MARINE TECHNOLOGY REPORTER

September 2018

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Voices
Jill Zande, MATES II

Discovery
The hunt for U-Boat UB29

XPrize
Mapping the Future

Volume 61 | Number 7

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The boat is crossing multiple times three large bridges including one made of steel.

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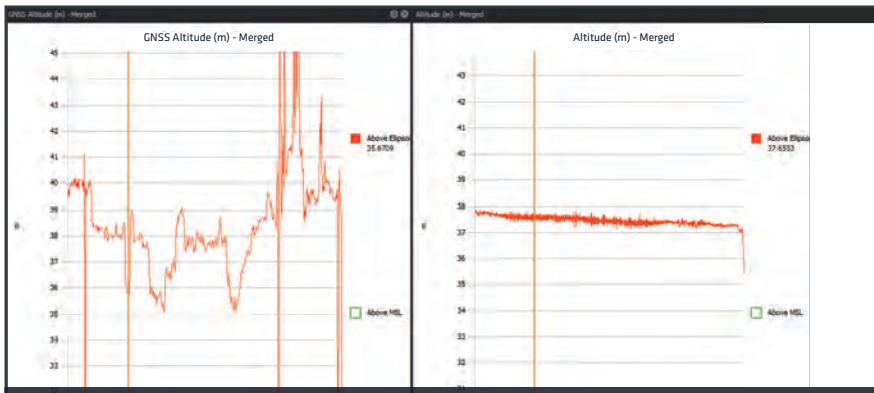

Altitude – Left GNSS only, Right: Post-processed

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Many thanks to Hydro Systems Development (HSD Japan) for their kind collaboration.

Full data available upon request at marketing@sbg-systems.com
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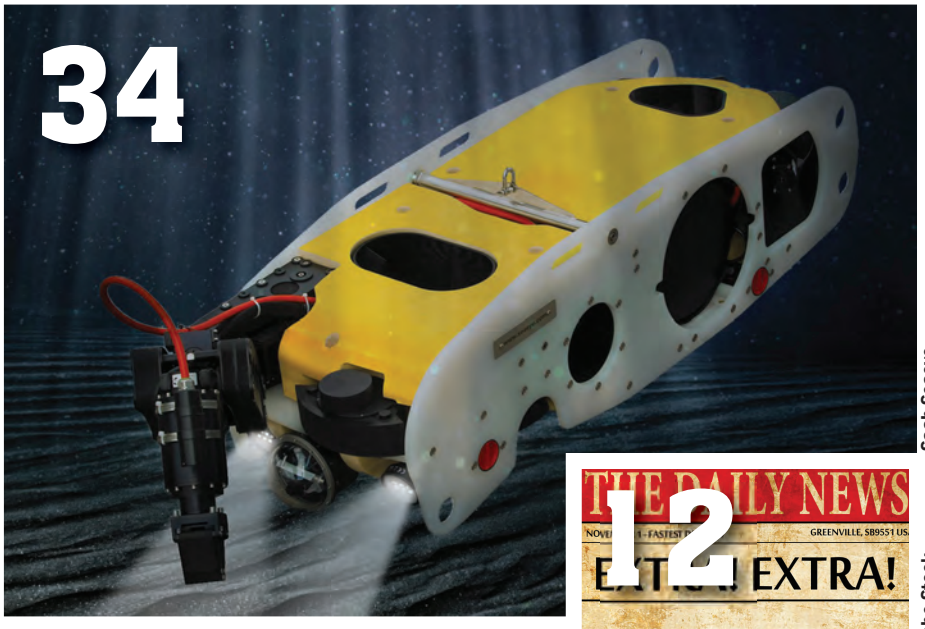
SBG SYSTEMS

September 2018
Volume 61 • Number 7

Contents

MATE II



Saab Seaeye

Kongsberg

Image: © Argus/Adobe Stock

Subsea Archaeology

12 U-Boat UB-29
A wreck-diving archaeologist and his quest to discover a missing submarine.

By Joshua Levin

Voices

24 Jill Zande
The MATE executive director speaks on the importance of attracting the next generation.

By Greg Trauthwein

Vehicles

30 Seafloor Crawlers
New robotic tools tackle challenging missions – through surf zones and into the sea.

By Justin E. Manley and Arnis Mangolds

Defense

34 Unmanned Reach
The defense sector looks to extend its capabilities with underwater robotics, autonomous systems and sensors.

By Elaine Maslin

XPRIZE

42 Mapping the Future
MTR checks in as the conclusion to the $7 million Shell Ocean Discovery XPRIZE fast approaches.

INTRODUCING

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Editor's Note

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Coming off of the MTR100 edition is always bittersweet: sweet because this monumental task is in the rearview mirror for another 12 months, bitter because as soon as that magazine closes we start to feverishly dig in on the remaining editions of the year.

This edition is packed, starting with our 'Voices' feature with **Jill Zande**, president and executive director, of MATE II, starting on page 24. As you (hopefully) remember, Zande and MATE II were featured in short in the July/August "MTR100" edition, and she will heretofore be known as "Number 5", one of our "Top 10" ocean influencers. As we had an over-abundance of information from this interview ... too much to cram into the previous edition ... we opted to present the interview in full format here in September, a perfect addition to our 'Vehicles' coverage.

Next, starting on page 30, **Arnis Mangolds** and **Justin Manley** provide an insightful look at *"Seafloor Crawlers: New Robotic Tools for Challenging Missions."* As you all are fully aware, there aren't many missions in the oceanic environment that aren't 'challenging', but the evolution of vehicles and systems is central to making these missions increasingly efficient and valuable. C-2 Innovations has developed a family of seafloor crawling robots – the Sea Otter and the Sea Ox – to take users back through the surf zone and into the sea.

Last, but certainly not least, **Elaine Maslin's** cover story report *"Extending Unmanned Capabilities"* looks at the defense sector and ways to extend its reach and capabilities with underwater robotic and autonomous systems. Maslin has been a tremendously valuable addition to the *MTR* team, as she is seemingly everywhere, making my travel schedule look positively docile! Enjoy her report, starting on page 34.

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Claudio Paschoa is MTR's contributor stationed in Brazil.

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Caribbean States Kick Off Green Defense

Photo: Caribbean Climate-Smart Accelerator

British billionaire Richard Branson pictured with Usain Bolt. Two dozen Caribbean nations and territories announced in Jamaica the creation of the Caribbean Climate-Smart Accelerator, a multimillion dollar program to turn the hurricane-prone region into a green tech hub resilient to disasters.

https://www.marinetechnologynews.com/news/caribbean-states-green-defense-563520

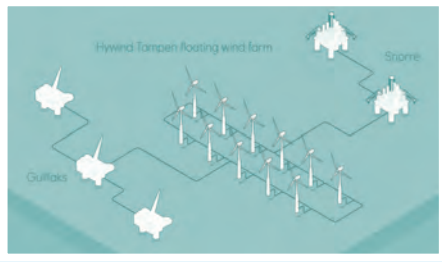

Image: Equinor

Floating Wind Turbines Power North Sea Oilfields

Norway's Equinor is considering building a pioneering $592 million floating offshore wind farm to supply electricity to the Gullfaks and Snorre oilfields in the North Sea as part of a strategy to curb greenhouse gas emissions.

https://www.marinetechnologynews.com/news/equinor-explores-floating-turbines-564028

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Drone Boats Face-Off in RobotX Challenge

Students facing off in the AUVSI Foundation's Maritime RobotX Challenge in Oahu, Hawaii from December 8-15 will battle for cash prizes and bragging rights by completing a series of tasks to demonstrate navigation and control; obstacle detection and avoidance; station keeping and docking; and observation, identification and reporting of a specified target.

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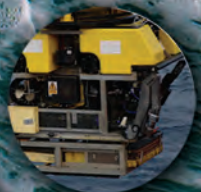

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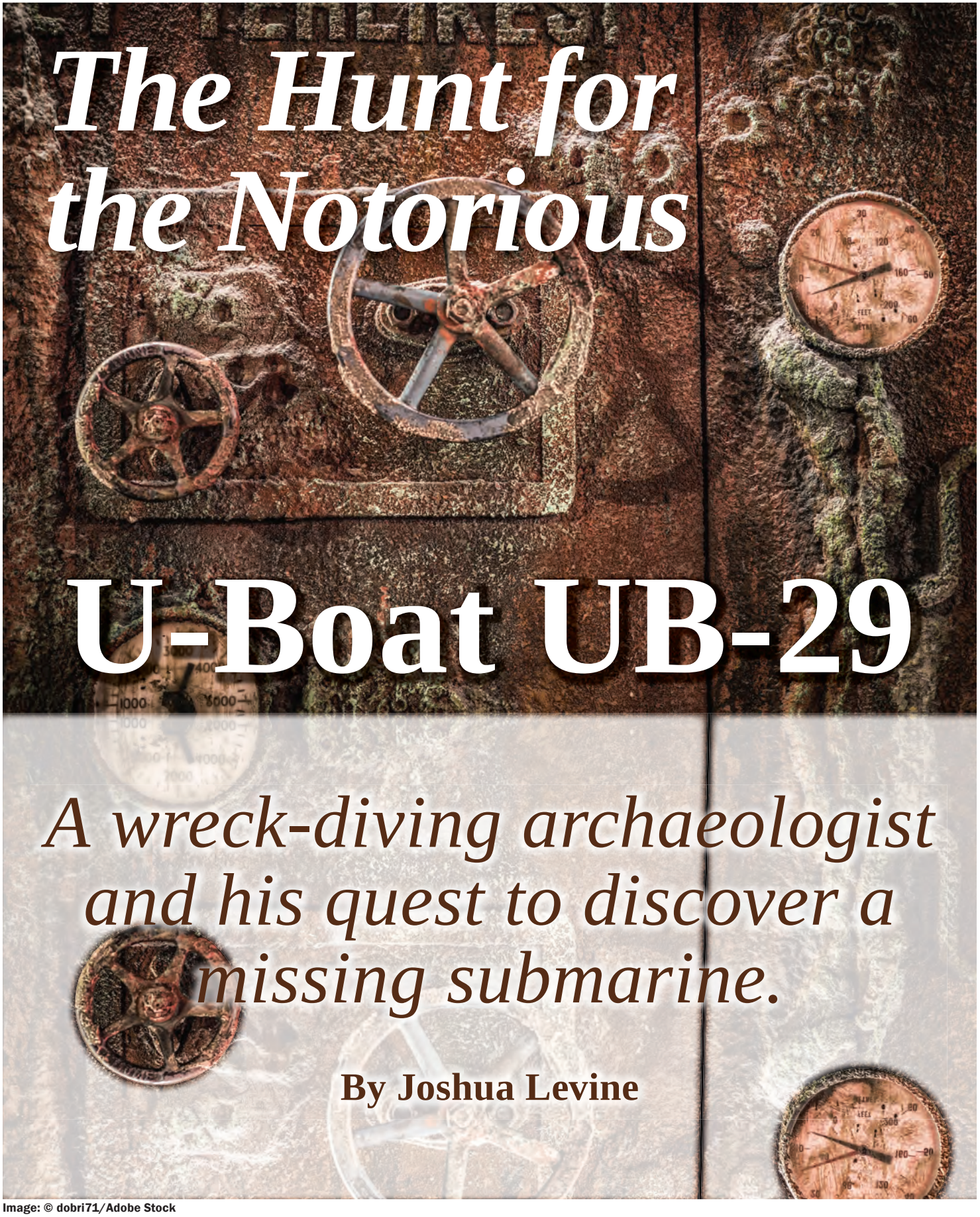
The Hunt for the Notorious U-Boat UB-29

A wreck-diving archaeologist and his quest to discover a missing submarine.

By Joshua Levine



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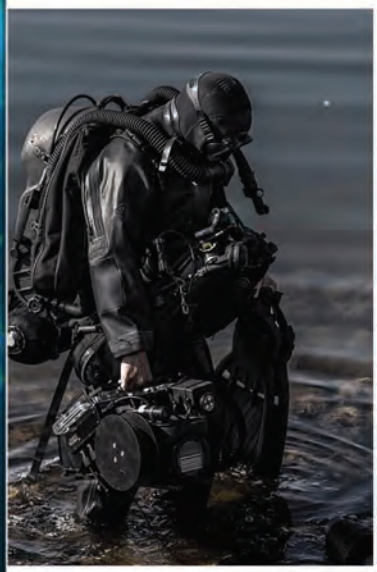

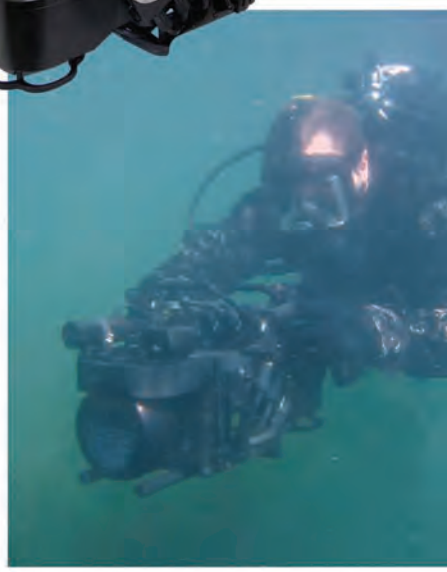

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You get an idea before you even walk in his door that Tomas Termote's life is bound up with the sea, or at any rate what lies beneath it. Outside his house in Ostend, on the Belgian coast, stands the biggest anchor you've ever seen – over 16 feet high, weighing five tons. It was hand-forged for an old British man-of-war, and a trawler hauled it up from the seabed of the English Channel, a stone's throw from here.

Out in the backyard, there's a creepy-looking mine from the First World War, about a foot in diameter and prickly all over with detonators. It too came from nearby waters. The Germans occupied the entire Belgian coast during World War I. Their U-boats were based farther inland in Bruges, just outside the range of British naval guns, and passed through canals that fed into the channel at Ostend and the nearby town of Zeebrugge. The dunes outside Termote's house are still lined with concrete bunkers built by the Germans to defend its U-boat bases from British attack. It was mines like the one in Termote's backyard that sent more of Germany's WWI U-boats to the bottom of the channel than anything else.

Termote started diving the icy English Channel at age 14 with his father, Dirk, a retired hotelier. Along the way, he picked up a degree in marine archaeology – a subject that barely existed when he started studying it – and has been studying wrecks around the world ever since. But the vast U-boat cemetery that starts just outside his front door is what he most loves to explore. To date, he has found the remains of 28 U-boats down there, 11 in Belgian waters. His book about U-boats, War Beneath the Waves, was published last year. One newspaper headline called him "the Flemish Indiana Jones."

Termote is a compact, broad-chested man, soft-spoken and amiable. For most of the year, he makes his living diving commercially around the Belgian ports. Summer is for combing the local waters for wrecks, which are getting tougher to find all the time. The seafloor has been well mapped and picked over by now. Yet only last summer Termote stumbled across his most important discovery yet.

In the spring of 2017, Termote was checking Belgian hydrographic department documents online to see if any previously charted wrecks had shifted on the seabed. He took a passing look at one of these flagged wrecks lying some 80 feet deep about 12 miles straight off Ostend. "She's been on the chart since 1947," says Termote. "In the 1980s, she was identified as an upturned landing craft, like the ones in Saving Private Ryan. So it didn't sound very interesting." Modern multi-beam echo-sounders – the sonar devices now used for hydrographic surveys – are far more sensitive than earlier technologies. "Today you can almost see the links in an anchor chain. This was obviously not a landing craft. It wasn't shaped like a biscuit tin, but like a cigar, with two pointy ends and a tower in the middle. The surveys also give you the length, and this was 26 or 27 meters. I was like, Bloody hell! This has to be a submarine!"

Image: © Argus/Adobe Stock

The original faulty identification had almost certainly thrown other wreck hunters off the scent. It helped, too, that the sub lay in the middle of a shipping lane, further discouraging the curious. "Every 15 or 20 minutes, you get 200-meter tankers passing over it – it would be like diving on a freeway."

Since 2013, the governor of West Flanders, which includes Belgium's short seacoast, has been Carl Decaluwé. In addition to his other duties, Decaluwé is Belgium's Receiver of Wrecks, which means he has authority over anything found in Belgian territorial waters. He's another of Termote's old friends, not to mention a maritime history buff. So when Termote went down for the first time last June, maritime police were standing by and coastal radar had been alerted; a 1,000-foot exclusion zone kept commercial shipping from the dive site. "In the first half-minute, I knew it was a German UB II-class submarine," remembers Termote. "After 30 U-boats, you just feel it. I can't describe the elation I felt when I came up."

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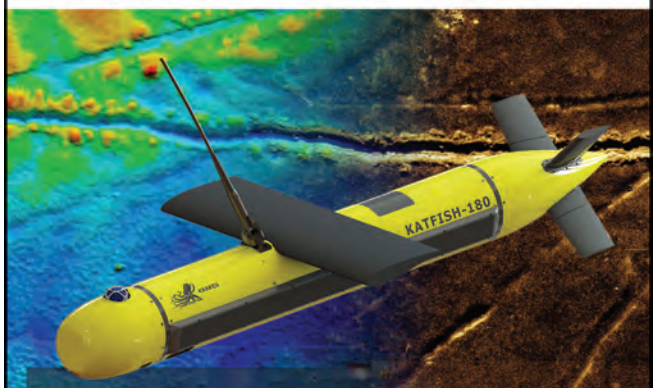

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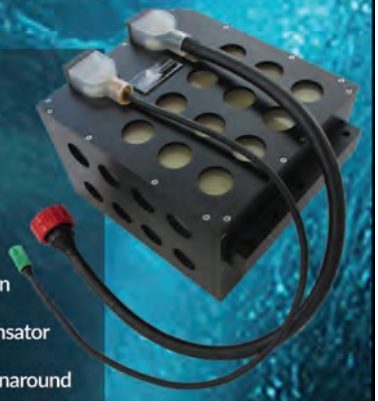

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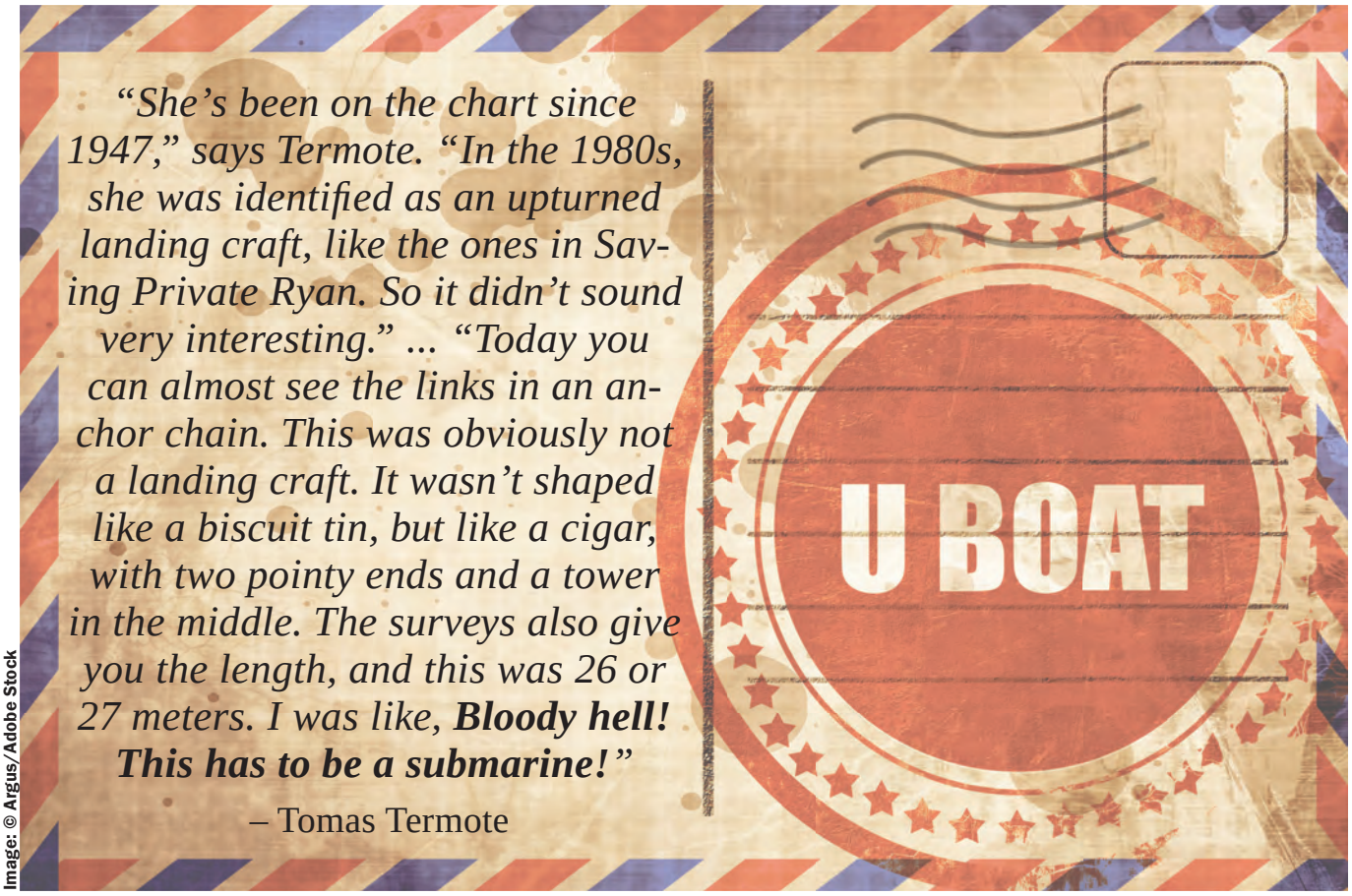

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– Tomas Termote

Image: © Argus/Adobe Stock

Termote made six dives that summer. The submarine was indeed a UB Class II U-boat. Both periscopes had been bent forward. Swimming around the bow, Termote saw that the top starboard torpedo tube had been twisted and ripped in what must have been a massive explosion – UB II-class subs had two tubes on each side, one on top of the other.

Miraculously, given that it had been so violently sunk, the sub had escaped more extensive damage and was largely intact. "Finding a U-boat in such a condition is unique," says Termote. "Most are heavily damaged – blown in two, or heavily salvaged. You won't find another like this." Still, the identification number painted on the conning tower was missing, corroded over time. At a press conference last September, when Belgian authorities announced the discovery, the sub's identity remained a mystery.

In the absence of tower markings, the surest way to identify a U-boat is by its bronze propeller, often stamped by date and, if you're lucky, serial number. Termote went down again and examined the U-boat's stern. The port-side propeller had been sheared off. Termote suspects it was lost when Belgian authorities had "wire-dragged" the sea down to 25 meters to make sure nothing sticking up any higher could endanger local shipping. The starboard propeller was still there, but was made of iron and unmarked – the first time Termote had found a U-boat with an iron propeller. "By the end of 1916, U-boat crews knew they were on a suicide mission because the British had gotten so good at detecting and destroying U-boats," says Termote. "Why bother putting a nice propeller on her?"

Termote made a final dive before winter last November. To put a name to his U-boat, he hoped to match a number on the periscope with records from the optics supplier, Berlin's C.P. Goerz. He did find the number – 417 – but the Goerz archives, he learned, no longer exist. "On the dive, I started cleaning the torpedo tubes; you can find markings there," says Termote. "Clean, clean, clean – and this ten-centimeter plaque comes free. It says, UB-29. I can't describe that feeling."

UB-29 was based in the medieval town of Bruges as part of the Flanders Flotilla, Germany's English Channel fleet. The sub first took to sea in March 1916. At the helm was Herbert Pustkuchen, who was to become one of Germany's most deadly U-boat aces. Pustkuchen ranks 31st among 37 commanders who each sank over 100,000 tons of Allied shipping during World War I. For this he won two Iron Crosses and the Royal House Order of Hohenzollern.

Pustkuchen is best known not for the ships he sank, but for one he didn't. On March 24, 1916, Pustkuchen sighted a cross-channel ferry, the SS Sussex, en route from Folkestone in England to Dieppe in France with 325 passengers aboard. With no prior warning, UB-29 fired a torpedo from 1,400 yards, tearing off the ferry's bow. Lifeboats were lowered, but several capsized. At least 50 passengers lost their lives. The Sussex managed to stay afloat and was towed, stern-first, to France. There were Americans on board the Sussex, and several were among the wounded. Pustkuchen had kicked a hornet's nest.

Less than a year before, a German U-boat sank the liner Lusitania in the Irish Sea, and 128 Americans died. President Woodrow Wilson put Germany on notice that "unrestricted

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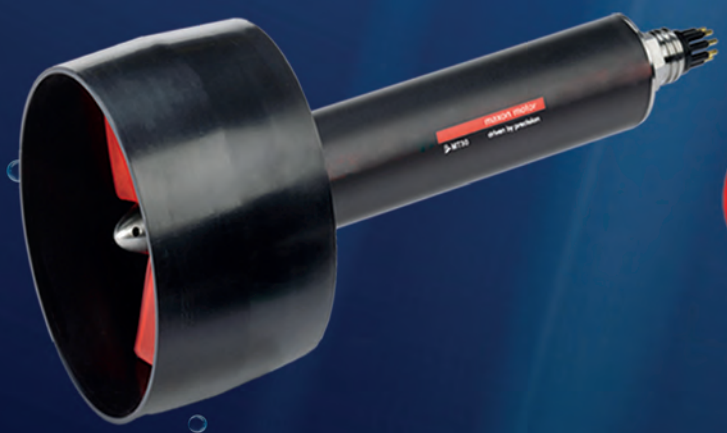

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submarine warfare"– the shoot-first tactic that U-boat skippers took up after early losses – would bring the United States into the war. Now UB-29 had done it again, and Wilson threatened to break diplomatic relations. Cowed, Germany signed the "Sussex Pledge." Henceforth, her U-boat captains would surface and search merchant ships for munitions. If armaments were found, the sub crew could sink the ship, after allowing its merchant crew to board lifeboats. Passenger shipping would be spared. These were known in maritime law as "cruiser rules," reducing the effectiveness of U-boats, now denied their surprise torpedo attacks.

UB-29's last patrol came less than a year after it entered service, under a new captain, Erich Platsch. (Herbert Pustkuchen went down with his crew in June 1917, when his UC-66 was bombed by a Curtis flying boat near England's Scilly Isles; the wreck was found in 2009.) It was Platsch's second time out. On December 13, 1916, UB-29 was spotted by the British destroyer HMS Landrail near the Strait of Dover. The Landrail managed to ram the sub before it could fully submerge. The destroyer dropped several depth charges over the side (the depth-charge launcher had yet to be invented). UB-29 was never seen again. Around midnight, Landrail's searchlights picked out oil and debris on the surface of the water.

The weather was bad and the night was black. Landrail headed for home. In the absence of conclusive evidence, Landrail was never credited with an official kill, but the crew was awarded prize money anyway. English authorities marked the unseen grave of UB-29 southwest of the Goodwin Sands, six miles off the coastal town of Deal in Kent.

By early 1917, the German high command had concluded that it would be hard-pressed to win the war of attrition on the Western Front. The Allies could shovel men and arms into the mouth of war faster than Germany. Some two weeks after UB-29 went down, German Adm. Henning von Holtzendorff, in so many words, called for an end to the pledge it had provoked, and urged Germany to let U-boats fire at will. Holtzendorff predicted that Allied shipping losses would climb to 600,000 tons a month for the first four months, almost double their rate under cruiser rules. Losses would continue at 400,000 tons a month. England, crippled by falling food stocks, industrial strikes and economic chaos, would sue for peace in five months. At a conference in the German town of Pless on January 9, 1917, the German High Command decided that unrestricted submarine warfare would commence February 1.

Here's what Termote thinks happened to UB-29. When the Landrail rammed the sub, the impact bent the two periscopes simultaneously, which is why he found them at the same angle. The depth charges wounded it and ruptured its oil tanks. But, he argues, UB-29 crawled away, slowly limping the 60 or so miles back home on compass. Platsch and his 21 crewmen must have felt a wild elation. "They were probably celebrating their escape –'We're going to be home in an hour! We made it! Let's party, drink champagne!' And then Boom!" Termote suggests that UB-29 hooked a mine with one of the twisted periscopes, dragging it down directly onto its hull.

UB-29's last moments must have been slow and horrible. "You can see the damage is limited to the bow, so you could imagine that the people from the command center up to the engine room might still have been alive afterwards. It's not like the U-boats you find blown in half where everybody dies immediately," says Termote. As the water rose inside the hull, the crewmen may have cut short their inevitable agony by shooting themselves with their long-barreled service Lugers. Or they may have stuffed cotton in their mouths and noses and drowned themselves. Both were known to happen. "Terrible," says Termote. However they met their end, they lie within UB-29's steel walls, buried in the sand that has filtered through its cracks for a hundred years.

Image: Subsea 7

Reviewing Sapinhoá-Lula NE BSR system

By Claudio Paschoa

The exploration and production of deepwater pre-salt plays offshore Brazil have triggered major technological challenges. Some reservoirs are located under 2,000 meters of water and have to be drilled through another 2,000 or so meters of salt. Although exploration challenges have been daunting, production challenges are no less formidable. With a number of production and injection wells placed over the large reservoirs, the difficulty of reliably and safely bringing the oil and gas to production FPSOs have been compounded by the extreme water depths involved.

In 2011 Subsea 7 was awarded a milestone subsea umbilical, riser and flowline (SURF) contract by national operator Petrobras for four decoupled riser systems to be installed in the Sapinhoá-Lula NE fields located in the Santos Basin, in the largest engineering, procurement, installation and commissioning (EPIC) SURF contract awarded to date in Brazil. The pioneering technology for connecting a large number of wells to a single FPSO was developed by the Petrobras' research center (Cenpes) and Subsea 7, with the support of UFRJ (Federal University of Rio de Janeiro) and USP (University of São Paulo). The project required the installation of four huge 2,800ton submerged buoys approximately 250 meters below the surface. The system was designed to accommodate a combination of 45 risers/umbilicals for each field in a small area in a decoupled arrangement. Subsea 7's scope was specifically 27 3.9km steel catenary risers of which 18 were 7.5-inch production lines, three 9.5-inch water injection lines and six 8-inch gas injection lines.

Buoy Supported Risers (BSR)

Petrobras and its partners selected the Buoy Supported Risers (BSR) system as the most effective solution for the project. Ivan Cruz, Senior Product Manager at Subsea 7, explained that in order to achieve the system's performance and installation requirements, various innovative technologies were applied. The creation of the Angular Connection Module (ACM) proved integral to the BSR system by connecting the flexible jumpers to the pre-installed buoys. With the large number of risers installed, the buoys can take up different positions and the ACM allows connections to be made at misaligned angles of up to 15°, reliably and safely, reducing offshore hook-up time. Within the BSR system the introduction of the ACM reduced fluid flow to a single interfacing point, thereby decreasing cost and enhancing reliability by eliminating further potential leak paths.

The main requirement for successful BSR mooring was to

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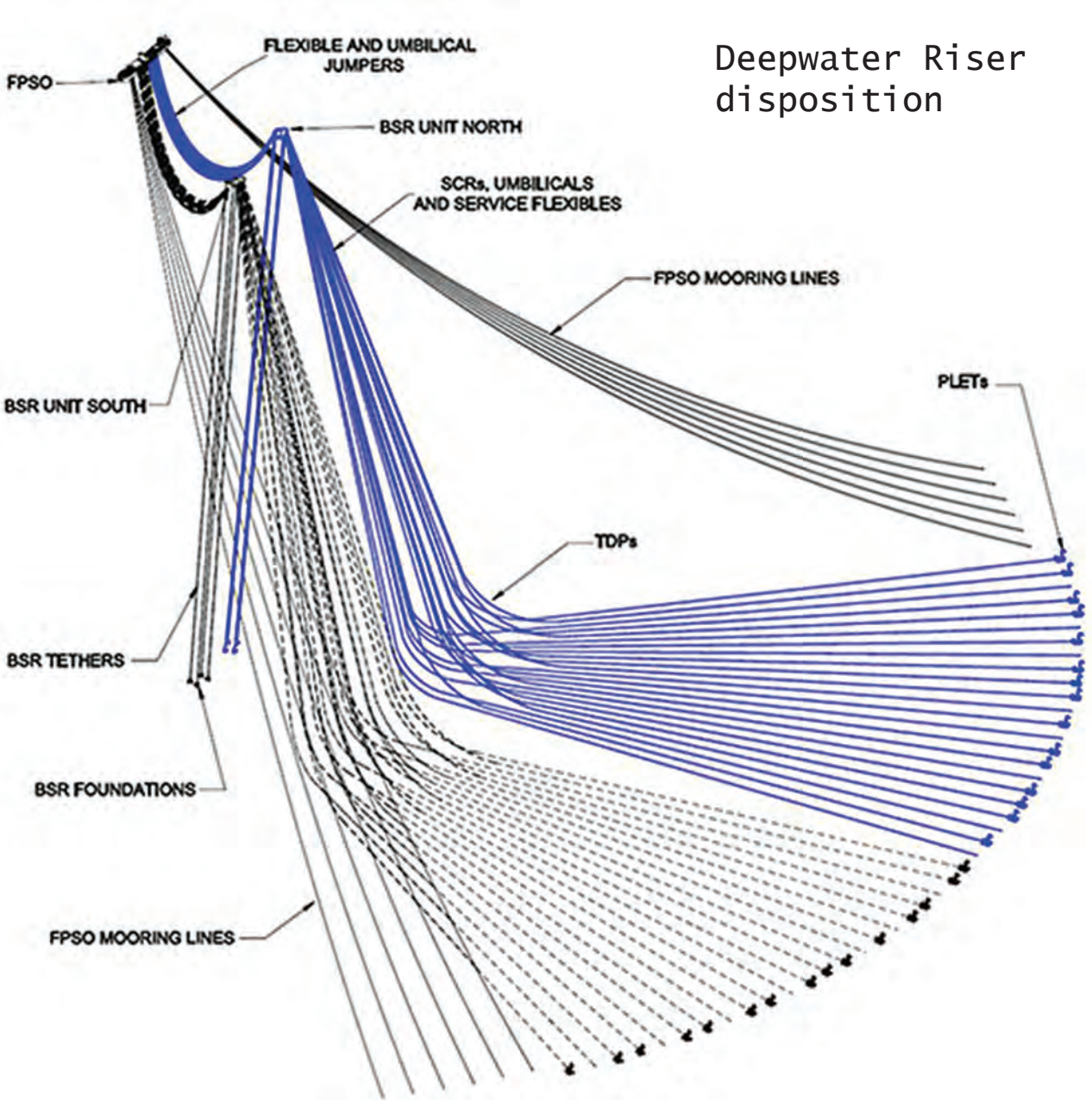
use tether adjustments to stabilize and position each buoy. The main challenge associated here was the selection of an appropriate tether material, helping to ensure that the axial stiffness was preferred in order to balance the desired tension adjustment, and to keep adjacent tethers closely together while controlling the initial slackening during fabrication and installation. Although steel air filled pipe is a commonly used material for Tension Leg Platforms (TLPs), a moderated decrease in the axial stiffness was preferred, this allowed for a simple top tension between adjacent tethers and length adjustments. A significant increase in tendon stretch, applied while the BSR was in vertical motion, would not have been an acceptable approach because of the high possibility of misalignment and damage to the system.

Another equally important technical issue which needed to be addressed was the submerged tether weight, that had the potential to minimize the impact on negative buoyancy and dimensions. Sheathed spiral strand wires (SSW) were finally chosen because the sheathed spiral strand wire has a long track record in other mooring systems and was found to meet all the requirements for 27 years of service life. The stretch is not excessive, but is enough to help minimize the effects of length measurement tolerances, being simpler to install offshore, including the locking of the lines in the connectors at the required point.

Deepwater Challenges

The development of the Sapinhoá-Lula NE reservoirs were



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major technological challenges. The innovative BSR concept was a unique design in the industry at the time and helped reduce the FPSO riser motions to a very minimal level. With this configuration, the movements of the floating platform are not transferred integrally to the rigid risers, reducing the damage because of the fatigue and guaranteeing their useful life even in severe meteoceanographic conditions. According to Ricardo Francis, consultant of the Management of Technology of Pipes and Risers at Cenpes, the buoys together are responsible for the production of 240,000 barrels of oil per day. "We studied a buoy system to take the dynamics of rigid lines because they internally have a coating that prevents corrosion of the steel due to the presence of gases such as H2S and CO2 and this coating has a more demanding calculation procedure, with the presence of the buoy, the useful life of these lines has increased considerably, making production feasible in the pre-salt fields. From there, flexible lines, called jumpers, are placed that connect the buoy to the production platform. In addition to bringing production to the PEUs, it is intended to absorb their dynamic movements. This is the main idea of the BSR," he says.

With the buoy holding the pipes that conduct the oil and gas from the well on the seabed to the FPSO, it relieves the load applied to the platform. Another advantage is to allow the installation of the risers even before the arrival of the production platform. "The economic advantage was the anticipation of production. If you prepare everything before you get to the production unit it simply connects the risers and you can anticipate 3 to 6 months of production," says Ricardo. Although there were teething problems in the installation of the first BSR, which led to delays in this first installation, the operators are adamant that the system has been working smoothly and with no major problems since it started operations in 2014 and that similar systems may be used in other deepwater pre-salt plays in future.

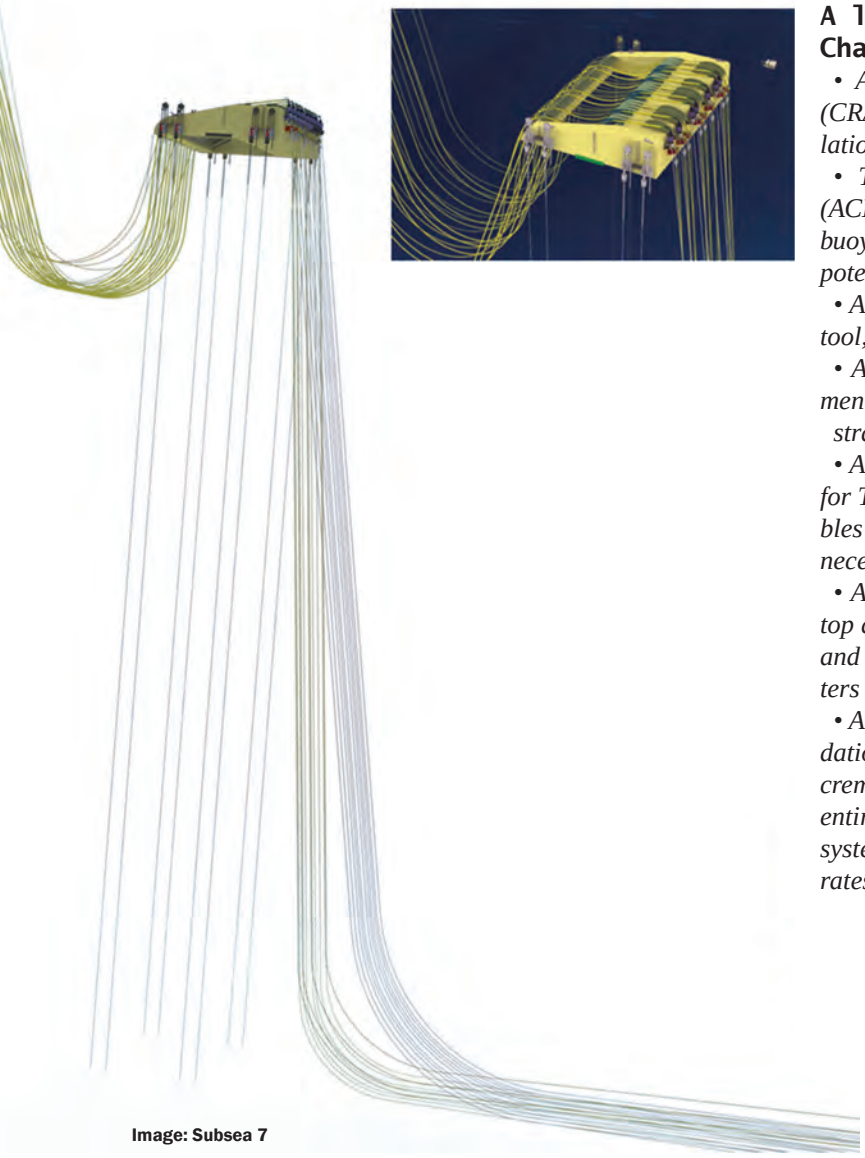

Image: Subsea 7

BSR system rendition

A look at some of the Technological Challenges associated to the BSR system:

• An efficient method to install corrosion resistant alloy (CRA) mechanically lined BuBi pipe by the reeled-lay installation method;

• The development of the Angular Connection Module (ACM). This unique engineering capability greatly simplified buoy hardware by minimizing the number of connections and potential leak paths;

• A fit for purpose 400 ton tension capable riser installation tool, allowing for the reliable deployment of 27 SCRs;

• A state-of-the-art fracture mechanics engineering assessment for plastically strained pipe joints made of alloy 625 welds;

• A novel tethered tensioned mooring system, similar to that for Tension Leg Platforms (TLPs), but using spiral strand cables and chains for installation simplicity and to achieve the necessary dynamic performance;

• A tether based tensioning system capable of withstanding top angle variations associated with the buoys natural offsets and the potential length variations of the almost two kilometers long tethers;

• A bottom connector device to simplify connections to foundations. The combined result of all these innovations, some incremental and resulting from existing technologies, and others entirely new and breakthrough, gave rise to the complete BSR system, which has been vital in maintaining the production rates and low downtime for the two reservoirs.

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Jill Zande

Jill Zande, President and Executive Director at MATE Inspiration for Innovation (MATE II) was featured in last month's "MTR 100" as a top ten ocean influencer. This month in MTR we present our full interview with Zande on the importance of attracting the next generation to a career in the oceans.

BY GREG TRAUTHWEIN

How did you come to a career at MATE?

As a research associate at the Dauphin Island Sea Lab (DISL), I thought that the only next step for me career-wise was to go back to graduate school, get a Ph.D., have a lab and take on graduate students. I saw the academic, Ph.D. path as my only realistic option; but I also knew down deep that it wasn't for me. I started exploring the idea of making a career switch into marine education, which included looking at DISL's Discovery Hall and the fantastic education programs it offers.

Then my former major professor at Louisiana State University told me about MATE. He had just returned from Monterey where he participated in the MATE Forum, which was hosted at MBARI. This was a gathering of marine-related industry, academic, and government professionals and was designed to discuss and lay out the critical issues facing marine technical education. The focus was on technician education; providing students with practical, hands-on learning. I realized that was what was missing from my education – the hands-on, applied piece.

He also said that MATE was just getting started with funding from the National Science Foundation and was looking to hire people. I had always wanted to head to Monterey – who wouldn't, with MBARI, the Aquarium, and the host of so many other marine-related institutions and organizations around the bay. I applied for the outreach program coordinator position and was hired, which was in August of 1998, so I'm just about to celebrate my 20th anniversary with MATE.

When you say MATE to most in this industry, the MATE robotics competition, I would argue, is the first thing to come to mind. Can you provide a history on your signature competition and its growth?

In the early days of MATE we conducted a number of workforce studies to help us identify the latest trends, occupations that needed well-educated and capable people, and "well-educated and capable" meant in terms of knowledge and skill sets. ROV technicians emerged as an occupation in need of skilled individuals.

At the same time we were researching this, two synergistic things happened: we found the little yellow book (How to Build Your Own Underwater Robot and Other Wet Projects) and the Marine Technology Society ROV Committee came to us looking for help. They recognized the need for ROV technicians and how those currently applying for the positions didn't seem to have the right skills. They also recognized the lack of awareness of the industry and its occupations; they gave the example that they had thousands of dollars of scholarships to give away, yet very few students were applying. They wanted to work with us to better connect with students, raise awareness of careers opportunities within the industry, and create a program that would encourage and help students to develop the necessary skills. So, literally, on the back of a napkin, the idea for the ROV competition was born. We needed someone to take the lead on this; I raised my hand.

MATE By the Numbers: Can you help provide size and shape to the organization and its impact in numbers?

The MATE competition is a labor of love. With only two full-time employees, some part-time help, and more than 1,600 volunteers, it showcases the amount of pride and passion that all those involved have for the program. Here at this year's international, 100 volunteers including 16 alumni will be

lending a hand, as will several parents of alumni. The event has become a family affair!

It's difficult to estimate the value of our volunteers' time and technical expertise, but we gave it a try! Each year, all total, the competition benefits from more than $1 million in volunteer hours. Volunteers not only support MATE events as judges, some also run regional programs, organizing teacher and student workshops, outreach to students and putting together competition events.

Discuss this year's ROV competition, and put in perspective how it has grown and evolved.

The MATE competition has grown significantly. It's hard to believe that the MATE international competition was first held in 2002 with just 22 teams from 2 countries – those being the United States and Canada. Now there are 31 regional events that take place each year. And that number will only grow with the addition of a regional in Tennessee (and possibly elsewhere!) in 2019.

For the 2018 competition season…starting in April, nearly 8,000 students representing 715 teams from across the country and around the world competed in regional events or submitted video demonstrations.

Nearly 800 students and 100 mentors qualified and participated in the international competition. 65 teams from 19 countries and 20 U.S. states tackled tasks that highlighted Jet City: Aircraft, Earthquakes, and Energy, which gave a nod to the location as this year's competition theme.

The competition has certainly evolved over the years – and not just in terms of numbers. About five years ago we added a fourth competition level or class called NAVIGATOR (the progress is now SCOUT – NAVIGATOR – RANGER – EXPLORER).

Why was that done?

We did this because, in 2008, we recognized that middle schools were the fastest growing population of competition teams. We certainly hadn't tried to proactively reach that population. As a matter of fact, our MATE grant focused on community colleges and linkages between high schools and 4-year-universities. But, with all of this interest, we recognized that we had an opportunity to make an impact at a level at which we tend to lose students in STEM. So, we went back to the National Science Foundation and got our first ITEST (Innovative Technology Experiences for Students and Teachers) grant. This provided us the resources to focus on teacher workshops, student outreach, curriculum, and ROV kits to specifically enable and support middle schools (and even elementary schools) to participate.

Is that the only way it has evolved?

Another way that we've evolved is in our approach. We had always appreciated that the competition encouraged creative thinking, innovation, and the development of project management and teamwork skills. But back in 2011 we had a bit of sea change; we were very deliberate in requiring students

Side scan sonar inventor and long-time MATE competition judge and supporter Marty Klein speaks to the all-female ROV team from Saudi Arabia during the 2017 international event.

Photo courtesy MATE II

to transform their teams into companies – to "think like entrepreneurs" – and structure themselves that way. Who would be their CEO? Who would be their CFO? Who would head up R&D? We wanted students to get an appreciation of business practices as well as how their specific roles fit into the bigger picture of a company structure.

To keep in line with the business acumen, we laid out our mission scenarios as an RFP. The student-lead, mock companies were to respond to this RFP by designing and building an ROV that could meet the specified requirements. In addition to the ROV, other required "products" included technical documentation, an oral presentation and a marketing (poster) display.

Adding this business, entrepreneurial approach was a real game-changer. Teams enthusiastically embraced it, creating company tag lines, business cards, and even "dressing up" in suits for their engineering (oral) presentations. In addition, they sought out students in other disciplines and programs to help meet their "employment" needs; they pulled in accounting students to help manage the finances and budget, graphic design students to create company logos and marketing displays, and technical writers to help with formatting and organizing their technical reports. So, students from outside traditional STEM disciplines got involved, learned about ocean issues, and gained practical, hands-on experience. One student featured in our 2012 video said it best. When asked if he had any opportunities like this as an accounting major, he answered, "no, it's all in the classroom, studying books…it's fun to get out of the classroom and do something real-world…"

We often speak of grooming 'the next generation.' It seems that you have already answered this question, but in a phrase, how is MATE helping in this regard?

That's what the MATE competition is all about! The competition challenges students to learn and creatively apply STEM skills to solve real-world problems in a way that strengthens their critical thinking, collaboration, entrepreneurship and innovation, and helps to prepare them for the workforce.

The competition tasks K-12, community college, and university students from all over the world to tackle missions based on scenarios from the workplace. The competition's class structure of beginner, beginner-intermediate, intermediate, and advanced complements the educational pipeline by providing students with the opportunity to build upon their skills as they engineer increasingly more complex ROVs for increasingly more complex mission tasks.

The MATE competition requires students to think of themselves as entrepreneurs and transform their teams into companies that manufacture, market and sell "products."

In addition to engineering their ROVs, the students prepare technical reports, poster displays, and presentations that are delivered to working professionals who serve as competition judges. The MATE competition encourages students to work together, network, and learn from technical professionals and each other. MATE's philosophy is that collaborative learning experiences best simulate the real world and will serve students – and their future employers – well in the workplace.

From your time with the organization, of what are you most proud/from what do you get the greatest sense of satisfaction?

Each year I am amazed at the innovation and entrepreneurship of the student teams. They come up with some creative and sophisticated solutions. I think that the teams are equally as amazed at the variety of solutions that they see when they come to the event

What also gives me a great deal satisfaction is the support and dedication of our volunteers. We have people like Marty Klein, who has volunteered since the very beginning and travels each year, no matter where we are, to be a part of the international competition. We have working professionals who make the competition a regularly scheduled part of their year, building their vacation around it and, in some cases, paying out of their own pocket to get there. We also have professionals who each year judge the teams' technical reports yet never have the opportunity to attend the competition and meet these teams in person.

And I have to say it is so rewarding (and humbling) to look out over the sea of students, teachers, mentors, parents, and volunteers during the opening and closing award ceremonies. To see how the competition has grown and brought together such a diversity of people and cultures, built a global community of learners, inspired career paths, opened up opportunities, and changed lives.

As it says in that 2017 international competition video, "it's where the product being developed is just as much the person as the ROV."

I'm honored to play a small part in helping to "groom the next generation" and inspire and motivate brilliant young minds to tackle these challenges.

Photo courtesy MATE II

Looking ahead, what is your biggest challenge?

I used to say managing the explosive growth (we went from 1 regional in 2002 to 31 in 2018), but now I say funding! Especially as we make the transition from a grant-funded center to a non-profit with a diverse – and hopefully growing – revenue stream.

You may know that the MATE Center was established with funds from the National Science Foundation (NSF), and continues to receive funds from NSF today. The Center has been around since 1997 as part of Monterey Peninsula College (MPC) in Monterey, CA.

We recently launched MATE Inspiration for Innovation or MATE II, a 501(c)(3) non-profit organization that was created to support the competition. MATE II's goal is to give the competition a life beyond federal grant funding and allow the program to continue well into the future. We want to keep the competition going and the dream alive for students who are "inspired to innovate" and tackle the challenges that our global community is facing today – and tomorrow.

MATE II has an MOU in place with MPC, so our address hasn't changed – and my office hasn't gotten any bigger. We have a fantastic and very active Board of Directors that includes Justin Manley, Fritz Stahr, and Debbi Kill along with the MATE Center PI Deidre Sullivan. I'm excited about this "new chapter" in my career and where it will take us with the long-term sustainability of the MATE competition. I look forward to continuing to work with the marine technology community – and beyond – to keep the competition going and growing and continuing to have a positive and life-changing impact on students and on the future global workforce.

Seafloor Crawlers

New Robotic Tools for Challenging Missions

BY JUSTIN E. MANLEY, JUST INNOVATION, INC. AND ARNIS MANGOLDS, C-2 INNOVATIONS, INC.

Back to the sea

It is widely said that life started in the ocean, and gradually moved on to land. In the case of tracked robots this trend is reversed. During the early 2000s, driven by significant defense demands, compact ground robots developed rapidly. Products like the PackBot from iRobot and the Talon from Foster-Miller pioneered man-portable high performance ground robots. The demands of operating in harsh environments made these tools robust and inspired fully waterproof variants. Unfortunately at the time limitations in energy storage, autonomy and telemetry made seafloor crawling robots a novelty rather than a productive tool. This has changed.

Through the surf

Today C-2 Innovations, Inc., (C2I) has developed a family of capable, production ready, seafloor crawling robots to take users back through the surf zone and into the sea. This family includes the compact Sea Otter and more sizeable Sea Ox.

The Sea Otter Surf Zone Crawler (SZC), Figure 1, is a second generation fully autonomous amphibious bottom crawler capable of operating at depths to 100-m through high water current regimes and onto land. Without a tether the system

Figure 1: **The Sea Otter Surf Zone Crawler**

can operate in regions and currents that previous systems could not.

The C-2i Otter can drive 16-km underwater or 20-km on land, and station-keep for a month; returning either on command or on a prearranged timeout. The ability to operate in mixed environments is unique, whereas the SZC allows access to areas that surface craft, swimmers or human based techniques could not. The Sea Otter SZC operates with negative buoyancy while operating in the lower energy boundary layer. The low profile further minimizes current drag. The vehicle has operated in 1.5-m plunging surf and can cross soft terrain that will not support human loads. Recent tests demonstrated the ability to carry 40-kg payloads as well as tow a 45-kg sled across various marine surfaces.

Specs of the Otter-SZC include:

- Symmetrical dual-sided operation for operation in the heavy surf
- Weight: 45-kg dry, 1-m long, 55-cm wide and 25-cm high (expandable in length and width)
- Speed: forward or reverse, variable up to 1-m/s
- Navigation: 3-axis IMU, FOG, dual encoders, dual-sided, dual-frequency GPS
- Control: user selects fully autonomous (pre-programmed), tether, or radio control
- Battery: rechargeable Li-ion
- Ports: charging port, programming Ethernet port, two guest Ethernet ports

The Sea Otter design is modular. The starboard and port side pontoons are core pieces, but the length, width and ground clearances can be changed by lengthening the idler sprocket brackets or changing out the connecting bridge. The current design includes two Ethernet guest ports and internal space for additional circuit boards such as data acquisition or video boards.

The modular design has permitted strap-on payloads to be mounted within minutes, without concern of payload shape, volume, or weight. Payloads have included salinity, turbidity, sonic velocity depth, various cameras, imaging sonar, release-able buoys, soil penetrometers, and electromagnetic sensor sleds, among others.

Batteries and all electronics are in-

Figure 2: **A Sea Otter Ladder Search Pattern**

cluded within the track volume maximizing free volume for the payload bay while minimizing "bottoming-out." The wide track results in ground pressures of less than 1.3-kilopascal, when dry or 0.43 kilopascal when submerged. Track design can be modified for more aggressive grip or made wider and longer to reduce the ground pressure contact. Fenders are added to minimize turbulence and drag.

Autonomous navigational accuracy is achieved by fusing data from a single axis fiber-optic gyro (FOG) and a 3-axis inertial measurement unit. A dual-band GPS receives a fix when surfaced and is used as a cross-check on position. Shaft encoders on each drive side measure distance traveled.

Accuracies of 2% of total range have routinely been achieved. Turn-in-place (TIP) and arc-turns are calculated to maintain path accuracy. Figure 2 illustrates a preprogrammed ladder search pattern along Wells Beach in York, Maine. Testing occurred while the tide was high and the system was submerged (note the photo is at low tide).

In addition to the Sea Otter, a larger variant is available. The Sea Ox is a versatile subsea bottom crawler designed for mapping and sampling the ocean floor. Like the Sea Otter, the modular design permits easy transport, storage, and deployment. The system is designed to operate either autonomously or by tethered or RF command. The Sea Ox is 122 x 122 x 30 cm in standard configuration but can be quickly extended to increase range or towing capacity. As shown in Figure 3, the Sea Ox has a 32 km undersea range, which can be extended by the addition of battery packs to 64-miles. Overall weight of the tractor is 113 kg and can be ballasted to 230kg if operating in high surf.

The Sea Ox was originally designed to tow an instrumentation sled that incorporated twin electromagnetic induction (EMI) coils designed by White River Technologies, Inc. The 60 x 180 cm sled weighs 30kg including instrumentation. Without a concern for buoyancy or volume considerations, the Sea Ox and its sled have been used to bolt-on additional customer instrumentation packages such as CTD, dissolved oxygen (DO), sonic loggers, acoustic imagers, and acoustic Doppler current profilers (ADCP). Under development is a multi-shot coring system to bring back physical samples from the seafloor environment.

Two compelling applications

Seafloor crawling robots are not simple novelties; they enable many critical applications. The Sea Ox's amphibious nature permits operation on land, through and including the transition zone to a depth of 100-m. A low 30-cm profile reduces drag by operating in the lower velocity soil/water boundary layer, and allows it to operate unobtrusively under surface traffic. The wide track creates an extremely low 0.0186 bar ground pressure that can transit extremely soft ground that is an order of magnitude less than humans. With a 16-km underwater range (32+ km surface), it can survey whole beaches in a single day. The modularity of the Sea Ox allows it to be hand carried through sensitive beach areas and can be launched and recovered by a single person from shore; reducing the cost of surveys to a fraction of conventional systems where the logistical costs can out-weigh the actual operation. Some recent applications have demonstrated this potential.

UXO Remediation

The Sea Ox is a man-portable bottom mobility platform for UXO investigations in the transition, surf and very-shallow water regions. Funded by Environmental Security Technology Certification Program (ESTCP), DoD's environmental technology demonstration and validation program, the Sea Ox demonstrated:

- A low profile design allowing the system to operate in the boundary zone minimizing exposure to currents and minimizing drag and wave impact
- A powerful, modular lightweight design permitting adjustment of the footprint and ballast to accommodate transit

Figure 3: **The Sea Ox with a towed payload sled**

Table 1

Specification	Sea Ox
Weight	250lbs (113kg)
Dimensions	48in (L) X 48in (W) X 12in (H)
Mission Range, Duration	20mi, 10hrs (single battery charge) / 2yr (sleep mode)
Max. Operating Depth	300ft
Control Options	• Teleop' via Radio/Buoy -or- Tether • Autonomous Waypoint Navigation
Recovery	• "Return to Home"- mode • Buoy/Tether
Payloads	(6) Configurable Power & Communication ports
Trailer Dimensions	72in (L) X 24in (W) (base-level)

across low bearing pressure soils and muck while providing traction for pulling instrumentation sleds

- Modularity and on-site assembly allowing one-man transport across environmentally sensitive or difficult terrain
- Very low self-generated electromagnetic (EM) and acoustic noise minimizing instrumentation interference

In this mission, the Sea Ox towed a White River Technologies, Inc. (WRT) marinized Flex-EM detector array. The project objectives were to:

- Assess the ability to conduct integrated geophysical investigations via carried and towed instrumentation packages across a range of terrain and sea states
- Develop maneuver strategies with a tow package
- Determine mapping, coverage precision
- Assess the operational advantages of the smaller modular design
- Show complete life cycle cost effectiveness including mobilization and demobilization, on-site specific vehicle modification for environment and payload support, stuck-vehicle recovery and maintenance and repair

These were accomplished. The more capable Sea Ox is modular with a single tool assembly and a 25kg max component weight. It can provide up to a full year year of station keeping for multi-location, self-deploying diurnal, and seasonal site characterization.

And onward . . .

Seafloor crawlers are an emerging category of undersea robotics. Enabled by improved component technology these tools are now delivering useful performance. For sustained, precise survey through the surf zone there are now viable robotic platforms taking us back to the sea.

Extending Unmanned Capabilities

The defense sector is looking for ways to extend its reach and capabilities, with underwater robotic and autonomous systems and sensors.

BY ELAINE MASLIN

Photo: Saab Seaeye

Saab Seaeye's Sea Wasp MCM ROV.

Extending the capabilities of submarine warfare systems without the need for humans is a key focus in the marine defense space. Navies feel under threat; they have limited budgets and worries about resurgent maritime forces from Russia and China, while new technologies – robotics, artificial intelligence (AI) and autonomous systems – are increasingly available to an ever-wider range of players, creating what are termed asymmetric threats in an ever-wider battle space.

Commodore Robert Anstey, Assistant Chief of Staff Submarines – Royal Navy, told the Underwater Defence Technology (UDT) conference in Glasgow earlier this year that a resurgent Russia in the maritime space is "sparking talk that Cold War 2 is already underway and that the West Atlantic is again a front line."

This is at a time when there's a concern that US and UK anti-submarine warfare (ASW) capability has been lost, as a result of ships being scrapped and research and development curtailment following the end of the cold war, Iain Shepherd, Technical Director, MARCOM Defence told UDT. "Iraq's invasion of Kuwait meant a land and air force focus," he said. "Today, I think we have lost 15-20 years in ASW development."

Marine autonomous systems (MAS), including AUVs, unmanned underwater vehicles (UUVs) and or "off-board" sensors are part of the solution, to extend the reach of existing systems and, longer term, potentially replace them, alongside better knowledge and use of the oceans (understanding the ocean environment to make strategic use of it) and data.

However, MAS can also be a threat, making advances in AUV and UUV technology, in parallel with work to better detect, monitor and potentially counter them, high on the agenda. "Commercial unmanned autonomous vehicles (AUVs) could be used for purposes we don't' want," says Shepherd. "If I was a terrorist, I would have a fantastic time at the moment, using underwater autonomy, causing disruption."

For these reasons, navies have been ramping up their activity in developing MAS and unmanned systems. "We are doing a lot of work in autonomy and automation," Rear Admiral Moises DelToro III, Deputy Commander for Undersea Warfare, Naval Sea Systems Command; Commander, Naval Undersea Warfare Centre, United States Navy, told UDT. "Over the past 2-3 years there's been a lot of work in unmanned systems. We have been able to deploy unmanned undersea vehicles from a US submarine. We're also experimenting with unmanned aerial vehicles," deployed from vessels, "in order to extend our reach."

XL UUVS

One focus area is larger unmanned underwater vehicles, which are likely to host payloads that include everything from forward supplies to smaller unmanned and or autonomous vehicles. While currently mostly used for ASW training, such as the UK's MSubs' 24m-long Mobile Anti-Submarine Training Target (MASTT) XL UUV, the view of many is that this process will lead towards using these systems operationally in the future.

The Dutch government, for example, has assessed use of larger unmanned vehicles to replace its manned, diesel-electric submarines, which are due for renewal in 2027. However, according to a joint paper presented by TNO Defence, Safety and Security, presented at UDT by Jan Bruggeman, the technology will not be ready in time, because it would be smaller and limited in firepower and range, is unlikely to have the required level of artificial intelligence by then, and that the algorithms required to deliver the level of autonomy needed would be costly and complex.

GROWTH IN MILITARY AUVS

More progress has been made in the AUV space and, according to Westwood Global Energy, global AUV demand will increase 37% between 2018-2022, with the military sector accounting for 70% of that demand. Nick Sheppard, Technical Director, Maritime Mission Systems, at Thales, and a UDT session moderator, says the AUV has been around and been quite successful for a number of years and is now a common tool in mine counter measures (MCM). But, he says that the potential to do much more than this was highlighted by Operation Unmanned Warrior in 2016, which showed navies that, when used in cooperation, maritime autonomous platforms could create a modular and extendable defence system.

LEANING ON COMMERCIAL SYSTEMS

Operation Unmanned Warrior also showed the defence sector that it could learn from commercial and scientific AUV technology, says Shepherd, where range, loitering time, swarm operations, autonomous behaviour capability and connectivity via surface vessels and satellite are being developed and extended.

Chris Lade, Defence Sales Manager at Saab, agrees: "More and more of the commercial world is spending time under the water and doing some clever stuff," – and in conditions as harsh as any defence environment. Saab already has strong links with the defence sector, through the main Saab business in Sweden, while its UK based outfit Saab Seaeye has a bigger footprint in the commercial space, with electric remote operated vehicles (ROVs) and AUVs.

However, since 2007, when Seaeye joined Saab, the two companies have been leveraging each other's expertise to build more cost-effective defence capable units, Lade told UDT, by drawing on its commercial systems, as well as more sophisticated commercial units, by drawing on its defence capability.

This resulted in the Sabertooth, which adopted aft thrusters from a military Double Eagle MkIII vehicle, and the Subrov, a military vehicle built with commercial components, says Lade. New vehicles, also sharing capabilities between commercial and defence are being assessed, says Lade, including a tethered Sabertooth Survey Vehicle, which would have higher power than existing Sabertooths by using Double Eagle

MKIII thrusters, and a Sarov Long Range, which would create a military Sarov with longer range by putting Sarov thrusters on a Sabertooth.

SEA WASP FOR MCM

Saab is also working with the Swedish Navy on MCM technology. The Swedish Armed Forces' Area Search Unit has Remus 100, Seabotix LBV150 and towed sonar from CMAX in its fleet, says Rasmus Andersson, Chief of the Area Search Unit. Earlier this year, it put Saab's Sea Wasp MCM robot to the test. Sea Wasp, at 1.7m-long, 0.05m-wide, 0.04m tall, weighs 9kg, was developed to find and then neutralise mines in harbour environments and around ships' hulls. It can work in 2.5knot of current and has <60m operating ability, with support from just a generator, for power (or ship's power), a pilot control station and a winch, says Andersson. Its station keeping mode works in relative and global modes and the vehicle can navigate itself to way points. Sea Wasp comes with a "very competent" electric gripping arm, although Andersson says he would almost prefer to have two arms, to be able to pull things apart. Sea Wasp also has two high-resolution cameras supported by lighting.

In tests, in -10 degrees C in Sweden, a Sea Wasp placed a 10gm plastic explosive with magnesium core on a steel plate accurately, then detonated it and relocated itself after the blast, having not suffered any damage.

A KRAITARRAY

While new platforms continue to be developed, what they can carry is also being extended. SEA's KraitArray is a towed sensor for smaller platforms, including autonomous surface vessels, AUVs and small surface vessels that cannot tow a full-sized towed sonar array.

The 16mm diameter KraitArray is a low profile miniaturised acoustic array which can be used as a low speed towed array or as a static array, horizontally or vertically. It comes in up to 50m connectable lengths, for up to 150m-long towed arrays, and operates down to 300m. It contains SEA's miniature Integrated Acoustic Sensor (mIAS), a high-sensitivity wideband hydrophone and low-noise pre-amplifier, and micro Non-Acoustic Sensors (µNAS), providing bearing and pitch to ±2deg accuracy, temperature and depth.

As well as ASW, it could be used for harbour surveillance, for marine mammal monitoring, environmental monitoring and vessel noise characterisation and even condition monitoring. A final proving trial, fully funded by an unmanned defence contractor, were completed earlier this year.

WIDENING THE BATTLE SPACE

Such technologies could help submarines expand their area of influence, says Anstey. But, for many, it's not so much about the platform any more, it's about how information from platforms can be integrated and used. Some think this capability will be what drives dominance in the defence space, from using AI in support of classification to give early warnings of UUVs or torpedoes, obstacle avoidance and target discrimination in a convoy. Versions of Shazzam – the app which can tell you what a piece of music is – and the techniques scientists use to detect stars without data training, were discussed at UDT.

Multi-static capability, where multiple sensors are deployed and feed data into one system, to enable greater sensor range and coverage, with fewer false alarms and quicker classification, are the holy grail. But, getting them right is hard and it would mean a degree of open architecture would be needed and sensors that can talk to each other, UDT heard.

Major General Robert Magowan, Assistant Chief of Naval Staff (Capability) & Chief of Staff Navy Command HQ, and Chairman of the Underwater Battle Space Capability Group, says that in the medium-long term, "the underwater battle space group is moving us towards an increasingly autonomous environment. Dispersed multiple sensors, more mobile, recoverable, and focus on capability rather than platform. We want to be able to reach out and bring stuff back and make sure the reach across the battle space is more than it is today, which will lead to increased collection of data. Our ability to handle and disseminate that data is going to be more challenged." This will mean using analytics, algorithms, on and off board. "Winning that information advantage is going to be more important."

SEA's KraitArray towed sonar array system.

Image: SEA

UFRJ Nautilus

A Brazilian AUV Project

BY CLAUDIO PASCHOA

The UFRJ Nautilus AUV is an academic project designed to develop autonomous underwater vehicle (AUV) technology in Brazil and participate in the annual Robosub competition. According to project founder, Lucas Armand, a Naval and Ocean Engineering graduate from the Federal University of Rio de Janeiro (UFRJ), the emergence of Nautilus has a lot to do with personal history: "I was having a difficult time in college, because I no longer identified myself with the course. The UFRJ Naval Engineering degree tends to be quite traditional – sometimes even old-fashioned – and I've always enjoyed technology," Armand said. "Besides, I was watching the market around me collapse; I felt that when I was educated there would be no good job opportunities to justify my effort to learn what did not satisfy me. Except that I had already invested almost three years of my life in that course, I did not want to lose everything. So, I decided on my own motivation."

Nautilus AUV ready for action.

Image: UFRJ Nautilus

"My idea was to bring something about technology to the reality of the course that I identified with. I decided that I would study autonomous vehicles and I tried to make intercessions with the course. Soon, I found the AUVs, a technology that had existed for some 20 years, with several applications in the area of oil and mining, but which is not very popular in Brazil. And I also found RoboSub, a North American university AUV competition. It made my eyes shine. From then on, I tried to apply the AUVs in all the subjects that I had to study in the university. For example, when we studied ship maneuverability, I talked to the teacher and asked if I could do a project on AUV maneuverability; It was not worth any credits, but he liked it and guided me. Doing these extra projects was what motivated me to study. After delivering this project, I talked to Professor Baraúna of Naval Engineering and he agreed to mentor the competition team. Soon, in early 2016, I sent an internal e-mail through the UFRJ network and some students proposed to participate," Armand explained.

Financing and Sponsorships

With regards to financing, UFRJ Nautilus had several moments. In the first one, they took resources from their own pocket to build the AUV and participate in the competition. It was the first 6 months of the team. Then they incorporated new members and increased their workforce. They received support from companies through donated material and some institutional support from UFRJ and engineering laboratories, with rooms, tools, etc. Now they are going through a third moment, with increased conversations with companies, collaborative financing, firmer ties with UFRJ, and strengthened partnerships with other governmental institutions (like the Navy Research Institute-IPqM). The project has begun to gain more freedom to grow and has a strong base to believe their future is promising.

Currently, UFRJ Nautilus is composed of about 30 members, undergraduate and graduate students. Among the specialties, there are Naval and Oceanic Engineering, Mechanical Engineering, Electrical Engineering, Electronic and Computer Engineering, Control and Automation Engineering, Production Engineering, Meteorology, Mathematical and Earth Sciences, Architecture, Product Design, International Relations, Defense and Strategic Management, Maritime Studies and Public Management. Given the complexity of technology,

multidisciplinary research and the high amount of resources demanded, the team structured itself into large areas for better organization. They are: Hydrodynamics and Mechanics; Electrical and Electronics; Software; Management of People and Resources; and Marketing – the first being the area with the highest investment.

The team has support divided into three branches: institutional, governmental and private. Institutionally, the university supports them with offices, to carry out the technical and administrative activities. In addition, they were able to sign several partnerships with important laboratories of belonging Coppe (UFRJ Technology Center), which provided them mechanical and electronic workshops, supported by technical professionals.

"Outside the university, we have secured the support of another government organization, which has been extremely productive and beneficial," Armand said. "Since 2016, the Navy Research Institute (IPqM) has supported us in the development of our software. Our work with the Acoustic Systems Group has developed the algorithms for the acoustic signal processing, implementing the beam forming algorithm for our AUV to find pings in the competition. This experience provided an unparalleled learning experience, because the institution is a reference in the sonar field. IPqM also provided us with its mechanics and electronics workshops for the development of Nautilus. Because of this enriching experience, the Director of the Institute made it clear that IPqM wants to increasingly strengthen the partnership and expand it to other lines of research within the institute."

UFRJ Nautilus also has several partnerships with the private sector. "In fact, the private sector companies are our main supporters, especially through the donation of parts, services, equipment and also financial donations. Organizations such as Wärtsilä, IBM, National Instruments, SolidWorks, MathWorks, OpenROV, Cortex, Forseti, Ciplast, DKR Engineering and Consulting, among others, believe in our design and capabilities. Currently, Wärtsilä Brazil has contributed most to the team," Armand said.

Below: Nautilus AUV team members checking the systems prior to competition-image UFRJ Nautilus

Right: UFRJ Nautilus AUV undergoing maintenance at the RoboSub in San Diego.

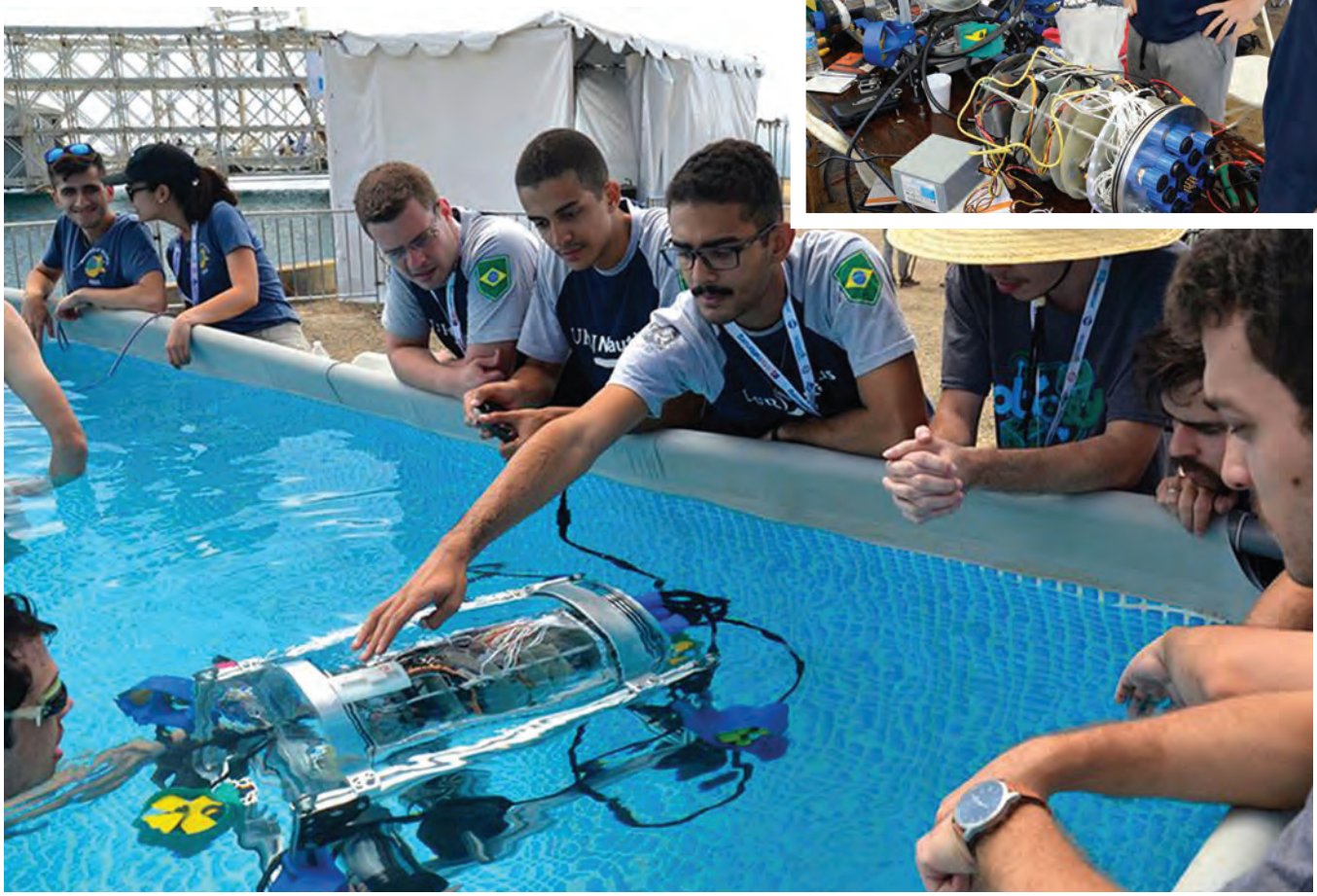


Image: UFRJ Nautilus

Robosub Competition 2018

"The main challenge was to structure the team, increase institutional support, recruit new sponsors, develop and research technical areas used in AUVs and start a new project from scratch, while being competitive. With so much work to be done, the team was structured so that it could act in both research and development (R & D) challenges. Major difficulties were that the knowledge about the subject was still embryonic in Brazil, and the instruments used in an AUV are very difficult to find in Brazil, many being nonexistent and needing to be imported. This factor, coupled with the fact that Brazil imposes logistic difficulties when importing materials, made it difficult to maintain our project schedule. However, this was somewhat good for the of us as engineering students, in dealing with difficulties and delays and thinking of solutions so that the problems did not interfere with the progress of the project," Armand said.

UFRJ Nautilus already participated in RoboSub in 2016, the year in which the team was founded. Due to lack of funds, they were unable to participate in the 2017 edition, but worked hard to return in 2018. RoboSub has existed for more than 20 years and is the main international academic competition for AUVs, Since 1997. The competition takes place annually in San Diego. It attracts a global participation, also attracting large companies such as Northrop Grumman, Raytheon, Siemens, General Atomics, MathWork, Teledyne, SolidWorks, BlueRobotics, among others, as well as the U.S. Navy. In this way, competition becomes a networking space between young engineers and specialists. "If we want to develop our skills as a team and as innovative national agents, we consider our participation in RoboSub to be essential," Armand said. "Being a Brazilian team and the first Latin American team in the competition is a great responsibility, but it also gives us great pride. Our result this edition was a great joy for all, we managed with our AUV to go to the semifinals of the competition, we could thus demonstrate our ability to develop cutting-edge technology as a university and as a nation."

MAPPING THE FUTURE

Image: Kongsberg

Marine Technology Reporter catches up with Dr. Jyotika Virmani, Ph.D, Senior Director, Shell Ocean Discovery XPRIZE and members of the GEBCO-NF Alumni Team as the conclusion to the $7 Million Shell Ocean Discovery XPRIZE fast approaches.

The Shell Ocean Discovery XPRIZE is a global competition challenging teams to advance deep-sea technologies for autonomous, fast and high-resolution ocean exploration. The prize will stimulate even greater exploration and mapping of the ocean floor, helping to uncover our planet's greatest wonders and resources for the benefit of humanity. The winner will be announced next year, but Round 2, 'Competition Testing' takes place in November and December of this year. It's the last chance for the nine teams still in contention to prove their design and engineering has what it takes. It's crunch time.

Round 2 is designed to stretch the underlying concepts, innovations and technologies that the teams have integrated and distilled to develop new solutions that will help map even more of the seabed. For the testing, all nine new technologies must launch from shore or air and with restricted human intervention. Once operational, each team will have a limited number of hours to explore the competition area (at depths of up to 4,000 meters) to produce a high resolution bathymetric map, images of a specified object and identify archaeological, biological or geological features.

MTR took a brief look at the nine finalists following their announcement at Oceanology International 2018 in our April issue and have since had a chance to catch-up with Dr. Jyotika Virmani, Ph.D, Senior Director, Shell Ocean Discovery XPRIZE and some of the minds behind one of the entries, the USV Maxlimer. Built by the GEBCO-NF Alumni Team, USV Maxlimer is based on a brand new USV called SEA-KIT, which can carry a deployable and retrievable payload of up to 2.5 tons – in this case, a Hugin AUV from Kongsberg Maritime. It's a unique AUV-USV concept, designed to enable more efficient, safer and cost-effective seafloor mapping operations, as well as providing a platform for numerous applications in a wide range of maritime sectors.

The SEA-KIT vessel itself provides a next generation, long-range, long-endurance ocean capability that is not available today. It is able to operate without assistance for months at a time and is the first of a new generation of craft that can truly operate independently. Built by British company Hushcraft, Sea-Kit, combined with the deep and rich expertise of the GEBCO-NF Alumni Team, the Hugin AUV and autonomy, positioning and communication technology from Kongsberg Maritime certainly has the potential to provide a new, more efficient way to map the oceans. Of course the other eight teams all have innovative new concepts to prove, making it impossible to predict the winner of the Shell Ocean Discovery XPRIZE. But we will find out soon.

Dr. Jyotika Virmani, Ph.D, Senior Director, Shell Ocean Discovery XPRIZE

What do you hope to achieve through the Shell Ocean Discovery XPRIZE?

The Shell Ocean Discovery XPRIZE aims to achieve three key goals: to accelerate technology in marine underwater robotics, especially mapping, imaging, and the autonomous detection of chemical or biological signals; to catalyze new markets by removing manned vessels and make it cheaper to access the deep sea; and finally, to inspire the public – these robots are discovering a new underwater planet with strange lifeforms and unfamiliar terrains. These exponential technologies can be used to assist in deep-sea environmental management, conservation, and even ecotourism. Ultimately, we envision this technology will be used to map the entire seafloor at a high resolution by 2030 – in alignment with the goals of Seabed 2030.

How does this particular prize fit within the overall aims of the XPRIZE foundations?

The Shell Ocean Discovery XPRIZE is part of our Ocean Initiative, which aims to put us on an unstoppable path to a healthy, valued, and understood ocean. Without understanding something, people are less inclined to value it, and without valuing something, we don't care about making it healthy. A map provides a fundamental piece of understanding the environment that surrounds us, but we only have a good map of 10-15% of our own sea floor at the moment. Without understanding what is out there, we won't truly be able to value this planet that we call home.

What do you see as the main challenges or obstacles to ocean exploration and how might the prize help the industry to overcome them?

The ocean covers 71% of our planet and the area to be explored is vast and difficult to access. The competition sets up the audacious goal of producing a high-resolution map of at least 250 km2 of a 500km2 competition area in 24-hours, which requires fast and autonomous solutions that will take us a long way towards quickly mapping the deep ocean floor at a high resolution and discovering what is in the oceans.

A key element of the competition is unmanned operations. Can you explain why this was chosen as a focus?

In developing this prize, one of the market failures that was identified was the expense of mapping the sea floor because of the need for manned ships at sea. By focusing on autonomous operations, we incentivize the development of a range of new vehicles and approaches that can be deployed from the shore and map an area without any humans at sea.

The finalists were announced in March; what were the key criteria used to select the teams that would proceed?

The team solutions were assessed on their performance against 11 criteria: autonomy, collision avoidance, data retrieval, depth capability, endurance, imagery, mapping resolution, navigation, seaworthiness, size and weight, and speed. These were chosen as a Technology Readiness Test and provided the judges with information on how a team would perform in a real-world scenario.

While the teams are primarily focused on winning the prize, do you expect to see much commercialization of the technology developed for the competition afterwards?

A number of the technologies, not just the winners, are expected to be commercialized. A range of technologies will be required in order to achieve the ultimate goal of mapping the entire seafloor by 2030, and once we have a map of this planet, there are others with ocean environments to be mapped.

The competition incentivizes teams to develop breakthrough technologies for ocean exploration; are there any innovations that you have seen so far that you can highlight?

In addition to autonomous operations at sea with shore-based deployments, the technology that teams are using to conduct the sub-surface work range from an aerial drone to deploying underwater pods, to swarms of underwater vehicles operating in tandem to cover the competition area, to a number of different approaches that require an autonomous surface vehicle that carries the subsurface component of the technology to the offshore competition area. We are also seeing a variety of approaches to rapidly mapping a large area, with teams using the traditional boustrophedon manner and two teams who are mapping circular areas as their underwater pods move vertically through the water column. One team is also mapping using laser instead of acoustic techniques.

With regards to the GEBCO-NF Alumni team's USV Maxlimer, can you tell us what impresses you most about the concept and technology?

This is a surface vehicle that can be controlled autonomously from shore and will carry the sub-surface component of the entry to the offshore competition area for deployment and recovery at sea. This is a wonderfully robust and versatile technology that will be able to handle a range of sea-states. Although we have only seen it operate with one AUV, the ultimate goal is that it can be adapted to deploy and recover a number of different styles of sub-surface technologies.

Can you tell us about the final testing – what will the teams' solutions have to do and how will you decide the winner?

The final round of the competition will challenge the teams' solutions to autonomously map the deep-sea floor (down to 4,000m depth) at a horizontal resolution of 5m or higher and a vertical resolution of 0.5m or higher and bring back 10 images from the ocean all within 24-hours. Our independent expert judging panel will assess the maps against a gold-standard baseline maps to see how well the solutions performed. They will, along with the help of the public, judge the images that the solutions bring back to us.

We understand that movie director James Cameron was involved in the early stages of the prize's development; is he still on board and actively working with you, or following developments?

Mr. Cameron has been a long-time advocate for ocean exploration, and, of course, mounted his own expedition to the Mariana Trench in 2012. He is also on the Board of Trustees for XPRIZE and was one of the people who brought the initial genesis of this idea to the attention of XPRIZE at one of our annual Visioneering events. From there, XPRIZE continued the full development and design of this competition.

Are there any other ocean-based XPRIZE's in the pipeline for the future?

As part of the XPRIZE Ocean Initiative, we are beginning some initial investigative work on a potential Saving Coral Reefs XPRIZE, as well as a Natural Disaster Prediction XPRIZE. Corals are a major ocean ecosystem and due to a variety of stressors, they have seen a severe decline over the last few years. Can we stop or reverse this decline? Natural Disasters such as earthquakes (and stemming from that, tsunamis) or tropical cyclones result in the loss of tens of thousands of lives (extreme events can result in losses of hundreds of thousands of lives) and billions of dollars in economic loss annually. Can we prevent such losses?

And then there were nine…

Out of 32 starters, nine teams are now in contention to win the $7 Million Shell Ocean Discovery XPRIZE.

- **ARGGONAUTS – Fraunhofer IOSB**
  Germany
- **Blue Devil Ocean Engineering**
  United States
- **CFIS**
  Switzerland
- **GEBCO-NF Alumni**
  United States
- **KUROSHIO**
  Japan
- **PISCES**
  Portugal
- **Team Tao**
  United Kingdom
- **Texas A&M University Ocean Engineering**
  United States
- **Virginia DEEP-X**
  United States

Rochelle Wigley, Director of the Nippon Foundation / GEBCO training program at the Center for Coastal and Ocean Mapping at the University of New Hampshire

Why was GEBCO training program established?

The Nippon Foundation / GEBCO training program was established in 2004 to address a number of points: It is the first program of its kind focused on Ocean Bathymetry and the skills required to do this effectively. It is a capacity-building initiative recruiting candidates from primarily developing nations. The program produces a new network of dedicated early-career scientists and ocean mappers to feed into global ocean initiatives and infuse younger members into GEBCO with an international diversity.

What are the key elements of your role as project lead for the GEBCO-NF Alumni team's entry to the Shell Ocean Discovery XPRIZE?

This is complicated technology and a complex project. Bringing together all the stakeholders, financial partners, technology providers and GEBCO Alumni volunteers was my primary challenge. There are several working groups and over 50 international individuals who work on this project. We all worked together cohesively towards a single goal for a successful Round 1 demonstration. My most important role was ensuring that communication lines between all groups working on the project were kept open.

Can you explain how and why you arrived at the unique ASV / AUV approach you have developed with the USV Maxlimer?

The Team recognized early on that most of the technology required to meet the Shell Ocean Discovery XPRIZE challenge existed commercially, but lacked a comprehensive, innovative workflow to work together. We wanted to utilize existing proven means in exciting new ways and leverage emerging technology, such as cloud- based data processing and unmanned surface vessels.

Alumni of the GEBCO training program come from all over the world; do you feel the international nature of the group has helped in terms of developing innovations for USV Maxlimer?

The boat designer was very good at listening to the expertise and knowledge of the team members and how this fulfilled requirements for the competition. This translated into the design and development of an innovative new surface vessel as our collective expertise guided Hushcraft's vessel designer and allowed him to combine his background with this new information to produce USV Maxlimer. The team is not only international, but from diverse backgrounds, and it is this diversity which is the team's strength.

Did the team come up with any other concepts for your Shell Ocean Discovery XPRIZE entry that might have made the cut?

Our focus from the beginning has been unchanged: "The team will leverage state-of-the-art surveying technology with new innovations in offshore logistics backed by industry leading companies to collect higher resolution bathymetric data through autonomous means." We planned therefore to combine emerging technology with established hardware and data automation.

Do you feel that autonomous operations are really the only way to efficiently map the world's oceans and what are the key benefits?

I think autonomous operation are only part of the solution to efficiently mapping the world's ocean. This is an enormous task ahead of us and it will require a variety of different approaches. Each innovation, however, plays an important role as we focus on understanding our oceans better. The key benefits to using a USV and AUV is that they are cheaper and safer ways to produce higher-resolution data.

You tested USV Maxlimer in Norway with Kongsberg Maritime last September. What were you aiming to achieve at this stage and did everything go according to plan?

Our sea trials over the summer prepared us well for the Shell Ocean Discovery XPRIZE Technology Readiness Tests and allowed us to successfully complete all 11 of the criteria defined by XPRIZE. We successfully operated an uncrewed (unmanned) dual USV/AUV operation with 11 km2 of data collected and then published in a GIS online environment.

We found out that the GEBCO-NF Alumni team was one of nine Shell Ocean Discovery XPRIZE finalists in March. Why has USV Maxlimer done so well in the competition?

I think the USV Maxlimer is only one part of our success. Each component of our solution is as important as any other and all had some innovation built in – and it is this cohesive approach to producing information from the bathymetric data collected that allowed our team to be as successful as we have been so far. Each piece is an important part of the puzzle – with the final products, whether images of the sea-floor or bathymetric charts showing the morphology and character of the seafloor, being the main objective of the team's entry. USV Maxlimer has been successful as she offers the means to deploy, retrieve and manage AUV operations flexibly, in either remote or autonomous modes.

Outside of your own entry, are there any other teams that you feel have developed something special?

One of the goals of XPRIZE is to stimulate and innovate technology. From what I've seen in other team's solutions, that goal has been achieved. Ocean Mapping has a long way to go and is open to exciting new innovations – and any work that brings this into focus is both important and essential.

As you move towards the final stages of the competition, are there any areas of the design or operation of USV Maxlimer that you are working on or looking to improve?

Hushcraft, the designer and builder of the SEA-KIT USV Maxlimer continues to design and develop the vessel to be the best possible and most versatile surface vessel available as a solution to a multitude of maritime tasks.

And finally, do you feel the concepts, innovations and technologies developed for USV Maxlimer could have wider implications and applications other than ocean mapping?

We are confident that there are a wide range of applications that USV Maxlimer will be useful for.

Image: Kongsberg

Yulia Zarayskaya, training program alumni and data group lead, GEBCO-NF Alumni

Why is entering the Shell Ocean Discovery XPRIZE important for the GEBCO-NF?

As part of General Bathymetric Chart of the Oceans community our bigger goal is to provide the most comprehensive publicly available bathymetry of the world's oceans and new technology is an essential component of major GEBCO-NF project Seabed 2030. Shell Ocean Discovery XPRIZE is getting us closer to this goal.

What is your role within GEBCO-NF?

I was coordinating the Data group during Round 1 overseeing the logistics of the group and the development of the data workflow.

Can you describe some of the data processes you are using to enable GEBCO-NF to reach its aims of mapping the world's oceans?

We are using existing software such as CARIS HIPS & SIPS and ESRI ArcGIS. The main goal of the Data team is to make our workflow as autonomous as possible and to reduce processing time. When we put an aim such as mapping the world's ocean the first thing is to develop equipment, however, then we are facing another big challenge – how to efficiently process a huge amount of data and reduce possible human errors. Our team concentrated its effort on efficiency of data processing.

Are you seeing enthusiasm for GEBCO-NF's work from government and industry in terms of collaboration and data sharing, with i.e. national hydrographic agencies or commercial entities?

We see incredible enthusiasm especially in industry. Autonomous data acquisition and processing is now one of the most competitive and pressing problems in the field. Our industry partners include mapping equipment developers, software developers, and service providers and this collaboration is useful for every side.

What are the key challenges you are facing in such a huge task?

The key challenge for data processing team is time. Big data sets should be processed and all information should be visualized in such a manner that it is easy-to-understand for general public and finally, in the context of the XPRIZE, it should be delivered online to judges within 48 hours.

Can you tell us what the product(s) that GEBCO-NF is working towards will be, how they will be accessed and by who?

The main product is a map of the given seafloor area that XPRIZE will assign to us and at least 10 images of any geological, biological or archeological objects. These products should be uploaded to online platform ArcGIS online where our account can be accessed by XPRIZE judges. We feel that

as members of wider GEBCO community this is also our opportunity to demonstrate what kind of derivative information can be obtained using bathymetry data.

And how will your product ultimately help maritime users?

Development in automated data processing and development of information products will ultimately benefit maritime users. We are working towards faster and more efficient ways of delivering products to end users and general public.

Maritime autonomous technologies are evolving rapidly. Our team concept is unique as it utilizes a new class of surface vessel that can transport, deploy and retrieve underwater data collection vehicles. This represents a tremendous leap forward in autonomous technology because it provides high resolution deep ocean mapping capability with a vehicle that can be launched from the shore. This does not currently exist in the market.

How does your role as Data Group Lead come into play in the context of USV Maxlimer and the XPRIZE?

The data group is in many ways the most important component of our solution as it is the data group that produces the information that is then accessible to the general public – that highlights the data collected and fosters excitement about the seafloor. The whole entry will be judged by its end result – the products that we will deliver. USV Maxlimer's essential role is to deliver the AUV to the mapping site and provide accurate positioning and mission control.

From 1899 to Seabed 2030

Seabed 2030 is a collaborative project between the Nippon Foundation and GEBCO. It aims to bring together all available bathymetric data to produce the definitive map of the world ocea-floor by 2030 and make it available to all.

Seabed 2030 builds on more than 100 years of GEBCO's history in global seafloor mapping. GEBCO was established as the sole international body responsible for the publication of ocean floor maps. In existence since 1899, the 7th International Geographic Congress held in Berlin nominated a Commission on sub-oceanic nomenclature that was also to be responsible for the publication of a general bathymetric chart.

The Commission convened in Wiesbaden (April 15-16, 1903), with Prince Albert I of Monaco in the chair, and adopted the characteristics defined in a memorandum by J. Thoulet. The 24 sheets of Carte générale bathymétrique des océans were then printed in Paris in 1905. Although not widely known, GEBCO has been responsible for all subsequent version of the paper charts and the current range of products, which includes global gridded bathymetric data sets; a global set of digital bathymetric contours; the GEBCO Gazetteer of Undersea Feature Names; the GEBCO Digital Atlas; the GEBCO world map and the IHO-IOC GEBCO Cook Book.

https://seabed2030.gebco.net

How could USV Maxlimer augment your existing processes if it went into full operation?

Now USV Maxlimer's role is primarily to deliver and retrieve the Hugin AUV (the primary data collector) and act as a communication hub during all operations. However, this vessel is designed for long-range, long-endurance autonomous operations offshore. For ocean mappers that means that with sufficient remote or autonomous onboard data processing capabilities and Cloud technology we can have instant access to information about the seafloor.

We are considering operationalizing USV Maxlimer after the Shell Ocean Discovery XPRIZE competition. It will be capable for nearshore, coastal and offshore missions. As the GEBCO-NF Alumni Team is fully supporting the goals of Seabed 2030, we hope to educate others and demonstrate autonomous mapping technologies.

Finally, do you feel that autonomy is the only way forward for improving efficiency in ocean mapping?

I wouldn't say that it is the only way, but this is definitely one of the most efficient ways to map vast areas of our oceans.

Bjørn Jalving, EVP Subsea, Kongsberg Maritime

With two levels of autonomy, below and above the surface, how challenging is it to ensure controlled, safe navigation of both vessels during mapping operations?

The system architecture of autonomy for planning, analysis and execution is similar for AUVs and USVs but there are differences in sensors and functions because of the environment. Lack of GPS and radio communication are fundamental constraints to AUVs that are solved by acoustics and aided inertial navigation systems.

USVs need advanced scene analysis and route planning to navigate safely in areas with maritime activity. There are significant thresholds to sufficient functionality and robustness of the individual systems. The most critical phases of the combined USV-AUV operation are launch and recovery. We will increasingly see swarms of USVs and AUV, which will make operations more complex.

Can you explain some of the core technology that allows both vehicles to operate fully autonomously? How does it work?

The core of the system, in both cases, is a set of modules that sense the environment and the vehicle, analyzes this information and executes according to a mission plan, utilizing a set of vehicle controllers such as heading and speed controllers, trajectory control and payload controllers. The brain of the system can sort this information according to when and where different states should occur, and in the future think of new ways to solve a specific challenge.

Image: Kongsberg

You've seen USV Maxlimer and the Hugin AUV in action during sea trials and Technology Readiness Tests; do you think it is ready to win the Shell Ocean Discovery XPRIZE?

I do think the GEBCO-NF alumni team has a very sound strategy. They build on commercially proven solutions such has the HUGIN AUV, HiPAP position and communication system and the HISAS mapping system, partner with SEA-KIT for a truly ocean going USV and focus on integration and data processing. The combined SEA-KIT/HUGIN system has a maturity level ready for XPRIZE. It will be exciting to compare with the other participants and learn the outcome of the competition.

Have you and your team come up with any alternative applications that the dual above and underwater autonomy approach could benefit, aside from seabed mapping?

The HUGIN AUV has had automatic pipeline tracking since 2012, so pipeline inspection is an obvious application to pursue. Because of the cost benefits, I think USV-AUV concepts will rapidly be applied to applications within survey, inspection, science and naval.

Kongsberg has been developing AUVs for subsea surveying since the early nineties; how has this experience informed your move in the last few years to developing Marine Autonomous Surface Vessels?

The Marine Autonomous Surface Vessels (MASS) program in Kongsberg builds on technology and experience from both

Images: Kongsberg

our advanced vessels systems and AUVs. Autonomy is a key enabling capability. However, a MASS comes with same advanced solutions as seen for larger vessels, for navigation, maneuvering, propulsion, automation and power as well as communication, remote operation and cloud functions. MASS is a major initiative. Kongsberg builds on mature products, invests in development and runs stepwise test and qualification programs.

Can you tell us about any recent developments in your AUV or USV portfolio for the subsea market?

In partnership with Eelume, Equinor and NTNU we bring forward new radical technology for subsea inspection, maintenance and repair. The underwater vehicle is called Eelume and is a self-propelled robotic arm that can transit over long distances and carry out IMR in confined spaces. Eelume is very hydrodynamic and capable of complex IMR. The vehicle is designed to be subsea resident, which we believe will disrupt IMR costs. Docking technology and wireless battery charging are common technology functions for subsea docking stations, USVs, AUVs and Eelume.

We are working on connectivity and cloud solutions to support remote operation, autonomy and ease handling of data. KONGSBERG has launched Mapping Cloud, which is an open ecosystem to store, analyze and share data. The first version of Mapping Cloud supports the Kongsberg EM multibeam echo sounder range. We work with partners for the data processing solutions. We are extending the Mapping Cloud to offer easy handling of all data recorded in AUV and USV operations, as well as the full range of KONGSBERG sensor systems.

Will your work with the GEBCO-NF Alumni team inform future autonomous vehicle commercial developments?

I think AUV-USV systems will see increasing commercial use because of clear cost benefits. There will be significant

New applications for proven technology

Kongsberg's autonomy controller technology is capable of being integrated with almost any vessel via an electrical interface. It provides adaptive waypoint following for survey and AUV operations while accepting sensor data for scene analysis and collision avoidance. It is an autonomous system designed to follow mission plans, in addition to providing global supervised operations or even direct operator control for complex tasks.

The solution is the common autonomous control engine to be used by unmanned and autonomous vessels delivered by Kongsberg Maritime including the fully electric container feeder, YARA Birkeland. It has been developed by the Kongsberg Maritime in conjunction with FFI, the Norwegian Defence Research Establishment and builds on a history of collaborative development projects, including the HUGIN AUV System.

In addition to the the autonomy controller solution, SEA-KIT will be equipped with Kongsberg Maritime's Maritime Broadband Radio (MBR) for high bandwidth direct communication to shore, SeaPath 135 with an MRU5+ for heading, attitude and positioning and the AIS300 Automatic Positioning System. KONGSBERG's HiPAP acoustic positioning and control system will be used to supervise AUV operations.

developments in autonomy and advanced sensor processing. But I believe the GEBCO-NF Alumni team has demonstrated that the technology is available and it is a matter of the ocean mapping community to bring the pieces together in systems that do the job reliably.

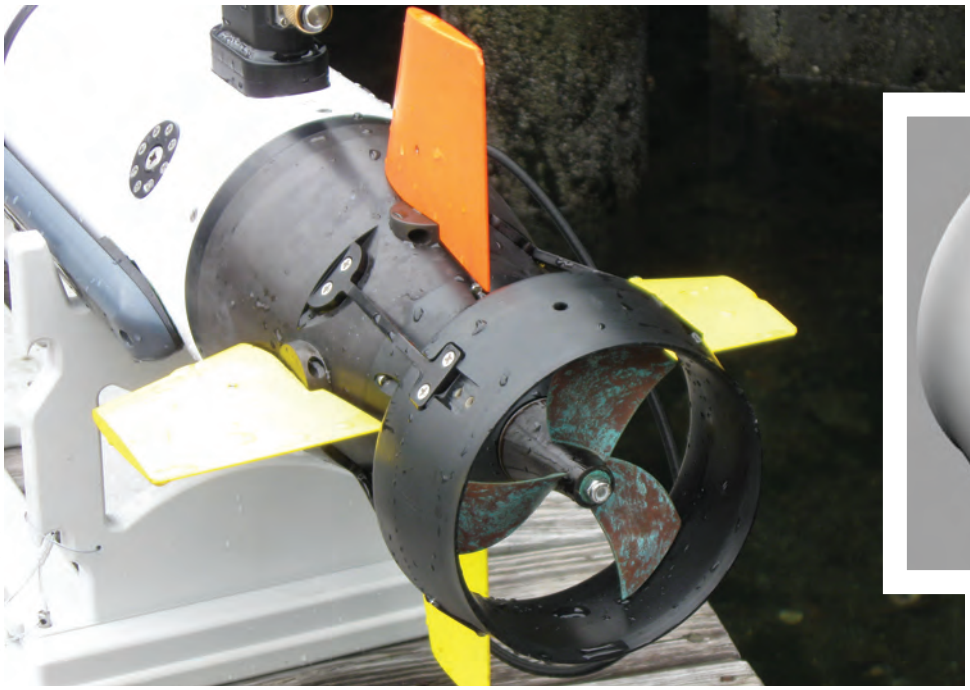
With final stages of the Shell Ocean Discovery XPRIZE competition closing in, is your work still ongoing? Have you had to overcome any obstacles recently to ensure that everything is ready?

Yes, there are many challenges to overcome. The team led by the GEBCO-NF alumni work very hard with SEA-KIT, KONGSBERG and all partners to get ready for Round 2. The Nippon Foundation GEBCO Seabed 2030 project has changed our view and ambitions for the ocean and seabed mapping. XPRIZE is a true challenge and will have significant impact. It is exciting to be part of the vision and solution for a sustainable ocean.

In addition to USV Maxlimer and Hugin AUV, what innovations have been achieved in your hydroacoustic surveying technology recently that could help deliver on Nippon Foundation and GEBCO's Seabed 2030 project?

The purpose is to map the seabed. The HUGIN AUV is equipped with the latest HISAS 1032 synthetic aperture sonar and also comes with an EM 2040 multibeam echo sounder acting as a gap filler. This combination provides a continuous wide swath of high accuracy, high resolution bathymetry, and in addition, the HISAS synthetic aperture sonars provide imagery at very high resolution.

The HISAS systems go deeper and wider, and we see very high area coverage rates coming. As a rule of thumb, doubling of area coverage rate enables seabed data at half the cost. Sensors with high area coverage rate, unmanned robotic platforms and cloud solutions for efficient storing, handling and sharing of data are an excellent combination for detailed mapping of the seabed.



Images courtesy HydroComp

Engineering Better Propulsion

By Eric Haun

"Propeller design has often been considered kind of a black art," said Donald MacPherson, technical director at HydroComp, Inc. But it's an art that MacPherson has always had a knack for, and today his company is known as experts in the field of hydrodynamic performance.

MacPherson co-founded HydroComp together with managing director Jill Aaron in 1984. The Durham, N.H. based firm's maritime software and consultancy services have aided a wide range of hull and propeller analysis and design projects – from large commercial ships to unmanned underwater vehicles. For any maritime vehicle, better hydrodynamic performance leads to reduced propulsion power requirements, freeing extra power for sensors and allowing more time for data collection. HydroComp, which has developed special expertise in the design of high-efficiency small propulsors (thrusters) for these submersible vehicles, helps the AUV/ROV industry to design and analyze their propulsion suites.

"We find the small propeller work really interesting because you use the same tools as you do for large propellers, but it's actually more demanding," MacPherson said. "Small propellers are influenced to a greater extent by viscous and frictional issues, so manufacturing tolerances have to be tighter."

The company's flagship resistance and propulsion analysis software, NavCad, aids in the sizing and selection of an appropriate thruster or propeller.

The software can estimate vehicle drag and quantify the impact on propulsion power from the addition of control surfaces, antenna and other appendages. NavCad can also be used to size propellers and predict the thrust, torque, RPM and power over a wide range of operating conditions.

For more in-depth propeller performance analysis, HydroComp's PropElements propulsor design software is capable of generating a custom wake-adapted propeller design for underwater vehicles. The hydrodynamic flow or wake around the vehicle is considered in the design resulting in a propulsor with improved efficiency over stock, off-the-shelf designs.

HydroComp regularly designs custom thrusters and propellers for specific applications. MacPherson said it is best to start by looking at the propulsion system as a whole before examining individual components such as propellers. "Successful propulsion, whether that's ships or small underwater vehicles, is a system problem first and a component problem second," he said, adding that even the best and smoothest thruster available could be completely inappropriate if it doesn't match the system.

"The big gains are from getting the system right and then the rest of the gains is from being able to design a high-efficiency thruster that fits the system."

MacPherson said he has also observed a trend away from a single design point where one propulsor is specified for a single operating scenario, with optimum performance at just one condition. "By looking at a total mission profile, which has become a part of our standard practice, you can actually look at the influences and consequences of how much time is spent at a different operating mode and the multiple operating modes that a vehicle might have," MacPherson explained. "Now we're trying to find the best compromise solution for overall system performance."

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Olis:
Manipulator Control System

Olis

Blue Robotics

OSIL: New ROV Tools

OSIL

Diamond Wire Saw

ROVQUIP

Manipulator Control System

Olis (formerly BluHaptics) says its new manipulator control system delivers an evolutionary leap over legacy robotic master controllers used by the offshore energy industry. The Extended Sense 1 (ES1) is the first in a new line of offerings from the Seattle-based technology company, offering intuitive controls and more efficient operations which combine to reduce risk, increase precision and save time. Key ES1 features eclipse legacy master control products with five new advancements. First, ES1 offers a graphical user-interface which reduces pilot stress. The control system then allows pilots the ability to rapidly select functions through a touch-screen or gamepad, and provides assistive constraints that can lock movements for cutting and torqueing tasks. Next, ES1 gives operators the option to pre-set the position for robotic arms and store new positioning on-the-fly. Finally, the latency and bandwidth resilient ES1 enables the ability to toggle between local (ship-based) and remote (control center) piloting. Olis ES1 will be available in mid-September 2018 and functions with the major manipulators utilized for subsea intervention.

OSIL: New ROV Tools

Ocean Scientific International Ltd (OSIL) has augmented its offering of deep sea sampling equipment for ROVs with a multiple water sample collection system with inbuilt water quality monitoring. OSIL's range of ROV tools now not only includes the instrumented water sample collection system, but also an undisturbed sediment sampling system, an instrumented pressure activated camera system, and a deep sea solenoid actuator, which can be adapted to suit application requirements. The ROV tools can be daisy-chained together to create a sampling network for rapid assessment work. All ROV tools are rated to 6,000m and have a wide range of potential applications including monitoring deep sea mineral retrieval and oil and gas operations, scientific exploration and environmental impact assessments.

Blue Robotics Gripper

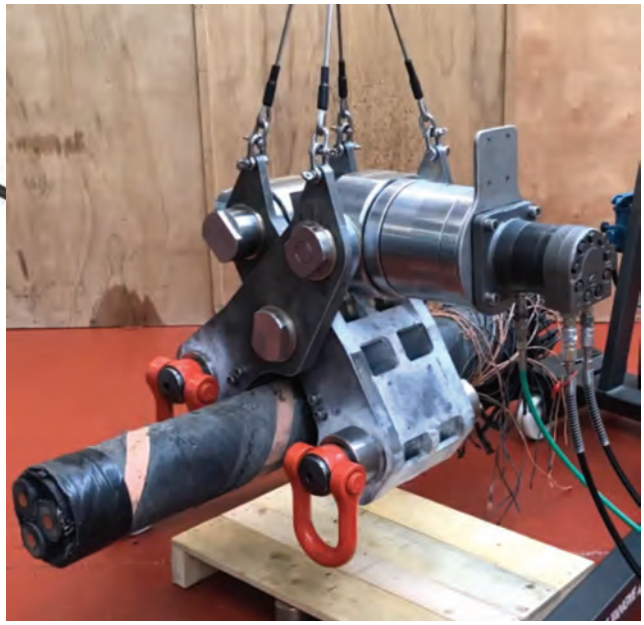
Blue Robotics' new Newton Subsea Gripper for the BlueROV2 and other subsea vehicles is a single function manipulator that's simple, robust and highly capable. It's controlled by a standard servo-style PWM signal, like Blue Robotics' thrusters and lights, and runs on 9-18v. It is rated to 300 meter depth. The gripper has jaws that open to grab objects up to 2.75-in. or 7cm in diameter. The plastic jaws are mounted with custom aluminum screws to create a corrosion resistant mechanism that doesn't need any lubrication. The jaws are driven by a linear actuator that uses a geared brushed motor and lead screw. The main body is air-filled and sealed with O-rings. The motor inside is controlled by a purpose-built brushless motor controller that accepts a standard servo-style PWM signal so that the gripper can be controlled just like our thrusters and lights. Power can be provided by the same battery that drives the thrusters as the gripper is compatible with 9-18v input and draws up to 6A current. It auto-

Blue Robotics Gripper

JFSE Ultra Low Draft Tool

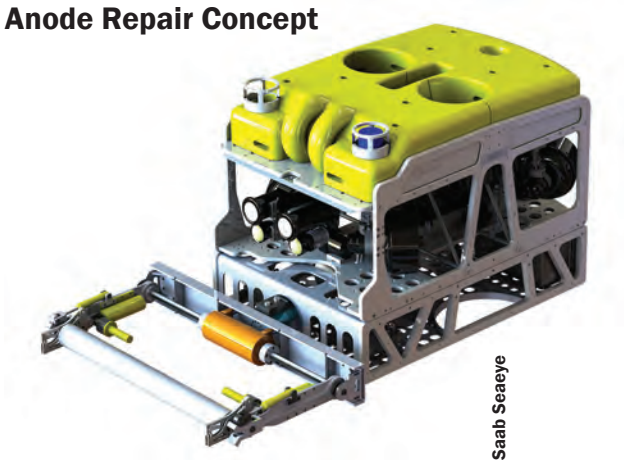
JFSE

New Cable Recovery Tool



Allspeeds

Anode Repair Concept



Saab Seaeye

matically detects motor stall conditions and stops the motor so that the gripper will always stop at the right moment.

Manipulator Mounted Diamond Wire Saw

Subsea tooling manufacturer ROVQUIP earlier this year completed the build and test of its first manipulator mounted diamond wire saw. Designed on the back of a project where we had to build a quick turnaround 30" saw the ROVQUIP manipulator mounted saw is the ideal tool for small cuts. With a stroke distance of up to 11" the saw is mounted to the wrist of the Rigmaster and can be stowed when not in use.

Anode Repair Concept

A new concept from SubC Partner is said to save up to 75% in costs compared to hydraulic delivered anode repair systems. It can be adapted for any size and shape of sacrificial anode, whether surface mounted or welded, and offers a very fast anode exchange procedure that avoids diver intervention and can be undertaken in extreme weather conditions. The system comes as a skid, available for the Saab Seaeye Cougar XT work class vehicle. The anode replacement system is capable of handling anodes weighing up to 40 kg and in lengths up to 1,100 mm.

New Cable Recovery Tool

Allspeeds said a production prototype of its new Webtool CRT200 cable recovery tool has been completed and initial testing has begun. The CRT200 cable gripper provides a streamlined cable recovery where the gripper, guided by an ROV, is lowered onto the end of the cable without requiring preliminary clearing of the soil around the cable. The mechanically locked gripping action ensures the umbilical cannot escape during retrieval; moreover, an internal clutch mechanism prevents damage from overtightening. By gripping the end of the cable, it makes subsequent handling much easier, enabling the cable to be recovered to a reeler or spooler on the surface vessel. The CRT200 cable gripper weighs approx. 600 kg and has a lifting capacity of 20 tonnes. It can be used at any water depth, and is available with hydraulic hotstab or torque bucket interface options. The cable and umbilical retrieval tool has received design verification approval from DNV GL.

JFSE Ultra Low Draft Tool

James Fisher Subsea Excavation (JFSE) has reengineered its Twin R2000 Ultra Low Draft controlled flow excavation (CFE) tool to be made capable of excavating at just one meter. The new iteration, used for trenching, deburial and backfilling works in water depths ranging from one meter to 3,000 meters, completed its first project uncovering sections of damaged cable and trenching the repaired sections and is now set for a number of key projects throughout the year. The Twin R2000 Ultra Low Draft will be based in Aberdeenshire, UK in order to efficiently mobilize for clients in the North Sea and European markets where there has been a particular demand for shallow water excavations.

CGG

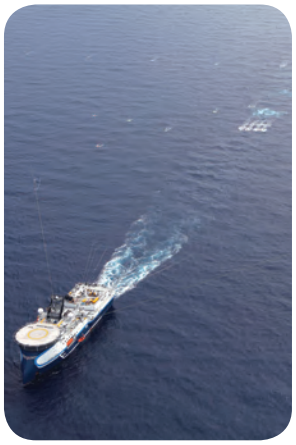


Photo: CGG

Yopak

Photo: Greensea

O'Sullivan

Photo: PDi

Hochoa

Photo: Bourbon Corporation

CGG Names Baidoukov CFO

CGG has appointed Yuri Baidoukov as Group CFO, effective September 1, 2018. He will be based in Paris and report to the Chief Executive Officer, Sophie Zurquiyah. Baidoukov brings to the role 25 years of international oil and gas industry experience, having most recently served as Group CFO at OiLSERV Group, a Middle East and North Africa Oilfield Services company. Prior to this, he was CFO of Maersk Oil US, and Group CFO of Integra Group, a CIS oilfield services company. Baidoukov spent 10 years of his career at Schlumberger in finance positions at the corporate and regional levels.

Yopak Joins Greensea

Greensea has appointed Regina Yopak as Applications Engineer, Service Manager. Yopak will work as a bridge between Greensea customers and engineering teams, provide technical support and expertise to customers and develop systems and procedures to ensure the company maintains exceptional customer satisfaction.

Yopak comes to Greensea with extensive at-sea experience having spent several tours as Lead Navigator and Mapping Specialist on board E/V Nautilus for the Ocean Exploration Trust. In addition to her offshore experience, she holds a Bachelor of Science degree in Physics and Environmental Science, and a Master of Science degree in Ocean Engineering from the University of Rhode Island.

PDi Taps O'Sullivan as New CEO

Project Development International (PDi) Ltd - part of the Tattva Group – has appointed Michael O'Sullivan as its new Chief Executive Officer and board member. O'Sullivan will be responsible for growing PDi's core installation engineering and decommissioning services, developing the international footprint of the company and expanding its subsea engineering design capability. He will be part of the leadership team that will drive the development of Tattva Group's global oil and gas business, through the integration of PDi's subsea expertise with sister company Results Engineering's topsides and onshore capability.

Bringing over 25 years' subsea oil and gas experience to PDi, O'Sullivan began his career in the subsea industry with riser consultancy MCS, serving in a variety of technical and managerial positions. This culminated in his appointment as Managing Director of MCS UK in 2009 - following its acquisition by Wood Group – a position he held until 2013. Subsequently running JP Kenny's operations in Aberdeen, he most recently held the position Vice President of Application Engineering for the Aker Solutions UK products business.

RE2 Robotics Hires Schneider

RE2 Robotics named Travis Schneider as its new Business Development Manager to drive commercial business development efforts and conduct market research, enabling RE2 to pursue emerging markets. Schneider comes to RE2 with a robust background in robotics, software and complex control algorithms. Prior to joining RE2, he worked for Parker Hannifin, where he most recently served as a business development manager for IoT Solutions.

Hochoa Takes Over as Bourbon CFO

French offshore services provider Bourbon Corporation announced Thierry Hochoa has been appointed as Chief Financial Officer effective as of August 6. He reports directly to Gaël Bodénès, Chief Executive Officer of Bourbon Corporation. Hochoa replaces Astrid de Bréon who resigned from her position as Chief Financial Officer from July 11.

A graduate of IAE Paris, ESCP Business School and also CPA, Hochoa began his career in 1994 as an external auditor at Arthur Andersen, then Ernst & Young (EY). In 2004, he joined Technip, first as Director of Internal Audit, then held various finance positions at Group level before becoming, in 2011, Corporate Financial Control Director. In 2013, he was appointed Chief Financial Officer of operations in Southeast Asia on the key Yamal project in Shanghai. In February 2016, he became Vice-President Finance & Group Controller in Paris and actively worked on the merger and integration project of Technip with the American FMC Technologies. In April 2018, Hochoa joined BOURBON Corporation as Director of the financial

Harp

Photo: WHOI

Heijermans

Photo: Boskalis

Garcia & Burke

ASA

Rebecca Garcia-Malone, ASA Education Committee Chair, presents Dr. Richard J. Burke, ABS Professor of Naval Architecture & Engineering, SUNY Maritime College, with an official invitation to join the ASA as the very first honorary maritime faculty member representative, July 20, 2018 at SUNY Maritime College.

structuring project for the three Standalone Companies created in the context of the #BOURBONINMOTION strategic action plan.

WHOI Hires Harp

The Woods Hole Oceanographic Institution has hired Samuel C. Harp as the Institution's first Vice President for Advancement and Chief Marketing Officer, responsible for communications, fundraising, and marketing groups at the Institution. Harp has spent much of his career in academic, technology, and research institutions and will begin working at WHOI on October 1.

Heijermans Joins Boskalis Board

Bart Heijermans was appointed to the Board of Management of Royal Boskalis Westminster N.V. for a term until the Annual General Meeting of Shareholders in 2022. Heijermans will be responsible for the company's offshore energy division, effective September 1, 2018.

Heijermans brings to the board extensive experience in the offshore industry, having recently served as CEO and board member of subsea services provider DeepOcean. Prior to that, he held various senior management positions at companies including Helix Energy Solutions and Shell. Heijermans has a civil engineering degree from Delft University of Technology.

Three Join Global Marine Bboard

Global Marine Systems Limited (GMSL) trading as the Global Marine Group (GMG), appointed Ian Bryan, Managing Director of Group Operations; Mike Daniel, Managing Director of Global Offshore and Mark Preece, Managing Director of CWind to its Board of Directors.

Personnel Changes at ARL

U.K. based autonomous underwater vehicle (AUV) developer Autonomous Robotics Limited (ARL) announced the appointment of Rear Admiral (retired) Jon Westbrook CBE and Commodore (retired) Phillip Titterton CBE as Defense Advisor to the Board and Defense Consultant respectively, with effect from August 1, 2018.

The company also hired additional engineering staff. Abhinav Bharti (lead software engineer) and Ella Richards (lead mechanical engineer) have joined the team led by Arran Holloway, ARL's Engineering Director.

The company's board also announces that Rafael Albea has resigned from his position as CEO to pursue other opportunities.

Paull Receives Francis P. Shepard medal

MBARI Geologist Charles Paull was recently awarded the Francis P. Shepard award for Excellence in Marine Geology by the Society for Sedimentary Geology (SEPM). Since joining MBARI in 1999, Paull has spent much of his time studying the movement of sediment in submarine canyons, including Monterey Canyon, which originates just offshore of MBARI's campus in Moss Landing. He has also mapped and explored methane seeps, faults, and a variety of other seafloor features using MBARI's state-of-the-art underwater robots.

ASA Names Burke Honorary Member

The American Salvage Association (ASA) welcomed Dr. Richard J. Burke, of SUNY Maritime College as the Association's very first honorary maritime academy faculty member representative. This initiative is designed to broaden the knowledge about the marine salvage and emergency response industry, and the academic community's access to it.

Dr. Burke graduated from the Maritime College with a degree in Naval Architecture in 1972 where he currently serves as SUNY Maritime's ABS Professor of Naval Architecture and Marine Engineering. Dr. Burke completed graduate work at the Massachusetts Institute of Technology (S.M., Naval Architecture and Marine Engineering, 1974) and the University of Massachusetts at Amherst (Ph.D., Industrial Engineer-

Photo by Julianna Smith, RoboNation

ing and Operations Research, 1990). He has worked in industry for Mobil Shipping and Transportation Company, the Knolls Atomic Power Laboratory, and at the United States Salvage Association.

Shearwater Buys Schlumberger's Seismic Business

Norwegian marine geophysical services company Shearwater GeoServices Holding AS has entered into a definitive agreement to acquire the marine seismic acquisition assets and operations of Houston-based Schlumberger's geophysical services product line, WesternGeco. The transaction, which remains subject to regulatory approvals and other customary closing conditions, is expected to close in the fourth quarter of 2018. Shearwater will acquire 10 high-end seismic acquisition vessels, including seven 3D vessels and three multipurpose vessels (MPVs) configured to serve the OBS market, 12 complete streamer sets with spares, as well as two source vessels.

The proposed transaction also includes WesternGeco proprietary marine seismic technology, as well as development and manufacturing facilities in Norway and Malaysia.

Students Face Off Underwater

Nearly 50 high school and university teams from around the world participated at the 21st International RoboSub Competition at the Space and Naval Warfare Systems Center Pacific Transducer Evaluation Center in San Diego. The autonomous submarine competition, co-sponsored by the Office of Naval Research (ONR) and the Association of Unmanned Vehicles International Foundation, tested students' mechanical, electrical, computer and systems engineering skills—as well as their presentation skills and teamwork while competing for cash prizes. Harbin Engineering University (China) took this year's top prize, while National University of Singapore and École de Technologie Supérieure (Canada) placed second and third, respectively. Smaller awards in specially judged categories went to the University of Maryland, Baltimore County; École de Technologie Supérieure; Texas A&M University; Washington State University; University of Puerto Rico at Mayagüez (Puerto Rico); San Diego Robotics 101; University of Alberta (Canada); Ohio State University; and Wroclaw University of Science and Technology (Poland).

Trelleborg Building Hyperbaric Test Site

Trelleborg's offshore facility based in Skelmersdale, U.K., broke ground on its new 630m² testing facility that will house two state-of-the-art hyperbaric test chambers. The new equipment will be able to simulate extreme deepwater pressure conditions, enabling accurate testing of subsea and drilling equipment.

Maersk to Help Clean Ocean Plastic

Offshore services provider Maersk Supply Service has signed onto a project that aims to collect tons of plastic waste littering the world's oceans. In the comping months, the Denmark based firm will provide marine support to the Dutch nonprofit The Ocean Cleanup, which will install its first cleanup system in the North Pacific as part of the planet's first large-scale initiative for collection of floating ocean-plastic debris. This fall the first offshore cleaning system will be installed in the Great Pacific Garbage Patch (GPGP), located 1,200 nautical miles off the coast of San Francisco. The system will be deployed by Maersk Supply Service's AHTS vessel Maersk Launcher.

Maersk Launcher

Maersk Supply Service

NOAA Awards

NOAA

TCarta Marine

Image source: Copernicus Sentinel data 2018

Shipping Firms Recognized

NOAA presented awards to 13 global shipping firms for their commitment in helping prevent ship collisions with whales off the coast of California.

The companies participated in a Voluntary Speed Reduction initiative by slowing their ships to speeds of 10 knots or lower while transiting vessel traffic lanes outside the Golden Gate during whale feeding season. Awards were presented to Mediterranean Shipping Company; Yang Ming Marine Transport Corp.; Polar Tankers Inc.; Celebrity Cruises Inc.; Hamburg Sud; ExxonMobil Corp.; Evergreen Marine Corp.; CSL Americas; Mitsui OSK Lines Ltd.; Kawasaki Kisen Kaisha Ltd.; OSG Ship Management Inc.; Tesoro Far East Maritime Company.; Chevron Shipping Company LLC.

NSF Grant for Project Trident

Marine geospatial products provider TCarta Marine was awarded a research and development grant by the National Science Foundation (NSF) to enhance and automate multiple techniques for deriving seafloor depth measurements from optical satellite imagery. The 'Project Trident' research seeks to transform existing satellite derived bathymetry (SDB) techniques by leveraging machine learning and computer vision technology to enable accurate depth retrieval in variable water conditions.

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- BlueTech Investors Day
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47	RJE International, Inc.	www.rjeint.com	(949) 727-9399
1,29	SBG Systems	www.sbg-systems.com	Please visit us online
11	Shark Marine Technologies, Inc.	www.sharkmarine.com	(905) 687-6672
41	Sidus Solutions LLC	www.sidus-solutions.com	(619) 275-5533
25	Silicon Sensing Systems Limited	www.siliconsensing.com	+44 (0) 1752 723368
27	Sonardyne International LTD	www.sonardyne.com	44 1252 872288
9	Southwest Electronic Energy Group	seasafetech@swe.com	(281) 240-4000
47	SubCtech GmbH	www.subctech.com	+49 (0) 431-22039 884
5	Teledyne Marine	www.teledynemarine.com	Please visit us online
C2	VideoRay LLC	www.videoray.com	(610) 458-3000

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Evo Logics®

SMART SUBSEA SOLUTIONS

S2C TECHNOLOGY: COMMUNICATION AND TRACKING COMBINED

- time, space and cost-saving solutions
- low power consumption for autonomous operations
- advanced data delivery algorithms, addressing and networking, remotely configurable settings
- extendable platform with multiple configuration options: power-saving Wake Up module, acoustic releaser, additional sensors, custom solutions, OEM versions availableh

USBL POSITIONING SYSTEMS

simultaneous positioning and communication - no need to switch between positioning mode and modem mode

- flexible SiNAPS positioning software
- reliable data transmissions
- range: up to 8000 m
- accuracy: up to 0.04 degrees

UNDERWATER ACOUSTIC MODEMS

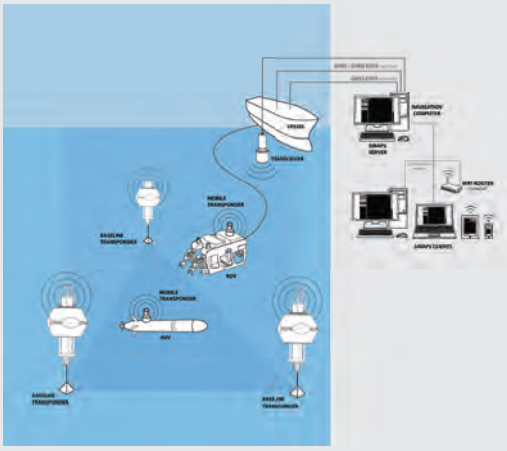
reliable data transmissions even in adverse conditions, customizable R-series modems, light and compact M-series "mini" modems, **new S2CM-HS high-speed modem**, special editions for developers, S2C communication and positioning emulator - remote access or standalone device

- range: up to 8000 m
- depth: up to 6000 m
- data rate: up to 62.5 kbps

LBL POSITIONING SYSTEMS

highly accurate, precise and stable performance, simultaneous positioning and data transmissions

- flexible SiNAPS positioning software
- reliable data transmissions
- range: up to 8000 m
- accuracy: better than 0.01 m



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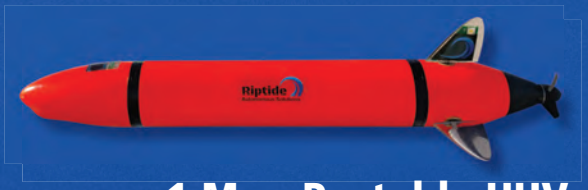
Riptide set out to change the undersea vehicle market by combining best in class hydrodynamics, ultra low power processing, and game changing new energy technology, while significantly reducing vehicle costs. To accomplish this, we introduced the small, yet highly-capable micro-UUV.

And now, the Family just got BIGGER

Introducing the Riptide Family of Low-Logistics, Man-Portable UUVs

Micro-UUV
4.875" Diameter
~25 lbs
300m rated



1 Man-Portable UUV
7.5" Diameter
~65 lbs
300m rated

2 Man-Portable UUV
9.375" Diameter
~120 lbs
600m rated

Riptide
Autonomous Solutions

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