PIG could get stuck."

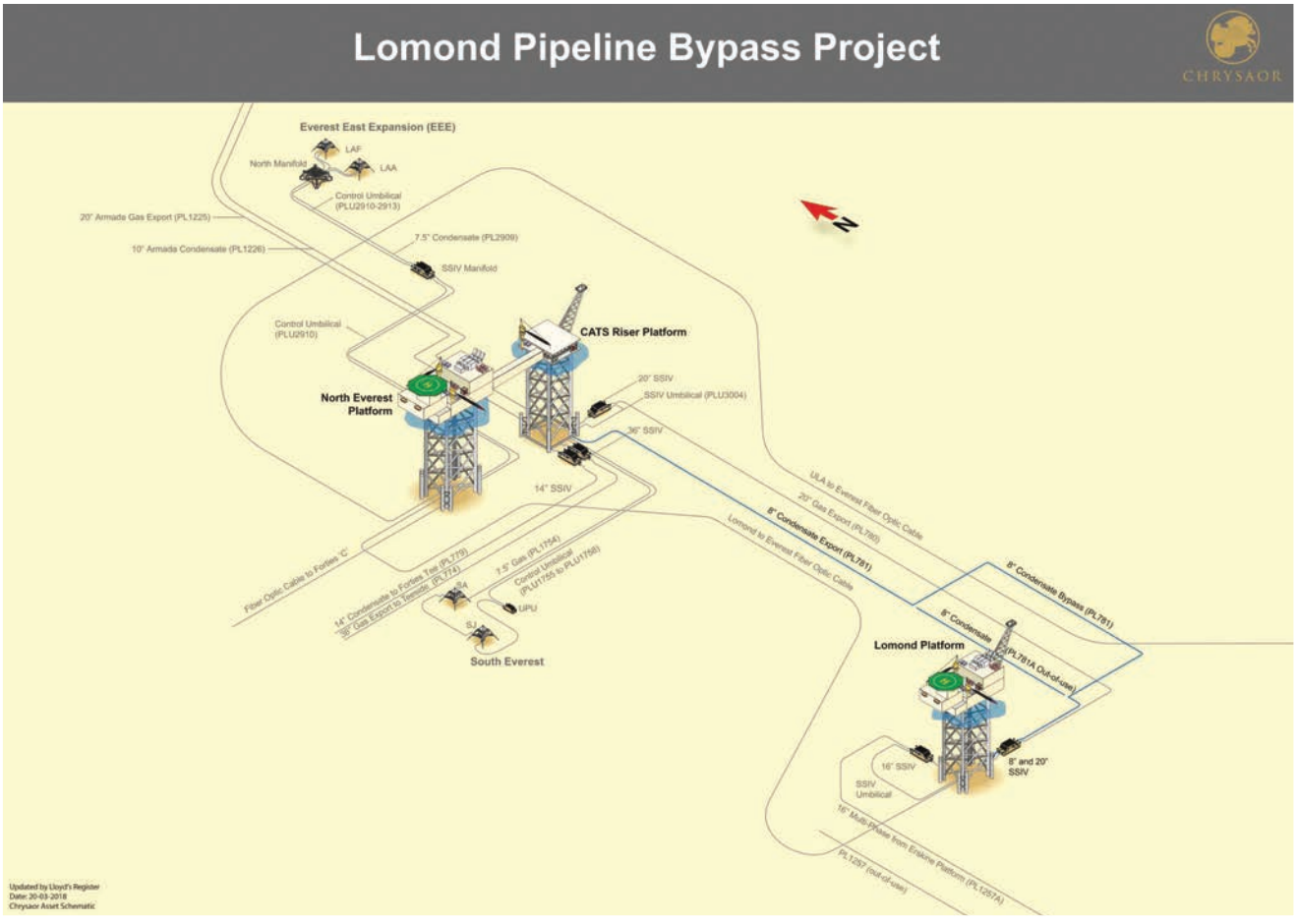
Chrysaor needed to clear the pipeline before it became blocked again. But, clearing it might not be that easy. "There was a debate if we should clear it or bypass it," says Eadington. "We decided to just try and carefully maintain flow rather than unlock it and, in the meantime, put in a bypass pipeline as the chances of it blocking while we were trying to unblock it were 50%." So, late 2017, while the pipeline was still flowing, Chrysaor started engineering work with Subsea 7, which had previously performed engineering on a solution for a bypass pipeline under a previous owner operator.

Then, in January 2018, the very day Chrysaor secured partner (Chevron and Serica Energy) agreement to invest in the bypass pipeline, the Lomond-Everest pipeline became blocked. The project's urgency was now escalated. What would normally be an 18-month project needed to be done as quickly as possible.

Navica Pulling Head welding onto Stalk #1

Images courtesy Chrysaor and Subsea 7

Images courtesy Chrysaor and Subsea 7



"We went into fast-track mode," says Eadington. "We didn't have a construction contract in place and were working quickly as a small team. We didn't want to man-mark Subsea 7's team to see what they were doing, so we put it in their hands."

"The partnership started at that point," says Alan Fyfe, Project Manager, Subsea 7. "We didn't have a written specification or scope of work that you would normally get with an EPCI (engineering, procurement, construction and installation) contract. The agreement developed as we went. We had the background work we had already done. We discovered issues en-route and we worked around them."

The original plan was to lay a new pipeline, shut down the still operating pipeline, flush it, then cut the ends of the existing pipeline to before where wax drops out to after the blockage, and connect in the new pipeline. Simple, in theory – anything flushed out would be sent on to CATS for treatment. With the pipeline blocked, flushing it out with a blockage in the middle was no longer so simple – fluids at the Lomond end would have to be flushed back to Lomond, which wasn't designed to receive fluids. This meant hot tapping the existing pipeline so the contents could be flushed back to Lomond and to CATS on the other side. In addition, a temporary pumping and filtration spread had to be set up to divert the flushed fluids back over Lomond and into the Erskine pipeline for temporary storage.

Offshore work started in mid-June, when the dive support vessel (DSV) Sevan Seven Eagle was sent in to find the existing blocked pipe. Having probed at the location where Chrysaor's inherited documentation suggested it should be, it was finally found some 4 4m away.

Mid-July the DSV Seven Pelican came in to do more preparation and hot tap work – i.e. tapping into the existing pipeline either side of the blockage to enable access to, first, run in barrier gel to isolate the wax section and then flush out any remaining hydrocarbons and towards CATS and back to Lomond.

From late July, the Seven Navica pipelay vessel laid the new 26km-long 8in pipeline - fabricated and spooled at Vigra spoolbase, Norway - and performed metrology for the spool piece construction, which had already started and ran through to the end of August. The original plan was to use the Seven Borealis for pipelay. But Subsea 7 decided that it could bring the Seven Navica out of cold stack in Leith, near Edinburgh, to speed up the schedule and do metrology works while it was on site.

The tie-in points were at Lomond, where there was a subsea isolation valve, which meant a relatively simple flange connection. At the other end, where the existing pipeline had been dredged out, to be cut, the pipeline's concrete coating had to be removed, then the pipe cut in order for the diver-installed mechanical connectors to be installed. As this work was being carried out it was discovered that the 8in pipeline was not the diameter expected. This was important in order for the connectors, construction of which had started already, to fit. Luckily, the connectors were able to be modified.

Once the new section of pipeline was installed, it was flooded, cleaned and gauged subsea, to check it clear of any damage, then inspected externally using an ROV. In August, the new pipeline was trenched in and the DSV Seven Falcon came into the field to flush and cut the pipe. Finally, the Seven Eagle returned to install spool pieces, which connect the new pipe to the ends of the old pipeline, completing its work in mid-late September. The system was ready on September 22 and production restarted on September 30 – just eight months after the project launched.

For both Eadington and Fyfe it was a project which faced

Reeling onboard Navca, Spoolbase in background.

challenges, hit problems and was dependent on subcontractors delivering. “We didn’t get it right all of the time, but enough of the time and very few things didn’t work for us,” says Eadington. “Most of the suppliers delivered on time, but when there was a delay we found time in the DSV schedule to make things happen and we got there faster as a result,” says Fyfe. “If we had planned the project, there would have been fewer campaigns. But, doing it when we had vessels available meant we got the job done faster.” Eadington adds: “a big gain from a schedule perspective was that Subsea 7 was able to accommodate changes as the project gained complexity and propose solutions.”

An advantage was also was that Chrysaor, as a small organization, was able to be nimble. When issues arose, those dealing with them were able to make decisions and run with it there and then.

“It was a real challenge, but it was great to be involved and solve it,” says Fyfe. “The project team in Subsea 7 was recognized for their work as a team but the reality is the team included Emily and her colleagues as well and there was very little demarcation in a client contractor sense. We weren’t being man-marked. We had a common goal.”

Images courtesy Chrysaor and Subsea 7

Communications, Telemetry & Data Processing

Tom Mulligan reports on the latest technologies and products being used in the maritime data processing sector

Cathx Ocean is an innovator in subsea imaging and measurement. The company's systems, software and workflows are in use globally, collecting and processing data across a broad range of marine applications. In addition, as integration specifications also differ from one vehicle type to another, Cathx Ocean has developed a range of imaging and inspection systems to address the various challenges and its product range includes:

- Hunter is designed to integrate with large and mid-size AUVs in the collection of single-swath stills and co-registered laser data. Enabling the acquisition of high-resolution, precision, flat-field images at speeds of up to 5 knots, Hunter is suited to a variety of pipeline, survey and search applications. Purpose-built for automated operation.
- Scout is a fully synchronized system delivering precision still imaging, laser profiling and video. With a specification list matching that of the Hunter AUV system, it also offers the additional functionality of a forward-looking video camera with lighting. This operates independently of the stills and laser cameras through time synchronization.
- Pathfinder is a fully integrated, laser and imaging system with co-registered laser, stills and video. Consisting of two Scout stills and laser configurations on a large work-class frame, alongside a single video camera, the system is designed to enable slower, large vehicles to collect dense dual data sets with millimeter precision.
- Designed for sled and towed vehicles, Prowler I is a drop camera imaging system for use in environmental, habitat and species mapping surveys when extremely detailed seabed images and mosaics are required. This high-resolution still imaging system can deliver resolving powers greater than 0.4 millimeters at 2-meter ranges and includes optional HD video output.

Remote asset inspection

Global mobile satellite service provider Inmarsat has developed the UAV Pop-up lab to help commercial drone companies develop remote inspection services to support offshore assets. The ability of Unmanned Aerial Vehicles (UAVs) to operate in hard-to-reach spaces has seen class societies making good use of the technology in close-up ship inspections, but satellite connectivity is now supporting 'beyond line of sight' applications offshore and is rapidly coming to include predictive maintenance.

Formally launched in February, the UAV Pop-up lab sees Inmarsat providing satellite connectivity and live mission testing to a partnership with terminal hardware provider Cobham and technology accelerator Starburst, alongside seven commercial drone companies, with L-band connectivity delivering real-time UAV control for long-range missions worldwide.

Applications include search and rescue, ground-mapping, forest firefighting and vaccine drops. Also possible are pilot initiatives for 'heavy infra inspection' offshore UK on behalf of Total O&G, BP and Siemens Games and Renewable Energy with UK-based UAV partners Intrepid Minds and FlyLogix.

Radio technology for mission-critical connections

SATEL is an innovator in independent radio networking technology that develops private radio technology solutions to enable secure, mission-critical connections with particular application for coastal maneuvers, docking in harbors and maritime weather and environmental monitoring, applications that demand high accuracy and 24/7 real-time data communications. Operations at sea also set high demands on equipment and SATEL's technology is designed to withstand extreme conditions such as salt water, high humidity, mechanical load and vibration and UV exposure.

Typical applications for the company's equipment include oil rig transport, ADCP data telemetry, seismic tail buoy tracking, AIS data for VTS systems, offloading telemetry for oil vessels, piloting and berthing systems, camera control for offshore surveillance, mareograph telemetry, weather sensoring, tide gauge telemetry, oceanographic sensor telemetry, and the monitoring of LNG bunkering.

Motion and navigation solutions

Navsight Marine from SBG Systems is a motion and navigation solution

for use in hydrographic applications. Navsight comes as a motion reference unit (MRU), providing roll, pitch, and heave, or as a full navigation solution with embedded tri-frequency receiver, or using an external GNSS receiver. The Navsight product range includes Navsight Ekinox Marine, a lightweight and easy-to-set system for portable sonar systems, highly suited for shallow-water applications and is available as an MRU, as an INS with embedded GNSS, and as an INS using the customer's own GNSS receiver. The IMU enclosure could be used as a surface version (IP68) or a waterproof one to a depth of 100 meters.

Navsight Apogee Marine is a highly versatile Navsight grade that delivers the best performance under GNSS outages, making it highly suitable for challenging shallow to deepwater applications. It consists of an Apogee grade Inertial Measurement Unit and is connected to Navsight, a rugged processing unit embedding the fusion intelligence and the optional GNSS receiver. Configuration is designed to be easy through an intuitive web interface and the 3D view helps the user check mechanical installation, sensor position, alignments, and lever arms. Navsight Marine Horizon Grade uses an FOG-based IMU and enables the Navsight system to be used in the most demanding environments such as highly dense areas, low dynamic surveys, and applications where only a single antenna can be used. Horizon IMU is based on a closed-loop FOG technology that enables ultra-low bias and noise levels while allowing robust and consistent performance in harsh conditions. Particular applications include use in USVs, ship motion monitoring and hydrography.

Gyro and IMU systems

In 2009, Sensonor was split from Infineon in an MBO supported by local investors to focus on MEMS-based sensors, aiming at applications and markets requiring high-precision sensors with a special focus on inertial systems (gyro

Image: Sensonor

Left: The STIM202 is a shock-capable, tactical-grade, ultra-high-performance MEMS gyro module designed for operation in high-shock environments.

Below: SATEL's radio networking technology based solutions are designed to enable secure, mission-critical connections in a range of maritime applications.

Image: SATEL

and IMU). Since 2012, the Norway-based company has been under the ownership of a Switzerland-based investment group. Sensonor designs and manufactures high-accuracy gyro and IMU solutions that are used in a range of industrial applications that often require cost-effective and small gyro and IMU solutions while maintaining very high performance and accuracy requirements. Typical marine and related applications include camera and mapping systems, ROV guidance and UUV/UAV guidance and control.

The STIM series gyro modules from Sensonor consist of 1,2 or 3 ultra-high-accuracy ButterflyGyro in a miniature package representing what the company says is a superior choice to FOGs regarding robustness, reliability, size/weight ratio, power consumption and cost. High-connect power and the STIM gyro module provide accurate measurements over an RS422 interface and an integrated 32-bit microcontroller that provides flexibility in the configuration, including choice of output unit, sampling frequency, filter settings and RS422 bit-rate and protocol parameters.

Electronic axis alignment is a standard feature and for advanced users, the service mode provides access to set the configuration parameters intermediately or permanently. Features such as electronic ID and advanced diagnostics with temperature measurements are also available. Sensonor designs and manufactures high-accuracy gyro and IMU solutions that are used across a range of maritime applications including multi-beam sonar systems, subsea surveying systems, navigation, helideck monitoring, heave compensation, underwater navigation for scuba divers, and drilling systems.

Underwater navigation

Sonardyne was founded in 1971 with the vision of improving the safety and efficiency of underwater navigation for divers through innovations in acoustic signal processing, hardware design and custom engineering. Two of the company's most recent innovations are BlueComm (featured on the cover and in a feature starting on page 26) a through-water wireless optical communication system developed to transmit subsea data, stream video and perform tetherless vehivle control at very high speeds; and SMART Subsea Monitoring Analysis and Reporting Technology, developed to cover a range of advanced subsea monitoring applications. BlueComm uses the electromagnetic spectrum rather than acoustic pressure waves to transmit high volumes of data and typically operates in the 450 nm blue light region of the spectrum. It can achieve data rates of greater than 500 Mbps through highly efficient optical data transmission, enabling 1 Gb of data to be transmitted over distances of more than 150 meters.

SMART brings together low-power electronics, long-duration data logging, subsea data processing, and acoustic telemetry into a single instrument and has

LEFT: AML Oceanographic's Moving Vessel Profiler is an automated, real-time solution for capturing data in underway profiling systems. **RIGHT: KVH's 1-meter, Ku/C-band TracPhone V11-HTS** provides global connectivity at data speeds as fast as 20/3 Mbps down/up, supporting critical maritime operations and business applications.

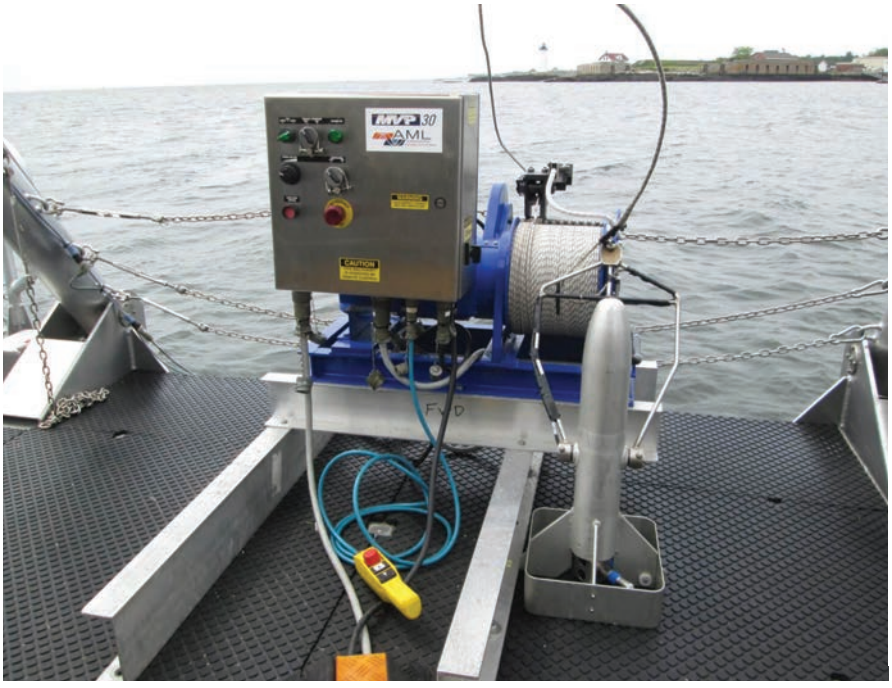


Image: AML Oceanographic

Image: KVH

the flexibility to interface with a wide range of internal and external sensors and other data sources utilizing standard or bespoke algorithms to provide key data.

Moving vessels: underway profiling systems

AML Oceanographic is a provider of marine survey instrumentation, has developed its Moving Vessel Profiler (MVP) for use in underway profiling systems. This automated, real-time solution has been used in thousands of successful surveys. Designed to remove both the technical and financial unpredictability associated with survey operations, the MVP is suitable for use in any situation including its use with small vessels and large ships, and in coastal projects, hydrographic surveys, offshore projects and in ocean science projects. The MVP comes in three versions, the MVP30/30-350 for efficiently surveying of coastal waters on a typical 25-foot launch; the MVP200, designed to collect all desired parameter data required for hydrographic and ocean science simultaneously; and the MVP300, which can collect multi-parameter data over the full water column at great depths.

KVH: Fast, Global Connectivity

To support maritime operations, Internet of Things (IoT) applications and crew connectivity, KVH introduced the TracPhone V11-HTS, a1 meter Ku/C-band maritime VSAT antenna designed to deliver global data speeds as fast as 20/3 Mbpsdown/up. The system's Ku/C-band design enables automatic switching to deliver expanded global coverage, including Northern and Southern latitudes. In addition, the antenna system features the Integrated CommBox Modem (ICM), a streamlined belowdecks unit including high-throughput modem, Voice over IP (VoIP) adapter, CommBox network management software, and built-in Wi-Fi and Ethernet.

Another feature of the TracPhone V11-HTS is its two-channel configuration, enabling users to experience both a high-speed data channel and an unlimited-use data channel from a single maritime VSAT antenna. With data speeds as fast as 20/3 Mbps down/up, the high-speed channel is suitable for videoconferencing, video chat, telemedicine, web browsing, and allocated crew usage. With data speeds as fast as 8/2 Mbps down/up, the unlimited-use channel is suitable for IoT data transfer, email, software updates, automated file transmission, weather updates, and unallocated crew usage.

For further information visit the following websites:

www.cathxocean.com
www.inmarsat.com
www.satel.com
www.sbg-systems.com
www.sensonor.com
www.sonardyne.com
www.amloceanographic.com
www.kvh.com

Sonardyne's SMART subsea technology brings together low-power electronics, long-duration data logging, subsea data processing and acoustic telemetry into a single, high-felxibility instrument.

Image: Sonardyne

Beacons, Flashers & Trackers: Products to Promote Safety at Sea

By Tom Mulligan

L3 Technologies, together with Sonardyne, will offer 6G-enabled capability across its commercial autonomous vessel product range. L3's C-Stat 2 and C-Cat 3 autonomous vessels will be offered factory-fitted with Sonardyne's 6G range of Ranger 2 Ultra-Short BaseLine (USBL) tracking and communications systems. These platforms and sensor combinations are designed to deliver optimized solutions for data gathering and subsea positioning tasks during inshore and offshore operational scenarios.

The C-Stat 2, equipped with Sonardyne's Ranger 2 Gyro USBL model, is designed for operators needing to position underwater assets with high levels of precision. The platform will enable a range of tasks, such as touchdown monitoring, seismic cable lay operations, Compatt 6 Long BaseLine (LBL) array box-in and remote LBL baseline calibration, vehicle tracking and subsea sensor data collecting.

The C-Cat 3, equipped with Mini-Ranger 2, will be able to operate as a gateway for Autonomous Underwater Vehicle (AUV) operations, enabling tracking and communications with up to 10 AUVs at the same time.

Underwater imaging sonars

The Oculus M series multibeam sonars from UK-based Blueprint Subsea are a new generation of imaging sonar, designed for use across a wide variety of underwater applications.

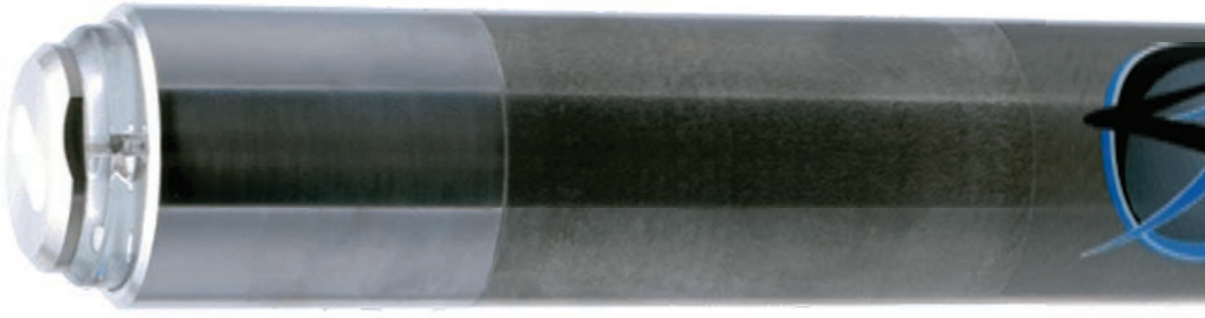
Their small form factor, weighing less than 400g in water, and dual-frequency capabilities make them ideally suited for deployment on micro sized platforms, while their rugged construction also makes them an excellent choice for larger work-class vehicles and subsea infrastructure.

With a 200m range capability, the single-frequency Oculus M370s is a cost effective alternative to traditional mechanically scanned sonars, typically being used for long range navigation and situational awareness, while the Oculus M1200d, which operates at both 1.2MHz and 2.1MHz (with a 130° and 60° field of view respectivley) is suited for specialized inspection tasks where image quality is critical.

The Oculus M750d is a general-purpose dual-frequency sonar offering up to 120 meter range capability at 750kHz, and 40 meter at 1.2MHz, with 130° and 70° horizontal fields of view respectively. With a weight in water of less than 400g, power consumption starting from 15 Watts (up to 35W) and options for 100-BaseT or 2-wire DSL high-speed communications, the M750d is ideal for mounting on small platforms, work-class ROV's or sub-sea infrastructure to provide navigation and high resolution imagery for near field target identification.

Flash pinger acoustic transmitter

Falmouth Scientific's ELPF-553 Flash Pinger For Asset Location and Recovery Applications, is a small battery-powered acoustic transmitter as well as an optical flashing recovery device. Multiple settings allow for selection of flashing, timing, and frequency options for use in a variety of different applications. The design uses an ultra-low power electronics and water turn-on sense circuitry which



The Apollo self-contained mooring beacon from Xeos Technologies Inc is an independently powered, self-contained mooring beacon that is fully submersible and is rated to 11,000m (36,089 ft) below sea level.

enable long battery life. The EPLF-553 is perfect for recovery of AUVs after mission duration has elapsed.

Self-contained LED lanterns

Tideland Signal has combined its solar module and battery self-contained package with the rugged Nova-65 LED Lantern to provide a low-maintenance and longer-range signal lantern, the SolaNOVA-65, while the company's SolaMAX-3 is a 'smart' self-contained lantern capable of ranges up to 3NM covering a variety of applications. The lightweight and compact design of the SolaMAX -3 makes it a suitable self-contained lantern for small marker buoys, docks, marinas and aquaculture sites while its specialized optics and high-efficiency solar panels make the it highly suitable for use at northern latitudes and in low-solar-radiation applications. The lantern's built-in controller allows for full monitoring and control functions via an infrared controller. Historical data can also be downloaded onto a PC for archiving and report generation.

Independently-powered mooring beacon

The Apollo self-contained mooring beacon from Xeos Technologies is an independently powered, self-contained mooring beacon with the power of an ultra-bright LED flasher combined with satellite communications that is fully submersible and has been rated to 11,000m (36,089 ft) below sea level, being designed to meet operational requirements for an ultra-deep-water submersible beacon. A LED flasher and Iridium communication highly efficient global and local retrieval options.

AToNs

JFC Marine offers a wide portfolio of marine aids to navigation product solutions including an extensive range of navigation buoys, solar marine lanterns and beacons, monitoring and control systems, navigation marker posts and top marks, and moorings and installations for a wide range of marine applications including marking out shipping channels, hazardous waters, aquaculture sites and a variety of other marine installations. These aids to navigation (AtoN) devices enable watercraft operators to determine position, course, warn of a danger and/or obstructions and indicate the location of safe or preferred channel routes. JFC recently introduced its new range of Seagull Navigation Buoys available in Ø2.6m and Ø3m, a range of modular polyethylene buoys designed for use for both inshore and offshore applications. The company also supplies a range of navigation lanterns that can be used to mark hazards in fixed or stationary locations on land but are often mounted on buoys in the water.

Broadcasting stations network

The original purpose of marine radio beacons was to provide signals for use by radio direction finders for coastal navigation. The frequencies allocated are in the range of 283.5 - 325.0 KHz. Depending on radiated power and environmental conditions, the beacon signals have a range from 10 - 250 Nm. Beacon systems have a number of advantages for broadcast of DGPS corrections. They are in place and maintained, have broad existing coverage, have the necessary frequency allocation, are relatively inexpensive to purchase and operate, and have sufficient power to provide an adequate range for coastal navigation. The modifications to the beacons to enable broadcast of DGPS corrections are straightforward, and do not cause any interference with direction finding. Also, the radio beacon equipment is reliable, and receivers for the Medium Frequency (MF) beacon signals are not inherently complex. All of these reasons have made beacons the logical candidate for worldwide coastal DGPS

MX Marine group of Navico developed the first Beacon DGPS system in 1990. The first Beacon Modulator MX50M and Beacon receiver MX50R were used by Maritime agencies for testing the Beacon DGPS systems with their Beacon transmitters. Many Beacon stations are at unmanned remote locations and therefore it was necessary to monitor the Broadcast Station from remote location. The first such system was developed and delivered by MX Marine based on DOS based operating system. Each broadcast station was developed with two DGPS reference Stations, one Integrity Monitor and control PC

SABIK MARINE is providing the Norwegian Coastal Administration (Kystverket) with remote monitored LED lanterns for their coastal waters.

Image: Sabik

software at Broadcast station and Central station. Modems with phone lines were used for communication between Broadcast station and central control station.

In 1996 MX Marine developed a New Generation of DGPS Broadcasting Stations Network. The network was developed as per the relevant standards and recommendations of the RTCM (Radio Technical Commission of Maritime Services), IALA (International Association of Lighthouse Authorities), and ITU (International Telecommunications Union). A paper (A New Generation of DGPS Broadcasting Stations) was published in ION (Institute of Navigation) conference in September 1988. A copy of this paper can be downloaded from publications menu. More than 90 such systems are supplied by MX Marine and are in operation all over the world.

Remotely monitored LED lanterns

SABIK MARINE is providing the Norwegian Coastal Administration (Kystverket) with remote monitored LED lanterns for their coastal waters under agreement. The Norwegian coast is known for its challenging conditions and difficult-to-navigate waters and the remote monitoring solution integrated in all Sabik Marine products is being used to reduce the operational challenges regarding the maintenance, positioning and monitoring of AtoN infrastructures.

All SABIK MARINE beacons meet current standards on vibrations, impacts, mechanics and watertightness and the company's LED Flashing Lanterns are manufactured with highly resistant and heavy-duty materials, such as fiberglass polyamide, marine aluminum or stainless steel, obtaining ranges from 3 to 31 nautical miles. They are fitted with optical elements made from UV-stabilized methacrylate, protected by impact-resistant acrylic lens covers and include an optical system of maximum luminous efficiency, with a wide divergence range from 5º to 30º; as well as by a user-friendly electronic control.

For further information visit the following websites:

www.l3t.com
www.sonardyne.com
www.blueprintsubsea.com
www.falmouth.com
www.tidelandsignal.com
www.xeostech.com
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Profile | Market Feature | Technical Feature | Product Feature

JAN/FEB

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Underwater Vehicle Annual

- Subsea Defense
- Southern California Cluster
- Autonomous Navigation GNSS MEMS
- Unmanned Vehicle Propulsion

Event Distribution
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Feb 25- 27, San Diego, CA
Underwater Defense & Security
Mar 5-7 Southampton, UK

FEBRUARY

Ad Close: Jan 22

MTR White Papers: Oceanographic

White Paper Electronic Edition Publication Date: February 2019

MARCH

Ad Close: Feb 21

Oceanographic Instrumentation: Measurement, Process & Analysis

- Ocean Business 2019 Technology Spotlight
- Fiber Optic Cables, Connectors & Slip Rings
- Marine Drones
- Hydrographic Sonar & Software

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April 9-11, Southampton, UK

AUVSI XPONENTIAL
Mar 29- Apr 2 Chicago, IL

APRIL

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Ocean Energy: Oil, Wind & Tidal

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- Underwater Lights & Cameras
- Buoyancy Technology
- Scientific Deck Machinery / LARS

Event Distribution
Offshore Technology Conference
May 6- 9, Houston, TX
Sea-Air-Space
May 6- 8, National Harbor, MD

MAY

Ad Close: Apr 21

Underwater Defense Technology

- Navy
- Comms, Telemetry & Data Processing
- Magnetometers & Streamers
- Beacons, Flashers & Tracking Systems

Event Distribution
UDT
May 13- 15, Stockholm, Sweden
MAST Asia
June 17-19, Tokyo, Japan

JUNE

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Hydrographic Survey: Single & Multibeam Sonar

- Research Institutions
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- GPS, Gyro Compasses & MEMS Motion Tracking
- Interconnect: Underwater Cables and Connectors

Event Distribution
Oceans 2019
Jun 17-20, Marseille, France

JULY

Ad Close: Jun 22

MTR White Papers: Hydrographic

White Paper Electronic Edition Publication Date: July 2019

JULY/AUGUST

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Seatrade Offshore Marine & Workboats
Sep 23-25 Abu Dhabi, UAE

SEPTEMBER

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Autonomous Vehicle Operations

- Subsea Engineering: Subsea Field Architecture
- ROV Technology: Work Class to Micro Systems
- Thruster Tech: Underwater Propulsion
- Underwater Tools & Manipulators

OCTOBER

Ad Close: Sep 21

Ocean Observation: Gliders, Buoys & Sub-Surface Networks

- Instrumentation: Profilers, Samplers & Sediment Corers
- Research Vessels
- Harsh Environment Systems for Arctic Ops
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Event Distribution
Oceans 2019 Oct 28-31 Seattle, WA

Clean Gulf
Nov 2- 5, Houston, TX

Blue Tech Week
San Diego, CA

NOVEMBER

Ad Close: Oct 22

MTR White Papers: Subsea Vehicles

White Paper Electronic Edition Publication Date: November 2019

NOVEMBER/DECEMBER

Ad Close: Nov 21

Acoustic Doppler Sonar Technologies ADCPs and DVLs

- Fresh Water Monitoring & Sensors
- Offshore Inspection, Maintenance & Repair (IMR)
- Underwater Imaging: Lights, Cameras & Sonars
- The 2020 Subsea Market Planner

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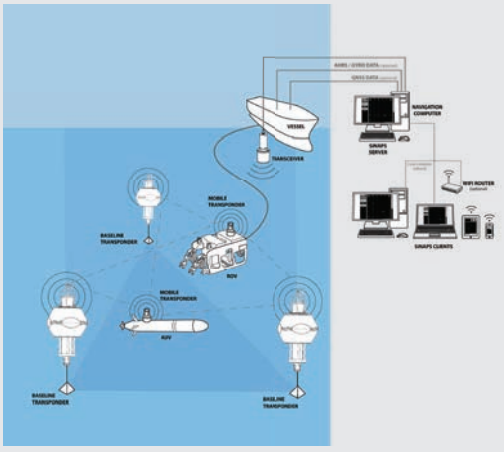

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