MARINE TECHNOLOGY REPORTER

March/April 2024
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Oceanographic Instrumentation

Exploring Submarine Volcanoes

When the Shooting Stops
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Subsea Mining
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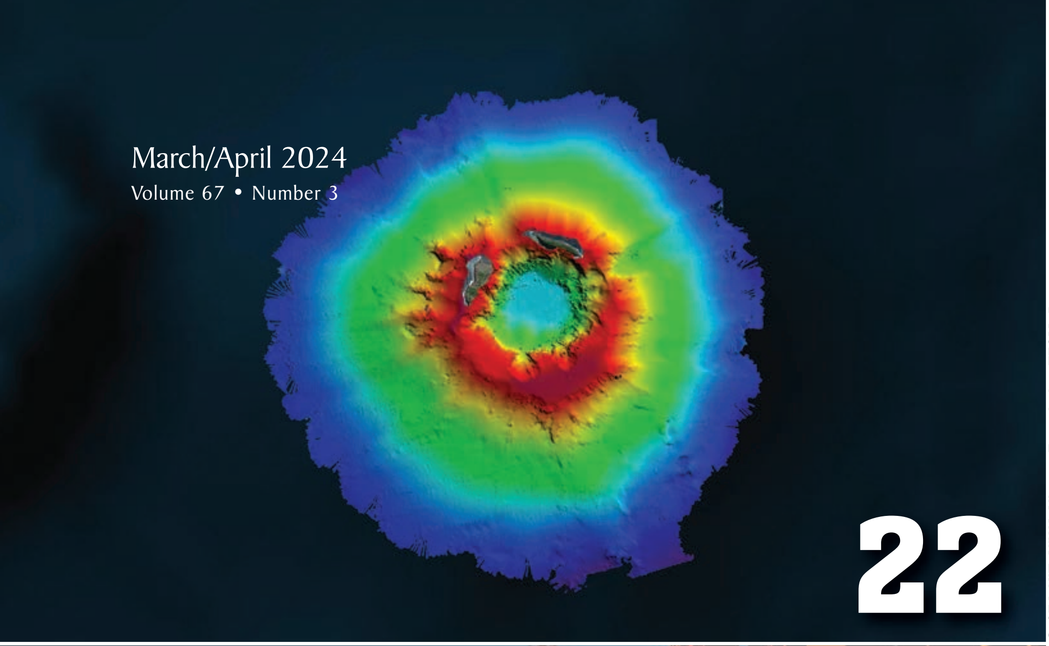

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On the Cover

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NIWA-Nippon Foundation TESMaP/ Rebekah Parsons-King

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Editorial

Justin Zuure

Last month marked the resounding return of **Oceanology International** in London, perennially one of the world's most important events serving the global subsea market. Personally, it was my first return to London for this event since 2018, as the 2020 '50th Anniversary' edition of Oi was relegated to an online only event; and the 2022 version – fresh off (most of) the world opening up post-COVID – was a mere shell of its former self. MTR participated in the 2022 event, but I skipped it as we went back out into the world with a minimalist approach in terms of the number of team members sent to specific events..

We have media serving the global maritime, subsea, offshore energy, ports and logistics markets, which in this context means that we attend a lot of exhibitions and conferences. Since we started attending 'live' again in 2022, the majority of events have re-emerged level or stronger; some have faded considerably, but more noticeably there seems to be an entire generation of new events. Invariably when I'm at one event, it always seems there are 2 or 3 others going on simultaneously that I could or should attend.

Oi has undoubtedly returned stronger, as evidenced by a packed schedule and an even more packed exhibition floor. By the end of Day 2, the recurring mantra from most was *"it's been so busy I haven't even had a chance to get out of my booth yet."*

While in London MTR again brought in it's professional video team, and with that we recorded nearly two dozen interviews across most ever geographic local and product/tech sector you could imagine; interviews that will fill our **Marine Technology TV** feed on www.marinetechnologynews.com/videos. This mass of editorial material will translate, in one form or another, to feature in our pages, print and electronic. Coverage of the Oi show floor, in case you were not in London for the event, starts on page 40.

Gregory R. Trauthwein
Publisher & Editor

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MTR Editorial Advisors

Gallaudet

The Honorable Tim Gallaudet, PhD, Rear Admiral, U.S. Navy (ret) is the CEO of Ocean STL Consulting and host of *The American Blue Economy Podcast*. He serves on several boards, is a fellow at The Explorer's Club, and is a strategic advisor for a few dozen startups, research institutions, and nonprofits in the ocean, weather, climate, and space sectors. Gallaudet is a former acting Undersecretary and Assistant Secretary of Commerce, acting and Deputy Administrator of the National Oceanic and Atmospheric Administration (NOAA), and Oceanographer of the Navy. He has a bachelor's degree from the U.S. Naval Academy, and master and doctoral degrees from Scripps Institution of Oceanography.

Hardy

Kevin Hardy is President of Global Ocean Design, creating components and subsystems for unmanned vehicles, following a career at Scripps Institution of Oceanography/UCSD. He holds patents in the field of ocean landers. He is on the academic advisory board of Instituto Milenio de Oceanografía at the Universidad de Concepción, Chile. Hardy received an honorary Doctor of Science degree from Shanghai Ocean University in 2018. He proposed making thick wall glass spheres to Nautilus Marine Service/Vitrovex (Germany) that opened the hadal depths to routine exploration. He writes for the *Journal of Diving History* and the *MTR*.

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WHEN THE SHOOTING STOPS: BLACK SEA MINE CLEARANCE WILL FEATURE ADVANCED TECH, CONOPS

By David Strachan, Senior Analyst, Strikepod Systems

Since the beginning of the war in Ukraine, mine warfare has played a significant role in both Ukrainian and Russian naval operations, underscoring how a cheap and largely unsophisticated underwater weapon can disrupt an adversary's operational and strategic plans. When the war began, a critical strategic objective for Ukraine was preventing a Russian amphibious landing in the northwestern Black Sea, which would not only have ceded control of Odessa, but enabled Russia to open up a second front. By all indications Ukraine was able to achieve this objective by laying mines in the approaches to Odessa, while Russia is alleged to have laid mines to further its own strategic objective of denying Ukraine access to the sea, threatening Ukrainian grain exports, and by extension the global food supply.

Although reports indicate that Soviet-era moored contact mines have been the weapon of choice for both sides, the true nature and extent of mining remains largely unknown. We do know that numerous drifting contact mines have been observed and neutralized in the western Black Sea, and it is believed that these are moored contact mines that have broken loose from their moorings during storms or heavy seas. They now pose a hazard to all maritime traffic, regardless of national origin, prompting Turkey, Bulgaria, and Romania to form a joint mine countermeasures (MCM) task force to help mitigate the mine threat.

As the war grinds on, sea mines will continue to pose a threat to Black Sea maritime operations, but the war will end - eventually, and this threat will need to be fully neutralized to ensure safe passage not only for commercial and naval vessels, but for the scores of fishing and recreational vessels operating from marinas along the western coast. The exact number of mines, as well as their locations, remains largely a mystery, although reports suggest that over three hundred have been deployed off the coast of Odessa alone. There are likely other minefields as well, the location and scale of which will only come to light once the war comes to an end.

Post-conflict mine clearance will require a multinational approach, leveraging both manned and unmanned technologies and their related concepts of operation (CONOPS) to “find, fix, and finish” a wide range of mine threats, including moored contact mines, floating contact mines, and bottom mines. Detecting drifting contact mines will be particularly challenging, as this will require visual detection from commercial, military, or recreational surface traffic, or electro-optical detection from the air using manned or unmanned aerial systems (UAS). And because they are adrift, these mines are also challenging to neutralize. Although explosive ordnance disposal (EOD) divers could be deployed, mines could also be neutralized at standoff range using supercavitating bullets fired from helicopter gunships.

While voluntary disclosure and intelligence reports will assist in localizing moored mines, airborne MCM rotorcraft utilizing laser detection systems can detect mines just below the surface, even those hiding in murky water. The Airborne Laser Mine Detection System (ALMDS) from Northrop Grumman can detect floating and near-surface targets using pulsed laser light emitted from a pod attached to an MH-60 helicopter. The Single-system, Multi-mission, Airborne Mine Detection (SMAMD) system from BAE Systems is a similar laser optical sensor system that can be integrated into multiple platforms, such as the US Navy’s MQ-8 Fire Scout UAV.

Once detected and identified, moored contact mines could be neutralized by EOD divers through controlled detonation, but unmanned systems are a safer and equally effective option. The SeaFox from Atlas Elektronik is a moored remotely operated vehicle (ROV) that enables standoff EOD from either a surface vessel or helicopter. Archerfish, from BAE Systems, is a similar system deployed from air, surface, or underwater platforms, and is currently in service with the U.S. Navy as part of the Airborne Mine Neutralization System (AMNS). More advanced, integrated MCM systems could also be brought to bear, such as the Raytheon Barracuda, a small AUV that can be deployed from an unmanned surface vessel (USV) to both

assist in identifying mines and act as a neutralization device.

Bottom mines pose even greater challenges. Unlike contact mines, bottom mines utilize a range of sensors to detect their prey – acoustic, magnetic, pressure – and as such pose a hazard to manned MCM vessels. To safely detect, identify, and classify these mines, AUVs would be deployed from standoff range to scan the seabed using high resolution underwater imaging systems, including sidescan and synthetic aperture sonars, as well as laser scanners. Ukraine is already in possession of six Remus 100 AUVs provided by the Royal Navy for MCM purposes, but a multinational mine clearance operation would employ numerous AUVs to measure minefield scale and density. Once mapped, the minefields could be neutralized by hunting one mine at a time, or sweeping them using a towed influence sweep system that emits acoustic and magnetic signatures to induce mine detonation. While sweeping can be a relatively quick and effective means of neutralizing mines, many modern bottom mines are equipped with "counter-countermeasures" - the ability to identify and ignore spoofed signatures, or to count ships and delay detonation, greatly complicating mine sweeping operations. Further complicating matters will be the countless natural and unnatural "mine-like objects" (MLOs) littering the Black Sea, including thousands of World War II-era unexploded mines and artillery shells.

Post-conflict mine clearance in the Black Sea will be critical to the safety and security of regional maritime operations. But this will be neither quick nor easy given the volume of mine-like objects scattered across the bottom of the Black Sea, and an unknown number and type of sea mines laid (and yet to be laid) by both Ukrainian and Russian forces. Modern MCM technologies and related CONOPS will finally come into their own, furnished with a live fire environment in which to refine techniques and procedures, and to build a valuable foundation of knowledge for use not only in future post-conflict clearance ops, but during future conflict scenarios as well.

About the Author
David R. Strachan is a defense analyst and founder of Strikepod Systems, a research and strategic advisory focusing on autonomous undersea systems.


Teledyne Webb Research Engineers deploy the Slocum Sentinel Glider in Cape Cod Bay for testing.

Teledyne Webb Research

AS THE GLIDER COMMUNITY GROWS, SO DO GLIDERS

By Shea Quinn, Slocum Glider Product Line Manager, Teledyne Marine

Anyone familiar with glider autonomous underwater vehicles (AUVs) is certainly familiar with the popularity this type of platform has seen over the past two decades, growing from emerging technology to one of the most widely used tools for oceanographic monitoring. In this time, the glider user community has also significantly grown, alongside the increasing number of use cases for which gliders provide a practical solution. Ocean monitoring – whether for environmental assessments, mammal monitoring, fisheries, physical oceanography, defense, or dozens of other missions – has driven advancements in glider technology to meet the modern demand for long-term data gathering of all kinds.

In response, Teledyne Webb Research has announced the launch of their newest product in the field of buoyancy engine driven underwater vehicles: the Slocum Sentinel Glider. The Slocum Sentinel Glider builds on the technology of Teledyne Webb Research's Slocum G3 Glider by expanding the capabilities and endurance of the vehicle.

Teledyne Webb Research (TWR) was founded as Webb Research in 1982 by Doug Webb, an engineer at the Woods Hole Oceanographic Institution and pioneer of buoyancy engine driven underwater vehicles – unmanned platforms that use a pump to create changes in vehicle density to move through the water column and collect oceanographic data. TWR uses this technology on its APEX Profiling Float and Slocum Glider products.

Since its inception as the first-ever gliding autonomous underwater vehicle, the Slocum Glider has grown to be the most-used glider platform in the world. These vehicles have been designed to be very efficient and can persistently gather oceanographic data for months or even a year at a time, communicating and sending data shoreside during surfacing events to its operators via Iridium satellite connections. TWR has delivered over 1,100 Slocum Gliders to scientific, academic, and defense customers in the past 25 years, with over 50 sensor and hardware options integrated for a broad range of missions.

"As the use of Slocum Gliders grew, so did demand for increased capability: longer missions, more sensors – especially high-energy sensors – and the need to operate in more diverse water conditions. The Slocum Sentinel Glider answers that need," said Shea Quinn, Slocum Glider Product Line Manager at TWR.

The Slocum Sentinel Glider scales the standard Slocum Glider through an increased diameter to gain better volumetric efficiency and is 8 feet in length. This expanded size allows the Sentinel to hold over 3.5 times as many lithium primary batteries as the standard Slocum Glider, and to physically accommodate up to 8 different sensor or hardware integrations.

"The size of the Sentinel gives it the energy capacity to increase mission length to over 2 years; or users can fit more high-energy sensors like active or passive acoustics, sensors with on-board processing, and imaging, without seeing a significant decrease in their overall mission length," said Quinn.

The Slocum Sentinel Glider will be driven by the industry's largest buoyancy engine, with a volumetric capacity of 4 liters – more than double any other available glider buoyancy engine. This affords the Teledyne Confidential; Commercially Sensitive Business Data Sentinel a standard glide speed of 0.75 knots. It additionally features dual thrusters on the aft of the vehicle, which users can choose to activate for a sprint speed of up to 3 knots.

"The Sentinel is the world's fastest glider – its buoyancy engine is large enough to deal with large density changes in the water column and its thrusters give it the ability to stay on track in strong currents or other difficult ocean conditions," said Quinn.

The Slocum Sentinel Glider uses the established piloting, flight control, and communications architecture of the Slocum Glider, and allows for the same sensor and hardware options as the standard-sized vehicle.

"We are excited to bring this new product and capability to our customers," said Dan Shropshire, Vice President Business Development and Program Execution, Marine Vehicles, "The Slocum Sentinel Glider represents the next generation in persistent ocean monitoring, and its features greatly expand operational opportunities for our customers."

The specifications of the Slocum Sentinel Glider open several new use cases for the glider community. With an increased need for environmental monitoring, especially to track the impact of offshore construction on the ocean ecosystem, the Sentinel can accommodate a greater number of environmental

Teledyne Webb Research

sensor options for longer mission periods.

For glider users working in fisheries and conservation, the Sentinel can run several high-energy passive and active acoustic sensors, on-board processing, and imaging hardware simultaneously for months at a time, extending deployments even in remote locations like the Antarctic.

And for users who tend to operate in areas with drastic changes in water density, strong currents, and storm conditions – such as the Gulf of Mexico or the Indian Ocean – the Sentinel's large buoyancy engine and optional thruster capability will keep the glider on track.

It is expected that the Slocum Sentinel Glider will continue the upward trajectory of glider use in a variety of applications, including new, non-traditional fields for glider use, such as oceanographic mapping and surveying. The glider user community and the diversity of their missions will continue to grow – and the Sentinel is big enough to take on the challenge.

About the Author
Shea Quinn is the Product Line Manager of the Slocum Glider at Teledyne Webb Research. Quinn came to Teledyne Webb Research from Lockheed Martin. He earned his Bachelor of Science in Electrical Engineering and Mechatronics at Villanova University and a Master of Engineering in Systems Engineering and Project Management from Cornell University.

MARINE TECHNOLOGY TV

Watch the interview on the Slocum Sentinel Glider with Shea Quinn and Clayton Jones from Oceanology International 2024 in London.

Image courtesy FORCE Technology

OPTIMIZING CATHODIC PROTECTION SURVEY USING NON-CONTACT SENSORS

By **Svenn Magen Wigen**, FORCE Technology

The principle behind sacrificial anodes, which are used to safeguard underwater pipelines and structures from corrosion, is relatively straightforward. Made of alloys like aluminum, Zinc and is some cases Magnesium, the anodes are more reactive in the electrochemical process than the steel used in pipelines and other subsea structures. When connected to a structure, the anodes willingly 'sacrifice' themselves by corroding first, effectively redirecting the corrosion away from the vital structures.

The methodology, known as Cathodic Protection (CP), is used on all underwater structures that consist of two or more touching metals, and therefore act like a battery in seawater, creating a current that causes consumption of the anode material. The practice significantly extends the lifespan of underwater structures, reducing the need for frequent repairs and replacements, which also aligns well with sustainable operational practices in the offshore industry. However, in order to protect underwater assets effectively, the condition of CP anodes must be regularly surveyed to determine when replacements are required.

Survey Methods

CP survey is part of a larger underwater integrity management strategy, normally consisting;

- Identification of threats,
- Assessment of risk associated with the identified threats,
- Inspection, testing and maintenance planning,
- Inspection, monitoring and testing activities,

- Integrity assessment, and
- Mitigation, intervention and repair.

Selecting the best method for collecting the data these workstreams demand can have implications across the board, from reducing the risk of spill events on pipelines to saving time and money across decades long maintenance regimes.

There are several methods available for measuring CP condition, and a combination of these methods may also be used to obtain a comprehensive understanding of the anodes' condition. The choice of method depends on factors like the structure's location, depth, environmental conditions, and the specific requirements of the maintenance plan.

The most common form of measuring CP systems is known simply as 'stabbing'. It involves the use of a contact probe (a.k.a., 'CP stabber') making direct contact measurement to the steel structure and the anodes, either by divers or ROVs. The probe typically consists of one or two silver/silver chloride (Ag/AgCL) reference electrodes. A voltmeter measures the potential difference between the structure and the reference electrode.

The CP level of structures can be measured with conventional CP probes, provided that the structure is not buried or otherwise covered, e.g., by rock dump. As for depletion of sacrificial anodes, this can be difficult or even impossible to estimate due to poor visibility, the presence of marine growth and/or corrosion products, or due to the anode being buried in seabed sediments or under rock dump (pipelines).

Proximity or cell to cell technologies which also required frequent calibration stabs are limited to just providing a potential profile on the structure/pipeline based on known formulas. Such technologies will not be accurate enough to provide accurate calculations of anode currents to assess remaining life, nor determine issues with current drain to or from adjacent structures.

Field Gradient Technology

Data quality and value improves through the use of non-contact surveys using field gradient sensor technology. Standard sensors in this field work by detecting potential differences between the Ag/AgCl cells, placed approximately half a meter apart, to gauge anodic and cathodic activities. However, these cells are prone to drifting and necessitate regular recalibrations — typically after every kilometer of pipeline surveyed, or every hour.

There are also weaknesses in terms of accuracy because of signal noise and the ability to detect small field gradients. In this process there is a risk that possible issues like coating damages are not discovered. This can happen because some of the signal peaks are interpreted as noise instead of being picked up as coating damage.

In contrast, a new generation high sensitivity field gradient sensor for use on ROVs and AUVs developed by FORCE Technology employs a novel approach with its electrodes mounted on a rotating head. Called FiGS, the design effectively counters the issue of cell drift and the need for calibration. Moreover, the rotating mechanism enables the sensor to determine the direction of the electric field. This directional insight not only provides a relative positioning for the findings but also ensures that the sensor's readings are consistent, irrespective of the varying positions of the ROV during the survey.

FiGS technology integrates field gradient detection with the measurement of protection levels (potential) using non-contact sensors. The collected data is then merged with CP modeling to provide a comprehensive analysis. This analysis includes accurate predictions of the asset's lifespan, anode current output, and a potential profile, offering a more efficient and thorough assessment of maritime structures' protection against corrosion than possible with stab surveys or dual cell field gradient surveys.

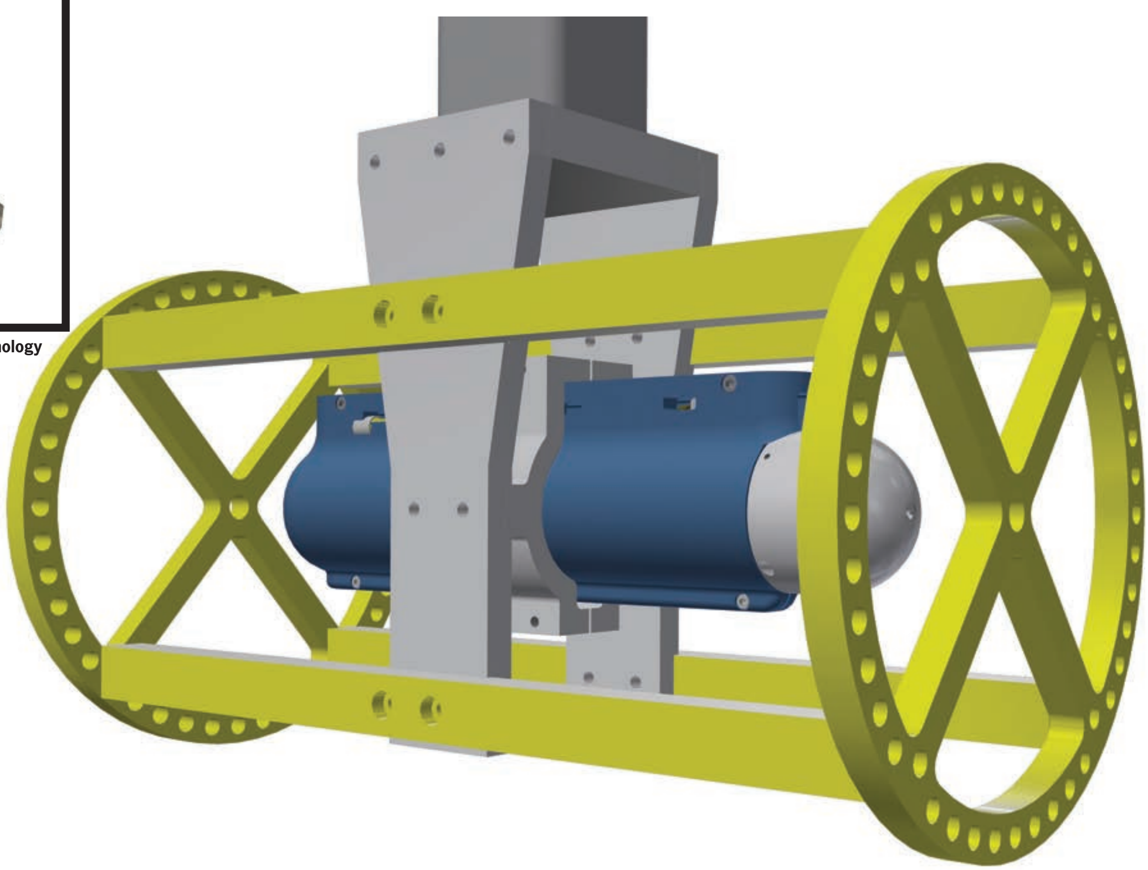
FiGS Operations and Benefits

Conventional approaches to evaluating cathodic protection (CP) systems offer only a momentary glimpse into their status. This limitation compels operators to schedule CP inspections at predetermined intervals, typically every three to five years, or to conduct CP assessments opportunistically when in the vicinity. FiGS, however, revolutionizes this process by providing detailed insights into the lifespan of the CP system. This capability enables operators to tailor survey schedules more effectively, basing them on the residual life of the anodes, thereby optimizing the frequency of inspections and reducing maintenance costs.

The system can also collect data faster than other measurement methods. A FiGS pipeline survey can be conducted with an ROV flying at a speed up to 6-8 km/h without losing valuable information. This is faster than any other advanced CP inspection tool on the market. FiGS can also be positioned higher above the pipeline and still obtain valuable data. The increased speed saves costly vessel time, while the larger measurement distance lowers the risks associated with the flight of the ROV.

Crucially, the system can be used on buried, trenched or rock dumped pipelines, obtaining the same information as for an exposed pipeline. It integrates with active pipe trackers (e.g., TSS440) as the signals from the tracker do not affect the sensor readings. This feature reduces offshore time as a pre-sur-

Images courtesy FORCE Technology



New version of FiGS in the inspection arm.

vey with the pipe tracker is not required, resulting in significant cost savings, mainly related to vessel charter.

The major advantage of using FiGS on any type of subsea structure is the large amount of accurate information obtained over a relatively limited extent of time. Also, because FiGS data is combined with detailed CP models developed using FORCE Technology's SeaCorrTM software, it's possible to easily identify issues such as hotspots including areas of under-protection as well as the impact of CP current drain e.g., to wells, using simple visualizations such as heatmaps. The larger scope, e.g., combining pipelines and structures within a subsea field on one survey mobilization increases the advantages of using FiGS, as all connected assets will affect performance of a CP system.

A complete FiGS report includes; Potential profile plot for pipelines/Potential distribution plot for 3D structures to identify hotspots/areas of under-protection, Anode current output (pipeline and structure anodes), Effective steel current density (including coating breakdown for coated pipelines/structures), Life time expectancy of the CP system in years (i.e. remaining life of sacrificial anodes), Recommended time to next inspection based on condition of CP system, Current drain (from anodes on pipeline/structures to adjacent structures, e.g., drain to well from anodes on X-mas trees), and Coating damages, with position and current supplied.

Another unique aspect is that FiGS data can be used as part of a much wider system that incorporates all pipelines and subsea structures across an entire field. Combined with new cloud-based online reporting and visualization, FORCE Technology can provide a central portal for information on all CP at an entire development or even multiple developments. This can unlock new savings across assets and locations by informing a decades long data-driven maintenance program based on highly accurate lifespan prediction for every CP anode protecting the entire subsea infrastructure.

About the Author
Svenn Magen Wigen is a Cathodic Protection and corrosion control expert having worked across engineering, design, modelling, project management, inspection, sales, marketing and management in the sector since 2001.

MARINE TECHNOLOGY REPORTER

2024 Editorial Calendar

January/Febuay 2024
Ad close Jan.31

Underwater Vehicle Annual

- Offshore Wind: A Floating Future
- Subsea Defense
- Manipulator Arms & Tools
- Autonomous Navigation
- Battery Technology

Event Distribution:
Oceanology International,
London, UK
Subsea Expo
Aberdeen, UK
Floating Wind Solutions
Houston, TX, USA
Europe Offshore Wind
Bilbao, Spain

February 2024
Ad close Feb. 4

Digital Edition

MTR E-Magazine Edition:

Oceanographic

March/April 2024
Ad close March 21

Offshore Energy

- Oceanographic Instrumentation & Sensors
- Subsea Defense: The Hunt for UXO
- Inspection, Repair & Maintenance
- Underwater Communications
- Cables & Connectors

Event Distribution:
Offshore Technology Conference (OTC),
Houston, TX, USA
UDT
London, UK
IPF Wind Conference
New Orleans, LA, USA
AUVSI Xponential
San Diego, CA, USA

May/June 2024
Ad close May 21

Dredging Technology

- Hydrographic Survey
- Scientific Deck Machinery
- Workclass ROVs
- Seismic & Geotechnical Surveys
- Sonar, Telemetry & Data Processing Software

Event Distribution:
WEDA Dredging Summit & Expo
Las Vega, NV ,USA

July/August 2024
Ad close July 21

Autonomous Vehicle Operations

- Underwater Tools & Manipulators
- GPS, Gyro Compasses & MEMS Motion Tracking
- Subsea Defense
- Deck Machinery & Cranes
- Battery Technology

Event Distribution:
Oceans 2024, Halifax
Halifax, NS, Canada

August 2024
Ad close Aug. 4

Digital Edition

MTR E-Magazine Edition:

Hydrographic

September/October 2024
Ad close Sept. 21

MTR100

Focus on 100 Leading Companies, People and Innovations in the Subsea Space

November/December 2024
Ad close Nov. 21

Ocean Observation: Gliders, Buoys & Sub-Surface Networks

- Instrumentation: Profilers, Samplers & Sediment Corer
- ADCPs & DVLs
- Subsea Defense: The U.S. Navy
- Subsea: Electrification
- Underwater Imaging: Lights, Cameras & Multibeam Sonar

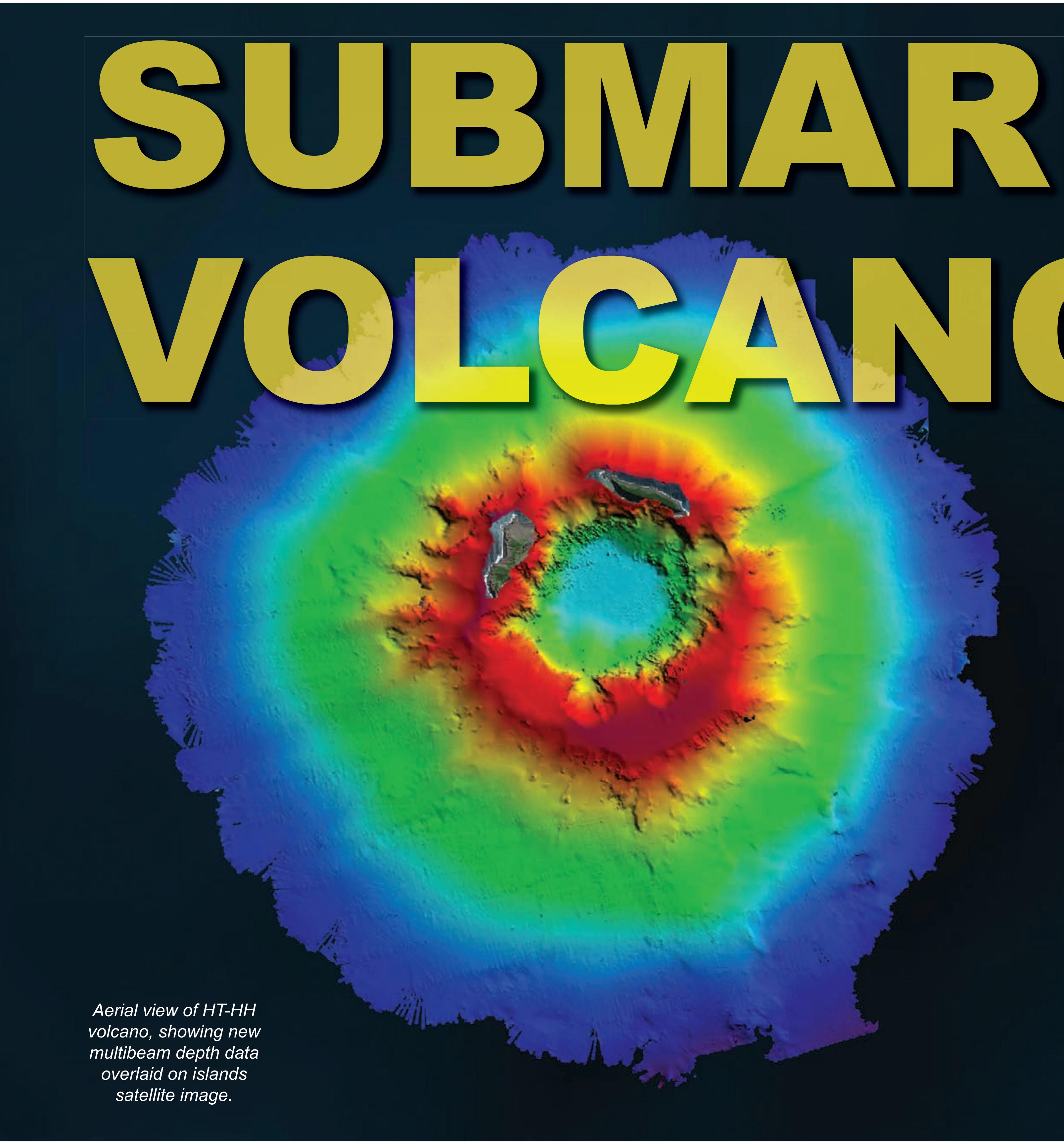
December 2024
Ad close Dec. 4

Digital Edition

MTR E-Magazine Edition:

Subsea Vehicles

SUBMAR VOLCAN



Aerial view of HT-HH volcano, showing new multibeam depth data overlaid on islands satellite image.

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OES

DETECTING THE UNKNOWN IN THE AFTERMATH OF THE HUNGA TONGA–HUNGA HA‘APAI ERUPTION

By Celia Konowe

Relatively inactive since 2014, the Hunga Tonga–Hunga Ha‘apai (HT-HH) submarine volcano began erupting on December 20, 2021, reaching peak intensity on January 15, 2022. This triggered tsunamis throughout the Pacific, destroyed lives and infrastructure, and generated the largest explosion recorded by modern instrumentation. Booms were heard as far away as Yukon, Canada; widespread atmospheric shockwaves and intense lighting storms were recorded; and satellites captured stunning images of the eruption. This catastrophic event not only shook the world but catalyzed an urgency for understanding submarine volcanoes, inspiring new research initiatives and highlighting ongoing scientific developments.

Submarine volcanoes are largely unknown, in contrast with their sub-aerial (above-ground) counterparts. Kevin Mackay, marine geologist at the National Institute of Water and Atmosphere Research (NIWA), New Zealand, said, “There are over one million underwater volcanoes, although only about 120 are known to have been active in the last 11,000 years—a number that is likely to be a gross underestimate.” He adds that submarine volcanoes have profound impacts on the marine ecosystem, supporting “habitat-forming animals such as deep-sea sponges, stony corals, sea pens, sea fans, lace corals and black corals form three-dimensional underwater forests.” These forests are a hotspot of biodiversity and species richness. Underwater eruptions are also known to change the chemical nature of the ocean in the vicinity, creating localized disruptions to the oceanic food chain. “Most volcanic activity in the world occurs on the seafloor, at least if you measure it in terms of the amount of crustal material produced by volcanoes,” added Jackie Caplan-Auerbach, geology professor at Western Washington University. “This is where new tectonic plates are created, and where hydrothermal vent and mineral deposits form.”

What’s All the Comm-ocean?

The HT-HH eruption added to the unknowns about submarine volcanoes. This type, a stratovolcano, is very common and not believed to generate an eruption of such magnitude. “Why was the eruption blast so powerful,” asked Mackay. “All communications with the nation of Tonga were immediately cut. What natural mechanism could cut the undersea communication cables that were tens of kilometers away from the volcano?” Moreover, the following tsunami came with no warning, despite a detection buoy being only 80 km away from the volcano and travelling faster than expected. Why was this?

While the answers might not yet be clear, scientists have continued employing technology to better understand the behavior of submarine volcanoes and their seabed surroundings. “Seismology and acoustics are both the study of what we call elastic waves, in which materials vibrate when force is applied to them,” explained Caplan-Auerbach. Seismology studies waves as they move through solid Earth, while acoustics examines those waves in fluids such as water or air, although the two overlap. Seismometers are best for studying processes that shake the ground, like magma moving underground. “These quakes are generally very, very small, so we need nearby instruments to detect and study them,” she adds. As sound travels efficiently in water, hydrophones are beneficial for detecting earthquakes over large distances as well as volcanic activity that releases energy into the water. Caplan-

DTIS from above, during the tow over the summit of New Volcano 1. This area is roughly 50km from Tongatapu and representative of how Hunga-Tonga Hunga Ha'apai would have looked.

Image courtesy NIWA-Nippon Foundation TESMaP / Rebekah Parsons-King

Auerbach explained that ideally, "one would have both instruments: seismometers to detect and locate subsurface activity, and hydrophones to study activity that couples into the water column."

TESMaP Makes it Mark

In April 2022, four months after HT-HH erupted, scientists from NIWA and the Nippon Foundation of Japan mobilized the Tonga Eruption Seabed Mapping Project (TESMaP) to understand the extent of impact and inform future management and recovery both in Tonga and the wider Pacific Ocean. Mackay, who specializes in seafloor mapping techniques, served as voyage lead. Phase one saw the scientist aboard RV Tangaroa, surveying the oceans around HT-HH and collecting video images of the eruption's impact.

Equipment on board included a deep-towed imaging system, multicorer, CTD (conductivity, temperature, depth), and autonomous ocean glider. Mackay's favorite was the multibeam echo sounder, generating 3D images of the seafloor using beams of sound waves. "This is the only way we can see what the seafloor looks like," he said. "To some degree it makes me feel like an explorer—the first human to ever set eyes on whatever we've just mapped. I have 'discovered' many mountains, hills, valleys and canyons that would rival anything seen on land."

Phase two, mapping inside the caldera, featured SEA-KIT International's USV Maxlimer and marked the first time an uncrewed surface vessel had been used to survey the aftermath of subsea volcanic activity. Controlled remotely from the company's base 16,000 km away in the UK, Maxlimer mapped the shape of the caldera and measured the environmental conditions of water above it. Sensors on board collected additional data, explained SEA-KIT Operations Director Ash Skett, including bathymetric and water column backscatter conditions, sound velocity, conductivity, temperature, turbidity, oxidation reduction and pressure with depth. The USV had a custom-fitted winch for sensor dips and tows to gather water column data as far down as 300 m. "This collection of oceanographic data identified layers of geothermal activity," noted Skett, "and the change in salinity and dissolved particles for comparison studies against samples gathered by RV Tangaroa outside the caldera." In all, Maxlimer mapped more than 800 km2 and travelled 1331 nautical miles over 34 days.

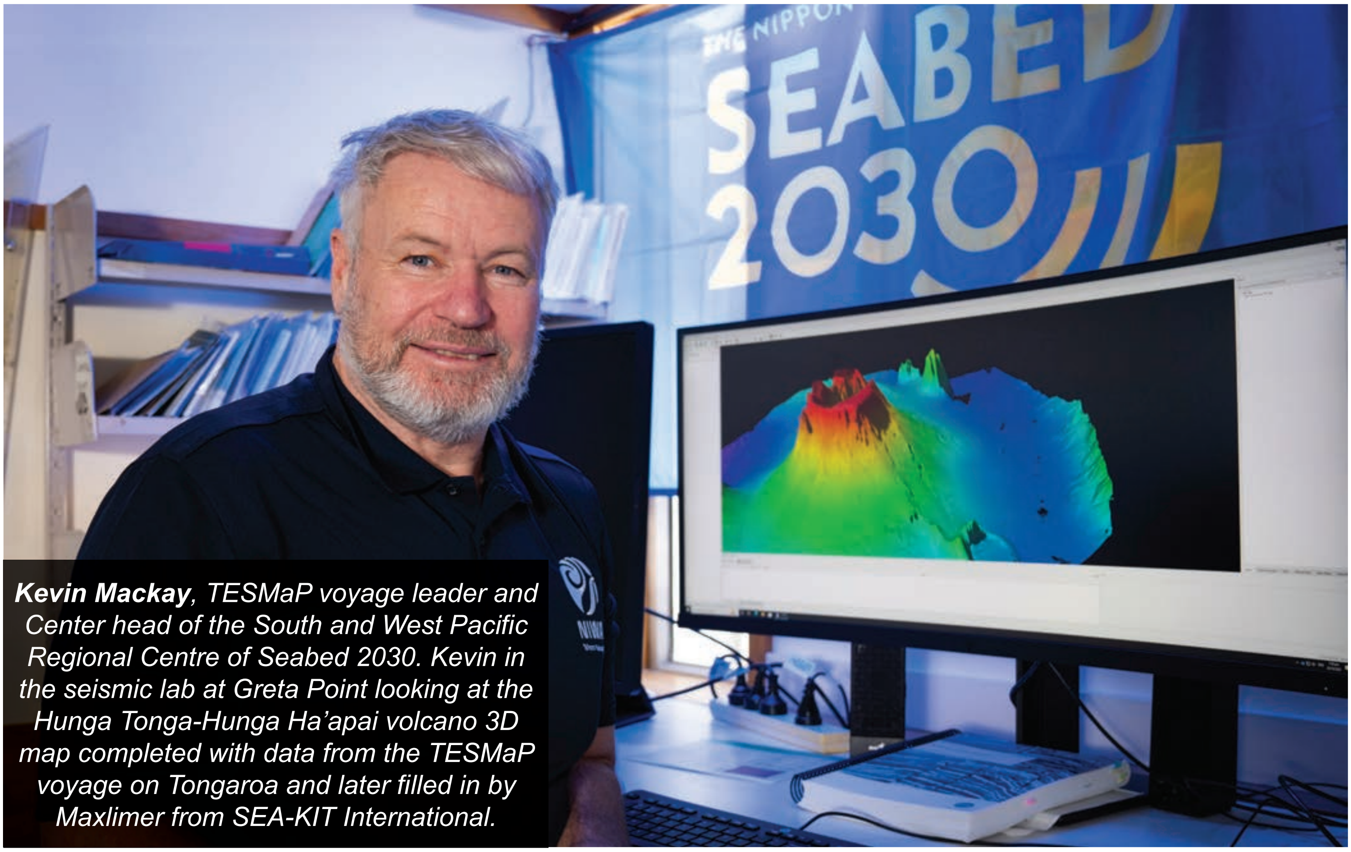
Surfacing Subsea Discoveries

Even before the recent HT-HH eruption, subsea technology helped scientists uncover the behaviors of underwater volcanoes. "We can use hydrophones to detect submarine landslides as well as earthquakes and eruptions," said Caplan-Auerbach, whose work has primarily focused on Kama`ehuakanaloa (formerly known as Lo`ihi, the youngest volcano in Hawai`i) and West Mata volcano in the Tonga arc. "We've seen a ton of landslides in acoustic data recorded off Kilauea and West Mata. Before that discovery, we had no idea how to tell if an undersea landslide had occurred."

At HT-HH, scientists mapped a total of 22,000 km2 of the seafloor and observed changes over an area of 8,000 km2. They found up to seven km3 of displaced material from the seafloor, according to a NIWA statement from November 2022. Tonga's severed domestic internet cable was buried under 30 m of ash and sediment, added Skett. Impacts on the ecosystem differed; the volcano was devoid of biology but features as close as 15 km away still had abundant life, including corals, sponges, starfish and mussels. This indicated the resilience of certain marine ecosystems, providing a new baseline for monitoring future recovery. "Preliminary water column data from Maxlimer show airborne ash that had yet to completely settle on the seafloor," said Skett. "There was also evidence to suggest the volcano was still erupting, with a dense ash layer found in the upper water column near the site."

Known Unknowns

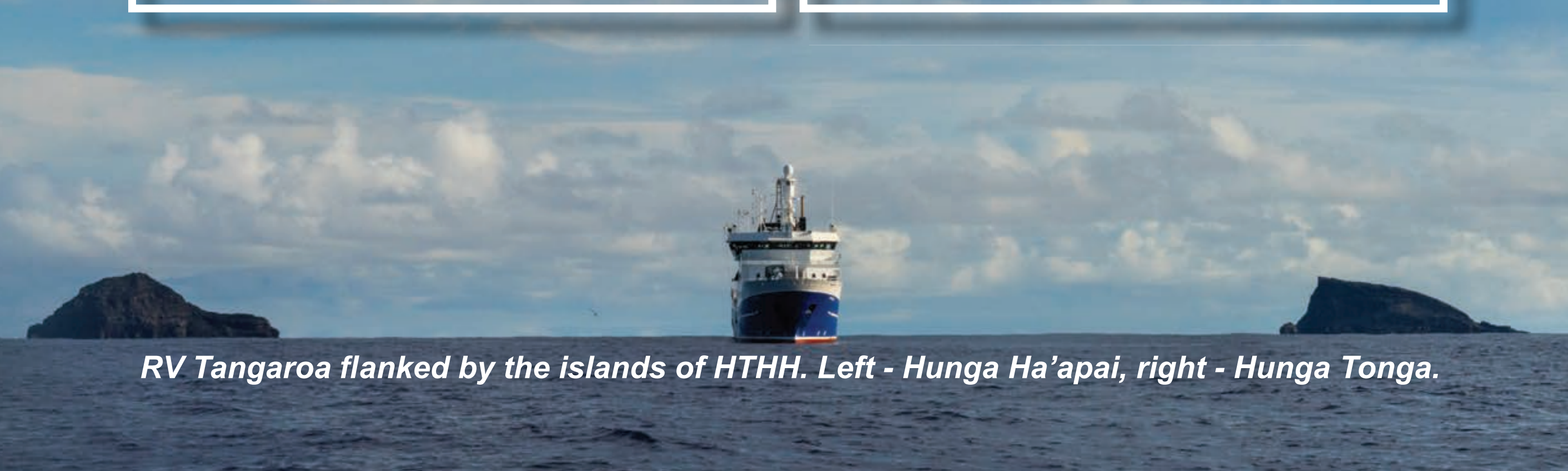
Much remains unknown about submarine volcanoes, explained Mackay, as researchers return to the eruption site more than two years later to gather additional



***Kevin Mackay**, TESMaP voyage leader and Center head of the South and West Pacific Regional Centre of Seabed 2030. Kevin in the seismic lab at Greta Point looking at the Hunga Tonga-Hunga Ha'apai volcano 3D map completed with data from the TESMaP voyage on Tongaroa and later filled in by Maxlimer from SEA-KIT International.*

Employment of technology during Phase One of TESMaP.

***Jasmin McInerney**, Ocean Instrument Engineer, talking to crew in the workboat deploying the glider.*



RV Tangaroa flanked by the islands of HTHH. Left - Hunga Ha'apai, right - Hunga Tonga.

SEA-KIT USV Maxlimer returning from HT-HH caldera in Tonga.

© SEA-KIT International

data and further assess ecosystem recovery. What is known, noted Caplan-Auerbach, is that the impact of submarine volcanoes on humans is rare. "The HT-HH eruption was a tragedy, but it was very unusual. It let us know that the hazard exists, but most submarine volcanoes are simply too deep to affect us in any way."

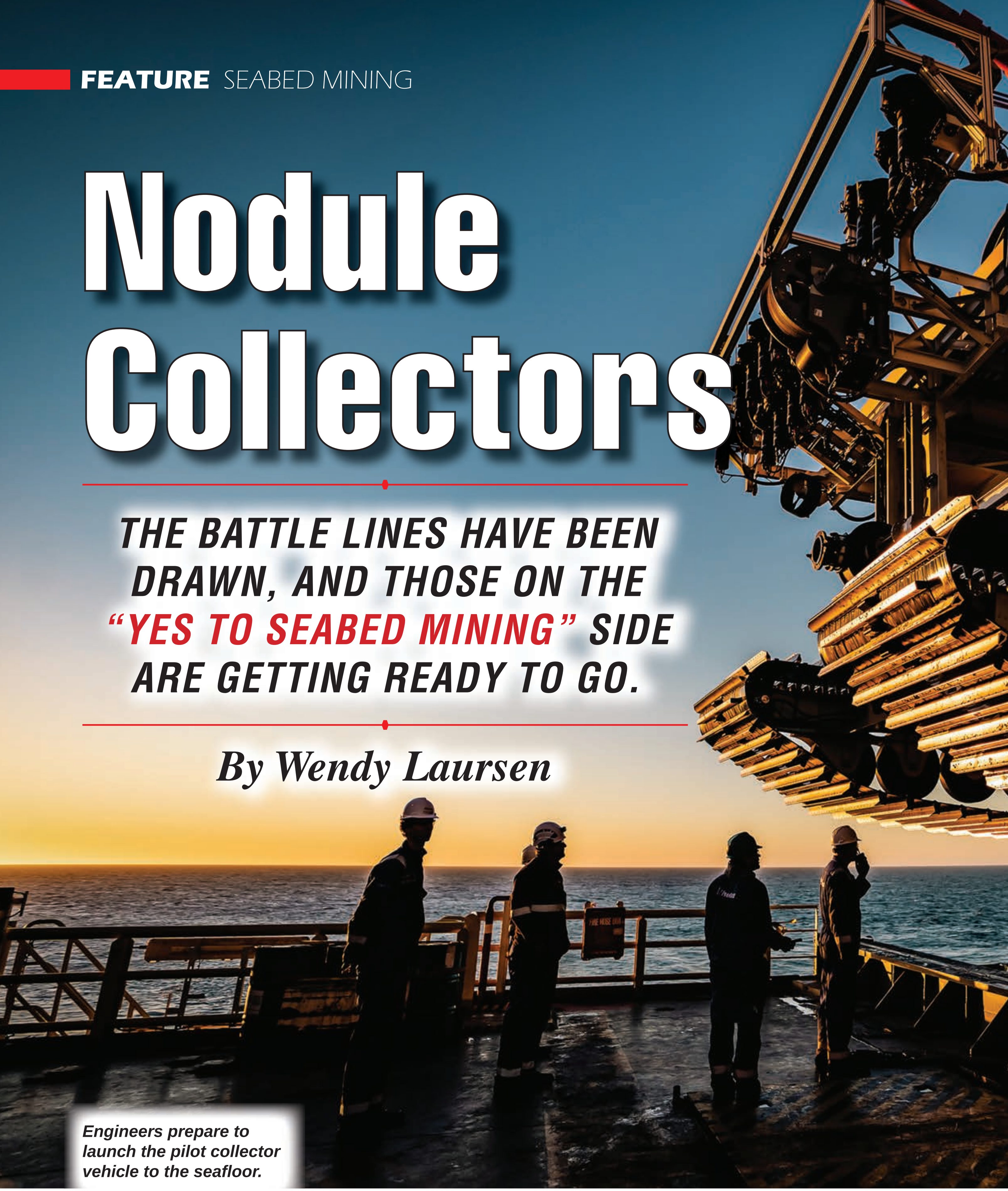
The uncommon eruption catalyzed global scientific collaboration and emphasized preexisting research on submarine volcanoes. "It highlighted a critical risk to society, exacerbated by a lack of knowledge, which could be beneficial for understanding similar volcanoes, particularly along the Pacific Ring of Fire," said Skett. USVs are also becoming more commonplace, pioneering new ways of understanding the ocean.

Current submarine volcano research suggests profound discoveries to come, featuring new technology. "Projects like TESMaP are literally rewriting our understanding of volcanoes in every measure we look at," said Mackay. Despite decades of research and new records broken, "there's still so much more to uncover."

Nodule Collectors

THE BATTLE LINES HAVE BEEN DRAWN, AND THOSE ON THE "YES TO SEABED MINING" SIDE ARE GETTING READY TO GO.

By Wendy Laursen



Engineers prepare to launch the pilot collector vehicle to the seafloor.

Image courtesy of TMC

In January, Norway said "yes" to seabed mining, adding its weight to the momentum that is likely to override the calls for a moratorium by over 20 countries and companies such as Google, BMW, Volvo and Samsung.

Those against mining aim to protect the unique and largely unknown ecology of the seafloor from physical destruction, sediment smothering and noise pollution.

However, the International Seabed Authority (ISA) has granted 31 exploration contracts in international waters and is expected to confirm mining guidelines this July, or perhaps next. Nearly two thirds of the licenses are for nodule mining, the most advanced sector.

Belgium-based GSR, part of the DEME Group, has Transocean as a cornerstone investor, and it conducted trials of a patented nodule collector, Patania II, at 4,500 meters in the Clarion Clipperton Zone in 2021. Full-scale trials will be conducted in 2027.

Patania II uses jet water pumps to lift nodules into a collection drum. Peer-reviewed research has indicated that released sediment-laden water led to a low-lying, laterally spreading turbidity current. Only 2-8% of the sediment mass was detected 2m or higher above the seabed and hadn't settled after several hours.

"All indications to date point to polymetallic nodules having the potential to become one of the most responsible ways to help meet the world's spiraling demand for metals," says GSR managing director Kris Van Nijen. "Our focus is on developing a source of high grade, low carbon minerals which can work alongside other strategies to reach the eventual goal of a circular economy and a stable planet."

Canada-based The Metals Company has partnered with Allseas which has a converted drillship, Hidden Gem, set up for nodule collection.

Onboard technology developments include the vessel's launch and recovery system (LARS) which deploys and recovers the collector and feeds its power and control umbilical. It has passive heave compensation which nullifies the wave, current and vessel motions that influence loads in the power umbilical. The LARS can operate in up to 3.5m wave height significant. The physical connection and disconnection between collector and power umbilical is performed subsea, and the LARS is fitted with a routing system that keeps the umbilical in a single plane during collector operations.

The collector's front-mounted Coandã-effect nozzles guide water over the seabed, creating negative pressure and a suction effect that picks up nodules. A diffuser at the rear creates an exit from where the sediment flows out, over 90% of which stays close to the seabed. The collector is fitted with low-impact tracks, and to further limit sediment disturbance, it has a fines rejection system.

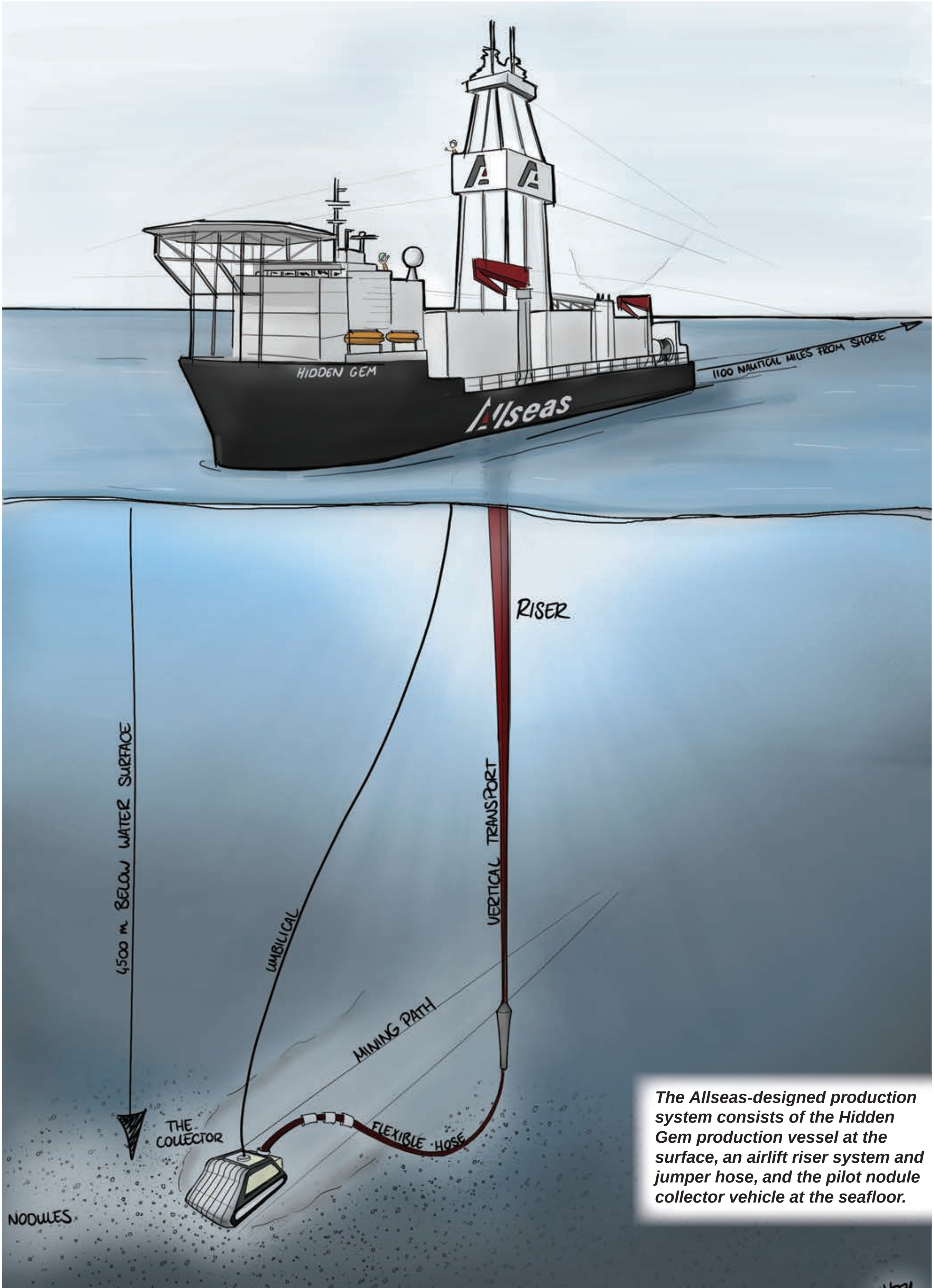
This type of technology was first tested successfully in the 1970s by major Western corporations like Shell, BP and Kennecott. "The focus since then has been on scaling while ensuring the lightest environmental impact," says The Metals Company CEO Gerard Barron. In-field collection system trials conducted in 2022 where TMC collected 3,000 tonnes of nodules have helped further advance the design.

Digital twin technology analyzes data gathered from multiple sensors and assets to enable 3D visualization of operations in real time. AI modelling can then determine the environmental impacts of the operation and test how, for example, how increasing production rate or collector speed would affect sediment mobilization and enable TMC to model different scenarios to reduce this impact, says Dr Greg Stone, Chief Ocean Scientist.

Research conducted by Nauru Ocean Resources, a subsidiary of The Metals Company, found that organisms continue to be present and alive 12 months after having been influenced

SMD developed the mining machinery planned for the Solwari 1 sulfides project.

Image courtesy of SMD



The Allseas-designed production system consists of the Hidden Gem production vessel at the surface, an airlift riser system and jumper hose, and the pilot nodule collector vehicle at the seafloor.

Image courtesy of Allseas

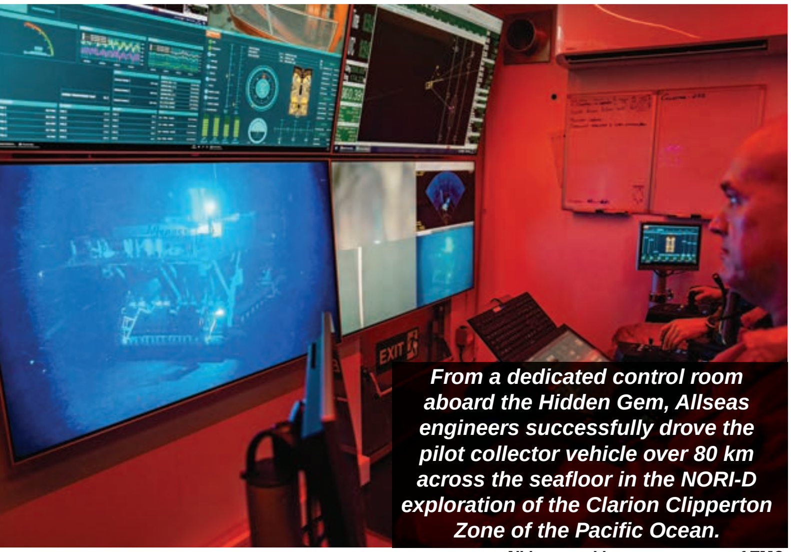
by a seafloor plume from its pilot collection system test.

The Metals Company recently signed a binding MoU with Pacific Metals Corporation of Japan for a feasibility study on processing 1.3 million tonnes of wet nodules per year, and the company is also exploring opportunities for the construction of a U.S. refinery - the Pentagon is expected to deliver an action plan on nodules by March 2024.

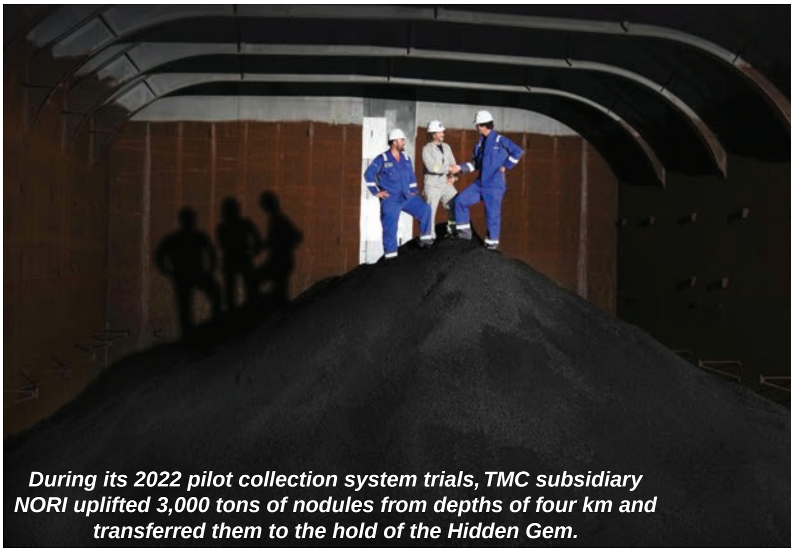
UK-based Soil Machine Dynamics (SMD) designed, developed and delivered the mining machinery planned for the Solwara 1 Seafloor Massive Sulphides project some 15 years ago, and it is now developing a patent pending, least impact, nodule collection system that utilizes mechanical and hydraulic technology.

The company's SMD Q-Collector range is available in a variety of sizes to suit vessel and client requirements. Engineered to have a low submerged weight, these vehicles are made with light plastic tracks and buoyant syntactic foam. The collection vehicle uses sonar to identify the position of the nodules and has attained collection efficiency rates of at least 97% in recent university trials.

Ian Maskell, principal engineer, says: "The eyes of the world will be on these projects, and this will be the most



From a dedicated control room aboard the Hidden Gem, Allseas engineers successfully drove the pilot collector vehicle over 80 km across the seafloor in the NORI-D exploration of the Clarion Clipperton Zone of the Pacific Ocean.



During its 2022 pilot collection system trials, TMC subsidiary NORI uplifted 3,000 tons of nodules from depths of four km and transferred them to the hold of the Hidden Gem.

All images this page courtesy of TMC

Engineers attach float sections to the flexible jumper hose that connects the four-km-long airlift riser pipe to the collector vehicle on the seafloor.

regulated industry in the world." However, commercial success depends on many factors, not least a predictable OPEX. Over the past four years, SMD has worked with Oil States Industries to calculate cost per tonne figures for prospective customers.

Oil States' Merlin riser systems were successfully deployed on both the TMC / Allseas and JAMSTEC 2022 pilot projects. They also hold a world record water depth for a producing riser system of 14,764 feet.

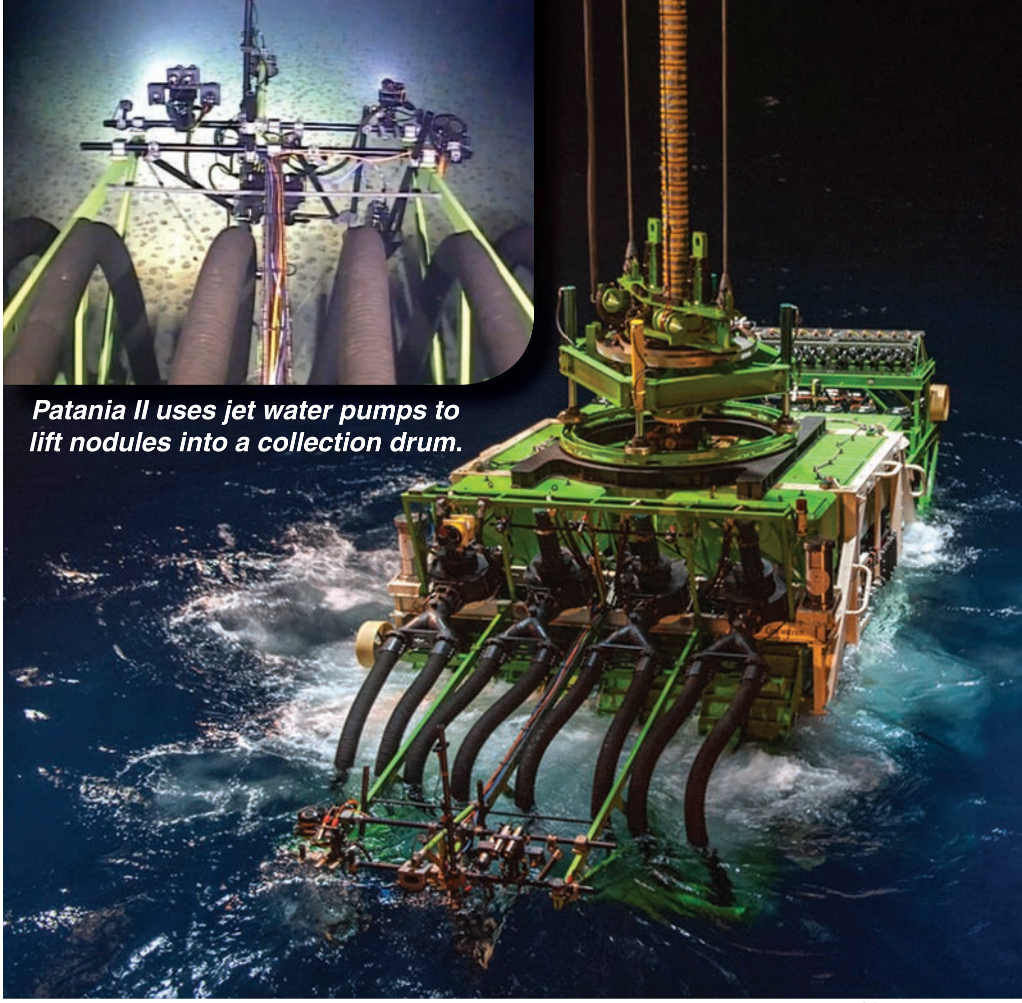
Impossible Metals is developing a nodule collector, unlike other technologies, is untethered and hovers above the seabed, picking nodules with robotic arms. CEO Oliver Gunasekara cites three unique developments: the battery-operated buoyancy engine, fast-acting robotic arms and the AI algorithms that guide them, identifying and avoiding nodules with visible life present.

A second-generation collector, Eureka II, is currently being tested off the US east coast. It has three arms, but the much larger Eureka III will have 16 arms. Gunasekara estimates that a fleet of around 16 of these autonomous collectors would be a break-even point for commercial operations, with scale up from there possible gradually.

Hundreds of collectors can be deployed concurrently. Once a collector has achieved its 6,000kg payload, it can return to the surface, and as the surface vessel reaches capacity, it can return to shore while the collectors continue to load on a second vessel.

There is no sediment release mid-water like the other technologies and no noise from pumps or the DP system of vessels. "We have really gone out of our way to mitigate all of the negative feedback that the industry has received."

Still, the pushback continues. A 2023 Planet Tracker report highlighted that, like crude oil, nodules take millions of years to form, so biodiversity loss would essentially be permanent. And in February 2024, the European Parliament passed a resolution raising concerns about Norway's mining intentions.



Patania II uses jet water pumps to lift nodules into a collection drum.

Images courtesy of GSR

LANDER LAB #10

BATTERY PACKS, CHARGING, AND CAPACITY TESTING

Photo Credit: Hanumant Singh / Woods Hole Oceanographic Institution.

By Kevin Hardy, Global Ocean Design LLC

An ocean lander has many strengths including flexibility of deployment location and tremendous seafloor persistence. Stored electrical power in batteries permit the untethered operation of seafloor instrumentation on ocean landers, activate the release of the descent weight, and power surface recovery beacons.

BATTERY BASICS

A cell generates electrical power through two galvanically active materials immersed in a conducting electrolyte. The galvanic difference between the cell anode and cathode is the potential and measured in volts. A battery is made from some number of cells in a series. The capacity of a battery is its ability to discharge current over a period of time, measured in amp-hours. A battery's energy, measured in watt-hours, is its capacity times its average potential. A battery pack is the assembly of batteries in series, to increase voltage, in parallel, to increase current capacity, or both.

There are two broad classes of batteries, primary and secondary. Primary cells can be used once, as the chemical process that produces the current is irreversible. Examples include alkaline and lithium cells. Secondary cells can be recharged by application of reverse current from a charger. The interior anode and cathode plates are refreshed in the process. The regeneration process is not perfect, and some material is lost in each discharge-recharge cycle. This limits the number of times the battery may be recharged, known as cycle life.

FACTORS EFFECTING CAPACITY

Batteries work on chemical reactions. The chemical reaction rates are largely driven by temperature. The colder temperatures of the deep sea will lower the capacity of most battery chemistries, some more than others.

Batteries are assigned a capacity rating based on some moderate Discharge Rate. If the actual rate exceeds that moderate discharge rate, the battery will be depleted faster due to increased internal resistance. Consult the manufacturer's datasheet for the discharge graphs.

Many batteries have a self-discharge rate, which means that even on the shelf under no load, the cell's reactants will slowly combine and reduce the amount of energy available.

Figure 1

A self-righting vehicle design with buoyancy high and weight low, WHOI's SeaBED AUV captures the attention of a pair of curious Antarctic penguins as it is deployed from the British research vessel James Clark Ross. Vehicle designers allowed for temperature reduction of battery capacity.

Rechargeable batteries may be put on trickle chargers to prevent this, as on a cabled-to-shore node, but untethered vehicle designers have to allow for this by adding additional capacity initially.

Some battery chemistries, principally Nickel-Cadmium (NiCd) and Nickel Metal Hydride (NiMH), have recharge memory effects. The condition describes the way these batteries gradually lose their maximum energy capacity if they are repeatedly recharged after only being partially discharged.

Increasing the ambient pressure on a battery capable of pressure compensation has no effect on the reaction rate as the solid or liquid materials are largely incompressible. Batteries in a metal case, including common alkaline cells, cannot be pressure compensated.

Physical Modifications to a battery, including means to pressure compensate the cells, can affect battery capacity.

COMMON BATTERIES IN MARINE APPLICATIONS

Certain chemistries have found wide use in the marine field for their availability, energy density, ease of handling, and cost. These include primary cells such as alkaline and lithium, and secondary cells including Nickel Metal Hydride, Nickel-Cadmium, Lead-acid, and recently lithium-ion and lithium-polymer. Each have advantages and disadvantages, and choosing one generally involves some measure of trade-off.

- **Battery Packs:** Soldering directly to batteries may damage the cell. Batteries can be purchased with spot welded nickel solder tabs that provide a ready way to join the cells into battery packs. Standard packs in rectangular geometries can be purchased from vendors such as Digikey. Numerous domestic manufacturers will assemble cells into custom battery packs. (Google "Custom battery pack manufacturers".) If you need to design your own, take a look at "Engineering Guidelines for Designing Battery Packs," at **PowerStream.com** (**www.powerstream.com/BPD.htm**).
- **Alkaline (alkaline-manganese dioxide):** These primary cells are available in the widest number of standard sizes, and are commonly available around the world. This is handy if you are in a remote port and need to cobble together a spare battery pack. Tip: Don't rely on spring-loaded battery holders for critical applications. Duracell reports that as the temperature drops to 0°C, alkaline cells loose about 1/3 of their capacity. As current drain increases, the temperature impact becomes more dramatic.
- **Lithium-iron (Li/Fe):** These primary cells from Energizer work as a replacement for alkaline batteries with a 1.5 V nominal voltage. Energizer Ultimate Lithium brand AA, AAA cells and 9v batteries employ this chemistry. These have 2.5 times higher capacity during high current discharge cycles than alkaline batteries, better storage life due to lower self-discharge, and more capacity at lower temperatures. The temperature effects on capacity only begin to show up after the cells pass below 0°C.
- **Lithium (Lithium-thionyl chloride, Li-SOCl2):** These primary cells have the highest energy density of all common cells, and the ability to deliver large amounts of current in a very short period of time. As a consequence of earlier misfortune, each cell is built with an internal fuse to protect it from being shorted and discharging rapidly with its attendant problems of outgassing and possible explosion. The metallic lithium, contained inside a thin stainless-steel cylinder, is extremely reactive with water.
- **Lithium-ion:** These secondary cells are not subject to memory effect, capable of moderately deep discharge, and much safer than primary lithium cells. They are used in applications requiring lightweight and high-power drains. They do require built-in protection against overcharging and over discharging. They have a relatively low self-discharge rate, about 6% per month. Li-Ion batteries are usually encased in a hard metal can to keep the electrodes wound tightly against the separator sheet, adding some weight and limiting the number of shapes and sizes.
- **Lithium Polymer (LiPo):** A lower cost version of the Lithium-ion battery. A LiPo battery uses a dry, thin electrolyte polymer separator sheet laminated between the anode and cathode plates in a construction called a "jellyroll". This method produces a thin cross section and wide range of flat shapes. LiPo batteries are considered safe for the trashcan and landfills once fully discharged, which manufacturers say can be done by dropping the pack into a bucket of saltwater.

Figure 2

LiPo pouch cells have been tested in oil-filled bags to pressures of 20,000psi without damage. Their solid-state BMS protective circuitry can likewise be pressure tolerant.

Photo courtesy EHAO Manufacturing

Of special interest for marine applications, LiPo batteries are offered in a "pouch" design, with a soft, flat body. The pouch is vacuum-sealed, with all voids filled by a gelled electrolyte. Thus, there are no implodable spaces, and so are candidate cells for pressure-balanced, oil-filled (PBOF) assemblies. This author has personally tested pouch LiPos to 20,000 psi immersed in mineral oil inside a Ziplock™ bag, and not seen nor measured any performance degradation. The potential advantage to designers is two-fold: 1) battery packs carried on the outside of a pressure housing only subtract their water weight from the overall buoyancy, while carried inside, they subtract their air weight; and 2) it is easier to exchange batteries on a small ocean lander or AUV by unplugging the spent exterior battery packs and plugging in the replacement charged ones. (See Lander Lab #5, MTR, November/December 2022)

On March 26, 2012, James Cameron's DEEPSEA CHALLENGER submersible and ocean lander DOV MIKE demonstrated the practicality of this approach, diving the Challenger Deep in the Mariana Trench using PBOF, BMS-protected lithium polymer pouch batteries. The submersible's power could be configured to be as high as 96KWh, though it was typically between 76KWh and 84KWh on the 12 manned dives. These came from a maximum of 96 PBOF LiPo battery packs, divided into three buses. The sub could operate off a single bus in emergency mode. All power and control signals were passed through the Pressure Hull via four discrete penetrators in the penetrator plate at the upper pole of the Pressure Hull. The ocean lander used the batteries to power its LED lights and camera systems.

Shipping any kind of lithium battery can be a challenge, and IATA regs vary with the batteries inside or outside an instrument housing. Freight companies, including DHL, FedEx, and UPS, have specific guidelines available on their websites.

Lead-Acid: The venerable lead-acid battery comes in three variants: 1) wet-cell or flooded, 2) Absorbent Glass Mat (AGM), and 3) gel electrolyte cells. The latter two are known as valve regulated lead acid (VRLA), maintenance free designs. Lead-acids are temperature dependent, and their capacity may fall to as low as 60% of rated capacity as they approach 0°C depending on current drain. Lead acid batteries can provide substantially higher capacities when discharged at a rate lower than 1C.

Lead-acid wet-cells must remain upright or the electrolyte, a 35% sulphuric acid and 65% water solution, will spill. They can be exposed to high ambient pressure, and can be mounted outside the hull, as was done on the bathyscaph DSV Trieste in the early 1960's. If exposed to seawater, they must be pressure-compensated. Any compensation fluid must consider specific gravity, miscibility, and surface tension with respect to the electrolyte.

If sealed with a rubber diaphragm, the battery must be vented to manage gases formed during charging. (Myers, 1968) An innovative means of pressure compensation was shown by Frank Snodgrass, Scripps Institution of Oceanography, in 1968. His wet-cell automotive batteries were open to the sea at the top, filed to the cat eye indicator with electrolyte. A PVC riser tube extended each cell and was filled with an im-

Used with Permission, Earthship LLC.

Figure 3

James Cameron's DEEPSEA CHALLENGER rests on its back on the deck of the R/V Mermaid Sapphire, prior to its historic dive in March 2012 to the bottom of the Challenger Deep in the Mariana Trench. The sail is to the left, the keel is to the right. The starboard side PBOF LiPo battery packs are located behind a clear polycarbonate panel mid-body above the thrusters. A second identical set of batteries is located on the port side of the vehicle. Individual battery packs are held in separate pockets machined into the ISOFloat syntactic.

miscible barrier fluid heavier than seawater (sg=1.026) and lighter than the battery electrolyte (sg=1.265). The original cell vent cap was screwed into the top of the riser pipe to vent the gases associated with charging. Wires were soldered to the lead (Pb) posts. The lead-acid battery was additionally used as an expendable ballast weight. Hence, the modified battery assembly was contained in a low-cost plywood box potted with hot tar. A pressure-compensated pull-apart connector allowed the simple disconnect of the electrical leads as the vehicle released from its ballast frame. (See Figure 4).

Absorbent Glass Mat (AGM) lead-acid batteries are constructed differently than the wet-cell battery. AGMs are considered a "Recombinant Gas Absorbed Electrolyte" battery. In AGM batteries, also called starved electrolyte batteries, there is a thin, ultra-fine fiberglass mat sandwiched between the plates of each cell that is saturated with battery acid to about 95% of what it can hold. This glass mat absorbs and immobilizes the acid while still keeping the acid available to the plates. The mat is slightly compressed between the plates when assembled in a frame. Because the plates and mats are packed fairly tightly, they are virtually immune to vibration. The remaining volume around the plates is air-filled, so that even if the case of the AGM battery is broken, no electrolyte will be spilled. It also makes the AGM battery lighter. Since the glass mat restrains the electrolyte, the AGM may be used in any orientation.

For an AGM battery to be adapted to a pressure-compensation system, thought must be given to the introduction of a compensating fluid other than electrolyte into the interior air-filled voids of the cells. The compensating fluid will have a dielectric strength, miscibility, and surface tension unlike the electrolyte. It is suspected that the compensating fluid preferentially wicks by capillary action into the glass mat, displacing the electrolyte. A reduction in battery capacity will follow as the opposing positive and negative plate areas are occluded by the intruding volume of compensating fluid. The terminal voltage will remain about the same, and charging will appear to proceed normally, but the adverse process reducing capacity will advance with succeeding charging cycles, presumably due to gas generation during recharge. A battery capacity test, described below with the West Mountain Radio CBA V, can be done to replicate this experiment yourself. (See Figure 7.)

- **Gel cell Sealed Lead-Acid (SLA)** batteries substitute a gel-type electrolyte for the liquid in basically a wet-cell lead acid battery. This permits it to be used in any position. They are operated at a lower potential to prevent gas generation, meaning they are never fully charged, resulting in the lowest energy density of all secondary batteries. They have low self-discharge rates, and no memory effects. They cannot be fast charged. They do have some promise of uncompromised function if pressure compensated, though this author has never tried that.

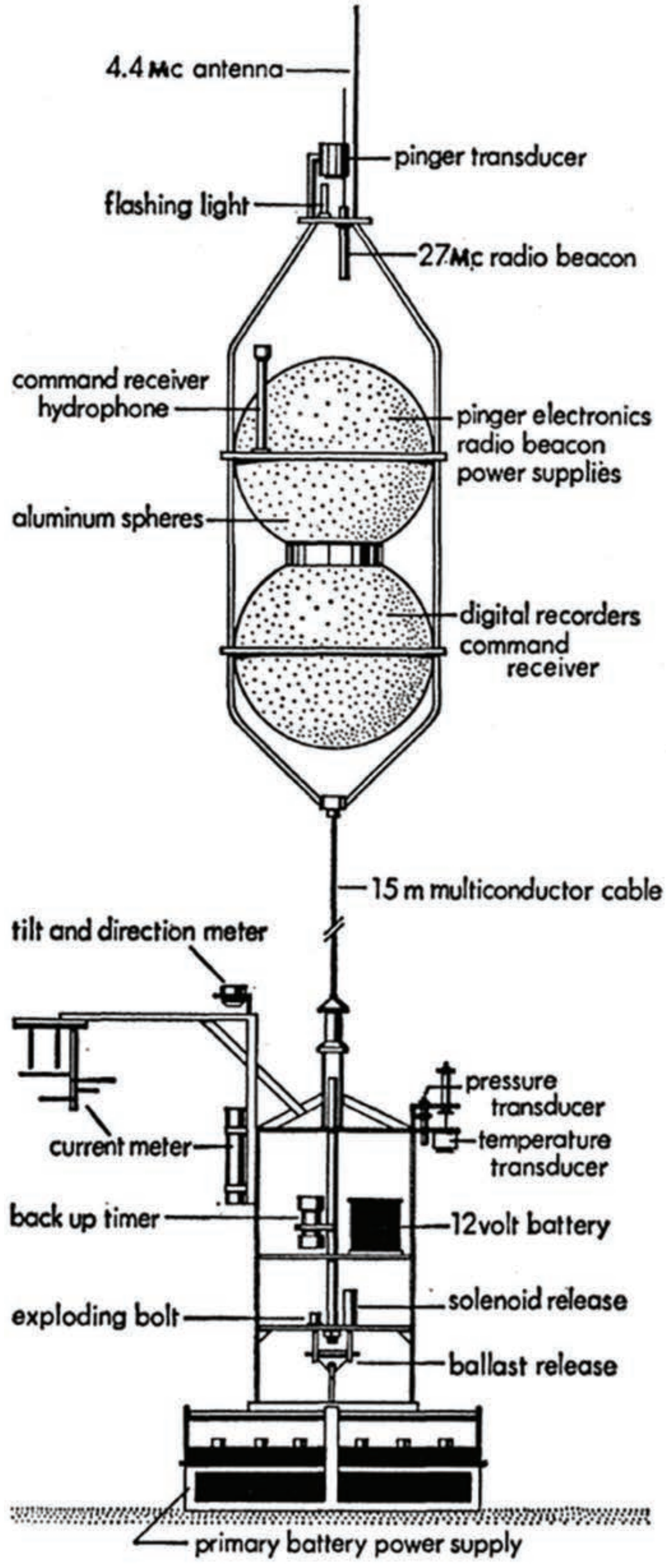


Photo Science, Vol 162, #3849, Oct 4, 1968

Figure 4

Scripps Institution of Oceanography's Munk-Snodgrass deep sea tide capsule with expendable ballast frame and lead-acid batteries, 1968.

Photo courtesy of Clarios/AutoBatteries.com

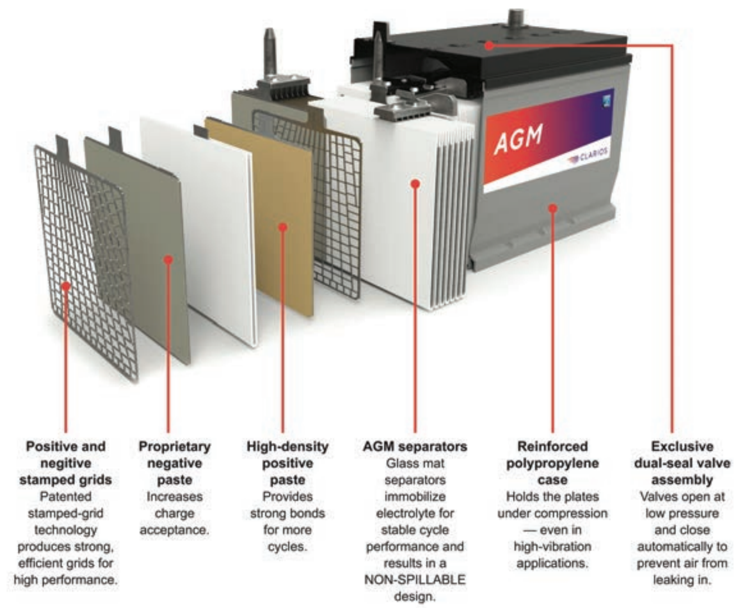


Figure 5

Exploded view of an AGM lead-acid battery.

Photo courtesy West Mountain Radio

Figure 6

The West Mountain Radio Computerized Battery Analyzer (CBA V) attaches to a laptop by a USB-B cable, and to a battery by Powerpole® Connectors.

- **Nickel-Cadmium (NiCad)** batteries have a lower nominal cell voltage of 1.2v/cell. They can be recharged up to 2,000 cycles. Self-discharge rate is 20%/month. They have a reasonably high power-to-weight ratio. The discharge curve of a NiCad battery is flatter than other batteries. The NiCad battery can handle very high discharge rates, on the order of 15C, with no damage or loss of capacity.
- **Nickel Metal Hydride (NiMH)** batteries have high energy densities, self-discharge rate of up to 30%/month, and display some memory effects. Their max discharge rate is 5C. NiMH cells are advantageous for high-current-drain applications, largely due to their lower internal resistance. NiMH can suffer longevity issues with deep discharge, but this may not be an issue if only a limited number of deployments are expected.

There is a low–self-discharge nickel–metal hydride battery (LSD NiMH). The LSD NiMH battery, known as Eneloop, is currently only available as AA and AAA.

CHARGING

Dependable performance and long battery life depend upon proper battery charging. Use a charger designed for the batteries you have. Universal smart chargers are pre-programmed for the correct charging profile for the different battery families. It just takes some user knowledge to set the charger for the right profile.

LiPo batteries can be ganged in parallel on a two-wire voltage bus, as was described in Lander Lab #5, "Lithium Polymer Batteries" (MTR, November/December 2022). Because each LiPo battery is regulated by its own BMS (Battery Management System) the batteries are individually balance charged and balance discharged on the same two-wire bus.

QUANTIFYING BATTERY CAPACITY

The best way to determine a battery's capacity is to measure its actual performance using a computer-controlled battery analyzer, such as the Computerized Battery Analyzer (CBA V), from West Mountain Radio (**https://www.westmountainradio.com/**). The CBA V can test any type or size of battery, any chemistry or number of cells, up to 57 volts, and up to 200 watts continuous. A 100v version is also available. The basic model is an affordable $189, while the Pro version is just $40 more.

The CBA measures the actual amount of energy stored in a battery, and reports that in units of amp-hours or watt-hours. The system graphically displays the voltage-versus-time on a single page using a constant current load. Displayed graphs may be saved and printed. Multiple test graphs of the same battery under different conditions, or multiple batteries under similar conditions, may be overlaid and compared. (See Figure 7.) Test result labels can be printed to put on the tested batteries.

The CBA's intuitive software is designed to protect both the CBA and the batteries being tested, providing automatic sensing of the battery cell count, a safety check of the test rate, and recommendation of a minimum safe discharge voltage.

This author has also used the CBA to check the function of a low-voltage cut-out (LVCO) to prevent over-discharge of a LiPo battery by setting the CBA cut-out voltage 0.50vdc lower than the rated LVCO minimum. The LVCO was confirmed to work as advertised.

Primary cells may be tested and used to predict performance

Photo courtesy Global Ocean Design

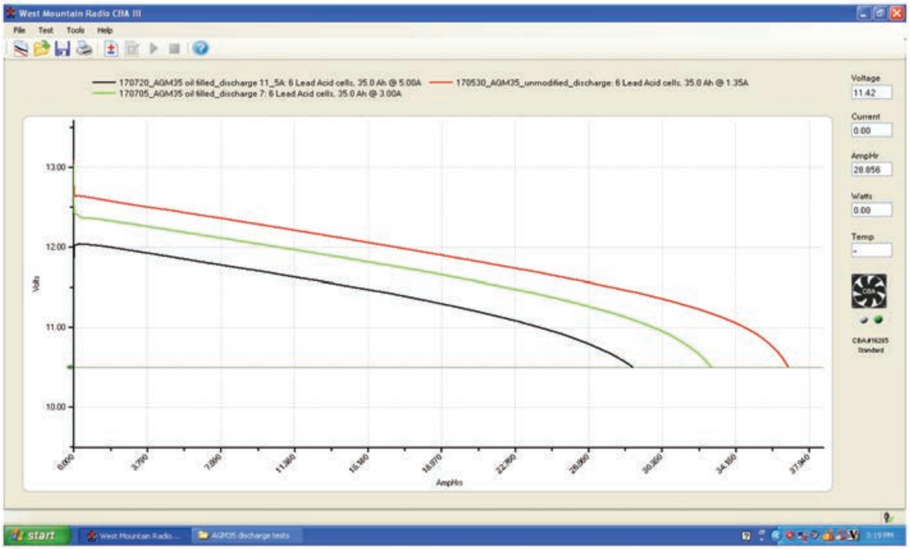


Figure 7

A 35Ah AGM lead-acid battery is tested using the West Mountain Radio CBA to show the effect of simply filling the battery voids with mineral oil as a compensating fluid. The CBA is programmed to cut-off at a voltage of 10.50v. The top line (red) shows the unmodified AGM battery capacity of 37Ah on its fourth discharge, exceeding the manufacturer's rating. It took 3 charge/recharge cycles of the new battery to rise to its maximum capacity measured on the fourth discharge. After the fifth discharge, the battery is recharged, the cell valves are removed, and the sixth discharge begun. Early in the sixth discharge cycle, the cells are filled to the top with mineral oil. Charge/recharge continues. The second line (green) shows the capacity on the thirteenth discharge, down to 33Ah. The third line (black) shows the capacity on the seventeenth discharge, further reduced to 29Ah. Starting voltages are all above 12v, while the energy capacity is progressively reduced. Max discharge rate is 1/7C.

of a larger battery pack. Once used, they are discarded.

Secondary cells or batteries may be tested then recharged.

Batteries intended for cold environments can be placed in a refrigerator or freezer and the leads brought out to the CBA V.

The CBA V can perform a Power Profile, useful for designers working with solar charging systems on buoys and unmanned surface vehicles (USV).

For very low currents, continuous or intermittent, the West Mountain Radio CBA HR (High Resolution) model is designed to test any small battery from 0.7 to 10 volts at load currents of 1 mA to 1000 mA, (10 watt maximum), in increments of 1 mA.

CONCLUSION

Battery testing may be done by manufacturers for quality assurance or end-users to characterize batteries before selecting one for critical use.

Testing must replicate the expected field conditions, especially temperature and current drain.

Use your own data to drive your decision.

FURTHER READING

Landereans are encouraged to follow their curiosity into this hugely fascinating field. There are many good published references available from the library. On-line, a good place to start is Battery University at <**www.batteryuniversity.com**>.

FEEDBACK

Readers are encouraged to share their ocean lander experience, projects, inventions, and feedback by writing to Kevin Hardy @ **khardy@marinelink.com.**

All photos courtesy MTR unless otherwise noted

NEW TECH, PARTNERSHIPS LAUNCH IN LONDON

*With Oceanology International now one month in the rear-view mirror, **MTR** takes a look at some of the interesting technologies launched before, during and after the London event.*

VEHICLES

Exail unveiled its new transoceanic Uncrewed Surface Vessel (USV), the DriX O-16. Benefitting from an autonomy of 2,500 Nm and a unique naval architecture that enables the USV to withstand the most severe ocean conditions, the new DriX O-16 has been designed for long-duration operations (up to 30 days) and can deploy multiple payloads and subsea assets.

The new DriX O-16 benefits from a hybrid propulsion, redundant architecture, advanced communication systems, as well as AI powered obstacle detection and avoidance capabilities.

In addition, the new USV is able to launch and recover a wide range of subsea assets such as Remotely Operated Towed Vehicles (ROTVs), inspection-class Remotely Operated Vehicles (ROVs), as well as Autonomous Underwater Vehicles (AUVs). Its gondola, located below the surface, can further host a wide range of payloads such as deep-water Multibeam Echosounders (MBES), Sub-Bottom Profilers (SBP), or acoustic subsea positioning and communication systems (USBL).

Image courtesy Exail

Image courtesy Outland Technology

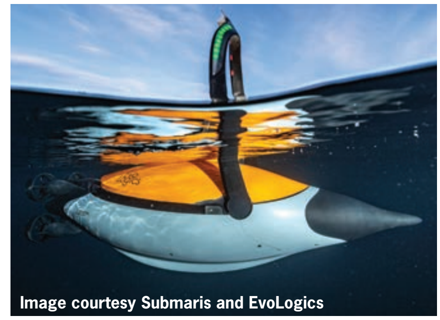


Image courtesy Submaris and EvoLogics

Vehicles

The ROV-1500 from **Outland Technology** represents a leap forward in underwater robotics, a compact remotely operated vehicle (ROV) weighing in at less than 40 lbs (19kg) the ROV-1500 is easy to transport and deploy. Similar to Outland's previous models, the ROV-1500 shares an easy to use control system and topside power. Field replaceable components continue to make maintenance a breeze.

EvoLogics launched the next iteration of the Quadroin AUV. Originally introduced in May 2021, the Quadroin vehicle garnered attention for its distinctive, penguin-like design. Engineered for monitoring and surveying, the fast and maneuverable Quadroin leverages EvoLogics' expertise in low-drag bionic design. Dr. Rudolf Bannasch, EvoLogics founder, delved into years of research on penguin locomotion, resulting in the AUV's remarkable hydrodynamic properties. With its low-drag shape, the Quadroin achieves speeds of up to 10 knots, minimizing energy consumption and enabling versatile deployments.

The initial series of Quadroin prototypes, developed in collaboration with Hereon for the Helmholtz Association's MOSES initiative, focuses on monitoring ocean eddies. These vehicles are equipped with sensors for collecting geo-referenced data on various physical water parameters, including temperature, pressure, oxygen, conductivity, and fluorescence, at different depth levels.

Building upon this foundation, EvoLogics has undertaken significant enhancements to the Quadroin platform, with a primary focus on expanding its instrument payload capacity and underwater AI computations. This evolution led to a comprehensive redesign of the vehicle's internal layout, integration of updated components, and optimization of sensor systems to accommodate a broader range of instruments while maintaining operational efficiency.

The Greensea IQ booth @ Oi impressed. There we found long-time friend and Greensea IQ CGO Rob Howard for an early start.

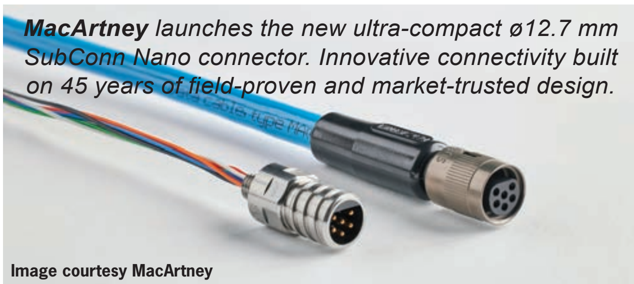
Images courtesy MTR

The new generation Quadroin now carries an expanded instrument payload. The side-scan sonar enables acoustic seafloor imaging. Additionally, two full-HD underwater cameras—one forward-facing at a 45-degree angle and one downward-facing—equipped with dimmable LED lights, provide a visual identification of the vehicle's surroundings.

The newly integrated EvoLogics AI-powered object recognition module allows detecting objects in the side-scan sonar and video feeds live during the mission with processing carried out onboard the vehicle. It is also to enable automatic collision avoidance through a front-looking sonar system.

The hardware and propulsion systems were redesigned with next-generation components for optimal performance. The Quadroin now features a Nortek Nucleus1000 integrated subsea navigation package that couples Nortek's DVL technology with additional position-aiding sensors for reliable vehicle control.

Image courtesy BIRNS



***MacArtney** launches the new ultra-compact ø12.7 mm SubConn Nano connector. Innovative connectivity built on 45 years of field-proven and market-trusted design.*

Image courtesy MacArtney

Cables & Connectors

Image courtesy Greg Trauthwein

Birns celebrated its 70th anniversary at Oi.

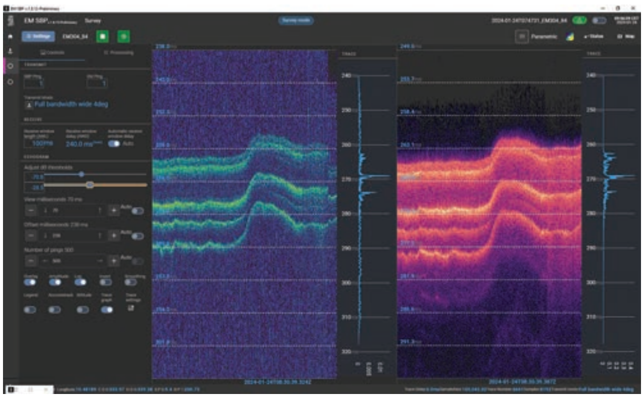


Image courtesy Kongsberg Discovery

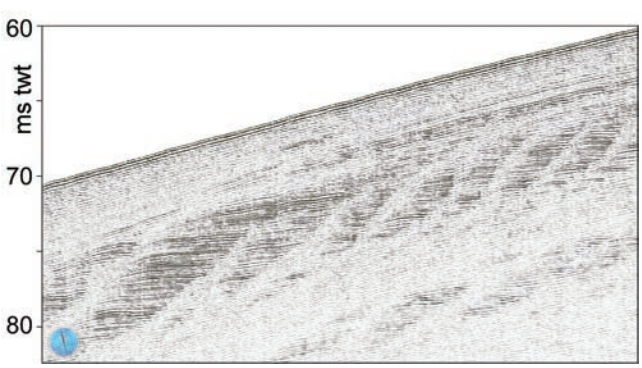


Image courtesy GeoAcoustics

Sub Bottom Profilers

CABLES & CONNECTORS

BIRNS made a splash at Oi at the company's Power Forward event, with the celebration of the company's 70th anniversary, and the launch of a new high amperage subsea connector series, the 225 Amp BIRNS Meridian line. The Meridian line, a robust, custom engineered dry-mate connector series is open face rated to 6km, and is well-suited for battery packs and thrusters for crewed and uncrewed subsea vehicles that require high amperage power transfer. Select sizes are already being DNV type-approved for 6km rated crewed submersibles. BIRNS Meridians are compact, and feature several pin configurations, with more in design for release later this year. The M40 pin configuration has a single 85 square millimeter/3-000 contact. Both standard and reverse gender versions are featured in the series, and all withstand reverse pressure, too, and can be installed into both dry and oil-filled canisters.

MacArtney introduced a space and weight-saving ø12.7 mm SubConn Nano, a Nano connector which offers a versatile and robust performance, making it suitable for multiple applications and the increasingly compact design of underwater instruments, equipment and systems. This splash and wet-mate connector is manufactured from high-grade titanium and neoprene to withstand deep ocean depths and open-face pressure ratings. The 2.5-turn locking sleeve has been specially crafted for seamless mating and prevention of anti-seizing.

SUB BOTTOM PROFILERS

Kongsberg Discovery introduces EM SBP software system offering sub-bottom profiling capability for Kongsberg's deepwater multi beam echo sounder (MBES) systems EM 124 and EM 304, without the need for additional hardware. EM SBP

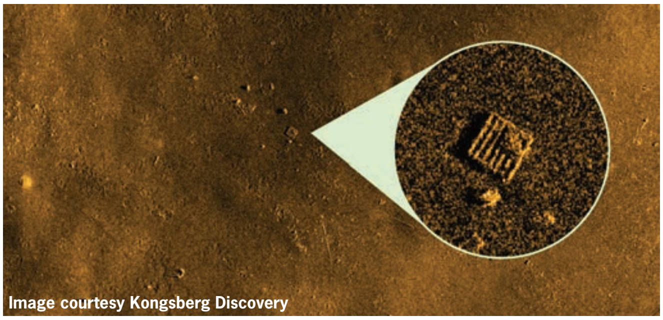
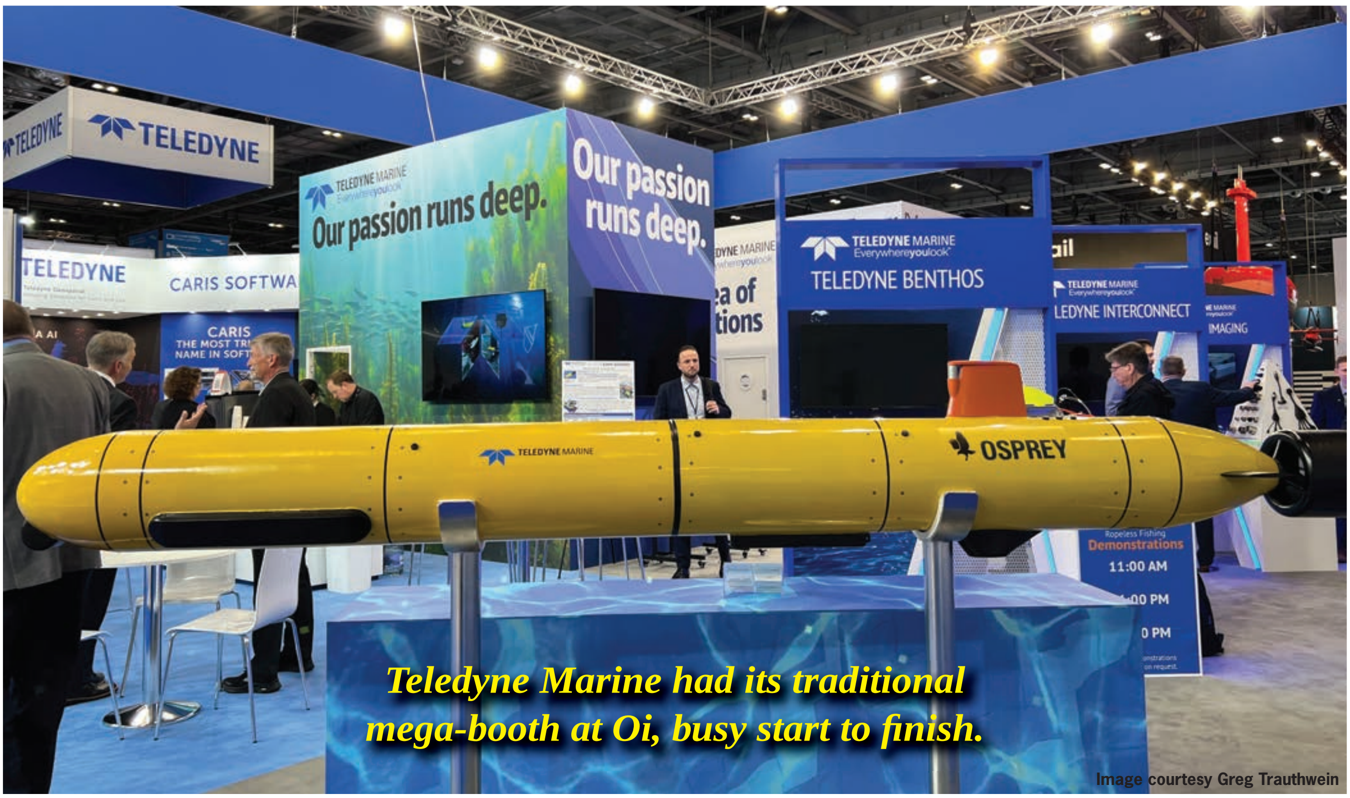


Image courtesy Kongsberg Discovery

Image courtesy Teledyne Marine

New Products



Teledyne Marine had its traditional mega-booth at Oi, busy start to finish.

Image courtesy Greg Trauthwein

offers quality sub-bottom profiling capability without the need for any dedicated transducers or cabinet of electronics. That means no additional hardware beyond what is used for the EM 124 or EM 304 MBES systems – which is in most cases already available on board the vessel. Essentially, the EM SBP software “borrows” the EM 124/304 hardware to transmit the downward-looking sub-bottom signals at a given interval. The sequence of sub-bottom versus multibeam signals, or pings, is user selectable. The EM SBP software configures the sub-bottom transmit and receive parameters, picks up the returned echoes, and processes the data to create sub-bottom images that are visualized and logged to file.

GeoAcoustics launched the GeoPulse 2 Sub-Bottom Profiler, which is a new generation of GeoAcoustics sub-bottom profiling technology, reaching into deeper waters for the acquisition of essential data for e.g., the development and operation of offshore windfarms. GeoPulse 2 introduces new capabilities that enhance both its operation and data quality.

The system is a drop-in replacement for the GeoPulse Pinger using the 5430A transmitter. It is fully digital and features a variety of waveforms unavailable with the previous generation of GeoPulse Pinger. The GeoPulse 2 is available in 4, 9 or 16 transducer configurations giving an operational depth range down to 5,000m. Achieving resolutions up to 6 cm and penetrating depths of up to 80 meters in fine clay and 20 meters in sand, GeoPulse 2 sets a new benchmark for accuracy and depth penetration.

NEW PRODUCTS

Kongsberg Discovery debuts a new analysis tool developed with Cathx Ocean that it says ‘radically’ reduces the time and effort required to detect and classify objects of interest in seabed surveys undertaken by Kongsberg’s HUGIN AUVs, auto-

Image courtesy Metron/Cellula

Pictured (L-R): Cellula Robotics, President, **Eric Jackson**, Metron Inc. President and CEO, **Van Gurley**, and Cellula Robotics CEO, **Neil Manning**.

Greensea IQ CGO Rob Howard (left) contracted BUVI Scandinavia (BUVI) to join its international sales team.

Image courtesy Greensea IQ

Image courtesy Teledyne Marine

Teledyne Marine acquires Valeport:
Matt Quartley, MD, Valeport and **Ole Søe-Pedersen**, VP & GM Teledyne Marine announce the deal in London.

Chris Blake, VP Survey, Unique Group; **Martin Wien Fjell**, President, Kongsberg Discovery; **Sahil Gandhi**, CEO Unique Group; **Che Keong Lee**, Senior Sales Manager, Kongsberg Discovery.

Image courtesy Unique Group

Sealing the deal(s) @ Oi '24

mating the object identification process using the SAS Target Assistant. The application runs in the background, leaving users to focus their mental capacity on the most valuable task of evaluating and classifying the potential objects of interest.

Teledyne Geospatial brought its latest advancements in ocean mapping hardware and software solutions to Oi '24. Featured were Optech CL-360 Marine, a 360-degree long-range laser scanner combining a scan speed of 250 lines per second with 2 mm range resolution, a plug & play solution, and an IP67 marine grade sensor making it the first of its kind high-accuracy marine grade laser scanner. The lidar sensor can be integrated with high resolution multibeam systems and the CARIS Ping-To-Chart workflow, allowing for full above-and-below- water image capture with survey grade accuracy in a single workflow. The sensor's 360-degree scanner and high collection rate provides a premier solution for mapping coastal infrastructure. The CL-360 Marine is the only lidar system designed for use on an uncrewed surface vessel (USV) that provides survey grade range and accuracy.

In addition, featured were the HIPS & SIPS 12 release, with new workflows for multiple frequency datasets and creating/managing vessel files.

DEALS

• Metron, Cellula Robotics Partner

Metron signed a partnership agreement with Cellula Robotics, USA Inc., to expand uncrewed underwater vehicle (UUV) capabilities for advanced operations in dynamic environments. The new agreement will address specific technical gaps in the UUV defense and offshore energy markets especially for long duration, multi-payload mission operations where communications are often denied or restricted. As part of the new alliance, Metron's Resilient Mission Autonomy portfolio will be integrated into Cellula's Solus and Imotus families of vehicles to deliver AI-enabled situational awareness and execute real-time onboard mission adaption, rerouting and replanning, all with a multi-payload management system and the flexibility for ship or port-to-port mission deployments. Cellula's Solus-LR and Solus-XR platforms will be equipped with Cellula's hydrogen fuel cell technology, supporting sustainable, long duration operations with zero carbon emissions

• Teledyne Marine Acquires Valeport

Teledyne Marine agreed to acquire Valeport a leader in the design and manufacture of underwater sensors and profilers. Valeport is one of the UK's leading manufacturers of oceanographic and hydrographic instrumentation. The independent family-owned business, which was established in 1969, designs and manufactures instrumentation for the oceanographic and hydrographic communities with a worldwide customer base that includes: subsea, hydrographic, metrological and positioning, oceanographic, ports, harbours, dredging, energy and scientific research sectors.

• Greensea IQ Signs Contract with BUVI

Greensea IQ, announced the signing of BUVI Scandinavia (BUVI) to join its international sales team, which follows another recent signing of the Spanish sales representative Uniformidad Y Suminstros De Proteccion (USP). Cumulatively these are milestones in Greensea IQ's continuous global expansion efforts, and Greensea IQ's footprint will now encompass Finland, Norway, Sweden, and Spain. The new business relationships will see BUVI and USP represent Greensea IQ and its complete range of Bayonet autonomous underwater ground vehicles (AUGVs). "We are excited to welcome BUVI Scandinavia and USP to our Growth Team," said Rob Howard, Greensea IQ's CGO. "Their representation in these key regions strengthens our efforts to provide Greensea IQ products and services on a global scale."

• Unique Group signed a contract with Kongsberg Discovery

Unique Group signed a contract with Kongsberg Discovery for $1.7m of seabed mapping and compact acoustic positioning technology for the APAC region. The agreement, for the delivery of cNODE Transponders, µPAP SSBL systems and the recently launched EM2042 multibeam echo sounder (MBES), allows Unique to boost its subsea equipment rental pool. The order will swell the capacity of Unique's Singapore base, giving customers in South East Asia fresh access to the calibration free µPAP SSBL systems and the lightweight, robust and user-friendly EM2042, launched in September 2023.

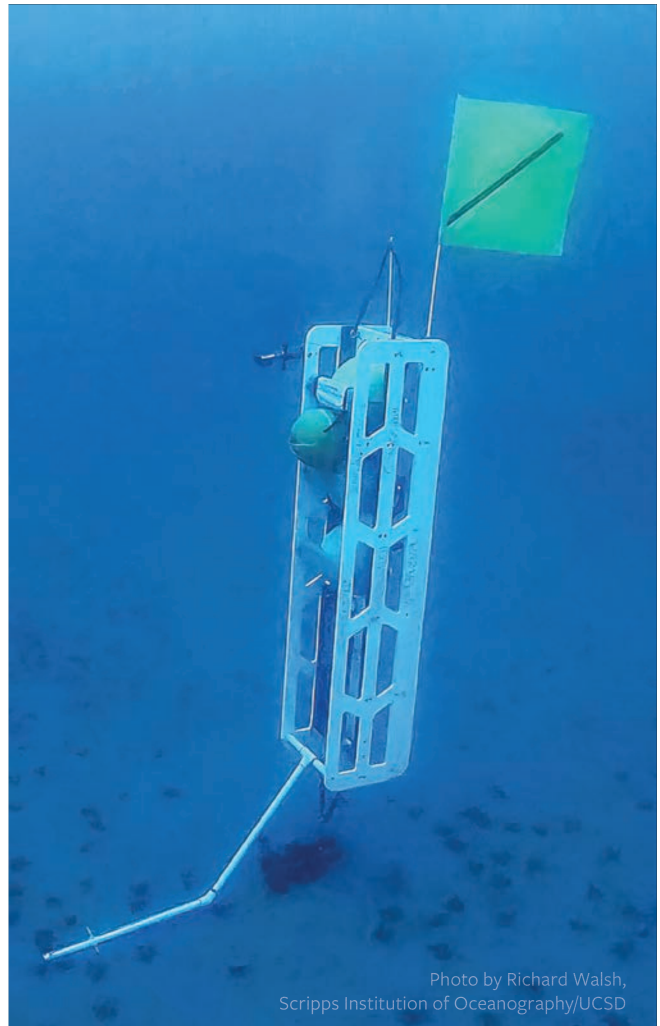


Photo by Richard Walsh, Scripps Institution of Oceanography/UCSD

MTR TV's professional video team was out and about at Oi in London for nearly 20 executive interviews, including [clockwise, starting top left]: Cellula Robotics' CEO* Neil Manning*;* Rob Dewell*, Integration Engineer, Saab UK who put the new* eM1-7 electric manipulator *through its paces (below); and SMDs Chairman* Mike Jones*, just after signing a deal with Jan de Nul on its stand.

Images courtesy *MTR*

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