ROV PLANET

25

The magazine of choice for Subsea Construction and AUV/ROV/USV Professionals

ISSUE
Q4 / 2020

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ISSN 2634-0291 (ONLINE)

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EVENTS CALENDAR

For more information about all events visit WWW.ROVPLANET.COM

DECEMBER 2020

OCEANOLOGY INTERNATIONAL
London, UK, VIRTUAL (1-3 December 2020)

WINDENERGY
Hamburg, Germany, VIRTUAL (1-4 December 2020)

APRIL 2021

MCEDD DEEPWATER DEVELOPMENT
London, UK (20-22 April 2021)

MAY 2021

UNMANNED MARITIME SYSTEMS TECHNOLOGY (UMS)
London, UK (12-13 May 2021)

MTS/IEEE OCEANS 2021
Porto, Portugal (17-21 May 2021)

SUBSEA EXPO
Aberdeen, Scotland, UK (25-27 May 2021)

DEEP SEA MINING SUMMIT
London, UK (27-28 May 2021)

JUNE 2021

UNDERSEA DEFENCE TECHNOLOGY (UDT)
Rostock, Germany (29 June – 1 July 2021)

JULY 2021

OCEAN BUSINESS
Southampton, England, UK (6 – 8 July 2021)

AUGUST 2021

OFFSHORE TECHNOLOGY CONFERENCE (OTC)
Houston, TX, USA (16 –19 August 2021)

SEPTEMBER 2021

MTS/IEEE OCEANS'21
San Diego, CA, USA (20-23 September 2021)

My name is Richie Enzmann, and allow me to welcome you all to the latest issue of ROV Planet!

WELCOME TO ROVPLANET!

Dear Reader,

I hope this quarter's issue finds you safe and well. Due to COVID and the various restrictions this year went past like no other before. Many industries and companies are facing uncertainty, but at the same time I've heard of many people being busy, especially in the defence and the offshore renewables sectors.

As for this issue, we have a lot in store for you. First, I had the honour of conducting an interview with Tyler Schilling before his retirement. His career has spanned 35 years in the industry and he has been instrumental in developing new subsea technologies, such as robotic manipulators, the HD and UHD ROVs, and now his final work the GEMINI: destined to be a true game changer. It's always sad to hear when such iconic names leave the industry, so I sincerely hope that we will still hear from him in the future and TechnipFMC will carry on his legacy. In the interview, Tyler explains to us the technical details of this ROV and gives us a glimpse into the possible future of how technology in the subsea industry might evolve.

Furthermore, in this issue we will look at the offshore renewables industry and a potential new application: installing and maintaining underwater data centres. Microsoft has recently completed Project Natick in the Orkney Islands and found that datacentres underwater are more reliable and secure than datacentres on land, while requiring less power and having a lower carbon footprint. With this incredibly positive outcome, it's possible that the company might scale up this application and even link these datacentres with offshore wind turbines to provide its power.

Finally, David Strachan, a wargaming analyst, shares his vision of the future of naval mine warfare. He discusses the key drivers and enablers and explains how this currently static technology will eventually fuse together with AUV/UUVs, where mines are no longer fixed platforms, but highly mobile, autonomous agents.

As you can see, we have a varied array of items for you to dive into, and I really hope you enjoy this issue. In case we don't see you before, here's to a happy, healthy, and productive 2021!

Best regards,
Richie Enzmann

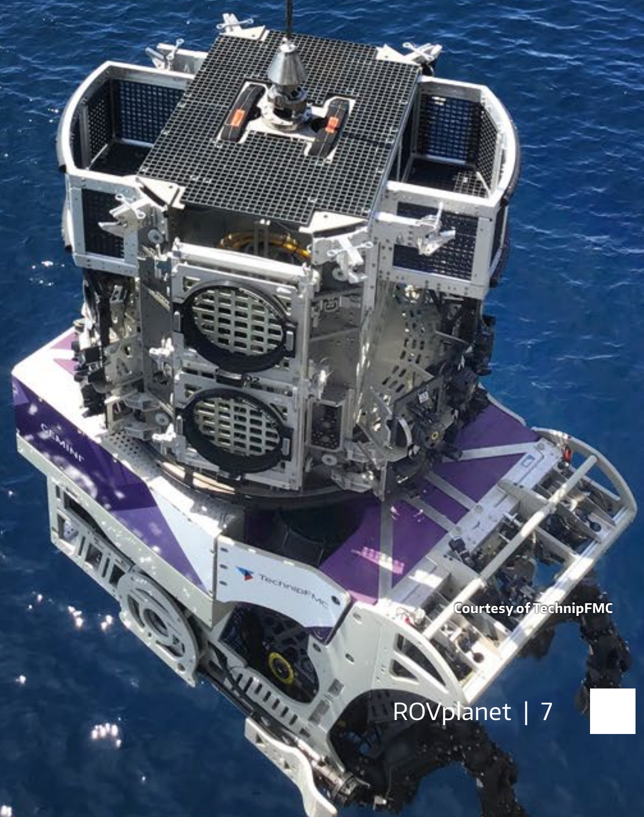
INTERVIEW WITH TYLER SCHILLING

GEMINI

A GAME CHANGER IN OFFSHORE PRODUCTIVITY

RICHIE ENZMANN: Hi Tyler, it's been a long time since we've heard from you. I recall our interview with you back in 2015 about the Schilling UHD ROV. Since then a lot has happened, including the downturn in the oil and gas industry and now the pandemic. Everybody is trying to adapt, but I've heard rumours that you've been working on something new that could be a game changer for the ROV and Subsea industries. Can you please tell us more?

TYLER SCHILLING: Certainly! Continuing what's really been a 35-year trajectory of looking for ways to transform customer productivity offshore, our most recent items have been the HD and the UHD ROV. Our latest breakthrough that's based on those prior developments is GEMINI.
It's called GEMINI because it has two identical robot arms on the front. In fact, in the developmental prototypes, one arm is named Castor and the other is named Pollux: the names of the Gemini twins. This is a very ambitious leap, and it involves a number of really important technologies, all of which are focused on allowing the work system to be on task at the worksite all the time. Furthermore, it makes successful operation of the machine and completion of these crucial tasks far easier than it's ever been.
The key technologies that we've adopted are, first of all, automatic tool exchange; the GEMINI system carries 30 different tools that can be exchanged automatically on either of the robot arms. Typically, it takes less than two minutes to swap out any tool on either arm, and this allows the machine to stay at the worksite (its objective is 30 days) and not have to make endless roundtrips to the surface. It's like if you were doing a home improvement project and the DIY store was 8 hours away, and every time you needed a new tool you had to make that trip. Clearly a push button exchange of the 30 tools is a really important transformation for the industry. In fact, after less than a week on its first job, the value of this was demonstrated to the customer.
The second really important technology we developed is force compliance in our robot arms. This mitigates all of the unintended forces when the tool comes into contact with



Courtesy of TechnipFMC

Courtesy of TechnipFMC

subsea equipment. For example, using a hotstab. When you insert a hotstab into the receptacle, the only force the user intends to apply is along the axis to make it go into the receptacle. All the other forces cause binding and potential damage. What force compliance does is detect any of those forces between the tool and the work piece and automatically moves the manipulator arm to drive those forces to zero. It's a very interesting thing to watch when you put the hotstab tip into the receptacle and you push on it and all of a sudden it aligns itself perfectly.

RE: I guess it would greatly reduce the time of a manipulation task compared to what is currently normal.

TS: Oh yeah. It dramatically reduces the time. If we stay with the example of a hotstab, the worst loss of time is if you damage a seal or something and you have to recover. The execution time for that task stretches to a very long extent. The third fundamental technology we call Visual Station Keep. This is one where we are using machine vision installed on the robot arms and the ROV itself. Visual Station Keep precisely locates and provides position control to both the ROV and the robot arms relative to whatever you're working on. This is the first system we have designed where the control of the ROV and the control of the robot arms are completely coordinated. I like to think of it as though you are only flying the tool, and the control system takes care of which part of the system should actually be used. At the end of the day, the ROV and the manipulator are just there so you can use the tool; it's the tool that is doing all the work.

RE: That's true! How do you actually achieve that? How does the machine vision system know the exact position of the arms? Are there some sort of markers, or is there some other kind of technology being used?

TS: So, this type of machine vision creates a continuously updated model of the objects that it's seeing in the environment. Simply by detecting features that are already there on the equipment edges and holes, changes in colour, etc, it's improving and updating the 3D model instantly. It happens in the background and isn't something that the user has to concern themselves with.
It's very similar to technologies that are used by Tesla, for self-driving. Unfortunately, we have the added complexity of being underwater. When we began the project, we didn't appreciate to what extent that makes the problem different. It's dramatically different as it turns out.

API53 Hi Flow Hot Stab

Dredge Tool

5" Brush Tool

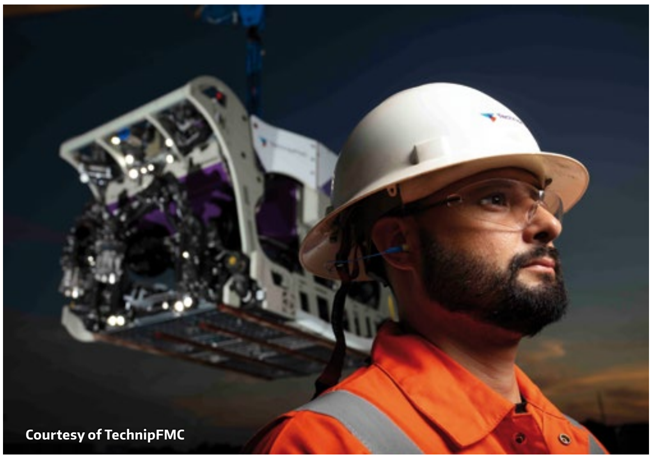
5" Gasket Tool

18 ¾" Hub Cleaner

18 ¾" Gasket Tool

3 Finger Jaws

Mega Jaws



Courtesy of TechnipFMC

RE: Do you have to calibrate before each dive? Or does that happen automatically?

TS: There are calibration activities you have to do when you change out pieces of hardware, but after that's done the operator doesn't have to recalibrate.

The fourth crucial capability that the machine has is one that is largely included in the UHD: a very high capacity for fluid intervention. This starts with a super capable and highly flexible pump we developed for the UHD. That's the same element. What's new with GEMINI is that we carry a hundred gallons of various types of fluid on board for fluid intervention, so we don't have to return to the surface. That capability – the combination of the pump and the fluid capacity – means that integrated into GEMINI is the ability to comply with API53 (the requirement to close and sheer the BOP in 45 seconds). That's inherent in the machine, without the need for additional skids. If you add all these together you end up with a machine that can do dives a month long. Not that you need to dive for a month, but there are really important times, like the spuddin of a well, when the machine would otherwise have to make many return trips, while the rig is waiting for the ROV. You put all of that stuff together and we are completely confident that this would end up being the largest leap in offshore productivity that the ROV industry has ever seen.

RE: I take it TechnipFMC have given some input to this development, right?

TS: Oh yeah. After becoming a part of TechnipFMC: the combination of their long-term vision, desire in the subsea robotics space, and their capabilities are what have allowed us to create such a gigantic leap forward. They've been central to the project's development. Driving down the cost of subsea development and its ongoing lifecycle cost is a fundamental principle that TechnipFMC has been investing in for years.

RE: I guess this is also a different business model than in the future because you are not just selling an ROV but a whole subsea lifecycle solution, and optimisation for an EPCI contract.

TS: When you have the capability like the tool exchange, visualisation, and the station keeping, it also unleashes the subsea equipment designers to come up with much more economical solutions. You can now make things unconstrained from the limited capabilities of the typical ROV.

RE: In the past, operations heavily relied on the operators. It sounds like this will change significantly, with the technology itself "doing the work".

TS: Yes, we really see it as a supervisory control transformation, one that I call the intent-based interface. We want to navigate to a model where the user supplies the intent, and the machine does the work. We are halfway there with GEMINI. You can think of it as a shared control function, where the human operator is supplying the very difficult cognitive functions, and then the machine is doing the other elements that humans find generally difficult; each party is supplying what they are best suited for.

RE: So, what would a typical operation look like with the new machine vision and force compliance?

TS: It's very similar to what an operation currently looks like, except all of the wasted time is taken out of the equation. So imagine if you have the best ROV piloting crew on the job and all of the activities go as seamlessly and swiftly as possible; you never have to bring the machine back to the surface, or bring the machine back for tools. That unproductive time is eliminated. The very best ROV crews in the world can execute things in a manner that's very similar to an average or typical ROV operator running the GEMINI. Unfortunately, they are like the top 3% of the workforce. This enables the other 97% to perform like the very best operators, while eliminating the need to recover to deck.

C 3-4 Torque Tool

2" Softline Cutter

1.5" Hardline Cutter

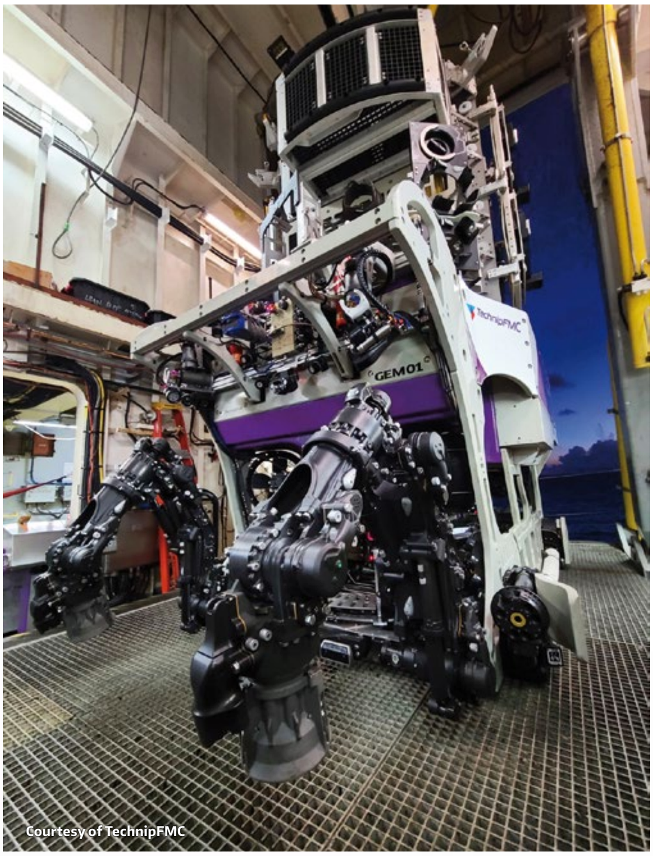
3" Hardline Cutter

Grinder

4 Finger Jaw

PH Meter

C 1-2 Torque Tool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Courtesy of TechnipFMC

RE: Are you able to tell us more about the manipulators? You said that they are identical, and as I saw in the video you don't have to grab onto the ROV panel on the Xmas tree anymore; the ROV can actually hover and station. What are the changes there? How can the ROV achieve the station keeping and exact location in reference to the panel?

TS: First the Visual Station Keeping. The station keeping that is currently on the UHDs/HDs, uses inertial sensors and a DVL in order to make the ROV remain motionless in world space. Most subsea equipment of course when on the seafloor is also motionless. So, you stay motionless relative to the thing you're working on.
Visual Station Keeping does it by making this 3D model of the area itself and then the machine only moves relative to this model based on the commands that the user puts in. This has the added advantage of not only being extremely precise, but it also works when the equipment is not on the seafloor. It can be dangling from a crane wire and actually in motion and the ROV will lock on to the object, which the other version of station keeping can't do because its reference is to the seafloor.

RE: If it moves downward with a constant velocity would it lock onto that as well?

TS: Yes, that's right: within the velocity limits of the ROV itself. It will track whatever it is and whatever direction that object moves in. The services that have to be routed through the manipulator arm in order to run all these tools are one of the principal changes in the machine. To be able to switch between all of these tools we have multiple fluid connections and they are all routed through the joints in the robot arm, so that you can use typical hydraulic fluid operating tools: torque wrenches, cutters, grinders, all of that stuff. But we also route intervention fluid through the manipulator arm for doing hot stabs, etc.
Additionally, in order to operate tools that require electrical power, we route the power through the arm and then


Dual Port Hot Stab


4.5K Seal Test Stab


15K Seal Test Stab

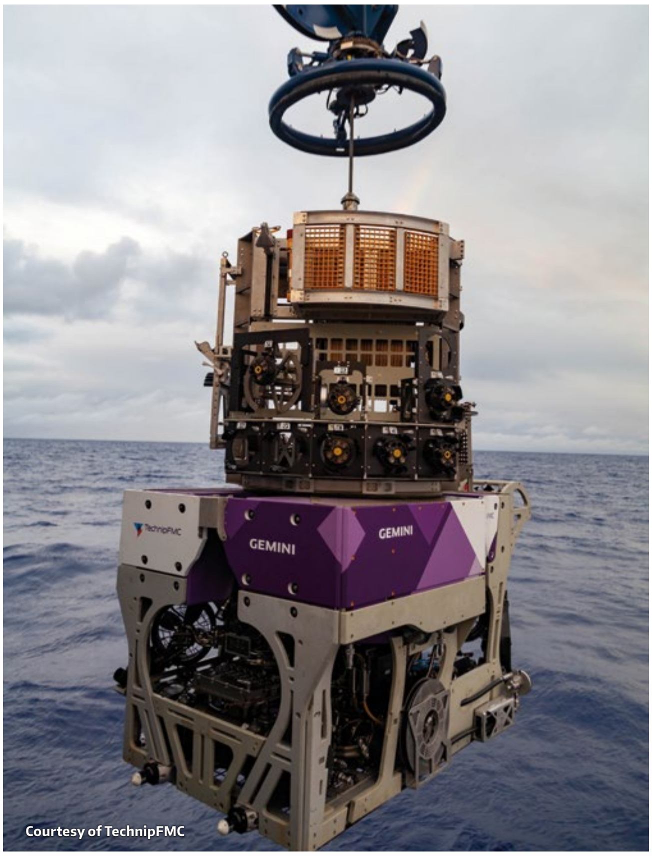

Suction Stab


Parallel Jaws


Hi-PSI Water Jet


Valve Tool


Hot Stab – Dual Port 1



Courtesy of TechnipFMC

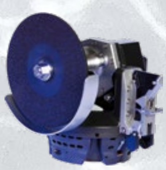
Courtesy of TechnipFMC

couple inductively at the tip of the manipulator to run tools. The last service is an optical link that's bidirectional to send data back and forth between the robot arm and tool to either send commands or retrieve data.

Another crucial improvement came about a number of years ago beginning with the HD ROV design. We started a design philosophy that we call 60 minutes service and repair. The objective of the design is that any replacement or repair can occur in 60 minutes or less. It transforms the way you think about design. It was enforced in every aspect of GEMINI, but most importantly in these robot arms.

One of my favourite examples is the control hardware that moves particular joints. Let's use the the elbow for example (although ea. of the joints are treated identically). All of the control hardware pieces for the joint, which include a servo valve, a position sensor and control electronics are all housed in an integrated module. All you need to service any of these modules is a 17mm socket. If you ran into a situation where you suspected that there was a problem with the elbow's function, you just have to remove a couple of bolts using a 17mm socket, and bolt on a replacement module. In all prior designs in that example, there are 3 different items, each of which could be causing whatever the issue is that you're seeing. That means diagnosis requires some expertise. Now they're all in one single module. Of course, this is extremely difficult from an engineering perspective, but we are all focused on making problem solving easier and faster for the user.


Gasket Tool 18 3-4 Inch 2


Grinder

RE: Many of the other ROV manufacturers focus on residency. You probably heard about the Equinor contract that Oceaneering, IKM, and Saipem have been working with. Some operators and people think that residency is the future and should be their main focus. I am curious to hear your opinion.

TS: I think residency has been defined too narrowly, which isn't uncommon when technological change is occurring. At the moment what I would say is that being on the bottom for 30 days is itself an important form of residency. The duration certainly qualifies it, but you still have to have a surface vessel for running the machine. So, you get some of the benefits of residency, but not all of them. I think that we are a little too early in terms of both scope and fundamental reliability for the objectives of residency to really bear fruit.

While I think that removing the need to bring a crew and a vessel to the work site is the clear goal in the long-term, what those machines can do in these early stages is extremely limited, and the current reliability of the equipment is going to make the economic benefits very illusive. When one of these machines malfunctions, you're going to be faced with either (a) sending a vessel out or (b) saying oh well we'll just let it sit there. Of course, both of those destroy the benefits of residency, but this is the way capabilities are pushed forward. People have been talking about it for as long as I've been in the industry, and usually if something has that amount of durability it's probably right.

RE: I agree that the scope of work is quite different then as well. It's one thing to be resident, but you also need to be able to perform work with the ROV. How do you see the advancement of ROV/AUV technologies being developed in the next 10 years in relation to digital twins, interaction with the subsea infrastructure, and artificial intelligence? You did mention that residency is the long-term goal, but I thought I would ask what else there that might be a fundamental.

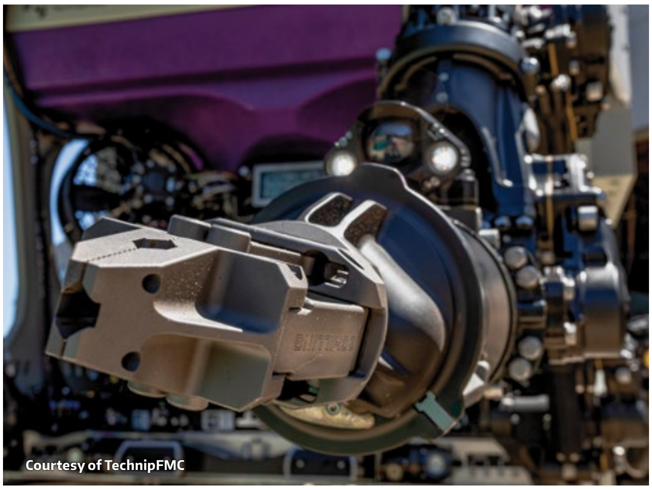
TS: I think that the biggest opportunity in the coming decades – whether it's for energy or other applications – has to do with the design of the machines that are going to be on the seafloor. The things that GEMINI, resident ROVs, or any other AUVs will have to work on has been a progression that has been going on for a long, long time. The first seafloor equipment that was tens of meters deep was all designed to be operated by divers. Then we transitioned to hotstabs and torque tools that made it easier for ROVs to do the work without hand wheels and goofy things like that. That progression needs to accelerate. The machines that sit down there have to reduce the degree of difficulty that AUVs and ROVs have in completing the work.

RE: Absolutely! In the future the valves, Xmas trees, and the subsea infrastructure need to have more intelligence capabilities, and to be able to interact with the ROVs themselves. What do you think about the artificial intelligence of learning patterns and machines making decisions on their own? Do you think that's in the future as well?

TS: I do. And just like our use of machine vision with Visual Station Keeping, the building blocks – software modules, or hardware elements – that are necessary to apply them to subsea use were actually developed for other industries and we would repurpose them. The reason for that is that they are extremely expensive and involve developments. For instance, GEMINI's machine vision uses the very same vision processing hardware that Tesla used in their earlier models. We could never have afforded to develop a piece of hardware like that. So yeah, AI would be as useful in the subsea industry as it's showing itself to be in others. In abstract or fundamental levels, the problems are all the same.

RE: It makes sense that other industries have more software development capabilities that can be adapted to replicate the same solution underwater. I guess at Schilling Robotics, based in Davis, California – in the heart of Silicon Valley – you must have taken a lot of software solutions and technologies from the local talent pool.

TS: That's right. And what we tried to do is only focus our development stuff on pieces of the puzzle that can't be procured elsewhere, simply because there is so much to do and all of it is very expensive. You want to procure as much of the solution as possible and do as little as practical, but never shy away from doing what absolutely must be done regardless of how difficult it is.



Courtesy of TechnipFMC

Courtesy of TechnipFMC

RE: You have actually done a tremendous amount of innovation in the last 35 years. So, what is going to be the next thing for you then? Are you fully retired or are you going to come back in the future? You might come up with a problem again that no one has thought about and it could become a big hit!

TS: It's possible but I would say unlikely. You know the reason that Schilling Robotics has been successful for three and a half decades is dependent on having the right people on staff. People attribute a lot of the innovations to me, but they aren't correct. What I really focused on throughout my career is making sure that I supplied what I thought was the right outcome that we wanted to achieve, and then to make sure that the people have the resources necessary to achieve it. And to keep doing that over and over again; that's really how we've been successful. Luckily, I've picked the right objectives, or approximately right objectives, and I was able to supply the resources, and to hire really capable and engaged people.

RE: Sounds like you've just told me the secret recipe for the Schilling success! Thank you very much for your time Tyler, I really appreciate it. It's been a pleasure talking to you again.

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IECEx & ATEX

SCALABLE AHC

REMOTE ACCESS

FULL REDUNDANCY

CONSTANT TENSION

SUPERVISED AUTONOMY

ROV/TMS MAINTENANCE ACCESSORIES

BLUE LOGIC WINS ONS INNOVATION AWARD

FOR SUBSEA DOCKING STATION

Blue Logic has been awarded the Innovation Award 2020 from ONS, in the SME category, for its development of an open-standard subsea docking station for underwater vehicles. The ONS Innovation Awards recognise the crucial importance of cutting-edge technologies and solutions. This year's awards were announced on September 1, during ONS 2020 Digital, this year's variant of ONS.

Open-standard subsea docking station (Courtesy of Blue Logic)

Blue Logic's seabed installed docking station enables underwater vehicles or drones to be permanently deployed subsea by providing access to power for charging and communications for upload/download of inspection and assignment data. The ability to long-term or permanently deploy underwater drones is seen as a benefit for several underwater applications, enabling a reduction in risk to personnel, who can operate the vehicles from shore, a reduction in the carbon footprint of subsea operations, that no longer necessarily require a support vessel on site.

A key component of the subsea docking station is Blue Logic's wireless connectors, which provide power and data transmission underwater. Development of the docking station also involved Blue Logic undertaking a significant amount of industry collaboration, with many companies and organisations contributing and participating towards the docking station's requirements and specifications in order to achieve a truly universal result.

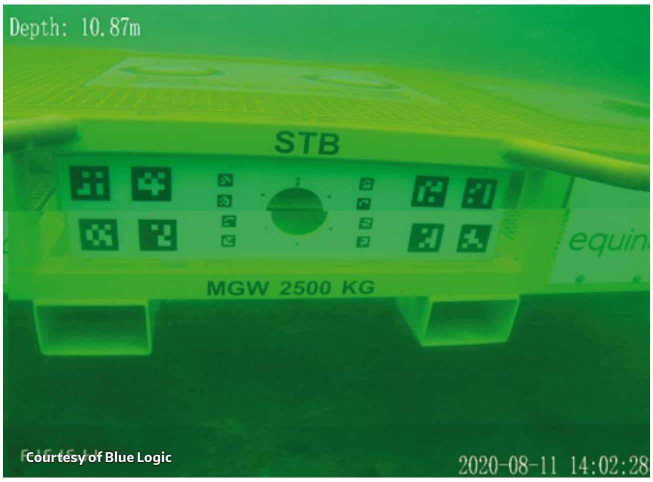
Stig Magnar Lura, General Manager at Blue Logic, states: "Equinor has been with us at the front throughout this process. Together, we have jointly developed specifications and requirements. By working together in this completely new way, where the focus has been on developing open solutions with a common interface, we believe we have succeeded in a universal solution which all subsea vehicles will be able to utilise."

Wireless Power and Communications (WPC) is behind the technology and solutions used in the inductive connectors and is also central in the work of creating a universal standard for the international market.

Founder of WPC, Geir Olav Gyland, says: "It's great to experience this recognition together with Blue Logic".

(L-R): Tina Bru, Minister of Petroleum and Energy, Helge Sverre Eide, Business Manager, and Stig Magnar Lura, Managing Director (Courtesy of Blue Logic)

Cheering employees at Blue Logic (Courtesy of Blue Logic)



Courtesy of Blue Logic

Courtesy of Blue Logic

Helge Sverre Eide, Head of Business Development at Blue Logic, adds: "Equinor used its entire internal network of expertise and all its relevant subcontractors to contribute to this development. As a result, we have in a very short time developed solutions that have been tested and refined at an unprecedented speed. We have also worked closely with the drone suppliers – Eelume, SAAB, Oceaneering and Saipem – and held several full-day workshops in order to refine this solution to ensure its functional for the various players."

As a committee member of the American Petroleum Institute (API), Blue Logic has also worked toward API 17H and with the DeepStar programme in the United States to ensure that its open innovation falls within recognized industry standards.

Designed and built close to Blue Logic's headquarters in Sandnes near Stavanger, multiple docking stations have already been tested, including at the Norwegian University of Science and Technology (NTNU) underwater test facility in Trondheimsfjorden, near Trondheim, as well as by SAAB in Sweden, Oceaneering at the Tau Autonomy Center near Stavanger. One is also due to go to Italy where Saipem will verify its functionality with its underwater vehicles.

"This work has been important in maturing drone technology in such a way that it is widely accepted throughout the industry," adds Eide. "In order to develop a market, we as an industry depend on a broad support where several oil companies use this technology. This is probably the biggest challenge in introducing new technology into a new market, a process that has taken 15 years."

The first underwater inductive product was introduced in 2005. Blue Logic has since developed several more products that can use and support the docking station, including inductive torque tools for valves, inductive fibre optic cable couplers, inductive couplers for drone tools and inductive subsea batteries.

"We have seen this potential at Blue Logic for some years now," adds Eide. "It feels like the rest of the world is now starting to open its eyes to its potential."

Courtesy of Blue Logic

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GREEN TECHNOLOGY FOR THE BLUE ECONOMY

Triumph Subsea Services (Triumph) is a technology company managed and operated by a team of world class subsea professionals, engineers, scientists, environmentalists, and oceanographers that specialize in Blue Economy operations. Their directors and management are passionate about the environment and the urgent requirement to combat climate change. To achieve these climate change goals and to reduce greenhouse gases they have designed and are building vessels that have pushed the envelope of technology with unrivalled innovations and industry firsts. They have incorporated all of the latest currently available advanced technology, robotics, safety systems and autonomous systems within their vessels and are at the forefront of future proof, environmentally friendly and Net Zero capabilities. The International Maritime Organization (IMO) is implementing numerous changes within the marine industry in regard to vessel emissions controls, pollution controls, and ballast water management systems. These new IMO rules in conjunction with the rapidly increasing technology in vessels engines and hybrid energy storage systems are rendering many existing vessels obsolete and therefore a new generation of vessels such as Triumph's are required to meet these growing demands.

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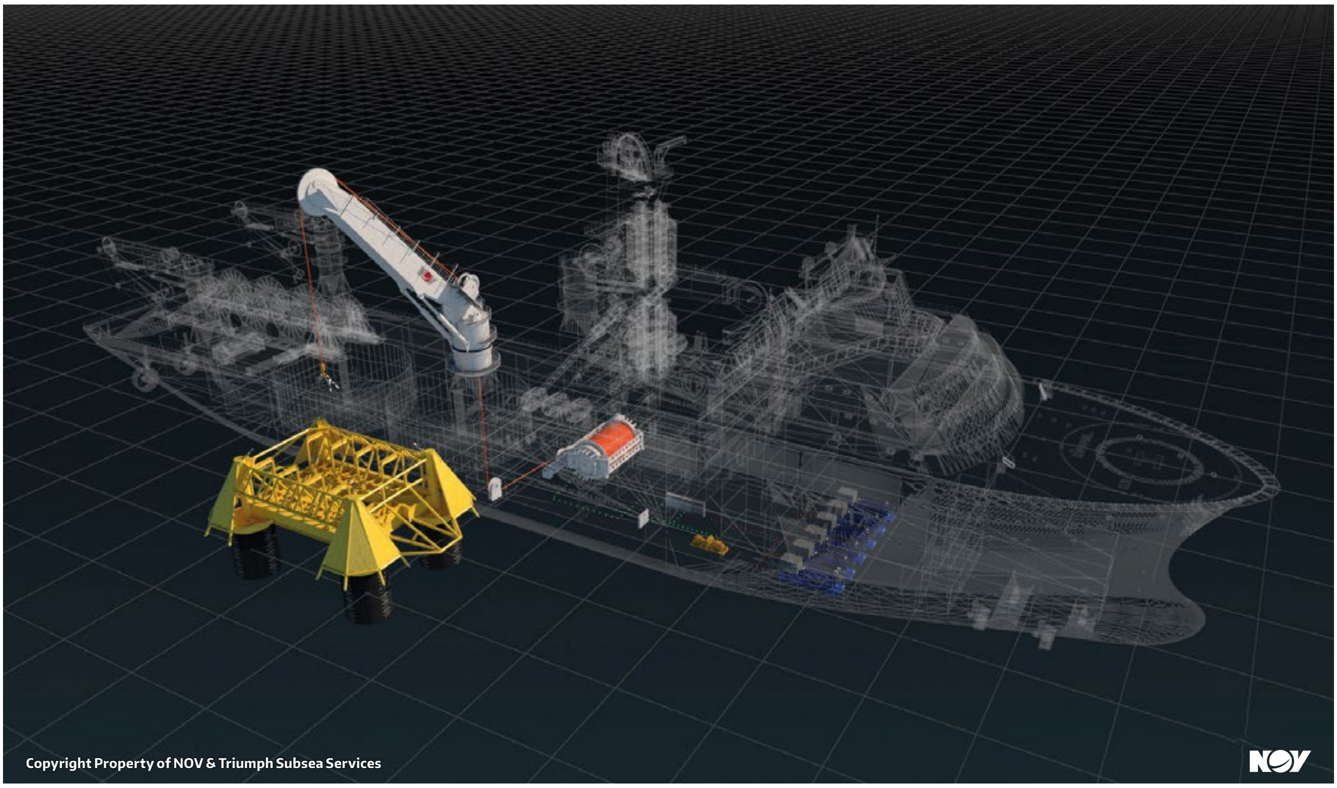
Triumph's vessel fleet meets and exceeds the IMO 2020 regulations and meets the Net Zero carbon emissions goals to combat climate change. As the world rapidly transitions from its reliance on fossil fuels and commences to focus on alternate energy sources such as wind, solar, and green hydrogen there is an ever increasing need to ensure that all operations pertaining to developing these alternate energy sources are based on Net Zero operations such as the Triumph vessels. New advanced technology, robotics, safety systems and autonomous systems are incorporated within the vessels and this places Triumph at the forefront of future proof, environmentally friendly and Net Zero capabilities.



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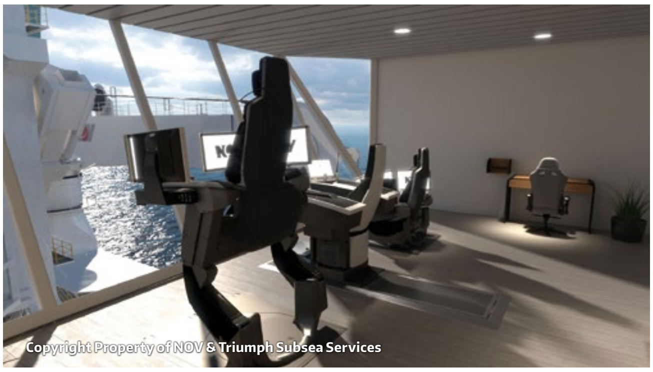

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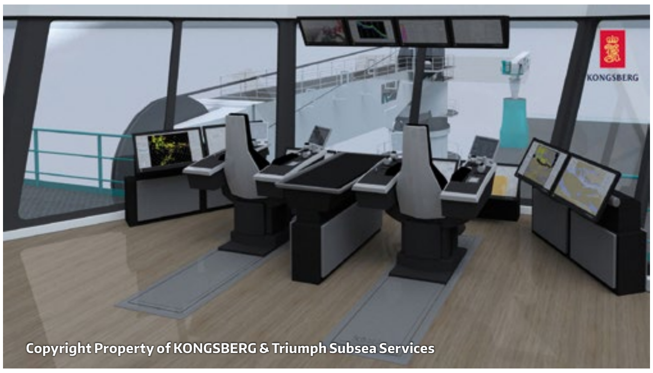

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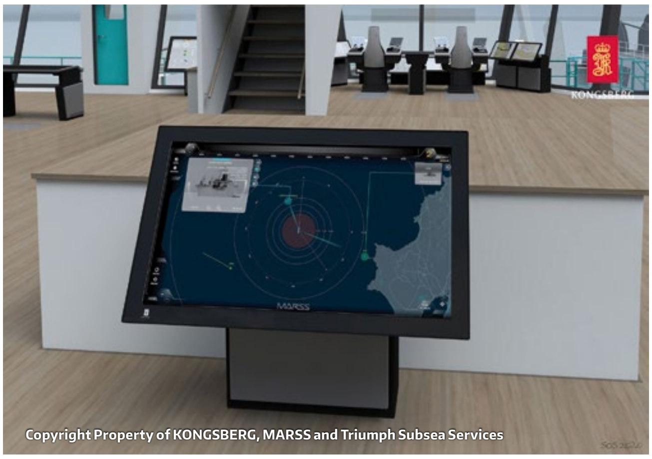
The vessels are autonomous and only reliant on shore-based facilities for fuel, food, and personnel transfers. Advanced reverse osmosis systems, water evaporator systems, wastewater treatment plants and waste disposal systems, all with redundancy, mitigate the requirement for shore-based disposal. All the vessels are diesel electric with hybrid battery systems and advanced energy recovery systems that greatly enhance the fuel consumption figures for the vessels and reduce greenhouse gas emissions.

Triumph's Field Development Vessel (FDV) is designed to be a truly multi-purpose turnkey solution for nearly all subsea construction tasks that can be encountered within the offshore oil & gas, subsea telecoms, decommissioning and renewables markets. Further to the standard equipment fitted to the vessels they are multi role and adaptable wherein modular pipe-lay systems for both shallow and deep water can be installed in either S Lay or J Lay configurations.

The Windfarm Development Vessel (WDV) is the same vessel as the FDV but with minimal changes so that it is more suited to be a turnkey solution for floating windfarm installations. The WDVs can install the anchoring system; suction piles, drag anchors or drilled pin anchors; mooring array installations; execute the hook-up of the floaters; install the export cable and array cables.

Triumph's FDV's and WDV's are fitted with National Oilwell Varco (NOV) equipment, including the revolutionary new RISE™ operator workstations for the vessels AHC cranes and VLS tower fitted with fiber rope winches. The vessels are the first to be designed utilizing NOV's revolutionary new AHC cranes that are fitted with fiber rope winches and controlled via remote operations stations. NOV's remote operations stations combined with the fiber rope capability redefine offshore crane operations and offer numerous advantages over traditional cranes with steel wire. The vessels have three separate operations rooms with two RISE™ operator workstations in each room. The NOV equipment has 'over the horizon' operation capability and can be supported from Triumph's dedicated onshore operations centre.



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The vessels are also equipped with NOV's PowerBlade™ (Kinetic Energy Recovery System) that creates an efficient power grid for the vessels. This system improves the environmental footprint and reduces fuel consumption by capturing and regenerating surplus energy from winches. PowerBlade™ eliminates power peaks, allows load levelling and allows generators to run at optimal loads which eases wear and tear and cuts the risk of a generator trip with a host of benefits that include fuel savings, reduced carbon footprint, less generator maintenance, better performance, and improved operational reliability. PowerBlade™ is one of the advanced technological systems fitted to the Triumph vessels that assists them in achieving their Net Zero goals.

Triumph's vessels are all fitted with Kongsberg equipment and the first within the offshore energy and renewable sectors to be fitted with the Kongsberg Safety Management & Control System. The fully integrated bridge and vessel control systems also interface with the MARSS MOBtronic™ automated man overboard detection / tracking system and NiDAR™ autonomous threat detection, surveillance and anti-piracy countermeasures system for enhanced crew safety.

Another key differentiator with Triumph is that they have partnered with key autonomous robotics companies such as Eelume AS (Eelume) and Houston Mechatronics Inc (HMI). Triumph has partnered with Kongsberg Maritime AS and Eelume AS to further develop the Eelume vehicle and resident garage, currently Eelume is available as a 500msw rated vehicle. The partnership will focus on the completion of the resident garage for 500msw operations and further development of the Eelume vehicles in 1500msw and 4000msw rated versions. The residency garages will also be developed into 1500msw and 4000msw rated versions after the completion of the 500msw rated system. A docking system will also be developed, allowing the Eelume's to be deployed with ROVs and subsea packages.

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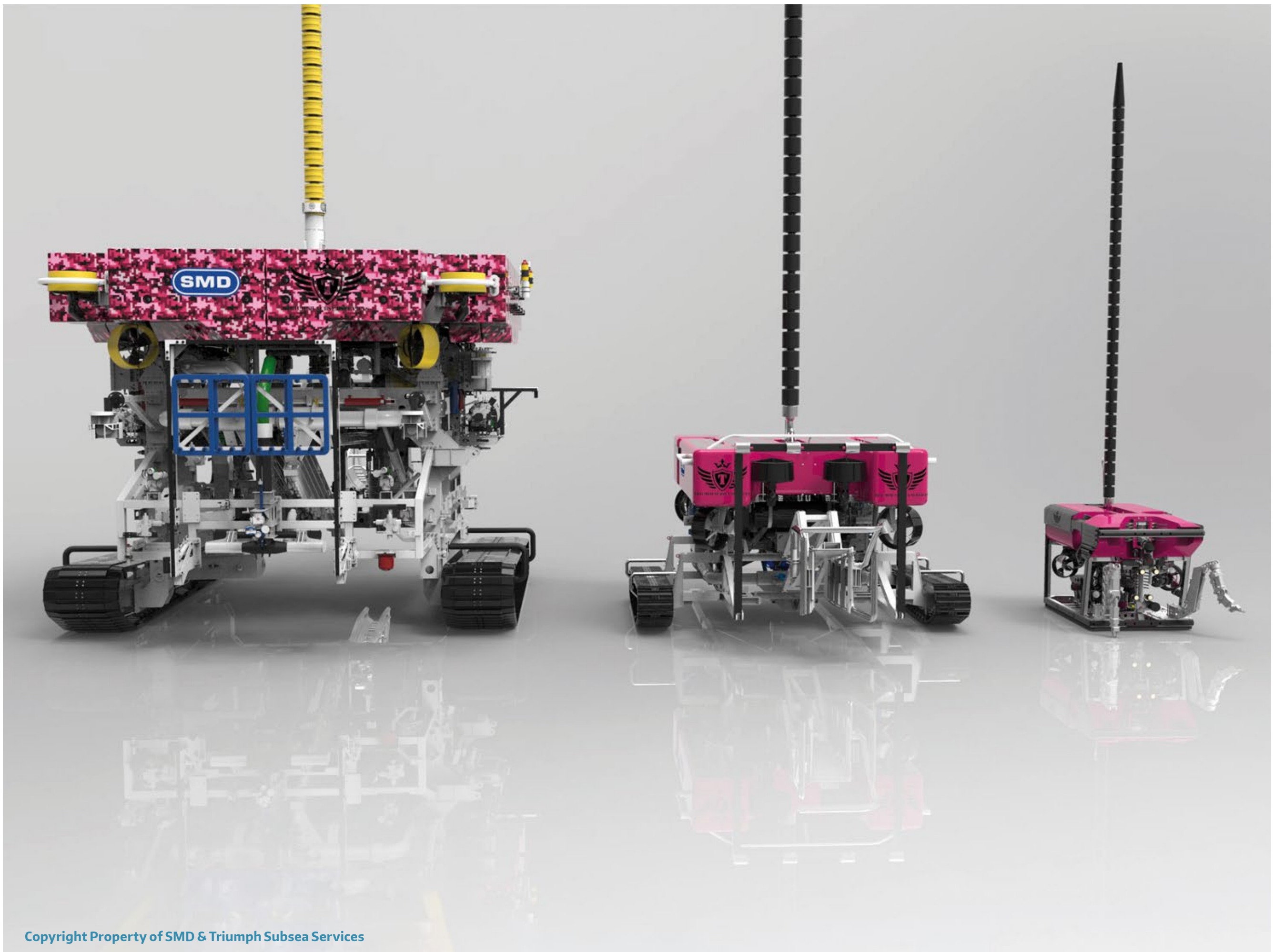
Triumph is acquiring a fleet HMI's all-electric subsea transforming AUV/ROV Aquanaut. HMI's mission services team will be providing supervised autonomy support services for Triumph's Aquanaut fleet. Triumph is also using HMI's all-electric Olympic arms for Triumph's Work Class ROV fleet. This represents the industry's first commercialization of this ground-breaking technology. Olympics' strength, weight and size characteristics as an electric manipulator makes it the first of its kind. Olympic will provide high precision, repeatability & dexterity, zero working fluid, lower overall power consumption, position & force feedback; intelligent path planning; and integrated tool changing HMI's Aquanaut and Olympic Arms represent a truly forward thinking offering to achieve more modern, cost effective, and sustainable subsea operations. This commitment is in line with Triumph's other announcements to bring disruptive technologies to the market and Aquanaut is a key differentiator in Triumph's portfolio which remains unrivalled in sustainability growth programmes.



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Kystdesign AS are supplying Constructor and Supporter WROVS fitted with the HMI Olympic Arms for the FDV and WDV vessels. The custom designed Kystdesign Constructor 220HP WROVs with KD10TMS units rated to 5000msw will be fitted on the FDVs for use in the Oil & Gas sector. Meanwhile the Kystdesign Supporter 150HP WROVs with KD10TMS units will be fitted to the WDVs for floating windfarm installation projects.

SMD are supplying Q500 and Q1600 trenchers for Triumph's WDV fleet along with the all-electric ATOM EV Wind fitted with the HMI Olympic Arms.

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The SMD 1200kW QT1600 is the most powerful and flexible interarray trenching ROV globally, with the ability to jet trench to 3m in 100KPa soil conditions or chain cut 4m MBR cable to 2m in 600KPa soil conditions. The selectable tooling skids allows options for freefly jetting to 2000m or hard ground chain cutting to 1000m, ideal for fixed or floating fields. The compact chain cutter system is highly manoeuvrable with a tight turning circle capability for second ends and also includes SMDs well proven hybrid cutter boom with integral jetting, for operations in soft rock or sands, making it ideal for variable ground. The QT1600 will be fitted with a Lloyds Sea State 5-6 cursor LARS system with a slack and snatch umbilical motion compensator, for rough weather operations which maximises the operational window.

Both the Kystdesign and SMD vehicles are 'over the horizon' operation capable and can be supported from Triumph's dedicated onshore operations centre.

These pink ROVs not only look cool, but the choice of their colour is backed by science. Pink increases their visibility underwater. Or as some might even say that, in the green technology of the blue economy, pink is the new yellow.


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Courtesy of Rovco

SUBSEA SERVICES AND THE RUSH TO RENEWABLES

Moray Melhuish, Commercial Consultant, and former Director of ROV Service Company ROVOP

It was not so long ago that the offshore wind sector was shunned by major subsea service providers. That may now seem like a distant memory, but during buoyant times – when the oil price was high and activity levels were good – the installation of offshore wind turbines was viewed with derision by many.

There were notable exceptions of course. ROV services provider ROVOP focused on offshore wind from the start, using the industry to grow and prove its systems before diversifying into oil and gas. Trenching contractors such as Canyon were kept busy supporting cable installation, and survey outfits such as Fugro deployed their survey expertise, irrespective of the industry.

How things have changed. The 2015-2016 oil price slump forced the hydrocarbon supply chain to look elsewhere for utilisation. This began a trend which gained even more impetus following the 2020 collapse in demand resulting from the COVID-19 pandemic.

DEMAND FOR BETTER RESOURCES

At one point, the subsea industry viewed offshore wind as a "cheap" market, focused on cost alone and therefore perfect to deploy equipment considered too old for oil and gas. The feeling was mutual, with offshore wind players often describing equipment and technology designed for the oil industry as "gold plated": too expensive for the needs of the renewable industries.

Harsh operating conditions and the productivity advantages of superior equipment soon ended that. Work that was originally undertaken by small electric vehicles or long-in-the-tooth work-class ROVs, was soon being completed by 150 or even 250HP ROV systems. Here their superior thrust and station-keeping were used to full effect in the high current, turbid, or shallow water conditions typical of many wind sites. Work scopes such as seabed survey for site investigation, and unexploded ordinance (UXO) detection/remediation, as well as monitoring minimum bend radius during export and inter-array installation, and watching as foundation structures are installed are all common for ROV crews today.

Initially work was attempted with cameras alone, but multibeam sonar soon became expected on every vehicle. For the most sought-after and profitable work – UXO detection and remediation – simultaneous operation of multiple high-spec sonar systems required multiplexers and fibre not available on the older, multimode ROV systems. Deployed in tandem with powerful dredge systems, these systems enabled pilots and UXO specialists to excavate the seabed and see objects in conditions where visibility was measured in the low centimetres or often zero.

LEARNING DIFFICULT LESSONS

Once clients had experienced the improvement in productivity of a modern work class vehicle and competent crew, there was no going back. The offshore wind market began to drive demand for the best ROV, sonar and dredge packages, with equipment impossible to find on the rental market during the peak summer season.

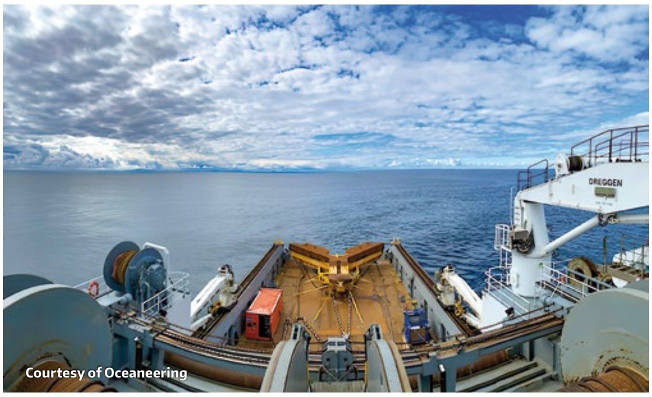
Many shallow water operating lessons were learned along the way, and some operators have experienced the pain and dented pride of an ROV, or its umbilical being destroyed by a vessel thruster during DP operations. Personnel skilled at operations in these difficult conditions were at a premium – as good ROV crew always are. While no team could be made up 100% of personnel with shallow water experience, this was soon factored into personnel selection as much as electric, hydraulic, and piloting experience had always been.

Operating in close proximity to vessel thrusters wasn't the only challenge which personnel coming from an oil and gas background had to face. Offshore crew with oil and gas accreditations found that they were suddenly being asked to undertake the Global Wind Offshore (GWO) training. At a cost of around £7,000 and taking one week for each trainee to complete, this duplicated many elements of offshore oil and gas training (not least offshore medical and working at heights). The irony for offshore wind – with its drive to reduce costs in constant pursuit of the reduction in the Levelized Cost of Energy (LCOE) – was that the unnecessary cost to duplicate these qualifications was always passed on to the client one way or another.

CHANGING STRATEGIES

Perhaps the most refreshing feature of this young, growing market in the early days was that procurement decisions were made quickly by project managers who wanted action, results, and on-time completion. Contrary to the reputation of the industry at the time, decisions were based on relationships and past performance alone. Contractually, the simple IMCA-based contracts of the ROV service providers were embraced and adopted. This was despite the contractors often being subject to significant punitive damages in the event of their project not being delivered on time.

For many this was a time of adjustment. The big customers for the ROV services providers were not end users or construction companies with their headquarters in Aberdeen, Houston, or Paris. Businesses such as Van Oord, DEME, Jan De Nul, and Boskalis – with their shallow water dredging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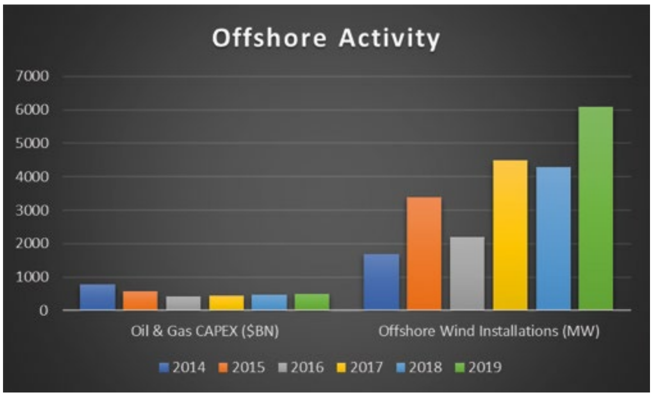

heritage – were increasingly delivering these offshore wind farms and using more specialised vessels to do so.

As the market matured it followed the same path that oil and gas had years before, with decisions on subsea technology and services increasingly made by procurement professionals determined to treat these services as a commodity. Each time the oil price tumbled, and more Work Class ROVs were released from their deep-water subsea contracts, the cost reduction job became easier. Desperate for revenues and determined to make up for their slow start in offshore wind, the largest ROV and technology providers were quick to target work in renewables. At one point this resulted in a drastic and considerable fall in in the day rate of the typical ROV spread.

GROWTH COMPARISON

The sustained fall in offshore oil and gas activity experienced in recent years could not be more different than the sustained and accelerating growth experienced by the offshore wind industry.

The following chart compares upstream oil and gas capex (in $Bn, according to the IEA), with offshore wind activity (measured in MW, according to the Global Wind Energy Council). Although analysts Rystad expect Capex in offshore wind to exceed that of upstream oil and gas in Europe by 2021, a straight dollar-for-dollar comparison is a difficult one due to the massive cost reduction achieved by offshore wind.


Courtesy of ROVOP

Even though some will see this as comparing apples and oranges, it does enable a comparison of the trend in each industry, and shows a 36% fall in oil and gas compared with a 358% increase in offshore wind activity between 2014 and 2019.

The reality today is that most subsea contractors have truly embraced the offshore wind market. Personnel are now more likely to find themselves installing cables in 30m waters in offshore France or Taiwan, than they are to be installing risers 3,000m deep off West Africa or Brazil. But involvement goes beyond contractors and personnel.

THE PUSH FOR NET ZERO

European oil and gas operators are increasingly investing in offshore wind as part of their drive to "net zero" carbon emissions. BP, Shell, Total, Equinor, and others have all pledged to achieve carbon neutrality. The oil and gas industry bodies who support these companies are also targeting a slice of the offshore wind pie.

The OPITO (Offshore Petroleum Industry Training Organisation) now markets itself as "the global skills organisation for the energy industry" and has launched a new training standard aimed at those planning to work in the offshore wind industry. Its aim is to reduce duplication of training, recognising previous offshore oil and gas training as relevant to offshore wind.

Likewise the OGTC (Oil and Gas Technology Centre) has recognised the importance of renewables in decarbonising oil and gas; parts of its interesting "Closing the Gap, Technology for a Net Zero North Sea" report of September 2020 read like a brochure for the offshore wind industry.

The recent alignment of these industries may have come about because of a survival instinct among oil and gas operators, the supply chain, and public bodies, but it is to be welcomed. The influx of capital, personnel, technology, equipment, and expertise will all be beneficial for the offshore wind industry as it strives to reduce the cost of offshore wind and continues on its global growth trajectory.


30
YEARS OF ENGINEERING EXCELLENCE
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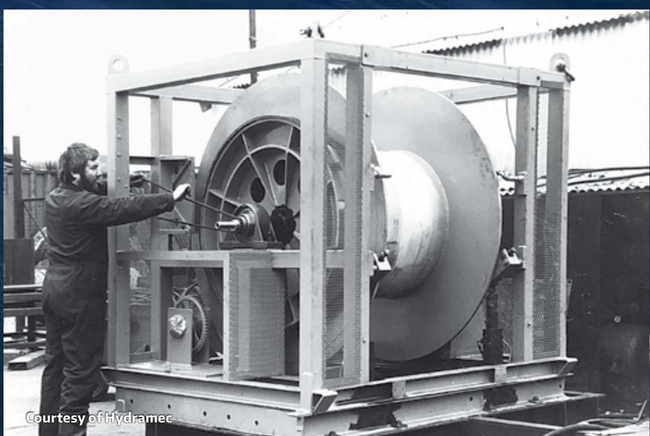
HYDRAMEC CELEBRATING 30 YEARS

Working in the industry for over thirty years, Hydramec have gained a wealth of experience designing and building Launch and Recovery Systems (LARS) and specialising in bespoke marine handling systems.

COMPANY HISTORY

Founded in 1990 by Peter Church, Hydramec started out repairing ships deck equipment and various hydraulic repairs for local clients in the Great Yarmouth area. Peter had been involved with the subsea industry from the late 70's, where he had worked for many years for OSEL, based in Great Yarmouth.

In 1996 Peter was approached by an old client from his OSEL days to design and build the first Hydramec LARS from scratch. This was a crane-based launch and recovery system: the RTL001. As a matter of fact, RTL001 is still up and running to this day, operating in great condition. As observation sized ROV's started to grow so did the requirements for safe launch and recovery, leading Hydramec to design and build its first A-frame based LARS in 1999. Since then, we have continued to use this as the basis for all our standard LARS' and to adapt and advance others, including Active Heave Compensation (AHC), constant tension systems, electric drive winches, and bespoke control systems.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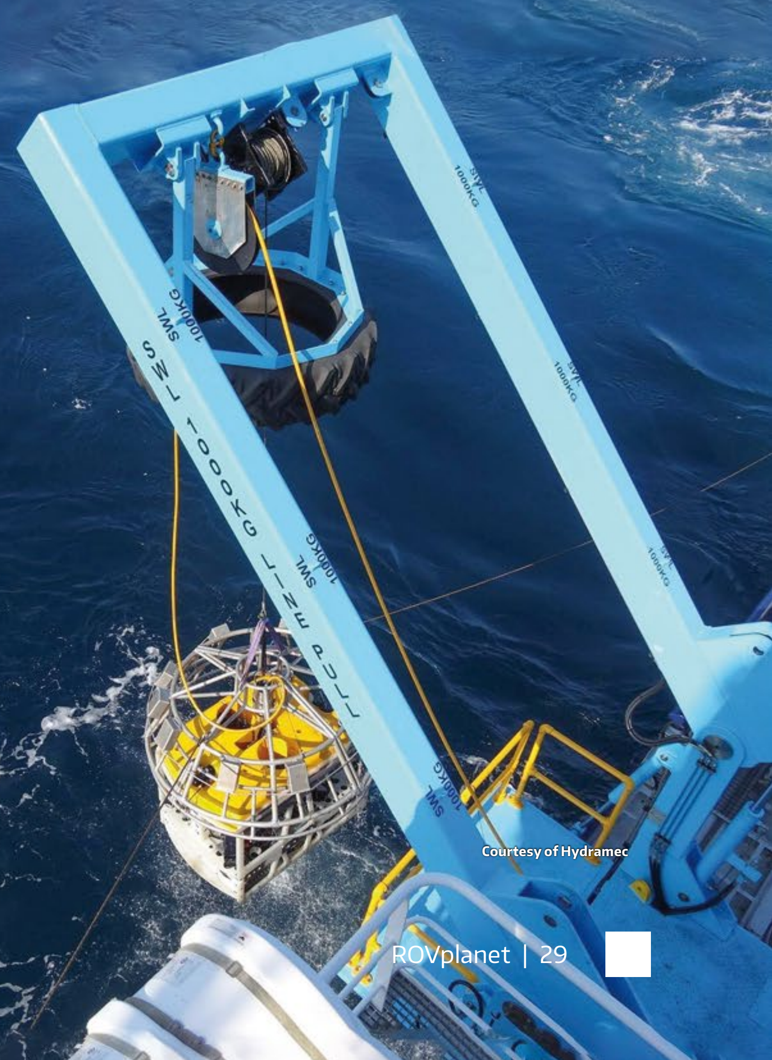


Courtesy of Hydramec

Courtesy of Hydramec

Courtesy of Hydramec

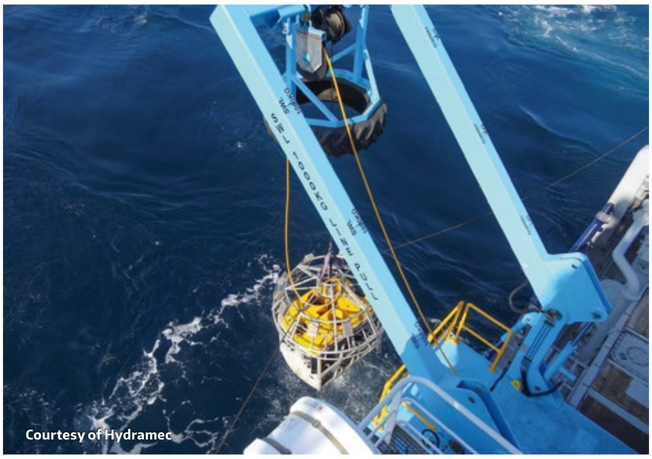
Having been in the firm since 1992, starting as an engineering apprentice, the business was taken over by Danny Church in 2013. Following this, Hydramec has continued expanding to become industry leaders in launch and recovery systems. We currently have 200 LARS'- A-Frame, winch, crane and bespoke systems operating around the world.

We continue to innovate and develop our systems suited for customer needs and are well-known for creating bespoke designs for our clients. In 2007 Hydramec built a bespoke design dipping A-frame allowing for a smaller air gap between the ROV and water interface during launch and recovery. This aids with recovery time and lowers risk to the ROV due to a shorter transit from the surface interface to the snubber and latch system.

The company has not only expanded in size over the years, but also our range of services. We are now able to offer full coded fabrication, offshore coatings, marine engineering, repair, and many other services all in-house. This allows us to have an even faster turnaround and expand the products we're able to deliver to customers.

EXPANDING MARKETS

Over the past few years, we have been working towards expanding the business into other areas of the industry, including Military Defence. 2019 saw us design, build, and integrate an electric AHC LARS supplied to the Royal New Zealand Navy.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The brief was very specific and required the winch system to be electrically driven and have AHC capabilities for operations up to sea state six. As well as this, the A-Frame was designed so it would dip 1.2m below the deck level of the launch hanger and needed to have an outreach of 5m from the vessel side. This was a great project for us to receive and allowed us to enter the Military Defence market.

With the wind and renewables sector now a huge global market, Hydramec have also been keen to move into this industry. An exciting project we were able to carry out was to design a subsea winch for pulling tidal turbines into position on the client's foundations. As well as this, Hydramec have already built multiple launch and recovery systems for the sector and are moving forward to design and build bespoke systems within this industry. We are excited for what's to come in the market.

In addition to this, Hydramec have also been working on remote and autonomous operation of its LARS and winches, realising that this is the rapidly growing future of the offshore energy sector. Having already been approached to design and build specific light-weight LARS that can be operated from the shore, we intended to use this as a springboard to ever advance the control of our systems.

MOVING FORWARD

These past thirty years has allowed Hydramec to grow organically and to make greater connections within the industry. We will continue to progress our knowledge and overall development to give clients the most cost-efficient and environmentally friendly products available. This means that Hydramec's LARS systems can be tailored to suit clients' ever-changing vessel requirements.

Looking to the future, Hydramec are hoping to launch our first full autonomous LARS, using learning protocols within the control system. This will assist onshore operators by monitoring wave and weather patterns to help forecast the best time to launch and recover. The end goal is to fully operate LARS through a simple push of a button, using cameras, step-by-step operation checks, and weather monitoring via the computer control system. This would mean greater safety for the personnel, and cost reductions for our clients.

Here's to the next thirty years!


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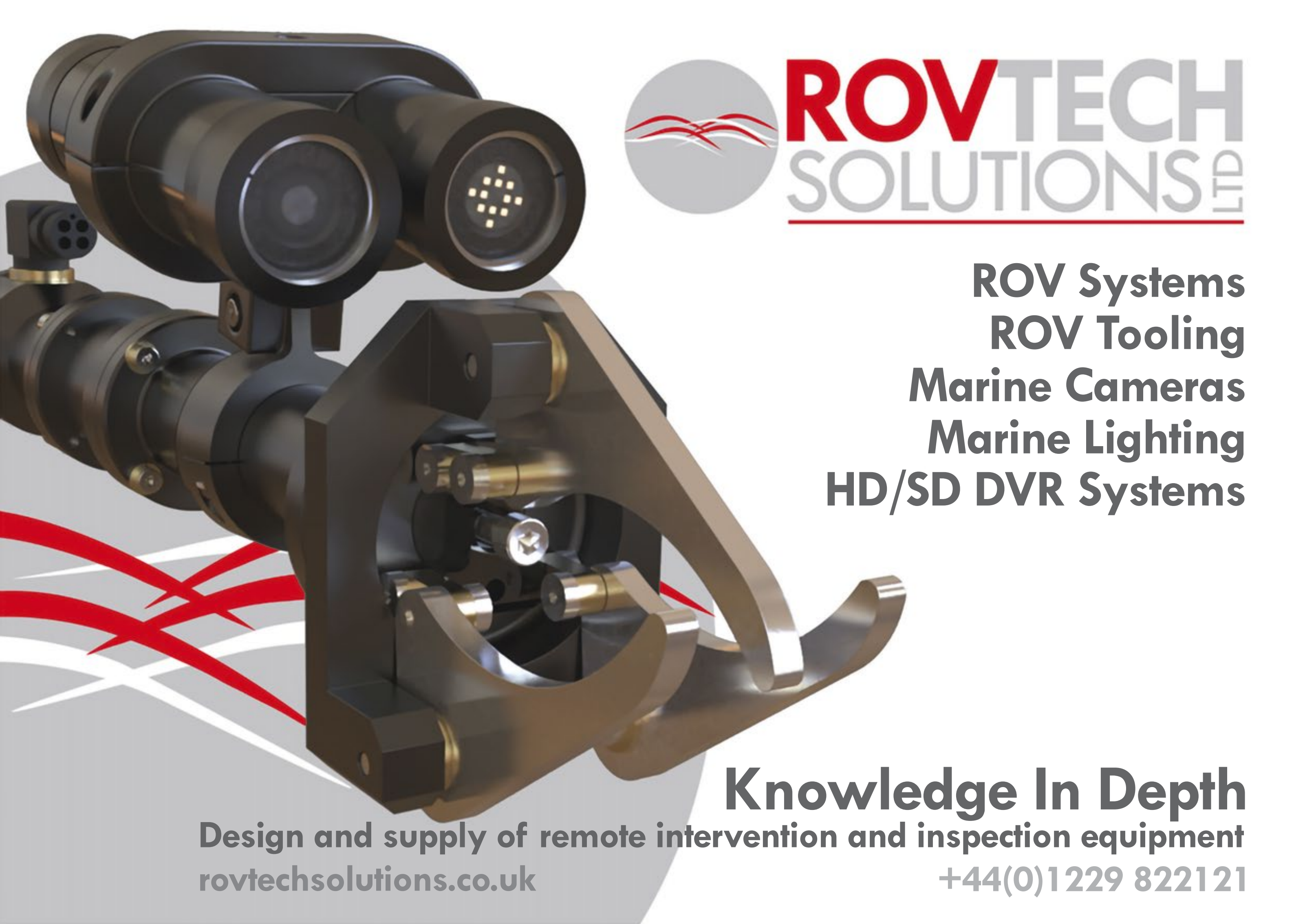
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MICROSOFT FINDS UNDERWATER DATACENTERS ARE RELIABLE, PRACTICAL AND USE ENERGY SUSTAINABLY

Earlier this summer, marine specialists reeled up a shipping-container-size datacenter coated in algae, barnacles and sea anemones from the seafloor off Scotland's Orkney Islands. The retrieval launched the final phase of a years-long effort that proved the concept of underwater datacenters is feasible, as well as logistically, environmentally and economically practical.

John Roach, Microsoft

Microsoft's Project Natick team retrieved the Northern Isles underwater datacenter from the seafloor off Scotland's Orkney Islands and towed it to a dock in the seaside town of Stromness. Team members power washed off a coat of algae, barnacles and sea anemones that grew on the datacenter during its two-year deployment. Afterwards, the datacenter was transported to the Scotland mainland. Photo by Simon Douglas.

Microsoft's Project Natick team deployed the Northern Isles datacenter 117 feet deep to the seafloor in spring 2018. For the next two years, team members tested and monitored the performance and reliability of the datacenter's servers.

The team hypothesized that a sealed container on the ocean floor could provide ways to improve the overall reliability of datacenters. On land, corrosion from oxygen and humidity, temperature fluctuations and bumps and jostles from people who replace broken components are all variables that can contribute to equipment failure. The Northern Isles deployment confirmed their hypothesis, which could have implications for datacenters on land.

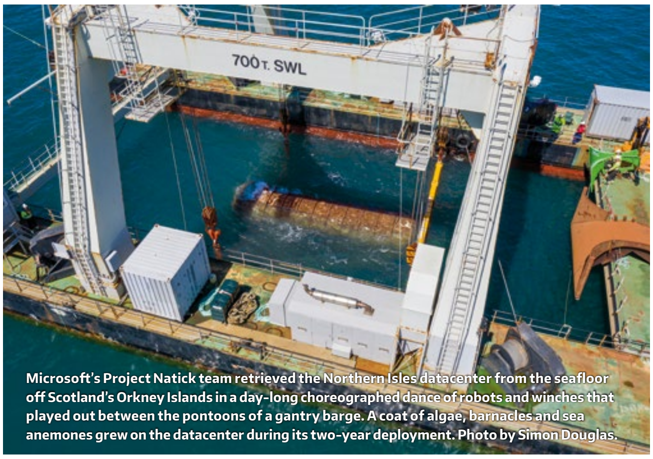
Lessons learned from Project Natick also are informing Microsoft's datacenter sustainability strategy around energy, waste and water, said Ben Cutler, a project manager in Microsoft's Special Projects research group who leads Project Natick. What's more, he added, the proven reliability of underwater datacenters has prompted discussions with a Microsoft team in Azure that's looking to serve customers who need to deploy and operate tactical and critical datacenters anywhere in the world.

"We are populating the globe with edge devices, large and small," said William Chappell, vice president of mission systems for Azure. "To learn how to make datacenters reliable enough not to need human touch is a dream of ours."

PROOF OF CONCEPT

The underwater datacenter concept splashed onto the scene at Microsoft in 2014 during ThinkWeek, an event that gathers employees to share out-of-the-box ideas. The concept was considered a potential way to provide lightning-quick cloud services to coastal populations and save energy. More than half the world's population lives within 120 miles of the coast. By putting datacenters underwater near coastal cities, data would have a short distance to travel, leading to fast and smooth web surfing, video streaming and game playing. The consistently cool subsurface seas also allow for energy-efficient datacenter designs. For example, they can leverage heat-exchange plumbing such as that found on submarines.

Microsoft's Project Natick team proved the underwater datacenter concept was feasible during a 105-day deployment in the Pacific Ocean in 2015. Phase II of the project included contracting with marine specialists in logistics, ship building and renewable energy to show that the concept is also practical.



Microsoft's Project Natick team retrieved the Northern Isles datacenter from the seafloor off Scotland's Orkney Islands in a day-long choreographed dance of robots and winches that played out between the pontoons of a gantry barge. A coat of algae, barnacles and sea anemones grew on the datacenter during its two-year deployment. Photo by Simon Douglas.


A member of the Project Natick team power washes the Northern Isles underwater datacenter, which was retrieved from the seafloor off the Orkney Islands in Scotland. Two years underwater provided time for a thin coat of algae and barnacles to form on the steel tube, and for sea anemones to grow to cantaloupe size in the sheltered nooks of its ballast-filled triangular base. Photo by Simon Douglas.


Photo by Jonathan Banks.

Photo by Jonathan Banks.

"We are now at the point of trying to harness what we have done as opposed to feeling the need to go and prove out some more," Cutler said. "We have done what we need to do. Natick is a key building block for the company to use if it is appropriate."

ALGAE, BARNACLES, AND SEA ANEMONES

The Northern Isles underwater datacenter was manufactured by Naval Group and its subsidiary Naval Energies, experts in naval defence and marine renewable energy. Green Marine, an Orkney Island-based firm, supported Naval Group and Microsoft on the deployment, maintenance, monitoring and retrieval of the datacenter, which Microsoft's Special Projects team operated for two years.

The Northern Isles was deployed at the European Marine Energy Centre, a test site for tidal turbines and wave energy converters. Tidal currents there travel up to 9 miles per hour at peak intensity and the sea surface roils with waves that reach more than 60 feet in stormy conditions.

The deployment and retrieval of the Northern Isles underwater datacenter required atypically calm seas and a choreographed dance of robots and winches that played out between the pontoons of a gantry barge. The procedure took a full day on each end.

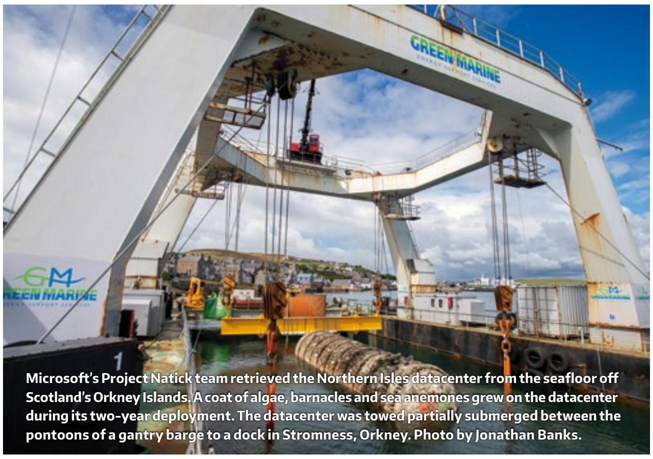
The Northern Isles was gleaming white when deployed. Two years underwater provided time for a thin coat of algae and barnacles to form, and for sea anemones to grow to cantaloupe size in the sheltered nooks of its ballast-filled base.

"We were pretty impressed with how clean it was, actually," said Spencer Fowers, a principal member of technical staff for Microsoft's Special Projects research group. "It did not have a lot of hardened marine growth on it; it was mostly sea scum."

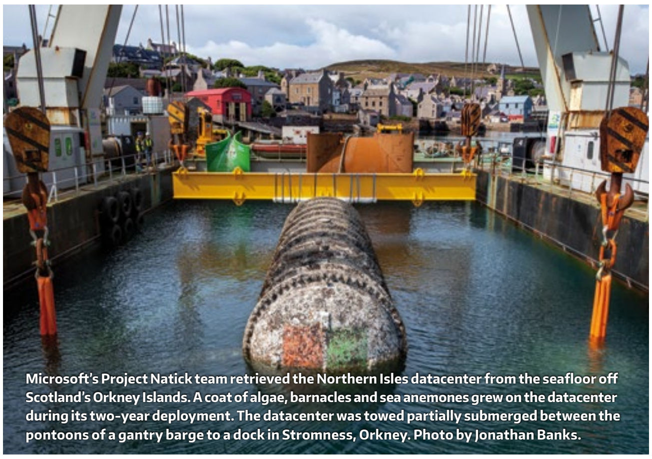
POWER WASH AND DATA COLLECTION

Once it was hauled up from the seafloor and prior to transportation off the Orkney Islands, the Green Marine team power washed the water-tight steel tube that encased the Northern Isles' 864 servers and related cooling system infrastructure.

Photo by Jonathan Banks.

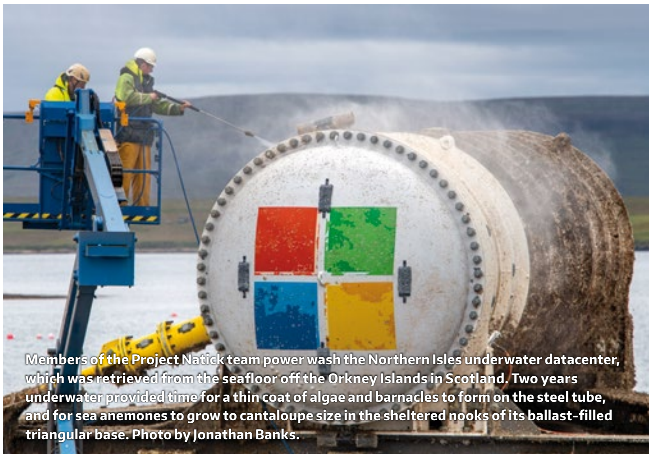


Microsoft's Project Natick team retrieved the Northern Isles datacenter from the seafloor off Scotland's Orkney Islands. A coat of algae, barnacles and sea anemones grew on the datacenter during its two-year deployment. The datacenter was towed partially submerged between the pontoons of a gantry barge to a dock in Stromness, Orkney. Photo by Jonathan Banks.



Microsoft's Project Natick team retrieved the Northern Isles datacenter from the seafloor off Scotland's Orkney Islands. A coat of algae, barnacles and sea anemones grew on the datacenter during its two-year deployment. The datacenter was towed partially submerged between the pontoons of a gantry barge to a dock in Stromness, Orkney. Photo by Jonathan Banks.

The Northern Isles underwater datacenter was attached to a ballast-filled triangular base for deployment 117 feet deep on the seafloor off the Orkney Islands in Scotland in 2018. The Project Natick team retrieved the datacenter this summer. Two years underwater provided time for a thin coat of algae and barnacles to form on the steel tube, and for sea anemones to grow to cantaloupe size in the sheltered nooks of the base. Photo by Jonathan Banks.



Members of the Project Natick team power wash the Northern Isles underwater datacenter, which was retrieved from the seafloor off the Orkney Islands in Scotland. Two years underwater provided time for a thin coat of algae and barnacles to form on the steel tube, and for sea anemones to grow to cantaloupe size in the sheltered nooks of its ballast-filled triangular base. Photo by Jonathan Banks.

The researchers then inserted test tubes through a valve at the top of the vessel to collect air samples for analysis at Microsoft headquarters in Redmond, Washington.

"We left it filled with dry nitrogen, so the environment is pretty benign in there," Fowers said.

The question, he added, is how gases that are normally released from cables and other equipment may have altered the operating environment for the computers.

The cleaned and air-sampled datacenter was loaded onto a truck and driven to Global Energy Group's Nigg Energy Park facility in the North of Scotland. There, Naval Group unbolted the endcap and slid out the server racks as Fowers and his team performed health checks and collected components to send to Redmond for analysis. Among the components crated up and sent to Redmond are a handful of failed servers and related cables. The researchers think this hardware will help them understand why the servers in the underwater datacenter are eight times more reliable than those on land.

"We are like, 'Hey this looks really good,'" Fowers said. "We have to figure out what exactly gives us this benefit."

The team hypothesizes that the atmosphere of nitrogen, which is less corrosive than oxygen, and the absence of people to bump and jostle components, are the primary reasons for the difference. If the analysis proves this correct, the team may be able to translate the findings to land datacenters.

"Our failure rate in the water is one-eighth of what we see on land," Cutler said. "I have an economic model that says if I lose so many servers per unit of time, I'm at least at parity with land," he added. "We are considerably better than that."

ENERGY, WASTE AND WATER

Other lessons learned from Project Natick are already informing conversations about how to make datacenters use energy more sustainably, according to the researchers.

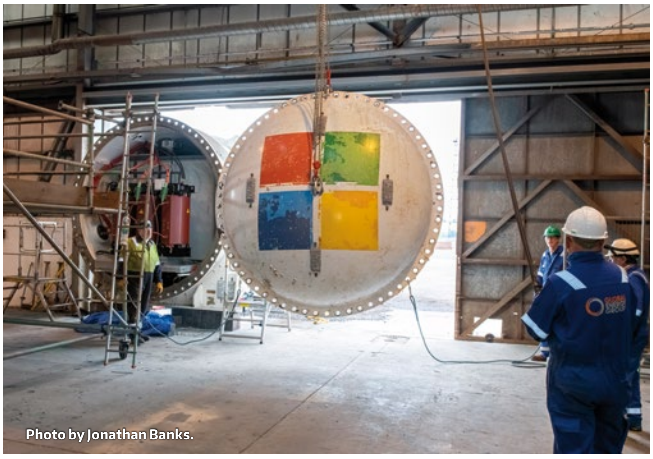
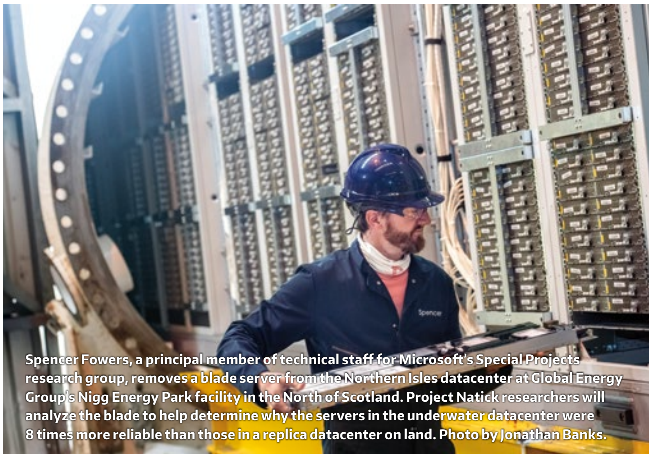


Photo by Jonathan Banks.



Spencer Fowers, a principal member of technical staff for Microsoft's Special Projects research group, removes a blade server from the Northern Isles datacenter at Global Energy Group's Nigg Energy Park facility in the North of Scotland. Project Natick researchers will analyze the blade to help determine why the servers in the underwater datacenter were 8 times more reliable than those in a replica datacenter on land. Photo by Jonathan Banks.

For example, the Project Natick team selected the Orkney Islands for the Northern Isles deployment in part because the grid there is supplied 100% by wind and solar as well as experimental green energy technologies under development at the European Marine Energy Centre.

"We have been able to run really well on what most land-based datacenters consider an unreliable grid," Fowers said. "We are hopeful that we can look at our findings and say maybe we don't need to have quite as much infrastructure focused on power and reliability."

Cutler is already thinking of scenarios such as co-locating an underwater datacenter with an offshore windfarm. Even in light winds, there would likely be enough power for the datacenter. As a last resort, a powerline from shore could be bundled with the fiber optic cabling needed to transport data.

Other sustainability related benefits may include eliminating the need to use replacement parts. In a lights-out datacenter, all servers would be swapped out about once every five years. The high reliability of the servers means that the few that fail early are simply taken offline. In addition, Project Natick has shown that datacenters can be operated and kept cool without tapping freshwater resources that are vital to people, agriculture and wildlife, Cutler noted.

"Now Microsoft is going down the path of finding ways to do this for land datacenters," he said.

GO ANYWHERE

Early conversations about the potential future of Project Natick centered on how to scale up underwater datacenters to power the full suite of Microsoft Azure cloud services, which may require linking together a dozen or more vessels the size of the Northern Isles.

"As we are moving from generic cloud computing to cloud and edge computing, we are seeing more and more need to have smaller datacenters located closer to customers instead of these large warehouse datacenters out in the middle of nowhere," Fowers said.

That's one of the reasons Chappell's group in Azure is keeping an eye on the progress of Project Natick, including tests of post-quantum encryption technology that could secure data from sensitive and critical sectors. The ability to protect data is core to the mission of Azure in multiple industries.

"The fact that they were very quickly able to deploy it and it has worked as long as it has and it has the level of encryption on the signals going to it combines to tell a pretty compelling vision of the future," Chappell said.

FACTS AND FIGURES

Datacenter Designation	"Northern Isles" (SSDC-002).
Pressure Vessel Dimensions	12.2m length, 2.8m diameter (3.18m including external components); about the size of a 40' ISO shipping container you might see on a ship, train, or truck.
Subsea Docking Structure Dimensions	14.3m length, 12.7m width.
Electrical Power Source	100% locally produced renewable electricity from on-shore wind and solar, off-shore tide and wave.
Electrical Power Consumption	240 KW.
Payload	12 racks containing 864 standard Microsoft datacenter servers with FPGA acceleration and 27.6 petabytes of disk. This Natick datacenter is as powerful as several thousand high end consumer PCs and has enough storage for about 5 million movies.
Location	European Marine Energy Centre, Scotland, UK.
Internal Operating Environment	1 atmosphere pressure, dry nitrogen.
Time to Deploy	Less than 90 days from factory to operation.
Planned Length of Operation Without Maintenance	Up to 5 years.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iXBLUE POWERS DEEP-SEA EXPLORATION FOR

IFREMER'S NEW STATE-OF-THE ART AUV, ULY^X

Ifremer (the French National Institute for Ocean Science) has recently unveiled its new 6000-meters AUV Uly^X. Designed for scientific exploration, this state-of-the art submersible vehicle will be able to navigate up to 48h autonomously and will be equipped with unprecedented capabilities to uncover the deep sea.

Associating multiple payload devices with navigation capabilities for either long range survey or close-to-bottom hovering, Uly^X will accomplish wide area acoustic mapping as well as target-based local inspection with optic imaging, photogrammetry, and in-situ scientific measurements in a single dive configuration. One of the small number of AUVs built for the exploration of the ultra-deep ocean and developed in collaboration with ECA Group, Uly^X represents a true technological breakthrough.

iXblue – a global high-tech company specialising in the design and manufacturing of innovative systems and solutions, devoted to inertial navigation, subsea positioning and underwater imaging – is taking part in this exciting adventure. Over the past 20 years, iXblue has developed advanced expertise in combining sonar, inertial navigation, and acoustic positioning technologies and offers one of the most advanced and accurate solutions for seabed mapping, imaging, and exploration.

"iXblue is thrilled to be onboard Uly^X, and to provide the most advanced acoustic imagery solutions to Ifremer scientific and hydrographic surveyors," states Lionel Fauré, technical and business Manager of iXblue Sonar Systems Division. "Pushing the limits of the technology and responding to our customers' challenges is a driving force for our teams. Several of our most advanced technologies are onboard the AUV: a Sams-150 Synthetic Aperture Sonar

Ulyx AUV, La Seyne-sur-Mer. Ifremer, Bodenes Ambre (2020)

(SAS), an Echoes 5000 sub-bottom profiler, a Phins C7 Inertial Navigation System (INS), and Delph Geo Software suite for SAS and navigation post-processing."

"Integrating iXblue's outstanding technology, Uly^X unites a range of state-of-the-art payload devices for hydrographic mapping, for visual inspection of local targets, and for in-situ measurement,"says Jan Opderbecke, head of Ifremer's Underwater Systems Unit. "[This is] accelerating scientific exploration by producing integrated multi-sensor data sets. Scientific exploration of the deep-sea onboard cruises of the French Oceanographic Fleet, will reach a new milestone!"

IXBLUE HIGH-END SONAR SYSTEMS SELECTED IN ULY^X'S EXTENSIVE SENSORS SUIT

Uly^X operates an extensive and unprecedented set of payload sensors, including iXblue's synthetic aperture sonar, and the Echoes 5 000 sub-bottom profiler. These run alongside a multi-beam echosounder, magnetometers, and still photo land laser line imaging, as well as a set of scientific bio-chemical and physical parameter sensors.

SAMS-150 SYNTHETIC APERTURE SONAR (SAS)

Uly^X will incorporate a Sams-150 SAS. SAS uses synthetic arrays to capture images of the seafloor, providing much more detailed resolution and high-quality images than conventional side scan sonar. SAS is used for seabed mapping, seafloor classification, sediment characterisation, marine habitat observation, and seabed features detection. Available as an AUV payload, iXblue Sams-150 expands the capabilities of side-scan sonars for shallow to deep-sea applications. Its interferometric sonar will deliver co-registered full-swath backscatter and bathymetry data. This will increase the achievable resolution and coverage rate from the deep-water surveys performed by Uly^X.

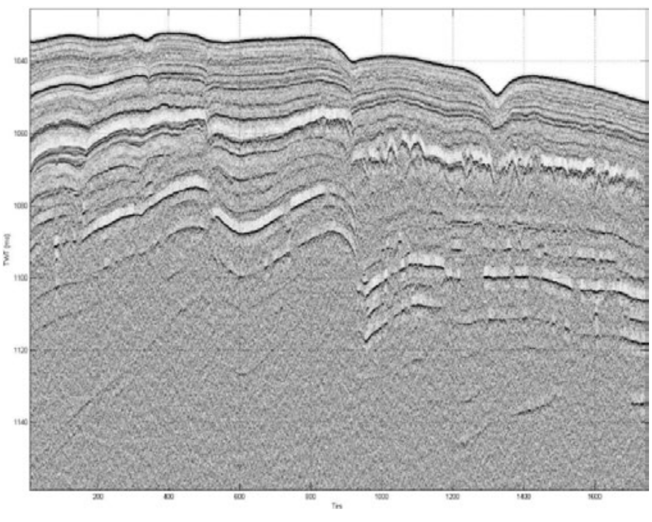
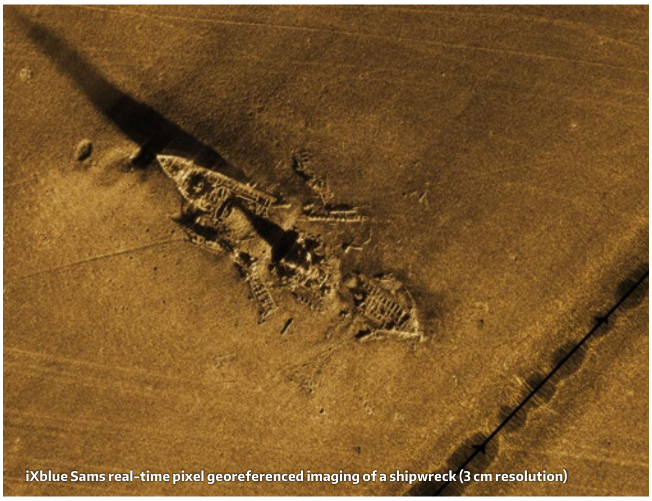


Figure 1: Acquired onboard of an Ifremer AUV, this seismic profile shows Echoes 5000 performances to highlight sedimentary architecture at about 1500 m of water depth.

Sams maps are gridded at a resolution of up to 3×3cm. They are fully corrected from geometric and sound propagation distortions and accurately positioned in real-time. The highest pixel's relative positioning precision is achieved through the high level of coupling with the Phins C7 inertial navigation system while the absolute submetric precision is given by the acoustic positioning system solution (USBL, Sparse-LBL, etc.).



iXblue Sams real-time pixel georeferenced imaging of a shipwreck (3 cm resolution)

ECHOES 5000 SUB BOTTOM PROFILER

Operable from shallow to 6000m-water depth, the Echoes 5000 sub bottom profiler is a complementary payload specifically designed for AUVs and is already deployed on Ifremer's AUVs. Echoes 5000 is a Chirp system with a frequency bandwidth ranging from 1800 to 6200 Hz, allowing about 70 m of penetration with 20 cm resolution, when the AUV is navigating between 50 and 100 m above the seafloor. It will thus provide high-resolution and high-quality records of the sub-surface sediment layers for geologists. All geological information is integrated, processed, and georeferenced in Delph Geo software when the interpretation of sub-bottom layers and rock architecture can be done.

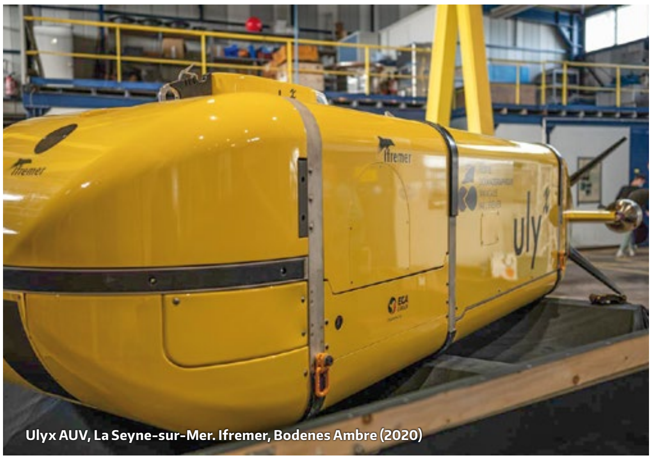
Courtesy of iXblue

DELPH SAS & DELPH INS SOFTWARE

Uly^X will also benefit from iXblue Geophysical Software, Delph Geo. SAS sonars require dedicated processing software for dealing with the great amount of multi-ping, multi-channel data. To ease the processing workflow, iXblue integrated SAS data processing in the established Delph Geo software, where it's managed like conventional side-scan sonar data with all the benefits of SAS technology. This dedicated module, Delph SAS, fully integrates SAS imaging and its derived bathymetry into the industry proven processing software, complying to survey workflows and data standards.

Delph fully integrates SAS data together with conventional side-scan sonar, bathymetry, sub-bottom profiling, magnetic and other information layers. All existing features

Ulyx unveiled. Ifremer. Dugornay Olivier (2020).



Ulyx AUV, La Seyne-sur-Mer. Ifremer, Bodenes Ambre (2020)

available in Delph Sonar Interpretation like batch data processing, sonar mosaicking, target picking and management, interpretation, seabed classification, and 3D visualisation are now also available for SAS imagery.

iXblue's inertial navigation post-processing software Delph-INS enables the fusion of surface USBL positioning and the AUV's INS in post-survey. Thus near-perfect line matching will immediately improve map consistency, data interpretation, and targeting accuracy.

Coupling iXblue Sams and navigation allows focusing on each pixel in the mosaic, thus rectifying the usual distortions and ensuring absolute data positioning. Each pixel's relative positioning precision is almost perfect, thanks to the coupling and reprocessing with the INS optimised absolute precision. Motion and acceleration tolerances are 10 times higher than other SAS solutions on market.

As the need for overlapping survey lines are reduced, the Ulyˣ coverage rate and autonomy will be maximised, thus saving time and cost by increasing the efficiency of operations.

iXBLUE'S INERTIAL AND ACOUSTIC TECHNOLOGIES PROVIDING NAVIGATION CAPABILITIES TO ULYˣ AUV

PHINS C7 INERTIAL NAVIGATION SYSTEM

Courtesy of iXblue

Based on iXblue Fiber-Optic Gyroscope technology, the Phins compact series offers a highly accurate and reliable navigation solution that enhances AUV autonomy. Adopted by all leading manufacturers of AUV around the world, Phins Compact INS does not interfere with sonars and other payloads' acoustic noise, while also providing increased autonomy to the subsea platforms thanks to its very low-power consumption. "The Phins C7 on board Ulyˣ is the most performant system of the Series," comments Fauré, "and will provide very accurate heading, roll, pitch, speed, and position, ensuring reliable navigation but also contributing to the quality of the data collected by the various sensors."

POSIDONIA USBL FOR ACOUSTIC POSITIONING

Courtesy of iXblue

The low frequency Posidonia USBL system developed by iXblue, and already onboard Ifremer's vessel, will be used for acoustic positioning of the AUV. Ulyˣ is also designed and prepared to host the iXblue Ramses tranceiver in a future LF (10-14kHz) version in order to allow for sparse LBL position updating.

"We're very proud for our navigation and imaging technologies to be chosen once again by Ifremer," Fauré says. "To be onboard such a disruptive AUV dedicated to ultra-deep ocean exploration is a strong endorsement of our technologies. A whole new adventure awaits, and everyone is looking forward to Ulyˣ's first exploration."

WEAPONS THAT WAIT NO MORE

MINE WARFARE IS ON THE CUSP OF PROFOUND TRANSFORMATION

Courtesy of Saab

By David Strachan, Strikepod Systems, LLC.

For centuries, sea mines have been weapons designed to patiently and silently await their prey. But now, with advancements in energy production, acoustic communications, and artificial intelligence, a quiet convergence of mines, torpedoes, and unmanned underwater vehicles (UUVs) is underway. By all accounts this would represent a quantum leap in mine technology, with far-reaching implications for naval warfare. And with the ingredients for this transformation already in place, it may occur sooner than we think.

AN INSIDIOUS THREAT

Since their inception, mines have been one of the most effective, if unglamorous, weapons of naval warfare. From the floating boxes of gunpowder of the Ming dynasty, to David Bushnell's drifting kegs of the Revolutionary War, to the moored contact mines of the Northern Barage, to the bottom-dwelling influence mines of the Cold War, for centuries sea mines have provided a low-cost force multiplier to navies worldwide. During World War I, Germany laid approximately 43,000 mines that claimed 500 British merchant vessels as well as 44 Royal Navy warships and 225 auxiliaries. During World War II, the United States laid over 12,000 mines in Japanese shipping lanes, sinking over 650 vessels and effectively strangling the Japan's economy. Since World War II, mines have been responsible for damaging or sinking fifteen U.S. Navy warships, more than any other method of attack, while mine-like devices and waterborne IEDs have provided terrorists and nonstate actors with a crude sea denial capability. Even without bringing destruction, mines can be highly disruptive. The mere possibility of their presence can strike fear into the hearts of sailors (and insurers), disrupting merchant shipping and effectively halting maritime operations as time and resources are expended to sanitize the area.

Though the sophistication of the weapons has changed, the operating model of mine warfare has been largely unchanged. Mines still must be deployed in quantity and throughout large swathes of water space, such as chokepoints, shipping lanes, or outside ports and coastal facilities. And it is a tedious and time-consuming endeavor, necessitating high-value platforms – ships, submarines, or aircraft – to lay the mines, and to return to sanitize the region once the shooting stops. But thanks to innovative technologies and operational concepts, this is about to change.

BLURRING LINES, CONVERGING OPERATIONS

Historically, the lines separating mines, torpedoes, and UUVs have been fairly clear cut. Mines were stealthy, standoff, but largely static weapons deployed in large numbers to saturate a region of water space, wait for their unsuspecting prey, and detonate either upon contact or when influenced by a sensory input. Torpedoes were fast, maneuverable, semi-autonomous homing weapons capable of tracking and pursuing their prey, while UUVs were for the most part research and reconnaissance platforms, largely unsuitable as a weapons platform due to their low speed, low endurance, and lack of technological maturity in areas such as communications and autonomy.

But as sharp as they seemed, these lines began blurring nearly six decades ago as the Cold War spawned a range of hybrid underwater weapons. The Mk60 encapsulated torpedo (CAPTOR) mine, for example, was an influence mine that combined the stealth and sensory capability of a traditional mine with the speed and mobility of a torpedo. The Submarine Launched Mobile Mine (SLMM) deployed via torpedo tube and transited to a preprogrammed waypoint, enabling the covert, standoff seeding of minefields.

The Cold War also spawned the convergence of torpedoes and UUVs. While first generation torpedoes were largely unguided, by the early 1970s torpedoes had evolved into fast-moving remotely operated vehicles (ROVs), tethered to the host via a thin umbilical wire providing two-way communication. This convergence continues today, as evidenced by Naval Group's new UUV, the D19, which is based on its highly successful F21 heavyweight torpedo. And in its RFP for a medium UUV, the U.S. Navy specified that it should be launched (and recovered) via torpedo tube. Both of these vehicles are highly modular and capable of carrying a wide range of sensor payloads, but they are also quite capable of being fitted with a warhead and acting either as a torpedo – fired directly at an undersea or surface target – or as a mine – transiting to a waypoint like an SLMM to rest on the seabed, or to hover in the water column awaiting communications or sensor influence.

But the true holy grail of mine warfare will be smart, mobile platforms that form integrated swarms or pods of undersea vehicles. We are already seeing this nascent capability with companies like EcoSUB Robotics and its networked micro AUVs, and Aquabotix with its hybrid USV/UUV, Swarmdiver. The ability to work collaboratively, to self-organize and operate in redundant, adaptive networks will be the defining nature of future mine warfare.

KEY DRIVERS AND ENABLERS

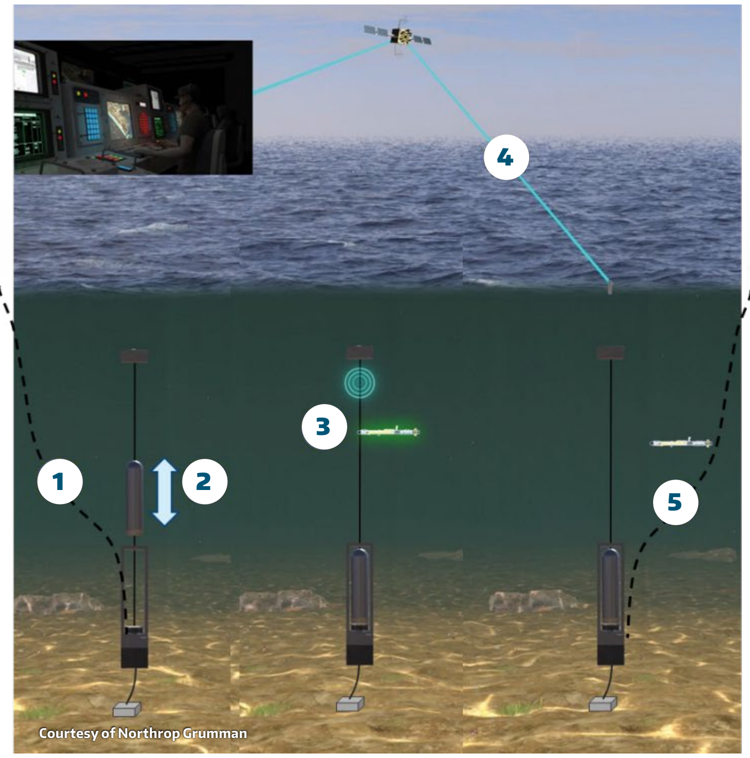
By all indications, the mine platform of tomorrow will exhibit the persistence, coverage, and lethality of conventional mines, the speed and maneuverability of torpedoes, and the modularity, mobility, and autonomy of UUVs. But in order to get there, engineers must overcome the unique technological challenges imposed by the complex undersea environment: energy, communications, and autonomy.

1

Launch:
System put into water & sinks while anchor, cable & float deploy on descent.

2

Thermal Energy (TE) Harvesting:
Buoyancy Engine module in the TE Pod propels the unit up & down the cable through the thermocline. Electrical energy is produced as the working substance changes phase and stored onboard the TE pod in batteries.



Courtesy of Northrop Grumman

5

Recover:
Once commanded, system releases anchor & floats to surface for recovery to surface ship, refurbishment & reployment.

4

Data & Status to end user:
Data & Status signal transferred up cable to Data Bubble in float which is released to the surface for satellite transmission.

3

UUV Recharge & Data / Status Transfer:
UUV homes & docks with NiobiCon™ section on cable to recharg the main batteries and transfer mission data & status to the UUV station.
UUV proceeds to next Mission.

Energy

Advancements in energy density and storage will provide the endurance necessary to enable persistent, wide area coverage, while improvements in power production will provide the higher cruising and sprint speeds needed for UUVs to pursue their prey like torpedoes. This is already happening with battery-powered torpedoes like the F21, the Black Shark, the Sea Hake, the MU90, and the Saab Lightweight Torpedo (SLWT) , all of which can reach speeds of 50 knots and enjoy an endurance of nearly an hour. And if high-density energy stores are unavailable, replenishment will be possible via in-situ recharging stations deployed to the seabed, such as a Forward Deployed Energy and Communications Outpost (FDECO), or a moored thermal energy harvesting system, such as the Mission Unlimited UUV Station from Seatrec and Northrop Grumman.

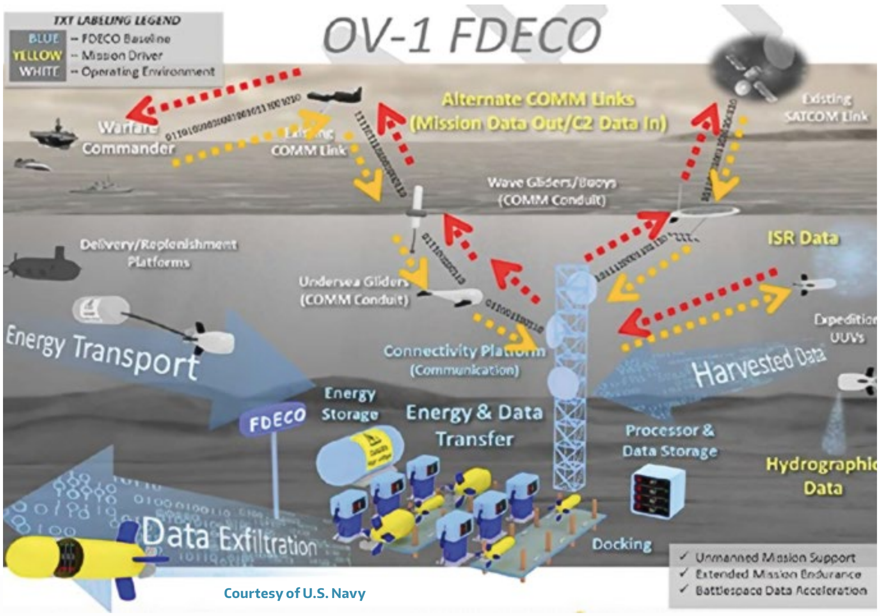
Communications

The arrival of robust, high-bandwidth underwater communications is enabling the development of an "Internet of Underwater Things" (IoUT). Much as the Internet and the electromagnetic spectrum provide mission critical connectivity to air, surface, and land platforms, the IoUT will enable undersea platforms – sensors, weapons, vehicles, energy depots, comms/data gateways – to share data, send and receive commands and instructions, and carry out extended missions. But obstacles remain. Acoustic transmissions provide long range (tens of kilometers), but are highly detectable, low-bandwidth, and subject to latency. Optical communication provides high bandwidth but is limited to short range (tens of meters) transmissions and is vulnerable to ambient light interference.

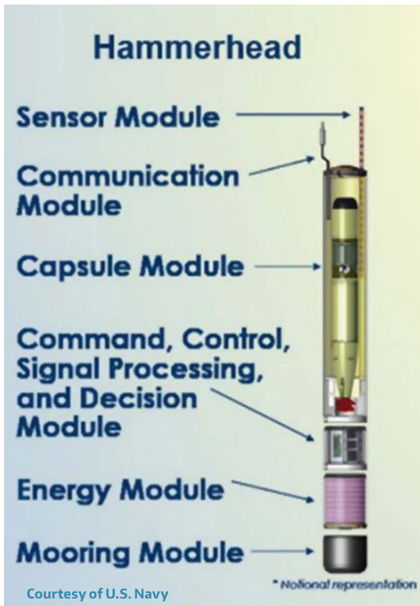
Nevertheless, underwater communication is improving, and we are already witnessing how this will alter undersea warfare. The U.S. Navy recently issued an RFP for a successor to the Mk60 CAPTOR, the Hammerhead moored torpedo system. Among a host of other technology upgrades, the Hammerhead will have an acoustic communication capability, a significant development as this will enable remote activation. With this capability, the U.S. Navy could preposition inactive Hammerheads in critical chokepoints, or outside adversary ports and naval installations during peacetime, thereby complying with international law while retaining the capability to hold enemy submarines at risk from the moment hostilities commence.

Autonomy

Even with advances in underwater communications and data transfer, the undersea domain will continue to be a challenging operational environment for the foreseeable future. Without the capability of covert, real-time communication, it will be necessary for UUVs to operate for extended periods without human intervention, maintaining situational awareness, and making decisions based on changing environmental conditions and rapidly unfolding circumstances. This will be particularly important as UUVs assume the kinetic roles of torpedoes and mines. Of course, handing over control to a weapons platform poses a host of operational and ethical considerations, but in reality, this has been the case with mine warfare for decades. Influence mines may not be "autonomous" in the current AI sense of the term, but they are automated, using onboard sensors and processors to "decide" whether to fire.



Courtesy of U.S. Navy



Courtesy of U.S. Navy

Courtesy of Saab

As a torpedo interceptor, or "hard kill countermeasure," Northrop Grumman's Very Lightweight Torpedo (VLWT) is illustrative of the mine/torpedo/UUV convergence - in particular, the transformation of mine countermeasures (MCM) from hunting, sweeping, and disposal to autonomous undersea combat. (Courtesy of Northrop Grumman)

COMBAT IS THE NEW COUNTERMEASURES

Despite the acceleration of this convergence, the need for traditional minesweeping operations will not disappear any time soon, especially given that some 50 nations possess an estimated one million mines spanning 400 unique models. And even with the integration of unmanned systems with sophisticated sensors, integrated USVs, and stand-off neutralization, MCM will remain a tedious and time-consuming endeavor. But as the convergence takes hold, and mines evolve into autonomous, mobile, distributed platforms, what will this mean for the future of MCM? We then move into the realm of Counter-UUV (CUUV) operations, where instead of detecting, classifying, and neutralizing static threats, MCM becomes more like a game of undersea combat, where "mines" are no longer fixed platforms, but highly mobile, autonomous agents, capable of detecting, evading, and even attacking adversary mine platforms. The mines of tomorrow may have to "fight their way to the fight," evading enemy mines or even engaging them using dedicated kill vehicles, or non-kinetically using decoys, acoustic jamming or cyber attacks. Or they may be charged with defending manned submersibles, surface warships, or seabed infrastructure against incoming enemy mine attacks. The idea of UUVs engaging in undersea dogfighting may seem like pure science fiction, but we need only look at developments in autonomous air combat to imagine the future of the undersea, such as DARPA's Alpha Dogfight competition, where artificial intelligence was able to defeat an experienced human fighter pilot. If autonomous air combat is within the realm of the possible, surely it is possible in the undersea domain as well.

INNOVATION BEGETS PROLIFERATION

The sword of innovation, of course, cuts two ways. Commercial off-the-shelf technologies and the IoUT will level the playing field, providing access to the undersea domain to those for whom it was once too complex or costly. And as we've witnessed with aerial drones, the potential for smaller powers to exert influence as drone superpowers by amassing a "poor man's air force," is quite real. Could this happen in the undersea domain as well? For now, the barriers to entry are quite high, but they are quickly falling, and it is certainly possible that rogue or nonstate actors could leverage the

Courtesy of Saab

IoUT to create their own "poor man's navy." Even a handful of crudely weaponized UUVs, strategically placed, could wreak havoc on global shipping, or provide an effective sea denial capability against a more powerful adversary.

IMPLICATIONS FOR FUTURE CONFLICT

Since the early twentieth century, the dominant undersea platform has been the manned submarine – a costly, complex, high value platform which has historically been called upon to perform a broad range of covert missions – tapping undersea cables, deploying sensitive seabed infrastructure, collecting valuable intelligence. But what if those and similar missions come to be performed by a cheap, expendable, autonomous platform? And when viewed against the backdrop of great power competition and operations below the threshold of war, could the undersea be the next front in "gray zone" conflict? With the United States reluctant to retaliate when a $220 million RQ-4A Global Hawk is shot down over the Strait of Hormuz, what are the implications for expendable, autonomous systems operating in an opaque and secretive environment like the undersea domain?

Words like "gamechanging," "revolutionary," and "transformative" are perhaps overused often when describing technological innovation, but if these words apply anywhere, it is in the realm of underwater technology. The coming decades will see dramatic changes in mine warfare, with the "mines" of tomorrow scarcely resembling those that came before.

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George Galdorisi, Director of Strategic Assessments and Technical Futures
at the U.S. Navy's Command and Control Center of Excellence

PERSPECTIVE

As readers of ROV Planet know, it is the oceans that sustain the planet. There is compelling evidence that the world's oceans are under increasing stress and that we must find a sustainable solution to protect them. An essential element of doing so is making data-driven decisions as to what steps to take to sustain the 70% of the planet covered by water.

Making these data-driven decisions depends on collecting the right data, at the right place, at the right time. This is not a trivial undertaking. Strong anecdotal evidence suggests that where those with stewardship for various aspects of ocean sustainment cannot find an affordable way to collect this data, it will simply not be obtained. These gaps lead to an incomplete picture of the ocean's health, and with it, sub-optimal solutions to achieving long-term ocean sustainment.

Some time ago, the failure to accurately assess bathymetric, hydrographic, temperature, current, wind, salinity and other ocean conditions could be forgiven, as there simply were not affordable ways to do so. But today there are, with unmanned maritime vehicles of various types, especially unmanned surface vessels, or USVs. While there have been some tentative attempts to employ USVs to collect such data, there have been few comprehensive evaluations of such a capability – until now.

A UNIFIED EFFORT TO COLLECT OCEANIC DATA

National Oceanic and Atmospheric Administration (NOAA) and the U.S. Navy have formed a partnership to obtain and utilize unmanned maritime systems and to codify the policies that govern their operations. A recent article in the maritime journal, Ocean News & Technology entitled, "NOAA, U.S. Navy Will Increase Nation's Unmanned Maritime Systems Operations," described this cooperation and highlighted the importance of ocean observation from both an environmental, as well as a national security, perspective.

The article pointed out that these two major oceans stakeholders, NOAA and the U.S. Navy, have signed a new agreement to jointly expand the development, acquisition, fielding and operations of unmanned maritime systems in the nation's coastal waters as well as in world's ocean waters.

(Photo: Jack Rowley)

(Photo: Jack Rowley)

This will enable NOAA to leverage the Navy's expertise, infrastructure, best practices and training to accelerate its science, service and stewardship mission.

Retired Navy Rear Admiral Tim Gallaudet, Assistant Secretary of Commerce for Oceans and Atmosphere and Deputy NOAA administrator, put the reason for this partnership this way: "With the strengthening of our ongoing partnership with the Navy, NOAA will be better positioned to transition unmanned maritime technologies into operational platforms that will gather critical environmental data that will help grow the American Blue Economy."

NOAA conducts research and gathers data about the global ocean and atmosphere to forecast weather, predict climate, protect the ocean and sustainably manage marine resources. These missions rely on a continuous process of testing and evaluation of new technologies such as unmanned systems to improve data gathering.

The U.S. Navy's Naval Meteorology and Oceanography Command's mission is to define the physical environment from the bottom of the ocean to the stars to ensure the U.S. Navy has freedom of action to deter aggression, maintain freedom of the seas and win wars. For over twenty years, Naval Oceanography has been a global pioneer in the development and use of unmanned systems.

Rear Admiral John Okon, Commander Naval Meteorology and Oceanography Command, emphasized why this partnership is important when he noted: "This agreement lays the foundation for collaboration, engagement, and coordination between NOAA and the U.S. Navy that our nation has never seen before. It will help us take advantage of each other's strengths to advance each of our strategic and operational mission priorities."

The new arrangement corresponds with rapid expansion and innovation in the use of unmanned systems across the government, academia and private enterprise. The new pact formalizes the Commercial Engagement through Ocean Technology Act of 2018 that directs NOAA to coordinate with the U.S. Navy on a wide range of functions including research of emerging unmanned technologies.

FROM ASPIRATIONAL IDEALS TO PROGRESS ON OCEAN OBSERVATION

This NOAA-U.S. Navy partnership is an important initiative that underscores the vital nature of robust data collection and why this is critical to ensuring the health and vitality of the world's oceans. For both the U.S. Navy and NOAA, a major appeal of unmanned systems is to provide a persistent sensor picture for a specific area.

Given the importance of ocean observation as a critical ingredient to ensuring the long term and sustainable health of the oceans, unmanned systems have a strong appeal.

Due to the prohibitive costs of using manned air or sea craft to conduct these observations, as well as the dangers of using these vessels in bad weather, in turbulent waters, or at night, the only effective solution may be to proactively pursue a substantial commitment to invest in affordable unmanned surface vehicles to conduct these observations.

This comports with the recently issued and concise NOAA Unmanned Systems Strategy: Maximizing Value for Science-based Mission Support. An excerpt from this document highlights the extent to which NOAA intends to leverage unmanned systems to support ocean observation:

"The purpose of the National Oceanic and Atmospheric Administration Unmanned Systems Strategy is to dramatically expand the collection and utilization of critical, high accuracy, and time-sensitive data by increasing the application and use of unmanned aircraft and marine systems in every NOAA mission area to improve the quality and timeliness of NOAA science, products, and services."

In support of NOAA and U.S. Navy objectives for ocean observation, one U.S. company recently demonstrated the use of commercial-off-the-shelf unmanned surface vehicles to conduct a comprehensive environmental monitoring evaluation. This month-long endeavor was conducted under the auspices of the Naval Meteorology and Oceanography Command or CNMOC. Under CNMOC's stewardship, an Advanced Naval Training Exercise (ANTX) was conducted in the Gulf of Mexico, south of Gulfport, Mississippi.

As part of this exercise, Naval Meteorology and Oceanography Command scientists outfitted a commercial-off-the-shelf MANTAS unmanned surface vehicle with a specially designed CNMOC Environmental Monitoring System. These systems and sensors were designed to be carried by this USV in order to provide a one-vehicle solution to important environmental sensing that was, in the past, conducted by multiple platforms. Key to the success of this ANTX was the fact that the catamaran-hulled, compartmented MANTAS USV was outfitted with solar panels which enabled it to remain at sea for thirty continuous days.

In order to have this single unmanned surface vehicle conduct comprehensive environmental monitoring of the Gulf of Mexico, CNMOC equipped it with seven sensors: Teledyne Benthos ATM603 underwater modem, FLIR M232 Camera, Teledyne Citadel CTD-NH Conductivity Temperature Depth Monitor, Teledyne DVL with ADCP Doppler Velocity Log, Norbit iWBMSh-STX Echosounder, Turner C3 Fluorometer, Quanergy M8-1 Plus LIDAR, Airmar WX220 MET, Meteorological Sensor, and SeaView SVS-603 Wave Height Sensor.

In order for CNMOC officials to have real-time information on ocean conditions, four different communication systems were utilized: Line-of-Sight (LOS), 4GLTE, Silvus radios, and Iridium Short Burst Data. The use of multiple communication paths was important to the ability of CNMOC scientists and engineers to change the paths of the USVs as different sets of data were collected and new search patterns were needed.

The first round of ocean monitoring was so successful that CNMOC employed a second unmanned surface vehicle (another MANTAS USV), this one equipped with a different suite of ocean monitoring systems and sensors. These included an iWBMSh-STX and Klein UUV 3500 side scan sonar. As testing continued with both USVs, CNMOC scientists and engineers provided vital feedback and suggested several enhancements to these vessels including improved solar amp meter gauges, collision avoidance improvements, fixed waterproof USB connections to payload computers, tracer self-configuration, Iridium functionality enhancements, and a system status indicator.

An important aspect of demonstrating the cost-effectiveness of employing commercial-off-the-shelf unmanned surface vehicles during this CNMOC ANTX was the ability of one operator to easily operate both USVs simultaneously and control them as they conducted surveys along specific paths, even with currents of up to five knots. The ability to conduct surveys in higher sea states had thwarted other unmanned surface vehicles in the past, and was one of the highlights of this month-long event.

Beyond the collection of vial ocean data, another area where unmanned surface vehicles can make an important contribution is in response to real-world challenges. The testing described above occurred in the littorals of the Gulf of Mexico, an area that has more than its share of environmental challenges. Unmanned surface vehicles provide the ideal asset to evaluate the extent of damage as a first step in triaging the problem.

One persistent issue well-known to those familiar with the Gulf of Mexico is the fresh water runoff from the Mississippi River. Periodically, this runoff reaches levels that can damage the near-shore areas on the Gulf. The Mississippi River had a huge runoff of fresh water enter the Gulf of Mexico in 2019. This did two things.

- This extensive fresh water runoff killed a great deal of marine life, much of it essential to the economies of the States bordering the Gulf of Mexico. Knowing when and where this runoff is occurring is crucial to protecting the environment. Employing an unmanned surface vehicle such as the MANTAS T12 (or larger MANTAS) that is an environmentally friendly system that plays well with nature in its natural habitat is a good way to mitigating the impact of this runoff.

- The fresh water runoff described above also pushed fish and shrimp further out to sea and impacted the shrimping industry because fishermen had to go further out to sea, which cost them more money and thereby increased the price of shrimp for consumers. Identifying where the fresh water runoff is located is not only important for scientific research, but for alerting the fishing industry in a timely manner regarding runoff and its effects.


(Photo: Jack Rowley)

Green tides and red tides have a similar negative impact. Every time one of these events happens, it hurts tourism in a local region. Using a solar-powered unmanned surface vehicle that can remain at sea and monitoring the environment for up to thirty days at a time can alert communities to the extent of these green and red tides. This enables officials to be more exact in determining which beaches should close and which ones can remain open.

MOVING FORWARD WITH EFFECTIVE, AFFORDABLE OCEAN OBSERVATION ASSETS

It is clear that the need to monitor the health of the oceans will be an ongoing mission for a large number of stakeholders. The use of commercial-off-the-shelf unmanned surface vehicles successfully employed during this demonstration can be readily "scaled-up" in oceans, seas, bays, rivers and other waterways and can lead the way to enhanced data collection, transmission and evaluation of water conditions. The results will help sustain a healthier ocean.

As a major step forward in this effort, U.S. Navy officials have encouraged the MANTAS USV manufacturer, MARTAC Inc., to scale-up the 12-foot MANTAS used for this effort and produce larger vehicles. This was accomplished this year and a larger, 38-foot MANTAS USV, was deployed during U.S. Navy exercise Trident Warrior with positive results. These larger vessels (including 24-foot and 50-foot MANTAS USVs on the drawing boards) will also be ideal USVs to conduct ocean observation due to their ability to carry considerably more sensors and remain at sea for longer periods.

As one example of what this increased size provides vis-à-vis ocean observation, the 38-foot MANTAS, using an ocean bottom surveying speed up to 10-15kts, or more, can easily stay underway for up to 8-10 days until it needs refueling, after which it can again resume its survey mission. Multiple USV craft can be used to perform independent scans within the same area, thereby greatly increasing the amount of total area that can be scanned in a relatively short time. Even with multiple craft, only minimal manning will be required at the control station on the mother ship. During a recent webinar, NOAA's Deputy Administrator indicated that two of the primary priorities this year for NOAA are ocean mapping and ocean health. Leveraging these larger USVs to accomplish these priorities will go a long way to protecting the oceans.

The U.S. Navy, NOAA, and many other stakeholders recognize the critical need for understanding the ocean environment. Therefore, we envision a tremendously increased demand for unmanned systems prototyping and experimentation to support robust and continuous ocean observation. The vast array of technologies emerging in today's unmanned maritime systems provides a tremendous opportunity to move forward with an effective and affordable ocean observation taxonomy.

TELEDYNE LAUNCHES

NEW WAYFINDER DVL FOR MICRO VEHICLES

ROV Planet Interviewed Grant Jennings, Product Line Director at Teledyne Marine to find out more about the recently launched Wayfinder DVL.

RICHIE ENZMANN: Hi Grant, please tell us about the Wayfinder DVL. How is this different to the existing range of DVLs – such as the Pathfinder, Pioneer, Tasman, or Workhorse Navigator – that Teledyne has to offer?

GRANT JENNINGS: It's a new product for a new market. As you know, we've been pioneers of DVLs for the last 28 years. Everything we designed was mainly for work class ROVs and AUVs, but in the last 5 years we've seen a change of direction in the market towards much smaller vehicles and within the last 2 years, we've seen a lot of new customers moving towards the micro ROVs like those produced by BlueRobotics, SeaDrone, even smaller than the SeaBotix vehicle that Teledyne manufactures.
Three years ago, we launched Pathfinder, the smallest DVL we've produced, and it has done phenomenally well. The Pathfinder set a new standard for small DVLs in performance and quality of data, because we've utilized the past 20 years of our experience from designing and building DVLs.

Now Pathfinder is even too big for these micro vehicles. In the past we were talking $50-$70K for a small vehicle. Now they're $5,000. You can't sell a sensor that is over $10,000 for a $5,000 vehicle, especially one that's 12 inches long and 7 inches high.
We listened to our customer base and we sold a large number of Pathfinders for these types of ROVs, but for some customers, even the Pathfinder was too large. Hence, we kicked off a project last year and we produced something that is half the size of a Pathfinder. Now the Wayfinder is literally a 10cm square – a small cube – and it's everything in a self-contained unit.

RE: It sounds small.

GJ: It is very small! This is also our first product with our brand-new Doppler platform. The markets have changed, and we needed to shrink everything, about a year and a half ago we started to develop our new Doppler platform which is now the basis for all our future products.
With that we had to add more channels so we could do smarter things. It's not just having a simple 4 beam DVL; we're looking to the future. Customers who perform up down measurements for currents and bottom tracking utilize two sets of electronics. Now we are moving to do that with one single board set.
As you know electronics move on every year; they get faster, lighter, smaller. So that's what we've done. We adapted and got a brand-new set of Doppler electronics, and Wayfinder is the first product to utilise this new engine.

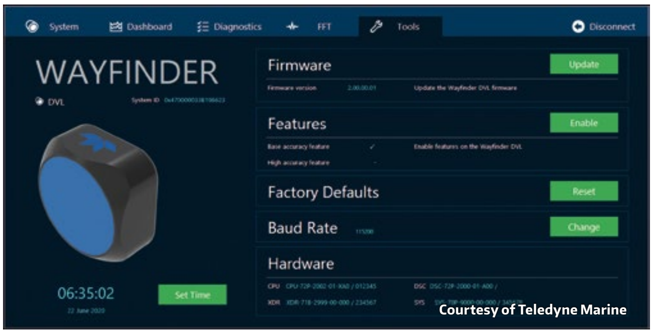
RE: So, the change of electronics helped you a lot?

GJ: A change of electronics and materials. These small ROVs do not need to go to 1,000m. Most of them operate in waters 100m or less, so you can shrink the thickness of the housing walls and use lighter materials when we are not reliant on going to deeper depths with greater pressures.

RE: And I guess the range and accuracy can be shortened as well then.

GJ: Yes, exactly. The nice thing is that we've actually taken the same transducer design from the deeper-rated Pathfinder. The high-end quality is still there, but how we build it is different. We only need a 60m bottom tracking range, not several hundred meters. Everything all comes together and allows us to shrink the package down in size.

Courtesy of Teledyne Marine



Courtesy of Teledyne Marine

RE: Do you make the transducers in house?

GJ: Yes! Everything. We take the raw ceramics and machine them on an incredibly precise diamond tip lathe. Everything is manufactured here in San Diego, and it's been like that for over 35 years. In this facility we build all our ADCPs and DVLs.

RE: Do you have any special features? I saw the other Teledyne DVLs measure temperature and depth.

GJ: This market doesn't need all the bells and whistles. The Pathfinder and the Tasman obviously have all of that. The first Wayfinder we launched into the market really is a bare bones DVL. We purposely kept all the features out because we want to keep it simple and affordable.
Wayfinder reduces the integration time, you connect power and RS 232 serial comms to the integrated cable, and then you're up and running. We actually designed a brand-new simplified binary data format, and we're giving our customers the Python drivers needed to read the data. So basically, we wrote code in Python to match the drone processors these ROVs are using.
We obviously have our SeaBotix vehicles, but we specifically purchased a Blue Robotics BlueROV2 to understand how this new customer base interfaces to third party sensors. We've had one for a couple of months now and we integrated the DVL into that. It's up and operating on the same platform that the typical marketplace is using.
I suppose the new features include a much-simplified user interface. You're literally wired into the electronics bottle. You cut and paste our code, which we provide, and you're up and running in a couple of hours.

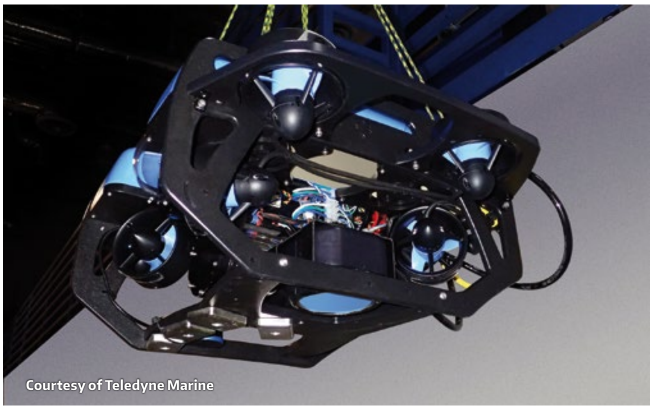
RE: Sounds like it is almost open source then.

GJ: It is. We will have all of this available via our website, and it'll be the first product that we'll allow our customers to buy online. We host all of these tools -now available on our new Shopify site, where customers in the US can also purchase online. This is another first for us.
Even to purchase a system we're keeping it simple. You won't need to call up to get a quote. You can just click and buy online.

RE: Did you have any challenges? Sometimes making it simple can be challenging as well.

GJ: The challenge for us was that we started from scratch.

Courtesy of Teledyne Marine


Courtesy of Teledyne Marine

Obviously, we had the transducer and our history, but because we wanted to make it flexible, simple but upgradeable in the future, we needed a new electronics setup. I suppose the only challenge was working with a new platform, but we have such an amazing engineering team here in San Diego who were all excited to work on this.
Actually, one of our main integration engineers used to be part of the AUVSI RoboSub competition, so his past experience made it very simple. The main challenge for us was to get familiar with this new platform, but the integration – the mechanical and electrical – was easy. That's what we do; that's our bread and butter.

RE: Is this the ROS (Robotic Operating System) platform? That seems to be quite popular these days.

GJ: Yes, that's correct. We have the Python drivers on our website that you just import into ROS. We created all the apps that you need for those different platforms, and it's all open source.

If you're using it for aquaculture, station keeping, cleaning nets, then the Wayfinder would work for you. But if you're doing mine hunting or precise navigation, then you would continue to use the Pathfinder.

In the past the Pathfinder was overkill for some of these more basic operations. It's a highly accurate system like the Tasman, but a lower depth rated package. For search and recovery or inspection the Wayfinder is all you need.

RE: What depth rating and price range are we looking at?

GJ: 200m as standard to match the vehicles that it's going on, and it's $7,500 USD. It's our first DVL under $10K.

RE: How is the launch coming along?

GJ: Excellent! We launched the product in late August alongside the official RoboSub virtual competition this year. The response from the industry has been phenomenal.

RE: Do you have plans to develop this range further?

GJ: Yes. As with other products, when customers need other features, we'll develop them over time. It was the same with the Pathfinder when we launched that. It was a basic DVL to start with, but soon we added current profiling, extended range bottom tracking, roll & pitch sensors, etc., so that really progressed. Our goal is not to take business away from the Pathfinder, it's in a great marketplace and it's been very successful. It's a brand-new Doppler platform, and we hope to see new developments every 3 months or so based on customer feedback. It's a new market for us; a smaller entry level platform. There are so many if you think of the RoboSub community. Last year when we attended, there were over 50 teams, with more than 50 vehicles, and every vehicle was different. The most common thing was the platform. They were all using the ROS. But every single vehicle was a different size or shape and had different capabilities. We've been talking to those teams over the last 3 years because of the Pathfinder. However, even though the Pathfinder is a low-cost sensor, it's still too expensive for these particular platforms. The Wayfinder opens that door for new applications and new needs for a DVL. It's interesting to see what people are doing with these vehicles.
There is so much emphasis on the ocean and the environment. And these vehicles are giving more scientists opportunities to survey and gather data that they never had before. You can go out with a very small boat and throw these $5,000 vehicles off the side and look at what's happening to the environment. The data the scientists are gathering from this class of vehicle is incredible, and we're going to enable them to gather better data by being able to navigate and hold station when recording certain data. In the water you need to hold station when there is current flow, and that's exactly what the Wayfinder has been designed for: to give them that capability. We're extremely pleased to play a role in expanding the value and capability of these powerful little vehicles.


Courtesy of Teledyne Marine

Courtesy of Trelleborg

SYNTACTIC FOAM MATERIALS FOR RESIDENT ROV APPLICATIONS

Muhammad I. Ali, Zaki Akhtar, Trelleborg Applied Technologies

Conventional remotely operated vehicles perform tasks at depth. Traditionally, these stay for short durations at operational depths between 1,000 to 4,000 meters subsea, typically for one to four hours before ascending to the surface. This mode of ROV surface-to-depth deployment is often referred to as a short-term cyclic operation.

Recent developments have seen several ROV manufacturers create a new class of ROV known as Resident ROV or RROV. These are specifically engineered for remote deployment permanently or for an extended period at operational depths, typically between 1,000 and a much lower depth of 6,000 meters subsea. This new generation of RROV offers significant economic and environmental benefits, including negating the need for costly support vessels and labour, the ability to operate in adverse weather conditions and to provide a smaller carbon footprint.

Historically, syntactic foam materials provide buoyancy (or up thrust) for ROV vehicles, satisfying the existing industry requirements for density, water absorption, hydrostatic crush strength and bulk modulus. However, in the case of RROV's, syntactic materials require a higher strength-to-weight ratio in order to withstand the constant and extreme hydrostatic pressure conditions experienced at depth for extended periods.

Research conducted by Trelleborg's applied technologies operation shows that an RROV engineered using existing syntactic materials based on published information and research offers a durability of approximately just six months. This brings a new challenge to materials scientists and engineers to develop innovative syntactic materials that offer serviceability well beyond six months to support the needs of the industry. The materials need to provide a greater resistance to water ingress and hydrostatic creep during long term immersion, particularly for applications in deep and ultra-deep subsea environments.

Recognising these new requirements for long term submersion, Trelleborg's applied technologies operation undertook a programme of development, testing and qualification of syntactic foam materials to address the specific and more demanding needs in RROV applications, aiming to ensure robust and reliable performance.

DEVELOPMENT OF SYNTACTIC FOAM MATERIALS FOR RROV APPLICATIONS

A systematic approach was adopted by Trelleborg in identifying potentially suitable syntactic foam materials. Derived from a combination of unique thermoset polymer matrices and high strength hollow glass microsphere technology (HGMS), TG-1000R, TG-2000R, TG-3000R, TG-6000R with depth ratings of 1000, 2000, 3000 and 6000 MSW respectively, all underwent stringent testing and qualification processes.

The evaluation of several resin matrix systems along with the screening of various grades of commercially available glass microspheres, and in-situ and ex-situ surface functionalisation of selected glass microspheres, were also included in the process.

Key performance indicators (KPIs) investigated during screening included:

1. Density
2. Hydrostatic Crush Pressure (HCP)
3. Water Absorption

ACCELERATED AGEING TEST METHODS AND WATER ABSORPTION FOCUS

An additional challenge faced was the lengthy testing programme. High performing RROV require an extended lifetime of greater than six months at constant operational pressure, meaning comprehensive testing of syntactic foam buoyancy materials in accordance with operational specifications is essential to ensure reliable and repeatable performance at the required depth.

Data had to be collected at specific timed intervals for analysis. This led to the development of an accelerated ageing test methodology, which allowed faster acquisition of data to accurately predict the material service lifetime, simulating the real-life application and reducing test programme duration.

Among the KPIs mentioned previously, water absorption was identified as one of the most critical parameters in the performance of syntactic foam materials for long-term immersion in deep-sea and ultra-deep-sea applications. Therefore, this became the focus of most of the testing and qualification.

It was assumed that the ingress of water into syntactic foam follows a molecular diffusion process that can be modelled by Fick's laws of diffusion. However, many researchers have found that syntactic foam materials very rarely obey true Fickian behaviour and this phenomenon is mostly observed in polymer materials. It is also well-known that diffusion is a thermally activated process and can be modelled by Arrhenius law if a linear correlation is found between water absorption and temperature.

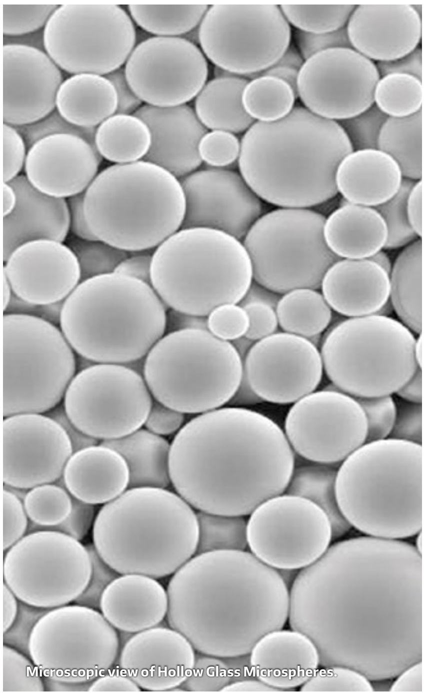
During testing, water absorption evolution at different temperatures was closely investigated, using time-temperature equivalence principle to fit the data to an Arrhenius model to make service lifetime predictions. This was followed by the validation of the model under real life conditions, at temperatures of +10 °C or lower to replicate the temperatures experienced by RROV at depth ratings below 500 MSW.

TESTING PROGRAMME

Comprehensive testing was performed on numerous development samples using Trelleborg's in-house pressure testing facilities. Water uptake findings and results for Trelleborg's TG-3000R material, which was subjected to ageing at different temperatures in the range of +10 °C to +50 °C under the operational pressure of 310 bar are highlighted below.

Material samples machined to different shapes and sizes with variable S/V (Surface area to volume ratio):

1. 100mm cube (100mm × 100mm × 100mm) with S/V 0.06
2. 50mm cube (50mm x50mm × 50mm) with S/V 0.12
3. 30mm cube (30mm x 30mm × 30mm) with S/V 0.20
4. 20mm cube (20mm x 20mm × 20mm) with S/V 0.30
5. Cylinder 25.4mm (diameter) × 50.8mm (Length) with S/V 0.20



Microscopic view of Hollow Glass Microspheres.

TG-R surface engineered syntactic materials highlighting water resistance properties.

A pass/fail criterion was set at less than 2% water absorption, which is Trelleborg's internal standard for buoyancy material testing for short-term cyclic applications.

Initial experiments were performed at elevated temperatures, with data used to verify whether the Arrhenius Law was followed. By plotting the water absorption against the inverse of absolute temperature, a straight-line relationship with good correlation coefficients validate the Arrhenius fit.

Testing of a wide range of materials identified Trelleborg's TG-R range of materials most closely fitted the Arrhenius plot, as indicated in the graph shown in Figure 1 for ageing temperatures of +30 °C, +40 °C and +50 °C respectively. This meant the TG-R range of material would give a reliable and repeatable fit to the Arrhenius plot for a reasonably accurate prediction of water absorption and buoyancy behaviour during long term immersion at the operational depth conditions.

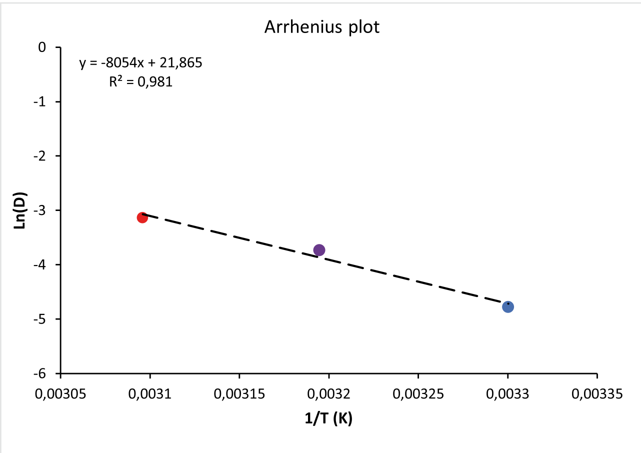


Figure 1: Arrhenius plot of TG-3000R at temperatures of +30 °C, +40 °C and +50 °C, respectively. The graph shows a linear fit with a good correlation coefficient. This clearly shows that the material follows an Arrhenius trend in accelerated ageing and that data can be extrapolated to predict the service lifetime at lower temperatures.

Stage two of testing, included experiments carried out at +10 °C in order to validate the model. The graph in figure 2 shows the results of model and experimental data for comparison. The service lifetime predicted by the model based on water absorption values from accelerated ageing data, aligns with experimental data at +10 °C.

The graph in figure 2 also shows that the model is slightly more conservative in prediction of service lifetime than observed in validation experiments in a model of 32 days versus an experiment of 45 days. This is due to the fact that at lower temperatures the value of water diffusion rate constant is likely to be lower than used in the model (a value of two has been used for the diffusion rate constant in this study) since water ingress into syntactic materials follows a diffusion process better at lower temperatures.

In addition to this, as temperature goes higher, other factors such as hydrolysis of glass and degradation of polymer matrix become important, meaning water ingress is not purely diffusion controlled. This trend has been identified in repeated experiments, giving confidence in the reliability and accuracy of the model.

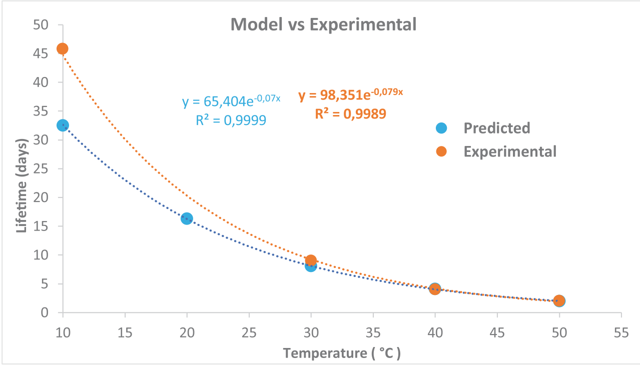


Figure 2: Graph showing validation of model for water absorption. The predicted lifetime of the model shows close agreement with experimental data.

After the successful validation of the model, Trelleborg launched an extensive testing programme on its TG-R range of materials utilizing both cube and cylinder specimens (different S/V ratio). For this purpose, TG-3000R syntactic foam material was chosen for testing, undergoing accelerated ageing at +50 °C under hydrostatic pressure of 310 bar, the pressure at operational depth of 3100 MSW, until the material reached 2% water absorption; the failure index value.

Validation experiments were set to run in parallel with the accelerated ageing, with data used to predict the service lifetime. The output of the model using the water absorption data at +50 °C predicts a service lifetime of two years at +10 °C.

SUMMARY

Trelleborg's applied technologies operation recognised the need for superior buoyancy to meet the more demanding requirements of RROVs. It developed and validated simple predictive models resulting in the identification of three syntactic materials capable of resident operation. The TG-1000R, TG-2000R and TG-3000R materials are predicted to offer a service lifetime of two years based on accelerated ageing test data, with a maximum typical water absorption of 2% or less over this duration. In doing so, Trelleborg has provided a reliable material solution for fast-emerging RROV applications.

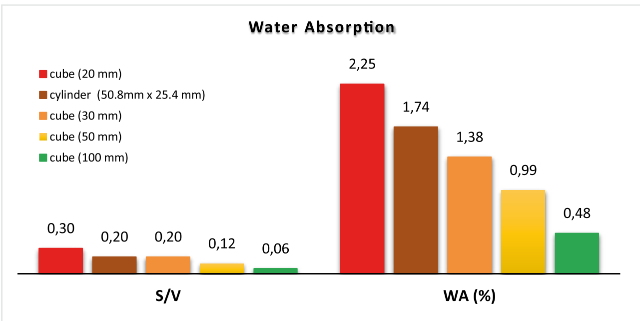
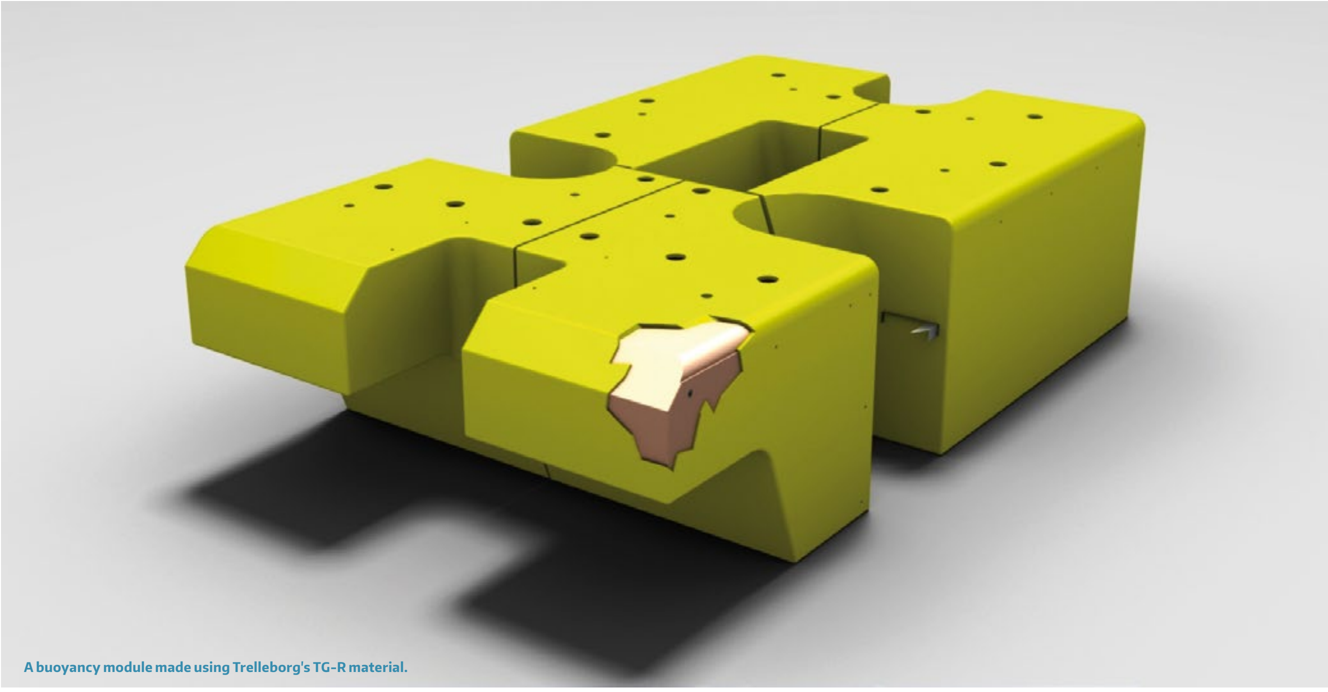


Figure 3. TG-3000R after 42 days of immersion at +50 °C under 310 bar. The data shows the water absorption is dependent on S/V ratio and sample geometry. The graph also shows relationships between S/V and water absorption; the higher the S/V, the higher the water absorption. Modelling of this data predicts service lifetime of two years at +10 °C.



A buoyancy module made using Trelleborg's TG-R material.

The overall results proved that these materials are unique within the materials buoyancy sector being fully qualified for long term continuous use at maximum operational pressure for up to two years. By developing TG-1000R, TG-2000R and TG-3000R, Trelleborg provides a solution for buoyancy materials for 1,000, 2,000 and 3,000MSW resident RROV sector, which are developed through accelerated ageing test models to ensure the application demand is fully satisfied. Validation and testing will commence shortly on TG-6000R material to confirm reliability for RROV applications at increased depths.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