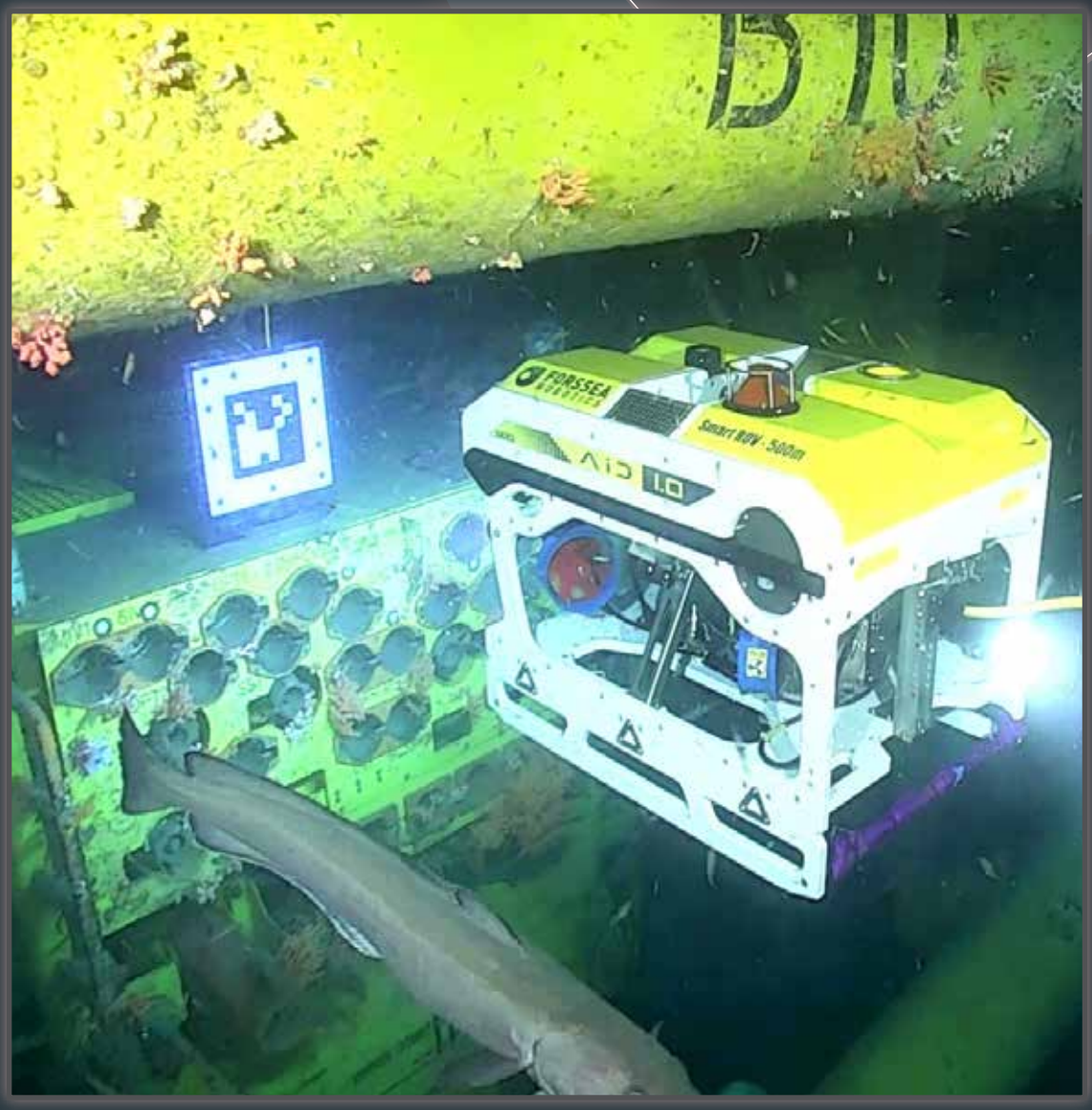
UNDERWATER ROBOTICS



ISSUE 5

SUT Society for Underwater Technology

MTS marine technology society

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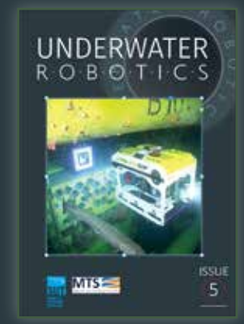


Argos ROV performing autonomous inspection of subsea template in the North Sea at 400mwd. The visual tag allows acoustic free INS repositioning thanks to Forssea's V-LOC

UV2 NAME CHANGE

Last year, we launched the speculative Underwater Vehicles magazine you are now reading, to capture the increasing interest in this burgeoning sector. We named it UV2 to provide an identifiable connection with its sister publication UT2.

Over the past year, the magazine has undeniably become a great success, attracting a considerable amount of interest in this niche underwater sector. It has become evident, however, that simply concentrating on underwater vehicles is not fully consonant with the direction of that we wish to take the publication.

For many years, the Society for Underwater Technology has had a very active and successful Underwater Robotics Group, and we have decided to rename the publication, before the UV2 title becomes irreversibly established, to better in encapsulate these aims and directions.

Like its predecessor, the new Underwater Robotics magazine will be published four times a year, while UT2 will remain at six times a year.

Sometimes, these publication dates coincide and once such occasion, this issue, falls close to the Oceanology 2022 event being held in London.

We will therefore include some of these articles in print form, to be distributed at the show.

THREE GAVIA AUVS TO TERRADEPTH

Teledyne Marine has confirmed that Terradepth has greatly expanded its survey operations capabilities by acquiring three Teledyne Marine Gavia autonomous underwater vehicles (AUVs) to support the rollout of its Ocean Data as a Service and Absolute Ocean data platform.

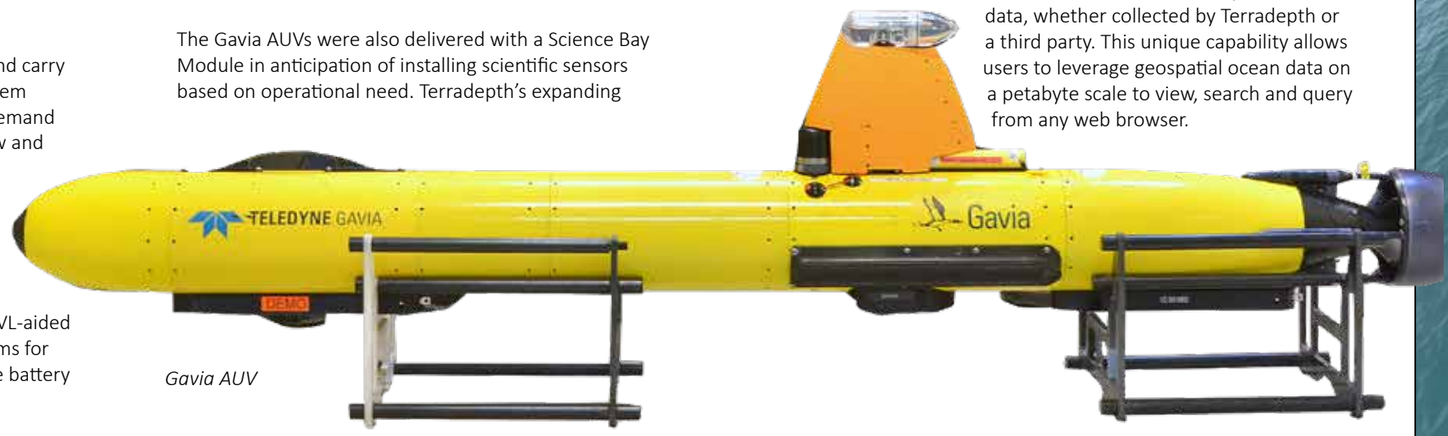
The Gavia AUVs are highly configurable and carry a depth rating of up to 1000m, making them ideal components to meet the growing demand for Terradepth's survey services in shallow and medium depths.

To help achieve these services, the three Gavia AUVs are each equipped with an Edgetech 2205 600/1600 kHz Module that retrieves both Side Scan Sonar and Bathymetric Sonar data, RDI DVL-aided IXBlue PHINS C3 Inertial Navigation Systems for accurate navigation, and field-replaceable battery modules from Teledyne Energy Systems for longer endurance.

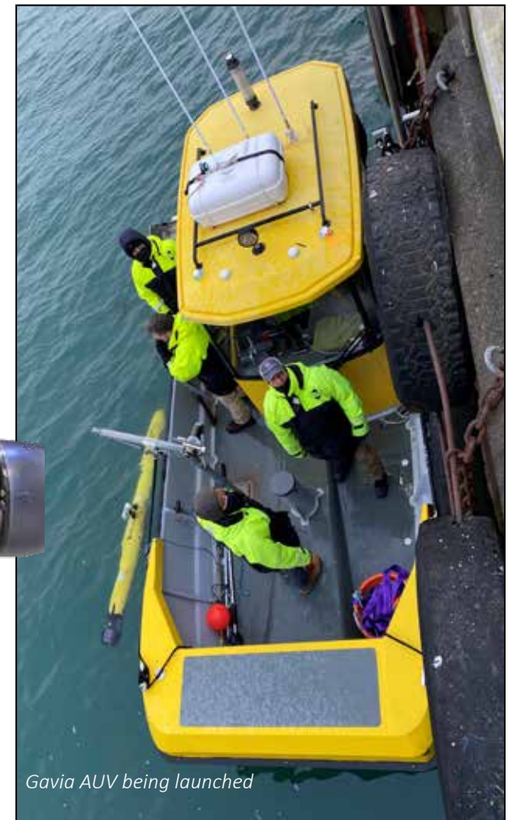
Future updates include Teledyne T20 Multi-beam Sonar and Sub-bottom profilers.

The Gavia AUVs were also delivered with a Science Bay Module in anticipation of installing scientific sensors based on operational need. Terradepth's expanding services have also received a boost with the introduction of Absolute Ocean, which combined, comprise Terradepth's survey-as-a-service offering.

Absolute Ocean (AO), a cloud-backed, browser-based, geospatial data platform, enables storage, search, visualisation and analysis of ocean data, whether collected by Terradepth or a third party. This unique capability allows users to leverage geospatial ocean data on a petabyte scale to view, search and query from any web browser.



Gavia AUV



Gavia AUV being launched

DIVE ACQUISITION

Defence technology company Anduril Industries has acquired Boston-based start-up Dive Technologies.

This acquisition expands Anduril's suite of autonomous systems, extends its unmanned capabilities to the undersea domain, and significantly accelerates the company's strategic growth.

Dive Technologies enables safe and successful access to the greatest depths of the world's oceans with reliable, flexible AUVs. Their DIVE-LD is a modular and customisable AUV that can be optimised for a variety of defence and commercial mission types such as long-range oceanographic sensing, undersea battlespace awareness, mine countermeasures, anti-submarine warfare, seabed mapping and infrastructure health monitoring.

Dive uses Large Format Additive Manufacturing (LFAM) techniques and a novel system architecture to rapidly produce the DIVE-LD at a fraction of the time and cost of existing AUVs.

The company hopes that when integrated into Anduril's autonomy software, Lattice OS, the next iteration of DIVE-LD will disrupt this segment of the market.

CLICK HERE to find out more about the DIVE-LD
Page 38-40

DIVE-LD

REACH ACQUIRES OCTIO

Reach has entered an agreement with Equinor Ventures to acquire OCTIO, a provider of monitoring solutions for hydrocarbon producing fields and CO_2 storage reservoirs.

"The acquisition of OCTIO will deepen Reach Subsea's technology competence and expand our value chain, accelerating the Company's strategy to become a full-service provider of subsea data and solutions for clients globally," said Jostein Alendal, CEO of Reach Subsea.

"We have worked with OCTIO for several years and are well-acquainted with how their cost-efficient and highly-accurate survey and monitoring technology enhances data value for clients and provides optimal solutions for monitoring of future CO_2 reservoir storage. In addition, OCTIO's patented technologies and competence will strengthen the data gathering, data processing, and data analytics capabilities of Reach Remote, the unique USV solution that we will introduce in 2023."

Under the terms of the agreement, Reach Subsea will acquire Equinor's interests in Bergen-based OCTIO, as well as the associated company MonViro, owned by OCTIO employees. Reach Subsea will settle the acquisition in cash, which will be funded from our available financial resources.

Reach ROV

OCEAN INFINITY EXPANDS ROBOTIC FLEET

Ocean Infinity has signed an order for six HUGIN Autonomous Underwater Vehicles (AUVs) rated to 3000m depth. The vehicles are equipped with a geophysical sensor suite and the latest generation KONGSBERG batteries.

The new vehicles will be mobilised for global operations, enabled by Ocean Infinity's remote operations infrastructure. The vehicles will integrate as part of the Armada fleet of uncrewed and optionally-crewed vessels and will augment the company's existing AUVs, rated to 6,000 metres depth.

This latest order from Ocean Infinity takes their fleet of HUGIN AUVs to more than 20. The introduction of some new capabilities enable operators to interface more easily with third-party software and also control adaptive behaviours in response to data collected in-mission.

These new AUVs include special software interfaces which will allow the integration of remote operations technology, mission planning and dive management software, along with a backseat driver allowing the vehicle to react to payload sensor output.

85M ROBOTIC VESSELS

Ocean Infinity has contracted VARD for the design and construction of a new series of six 85-metre robotic multi-purpose offshore vessels, all of which will be operated from shore and will eventually utilise green ammonia as fuel. This will take Ocean Infinity's remote vessel fleet to 23 vessels – the largest in the world.

With Ocean Infinity's control infrastructure and remote control centre currently undergoing commissioning, transformational low-emission remote operations are becoming a closer reality for the global maritime industry.

This new contract between Ocean Infinity and VARD facilitates the next phase of joint development between the two companies, including VARD's subsidiaries, Vard Design, Vard Electro and Seaonics. VARD's vessel systems management and automation techniques coupled with Ocean Infinity's systems integration capability and remote operations infrastructure will enable remote ship operation on a uniquely global scale.

The new vessels of VARD 9 80 design will augment Ocean Infinity's current Armada fleet of nine 21-metre and 36-metre vessels, plus eight 78-metre vessels which are already in production.

VARD won the contract to design and build the eight highly advanced, 78-meter vessels in November 2020. The first four are underway while steel cutting for the fifth began recently at Vard Vung Tau in Vietnam.

The new series of six vessels are scheduled for delivery from Vard Vung Tau in 2025. The first vessels will have the full suite of new technology and equipment installed and integrated at one of VARD's shipyards in Norway utilizing VARD's global integrated value chain.

New Ocean Infinity vessel

‘THE PHAROS OFFSHORE JET TRENCHER UTV-400 COMPLETING CABLE REPAIR WORKS OFF THE COAST OF CANADA’

YUCO

Micro AUV manufacturer Seaber recently launched YUCO, an affordable single task “off-the-self” vehicle.

While a number of companies have gravitated towards developing large multi-purpose AUVs able to carry increasingly heavy sensor payloads, Seaber has taken a very different approach. The design of its new Yuco vehicle is based on the premise that for many dedicated operations, a small single-purpose AUV can be the most cost effective method of carrying out specific missions.

Micro designs can further improve economics by minimising handling and launching costs. Depending on the payload, the lightweight YUCO weighs no more than 9kg in air. These small designs also invite a range of launch scenarios including directly from shore, the use of a small fast rigid inflatable boat or even the deployment from the largest of vessels of opportunity.

"The main drive behind the Seaber design was to develop a minimal vehicle compact enough to be transported by a single person but with a navigational range approaching 50-60km, making it suitable for operating over a wide area," said Business Development Manager , Luc Simon.

"It has to be able to accommodate a range of work packages, but rather than multiple payloads in a single vehicle, the engineers envisaged a two part design. The rear two-thirds of the vehicle are assigned to the delivery system, housing everything the AUV requires for motion and navigation. In this watertight enclosure, lies the power system, actuators, localisation sensors and embedded electronics.

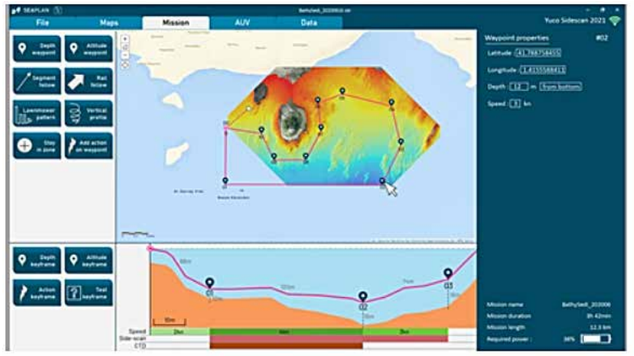
It is powered by rechargeable batteries not only giving it mission endurance in the order of 6- 10 hours, but at a speed of 2.5 to 6 kts From an operational viewpoint it is considered as a sealed unit and intended never to be opened by the user.

At the very rear is the thruster surrounded by a Kort nozzle and in front, three fins protruding outwards. The critical parts like mast and fins have been optimised to withstand the rough conditions, while maintaining a hydrodynamic form.

The front (nose),meanwhile, houses the interchangeable payload. This section is designed to allow water within the hull, which can help to reduce buoyancy and possibly have a cooling effect for sensor electronics.
These contain Subconn connectors for the rapid plug-and-play integration of new sensors.

NAVIGATION
Seaber has developed its own navigation system for the YUCO. Called the INX, it is based on in-house advanced underwater navigation algorithms that give the operators the capability to optimise and continuously improve the navigation.

"Integrated Doppler velocity log (DVL) and depth sensors



MINI AUV: YUCO

are key to the most cost efficient micro-AUV navigation in coastal waters without requiring external action," said Luc Simon. "It is able to achieve navigation accuracy better than +/-1% without requiring any external elements such as acoustic telemetry."

The navigation system works closely with the mission planning system called SEAPLAN.
Backed by a modern graphical user interface, SEAPLAN offers a wide range of navigation patterns at various depths to be programmed into the YUCO including unique navigation modes dedicated to specific payloads. The vehicle can also be recharged while being programmed.

One feature of the programme is the *shutdown-surfacing*. In this, the YUCO shuts the engine down on demand whereupon the positive buoyancy causes the vehicle to gradually surface at around 30cm/sec. This feature allows the AUV to take georeferenced physico-chemical profiles.

"One of the main risks in using any AUV is to lose it at sea," said Simon "That is why the vehicle has a positive buoyancy neon pink body colour, powerful flashing LEDs and differnt types of communication. There are two main ways of communicating with the YUCO – radio and satellite.

"The design also includes a handheld remote-control called SEACOMM which displays GPS positions when the vehicle lies at the surface. From a distance of up to 2km, it can trigger the YUCO to dive autonomously. Conversely, when the AUV arrives at its designated GPS location, it can emit its position signal allowing the SEACOMM unit to lock on to the bearing and distance."

The basic YUCO carrier can accommodate a package or sonde up to 2kg in weight and 45cm in length but for more functionality, there are four main versions.

YUCO-SCAN
YUCO-Scan is a simple and cost-effective way to perform side-scan sonar surveys, typically for marine, coral reef, coastal or lake habitat monitoring that often based on

single person deployments. With an autonomy up to 8hrs and speed up to 6kts, it can work at depths of300m.
The main feature of the YucoScan is the 680kHz Side Scan Sonar from DeepVision. This can be used in association with a DVL and pressure sensor to keep its altitude.

YUCO-CTD
The YUCO-CTD version is based on a RBR Legato CTD

sensor which located on the uppoer surface of the vehicle for optimum measurement in flow. This package is used to monitor salinity and temperature in ocean, coastal environment and lakes, especially to understand thermoclines and possibly the association with climate change.

This may be coupled with an optional, downward-pointing DVL, which can be used for greater navigation accuracy in current area.

"Following a saw-tooth navigation pattern makes the YUCO CTD an ideal platform to make profiles over long-distances," said Simon," while the fixed altitude from bottom- measured by the DVL, maintains a known distance from the seafloor. Additional sensors such as dissolved oxygen and fluorimeter can be added to the CTD sensor.

"A proposal based on the YUCO-CTD was recent;y selected for the JERICO-RI European Infrastructure JERICO-S3 coastal observation programme. It will provide precise salinity data with spatial coverage in a coastal environment with waves, currents and tides."

YUCO-PHYSICO
This option satisfies demands for water-quality monitoring, offering a versatile solution to monitor

physico-chemical parameters in varied depth.
Instead of one or two sensors, it contains a fully autonomous AML-3 multiparameter sonde accommodating a number of sensor options such as Sound Velocity, Condicitivty, Dissolved Oxygen, Turbidity, pH, Chlorophyll A, Crude-oil, etc.

YUCO PAM
This system is designed for passive acoustic monitoring. Equipped with a Porpoise recorder from RS Aqua, it offers selectable sampling rates up to 384kHz and storage capacity up to 4TB.

The Porpoise recorder can be either programmed separately or triggered by the AUV to synchronise its recordings with the YUCO-PAM. This makes it capable of monitoring anthropogenic noise such as pile driving and ships, as well as monitoring marine mammals even in the higher frequencies such as the harbour porpoises.

EELUMINATING

ARGEO PLAN TO USE NEW AUV FOR CLEARER AND CHEAPER SURVEYS

Against the backdrop of the Winter Olympics, the concept of a 'Race to be Second' seems quite incongruous, yet this phrase accurately describes underwater technology and the offshore industry. Companies that would otherwise enjoy the advantages of new technology, quickly retreat from being its first adopter, due to the (fear of the) cost of it failing. It takes a brave company to employ any new technology and especially from a company without a track record

Brave, however, is exactly what Ocean Space company Argeo have been, with the recent announcement that it would become the first commercial operator of the Eelume UID (Underwater Inspection Drone). So what do they know and the rest of us don't?

“We are currently seeing a tidal wave of technology coming into the market able to do things they simply couldn’t do only two years ago,” said Argeo CEO Trond Crantz. “Now is the time to use these tools to drive the cost and efficiency changes out customers want to see."

EELUME

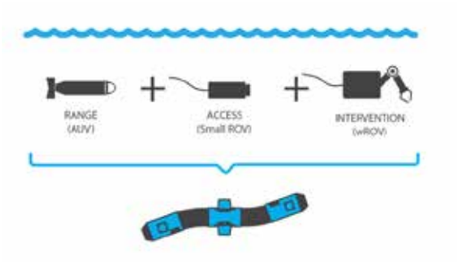
The Eelume is a self-propelled autonomous vehicle with a characteristic slender, articulated body that broadly emulates the form of an underwater snake or Eel. Uniquely, it provides unique shape-changing capabilities.

The vehicle is hydrodynamic enough to allow it to transit over long distances yet able to work in confined spaces not accessible by conventional underwater vehicles. By use of the thrusters and joints, the vehicle can assume any pose in the water. Importantly, it can hover and manoeuvre even in strong ocean currents.

An important feature of Eelume its is modularity. By combining thruster modules, joints, sensor modules and different payload modules can be mounted anywhere along the flexible body.

It can also achieve a dual-arm configuration by mounting tooling in each end and forming the vehicle body into a U-shape. One end of the arm can grab and hold to fixate the vehicle, while the other end can carry out inspection and intervention tasks. One end of the arm can also provide a perspective camera view of a tool operation carried out at the other end.

EELUME



The vehicle Eelume is a very good allegory for Argeo itself. Both are lean and agile, relatively small yet hide a huge potential.

Argeo’s currency is underwater data. Many companies have entered the underwater inspection market armed with visual imaging techniques such as subsea Lidar laser imaging and photogrammetry. Argeo, however, have travelled along a very different direction.

"Our roots lie in the seismic and geophysical industry, and this underpins most of our technology, especially electromagnetics, which, we believe, is grossly undervalued," said Crantz. "We see underwater vehicles simply as delivery systems for this technology.

"We have already invested in classic AUVs (Autonomous Underwater Vehicles). For many years, we have been operating a Kongsberg Hugin and to supplement this, recently ordered a pair of immensely powerful Sea Raptor vehicles from Teledyne.

These fast hydrodynamic torpedo-shape of these AUVs favour linear operations such as pipe and cable tracking, and these can be especially cost-effective over long distances."

There is, however, another quite different underwater market for the close quarter inspection of structures such as jackets and templates as well as revisiting areas of interest on pipelines. This has traditionally been the domain of ROVs (Remotely Operated Vehicles) and it is this area that Argeo is looking to disrupt.

“One important property we were looking for in a new vehicle was that it should hover," said Crantz. "This is universal in ROVs and allows them to carry out a variety of tasks that we see as crucial to our requirements. They are also able to carry out limited intervention tasks such as to open/close valves.

"The downside of using ROVs however, is the cost of support. This typically includes a surface vessel to provide power and control

DEVELOPMENT

While it is true that the vehicle is ’new’, it is underpinned by over 10 years of research," said Crantz. "

Eelume was established in 2015 as a spin-off from the Norwegian University of Science and Technology (NTNU). After a decade of research on snake robots in collaboration with the research organization SINTEF it was decided to further pursue subsea applications.


VIDEO: SNAKE ROBOT

In 2016 Eelume entered into a strategic partnership with Kongsberg Maritime and Equinor. This partnership ensured that the original vision to come into reality yet integrate all the latest technology.

EELUME in inspection mode

VIDEO: POTENTIAL USE ON ASGARD

for the underwater operations. At present, these surface vessels are mostly manned and very expensive to operate. Our intention is to go smaller, smarter and be more sustainable through autonomous operations.

"And by replacing the large labour-intensive surface vessels with small, unmanned surface vehicles, offers the oil and gas and offshore wind industries it is a way to dramatically reduce the cost of underwater surveying and inspection.

"The use of unmanned surface vessels is becoming increasingly common, but while deploying underwater vehicles from them and retrieving them has been carried out, it is still in its infancy. The prize for doing so, however, can be rewarding.

We estimate that 90% of these costs are conventional surface vessel related. "

Another direction that some companies have explored to solve this problem, especially for longer duration work programmes, is towards the use seabed residency where the vehicles can be mobilised 24/7 regardless of weather conditions.

"A continuous IMR capability near the subsea installations without the need for surface vessels means greener, safer and less costly subsea operations," said Crantz. "Eelume can permanently reside on the ocean floor, waiting to be activated for planned missions or using a docking station as a suitable subsea habitat.

“A single Eelume system has a range of about 80km2. "

Equinor, one of the Eelume partners, has been a key investor in supporting a wide range of AUV operations.

One technology it has been actively promoting, is the development of underwater docking stations as a platform to recharge the AUV batteries while allowing them to receive fresh instructions.

Eelume is fully compatible with this technology. Introducing docking stations in the centre of working circle immediately gives the Eelume a transit range of about 20km from one docking station to the next.

"This means that we can service

EELUME

a number of fields with this system. Some fields are directly powered from shore while some companies have proposed various micro-charging concepts based in locally-generated renewable energy sources. This gives it a low carbon footprint . We can already control underwater vehicles remotely from our onshore operations room.

"Another useful property of the Eelume is that it is modular. This means that we can always incorporate the correct tool or sensor modules for a given operation and quickly swap them out for the next. The vehicle is, therefore, always at its lightest, leanest and most efficient, and this results in reduced costs.

"Cost reduction is more important than ever, particularly as we transition from hydrocarbons to renewables," said Crantz.

"Offshore wind has a much lower margin than oil & gas, but companies still need to pay the same prices for offshore services. Using lower cost vehicles will help us be competitive, but using innovative sensor systems will also increase efficiency and data quality."

The vehicles are, however, nothing, without the tools that they carry. As such, Argeo has been trying to replace traditionally survey activities routinely carried out in the past.

"Typical sensors collect geophysical, hydrographic and geological data to produce uniquely detailed knowledge of the subsurface landscape," said Crantz. "These can be used to assist in the positioning of floating wind turbines, scanning the ocean floor to find the best anchoring points for them. Alternatively, they can be used to inspect oil and gas pipelines to determine if they need servicing.

"One tool we have been recently involved in developing is a high single to noise ratio cathodic protection (CP) system. Indeed, the signal in our Raptor AUVs is so strong that we can fly 20m pipeline in 4kt speeds service and carry out CP surveys very quickly and cost effectively. We plan to develop this as a module for our Eelume .

"For the offshore wind sector, we have developed an active control source electro magnetic system to look for unexploded ordnance (UXO). Most systems are presently based on passive sensors but we are looking, at active systems which permit a much more accurate mapping with larger footprints.

Over time the integrity of the equipment decreases. So, we need to know exactly when to do maintenance and repair, neither too early nor too late. Our inspection robots provide the data needed to perform this just-in-time maintenance, based on the actual condition of the equipment. Such an approach saves cost.

SEA RAPTOR AWARD

Argeo has successfully won a contract for ultra deep-water work for an undisclosed customer. The project will commence in March 2022 with an estimated completion in April. Argeo will use the 6000m-rated Teledyne AUV SeaRaptor “Alpha” The project will prove the SeaRaptor very near the limits of its build specification while making use of all the high-quality sensors integrated into the vehicle.

The SeaRaptor is a survey grade deep water autonomous underwater vehicle (AUV) designed to operate at abyssal depths. It will be equipped with the latest Kraken MinSAS 120 Synthetic Aperture Sonar (Kraken Robotics, Canada) providing large swath area coverage and high-resolution imagery and bathymetry data collection.

The vehicles will also be fitted with Teledyne Reason T50-S Multi-Beam dual frequency 200/400 kHz Echo Sounders, Teledyne Benthos Chirp III Sub Bottom Profilers, iXblue PHINS 6000 INSs coupled to Teledyne RDI Tasman DVLs, and CathX high resolution camera, laser scanning, and strobes in its Hunter Camera Systems.

All data collected will be processed onboard using Teledyne Caris OnBoard postprocessing and mosaicking software to allow quick turnaround during missions.

The AUVs are also fitted with a large variety of scientific sensors from RBR which will take Conductivity, Temperature, Pressure, Turbidity, pH, Dissolved Oxygen, Redox, CH4 and Magnetic measurements to provide valuable water column data which will contribute to better ocean basin characterisations.

MANTA RAY

Manta Ray AUV

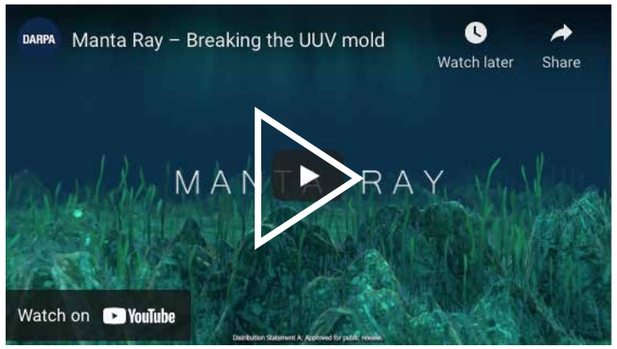
DARPA has awarded Phase 2 contracts to continue the Manta Ray program that began in 2020. The effort seeks to demonstrate innovative technologies allowing payload-capable autonomous unmanned underwater vehicles (UUVs) to operate on long-duration, long-range missions in ocean environments.

The two prime contractors, Northrop Grumman Systems Corporation and Martin Defense Group, are each developing unique full-scale demonstration vehicles.

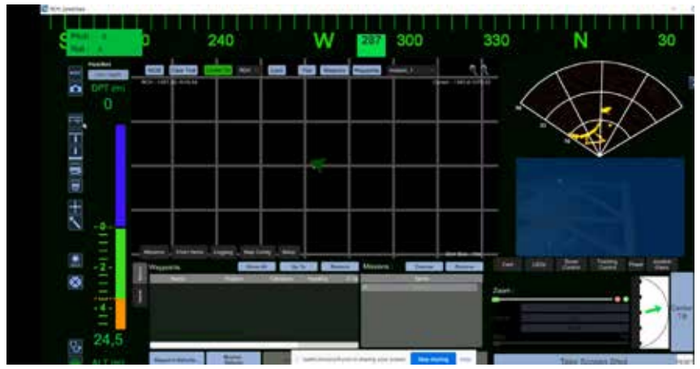
The Manta Ray program seeks to develop UUVs that operate for extended durations without the need for on-site human logistics support or maintenance.

In Phase 1 of the program, performers designed and conducted preliminary testing on novel approaches in energy management, UUV reliability, biofouling and corrosion control, navigation, and undersea obstacle avoidance, among other areas that directly enable long-endurance missions.

The Manta Ray program concluded Phase 1 with Critical Design Reviews that demonstrated design maturity and readiness for advancement to Phase 2. The selected performers will now work on subsystem testing followed by fabrication and in-water demonstrations of full-scale integrated vehicles.



SIMULATION



When Covid first struck in 2019, Scandinavian inspection company and VideoRay agent, EraMarine, went into lockdown. Unable to meet clients, they started work developing an ROV simulator. This simple, low cost software is now available.

“Good ROVs are relatively expensive, and getting the most out of them requires training,” said Managing Director Edvin Tousi. “We developed a system that can be downloaded on a computer and used with a joystick or Xbox controller.

During the development, EraMarine worked closely with Greensea, the company that provides the control software for VideoRay and other vehicles. They reportedly provided useful input to the project.

The simulator screen is divided into a number of sections, although each window can be viewed separately. In the classic version, a heading compass can be viewed across the very top, while the altitude, provided by a Doppler velocity log reading, can be seen along one side. The right hand side of the screen occupies a sonar image and below that, the view from a camera.

“It is possible to set resolution of the sonar to match that installed on the actually ROV," said Tousi, "and the screen visibility can simulate whether the water is murky or not.

"Just like the real vehicle controls, the rest of the screen occupies a grid map. This allows the user to set waypoints for the ROV to travel. Likewise, it is possible to take a point drag it somewhere, and see the vehicle follow on the screen. Below this, is a log while on the far left are the software's control icons."

An important part is the ability to simulate missions.

“The simulation starts from selecting one from a menu of VideoRay models," said Tuosi. "When selecting the Defender, for example, the user has six scenarios to choose from.

"In a typical exercise – a Wind Farm Landing – the pilot may be required to look up and down, possibly changing the full screen into a sonar or map.

Alternatively, in a Search and Rescue mission, the pilot is required look around a given area constrained by a box or border on the map.

"If the pilot successfully cues the mission, the ROV will search across the area automatically. The pilot may then be required to return to the place it started, either manually, or automatically by selecting the correct command.

“Many users of the VideoRay Defender are not full-time pilots, but have other jobs like fire fighting or in the Coast Guard. This system allows them to train when they are not on active duty. It also allows more than one person to be trained.

In order to introduce the element of competition between prospective pilots, the software designers have incorporated puzzles. In one, for example, 100m down and out of normal visibility, there is a simple challenge to use a manipulator to place a solid volume in a receptacle.

"Even grabbing the block can be quite challenging as the user has to learn how to operate the manipulators and how sensitive they are. They have to both rotate the arm and activate the grab function," said Tousi.

"We often get feedback from companies asking us to edit the software, add or even remove sensors if they aren't included in a model. We can easily change the sub menu, eg, to show images for pitch and roll and other missions.

REMOTE CONTROL

Oceaneering and bp conduct first ROV remote piloting operation offshore West of Shetland to increase safety and reduce environmental footprint

Oceaneering International has successfully conducted the first onshore remote piloting of a remotely operated vehicle (ROV) in the UK sector for bp.

The operations were conducted from Oceaneering's Onshore Remote Operations Center (OROC) in Stavanger, Norway.

Oceaneering was tasked with observing drilling operations at bp's Clair Ridge facility West of Shetland, at 141m water depth.

ROV remote piloting from shore can increase safety and reduce the environmental footprint of operations, potentially achieving up to 25% reduction in offshore personnel on board (POB) and provide a significant reduction in emissions associated with the work.

Oceaneering and bp worked together to ensure secure offshore connectivity for the remote ROV piloting operations. This required a complex setup process to establish a bridge between the data networks of both companies, without compromising their respective cyber security policies. The result of the collaboration established a secure data link via subsea optical fiber to the worksite offshore.

The Stavanger-based remote piloting team operated the ROV for over 70 hours during the campaign program with 100% uptime.

ONE CAMERA IS NOT ENOUGH

COMING TO AN ROV NEAR YOU

Specialist underwater Virtual Reality company Blue Ring Imaging is introducing the advanced diver-operated 360 deg camera technology it originally developed for Hollywood, to the small screen of the ROV control room.

Underwater operations can demand a wide range of camera types. Engineers involved in integrity inspection, for example, require cameras to be positioned as close as possible to the target in order to capture and record images in as great a detail as possible. There are other operations however, are that require the exact opposite in imaging properties – for the field of view to be as wide as possible.

This latter market could soon see a useful boost with optical technology company Blue Ring Imaging planning to introduce its enhanced 360deg 3D spatial awareness tools that it developed for the film industry, and apply them to a range of commercial underwater applications.

“These advanced imaging systems provide high levels of spatial awareness," said Casey Sapp principal of Blue Ring. "The largest market is probably the military, where improving situational awareness is paramount.

This is, however, is equally useful in helping perform complex manipulator work with ROVs, of conducting real-time oceanographic surveys, monitoring wider subsea communities and observing how they interact.

A VideoRay ROV with a Blue Eyes arrangement

"Perhaps a company involved in training a number of divers might want to send an ROV with a 360 degree camera to accompany the group, helping the diver supervisor ensure all the trainees are fully accounted for."

There are two main issues in setting up these enhanced visual awareness systems. The first is developing a camera system to capture these images, and the second, developing a system to view them.

CAMERAS

There are two main ways of increasing the field of view.

One is to use a “Fisheye” or other ultra-wide angle lenses. The problem is that the subsequent distortion can make the image difficult to interpret in two dimensions in an ROV console.

The other is to use more than one camera or a camera with more than one lens and stitch the images together.

Combining cameras, however, introduces more seams and rely heavily on disparity algorithms for stitching and depth than stereo pair camera systems. Subtle gradients, repeating patterns, and fine details are all very common in underwater footage where disparity algorithms also often fall short.

"At the time, the broadcast-quality cameras available had a number of faults such as constant overheating, persistent SD card failures, little or no ability to review footage in real time and there was a need for the images to be heavily compressed. The niche market was also small," he said.

“We set a goal to solve this problem without any preconceived notions, progressively developing 7 individual 360 deg camera systems to provide increasingly vivid and immersive effects for creators.

“We considered marinising established terrestrial Blackmagic cameras or ZCams, the advantage being that the cameras and drivers are already in existence,” said Sapp.

“Instead, however, we decided to start from a blank sheet of paper and built the cameras from the board up using NVIDIA and Sony components. In this way, the users will have more considerably greater control over how the data is processed, streaming latency and not least, advanced underwater color correction which is programmed into the camera.

VTRUL Underwater cameras

With these unique prototypes, we shot the first the native 3D 360 degree underwater content, followed by the first live 360 underwater broadcast, and ,co-developed an underwater theme park attraction, developed many of the first workflows to handle this type of footage processing. These were developed and managed under the VRTUL brand.

In 2016 saw the launch of the VRTUL 1 (V1) camera, followed the next

Underwater Filming

DEFINITION: 4K

4K is a standardised specification for digital projection with a pixel count of 4096(h) by 2160(v). It does not only pertain to a ultra high resolution, but also defines how the content is encoded. While a number of camera systems are capable of producing 6k or even 8k images there is a strong argument to say that 4k from an uncompressed source is superior to 6k or 8k from a compressed H.264 source.

This is especially the case in underwater footage when we see compression and lost details in low contrast areas or compression artefacts caused by caustics on the ocean floor or a turbulent surface.

3D AND DEPTH PERCEPTION

Underwater, the lack of shadows and depth cues present make distance perception difficult. Pilots may struggle carry out tasks requiring situational/ spatial awareness and manoeuvring.

Operations ranging from simple manipulator movement to work such as trying to cut a wire can be particularly to execute without depth perception.

One approach is to employ a universal 3D interface of the sort popular in some recreational video applications. Driven by this market the technology has accelerated rapidly while availability even premium end devices have become less expensive. It gives the appearance of parallax.

One method was based on splitting the field of view so that half of view is used for the left eye perspective and the other half for the right eye perspective.

More commonly, is a special camera using a twin lens in a stereo pair configuration which one takes the left and another, the right image.

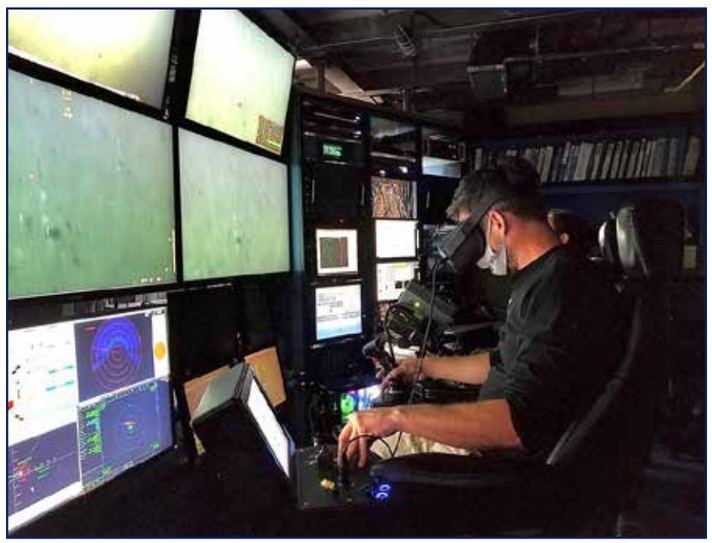
The lack of uptake in consumer television was due to the difficulty of displaying the image without specialised glasses. The use of a headset, however, provides binocular vision, similar to normal conventional sight.

year by the VRTUL 2. In 2019 the VRTUL 3 became the first 360 3D camera capable of shooting 12k per eye at 60fps in ProRes/RAW format.
It was in order to bring this technology to the commercial world, Sapp launched Blue Ring Imaging and immediately began working on bidding for DoD contracts through the Navy SBIR contracting process. Since then, the company has been awarded multiple SBIR Phase I and Phase II contracts to develop the technology for small ROVs, and even now other maritime vessels and AUVs.

Compared with the VRTUL 1, 2, and 3 camera series, today's systems are much more compact, less expensive, and made for real-time streaming. They are designed to be compatible with the demands of lightweight ROVs.

DISPLAYS
In industrial operations, Workclass ROV pilots and co-pilots typically sit next to each other in a control room facing a bank of screens streaming video from the vehicle's cameras along with an avalanche of critical information from the ROV sensors.

The pilots have to perform many tasks simultaneously including inspecting the underwater environment, and completing the mission tasks in addition to manoeuvring the vehicle.



Veiwing multiple cameras often requires multiple screens in a console. This can be overwhelming and often result in cognitive overload.

One answer is to use immersive Virtual Reality (VR) Head-Mounted Displays (HMDs). Blue Ring also builds integrated AR/VR "HUDs" or Heads-Up Displays which is a graphical interface used to control a vehicle similar to a screen on a car dashboard, but in this case all of the 3D visualization is available in an AR or VR HMD.

"We typically work with the Oculus Quest 2 and Microsoft Hololens 2 for a lot of their clients," said Sapp. Using these HMDs allows 360 3D camera videos to be displayed in their native format, compared to only getting a 2D perspective looking at a phone or PC screen.

Video showing 360 deg imaging seen using a VR headset

A VideoRay ROV with a Perch arrangement

Blue Ring connects these 360 cameras to all types of vehicles including ROVs and AUVs, and partners with the companies who builds the control systems such as Greensea to stream all of the important navigational and telemetry data into the AR/VR headset for these vehicle operators.

The enhanced view enables increased situational awareness and useability of the vehicle which wasn't before possible.

We have built many Multi-lens camera technology for 360 3D streaming. These systems are designed and manufactured in-house.

"Some are bespoke designs," said Sapp. "We have provided cameras for OceanX, Seamagine, MBARI and the US Navy for Explosive naval ordnance disposal.Each had different demands requiring different dimensions and resolutions. For the Seamagine work, keeping to a total weight of 30lbs was vital. MBARI, conversely wasnt particularly concerned about the weight but the camera had to be rated to 60000m.

"In each case Blue RIng built something that was unique to them."

OFF THE SHELF CAMERAS

Blue Ring has also developed a pair of Commercial Off the Shelf cameras.

The first, called **Blue Eyes** weighs 5.5lbs in air but neutrally buoyant in water.

The Plug and Play c system is based on a pair of 4K @ 60fps cameras for Low latency VR streaming at 30mb/sec . It features custom color correction for underwater visibility enhancement.

The second camera is the **Perch**. Slightly heavier at 6lbs in air but also neutral in water, it features three 4K @ 30fps Low latency VR Video Streaming.

Common terms when discussing cameras and imaging

FORM FACTOR
This describes incorporating a wide angle image in a single housing. Flat ports reduce the camera field of view by about a third so capturing native 360 3D images requires a dome port. Importantly, the nodal point of the lens needs to be placed at the nodal point of the dome.

BIT DEPTH
This describes the amount of colour information available for each pixel in an image. The more information, the more accurate representation of the colour. This affects the size of the image size.

DYNAMIC RANGE
Dynamic Range is the tonal difference between the lightest and darkest part of an image. The higher the dynamic range, the more potential shades can be represented,

The underwater environment is extremely demanding. Filming at depths of 20m–30m means that there is very limited available light and much of the colour information is lost.

Many camera systems record to a compressed H.264 format. This has low light performance and that subtle details such as particles in the water or distant objects are easily lost. There is very little latitude to colour grade shots in post-processing to bring warmth where most of the red spectrum has been lost.

Note the control on the top left.
It is possible to use this to steer the image view

ROV IMAGING

When Andy Marsh retired from subsea project management at Sonardyne International, he reasoned that this would give him more time to devote to his passion for Marine Conservation and filming marine life.

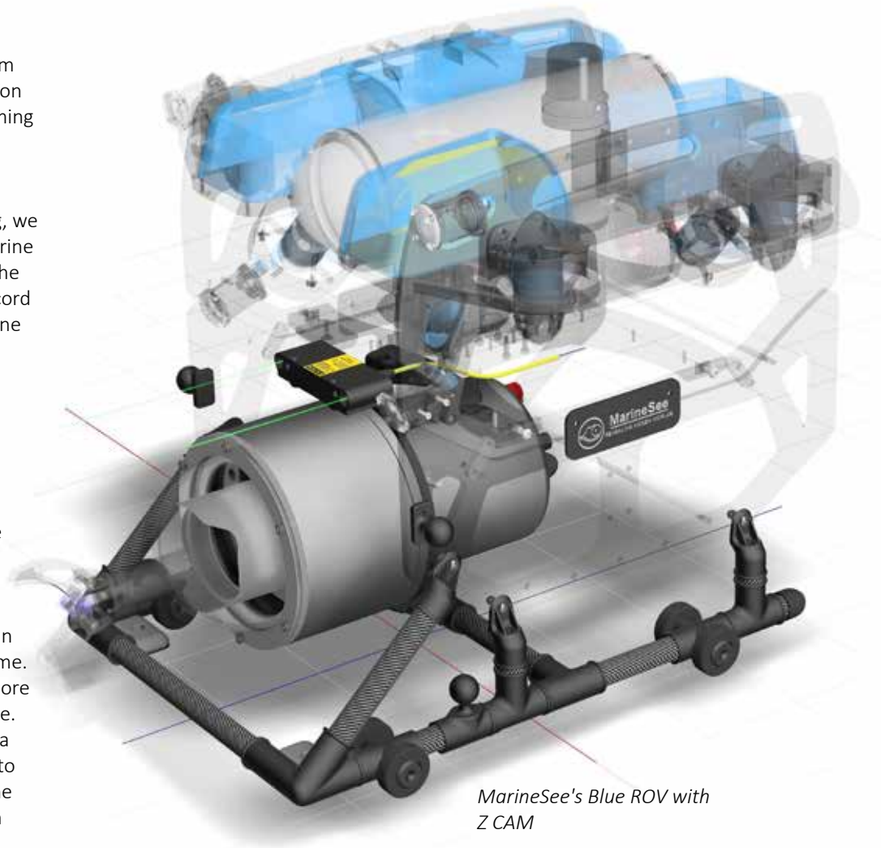
“Against a background of global warming and commercial fishing, we want to understand how the marine life is changing, especially with the influx of invasive species and record how ecosystems change when one particular species is removed or added,” said Marsh.

As such, for some time, he and other recreational scuba divers have contributed to Seasearch, a knowledge base, monitoring underwater habitats to track the health of marine environments.

In practical terms, diving in 25m water depth means no more than 30mins on-bottom at any one time. This made him look for a for a more practical, non-invasive alternative. One such was to trial and prove a tripod mounted subsea camera to provide a live video feed from the sea floor. The Pan, Tilt and Zoom cameras could be manoeuvred without disturbing the marine life.

The fixed tripod, however, presented problems in attaining the desired camera position while slow transits were also difficult to achieve. It was decided to invest in a ROV. He founded the company Marine See to commercialise the venture

"The BlueROV2 is easy to customise and its 6 thrusters provide a smooth and stable, yet



MarineSee's Blue ROV with Z CAM

Z CAM E2 Cinema Quality video camera

highly manoeuvrable performance" said Marsh.
"It also has depth lock for the slow transit filming."

Blue Robotics provided 3D computer models which enabled him to design a Pod for the Z CAM E2 Cinema Quality video camera

"Mounting the Z CAM in a

The Z CAM in a Waterproof Enclosure

watertight enclosure and connecting it to the surface via an Ethernet umbilical, allows the user to adjust the settings such as the focus, exposure and white balance while filming, vastly improving the quality," he said."

Marsh also built a sled frame to mount the camera and lights.

One problem with the new ROV was the considerable amount of cabling. Marsh employed skills learned at Sonardyne to design a surface control system where the umbilical from the ROV plugs directly into the box that separates the Ethernet ports. allowing the Z CAM to be viewed on a different virtual screen.

"Looking at a computer screen on the back of a boat in sunny weather is often challenging," said Marsh. "We came up with the solution,therefore, of using an Oculus 2 VR headset to view the Z CAM output. It is like looking at a huge screen in a cinema."

In practical terms, this arrangement enables the pilot to navigate using the main screen while the camera operator can independently monitor and control the live Z CAM video feed.

“The new arrangement is simple to use with exceptional clarity as the Z CAM can shoot 4K or even 6K," said Marsh." I have also used a Olympus M.Zuiko Pro f/1.2 Lens which means that even if it's dark or poor lighting, it still produces a good video.

“As the water depth increases, red is lost from the visible spectrum, so I have included a pair of red lights as well as four white lights at the top”.

“The Blue ROV also includes a manipulator arm, which has allowed us to take down some bait to the seabed, back off and film fauna scrambling over it. In one film, we saw three cat sharks, a spider crab and an edible crab all fighting over a carcass – something difficult to film by a scuba diver”.

Tripod mounted camera

One perennial problem with filming underwater is the difficulty of measuring subjects because of a lack of scale. Marsh therefore designed an instrument consisting of a pair of green type IIIa lasers 100mm apart that can be turned on and off from the surface.

It is simple to freeze frame and scale whatever the object is on the seabed.

Laser Measurement

Blue ROV arrangement

SAPIEN SEA CLASS ARMS

RE2 Robotics is developing its Sapien Sea Class manipulator arms. Originally launched in mid 2021, these evolved from core technology devised under its MDMS programme (UV2 2021 Issue 1). The company is carrying out research with the aim of coupling the manipulator to the main ROV controls.

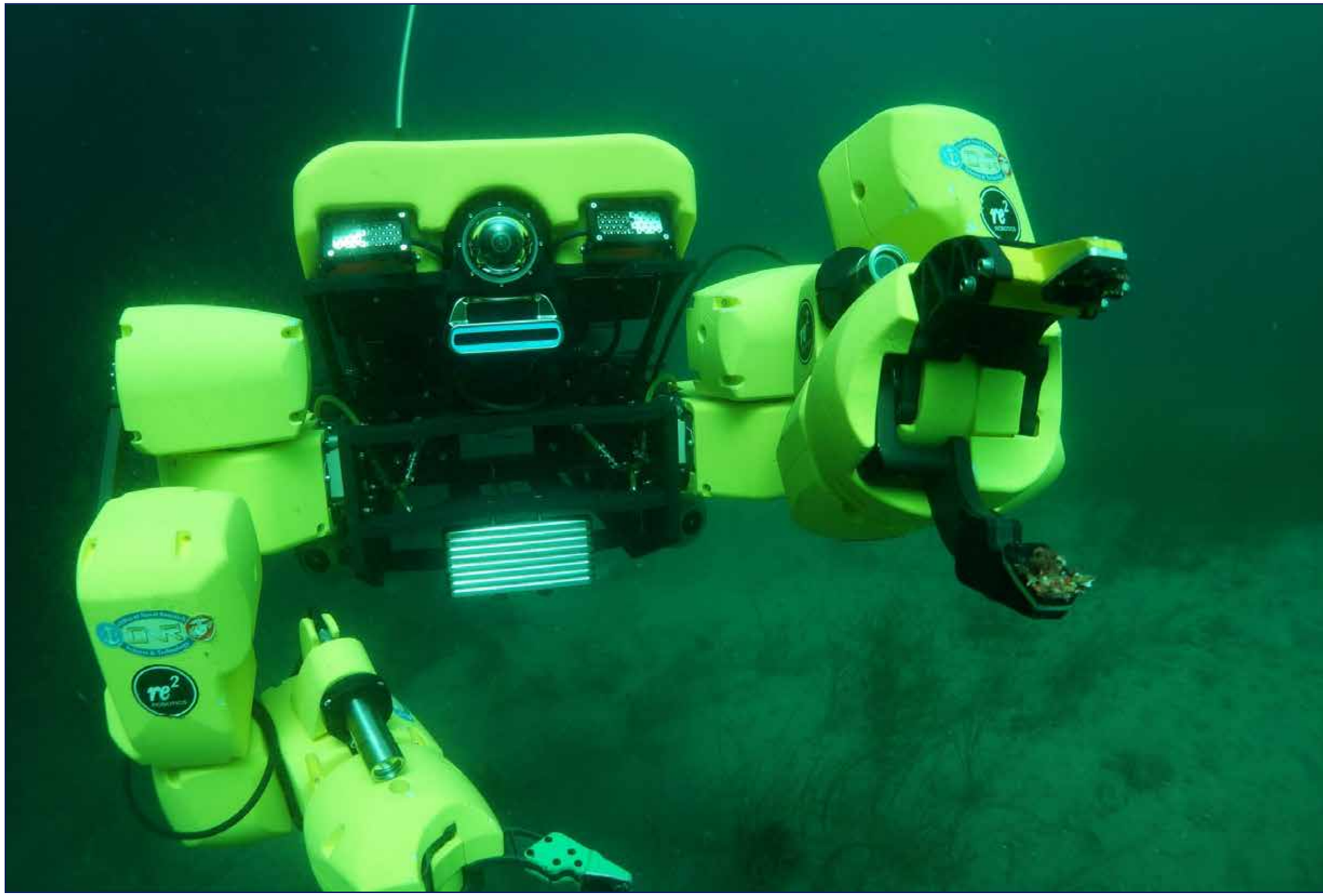
One particular application recognised the company is for underwater mine neutralisation. Last September, RE2 Robotics received a $9.5 million contract from the Office of Naval Research to create an underwater robotic system for the autonomous neutralisation system. Called Maritime Mine Neutralization System (M2NS), the programme will use the new Sapien Sea Class manipulators system to precisely place and attach neutralisation devices to both underwater and water-borne improvised explosive devices (WBIEDs). RE2 will serve as the systems integrator for this programme.

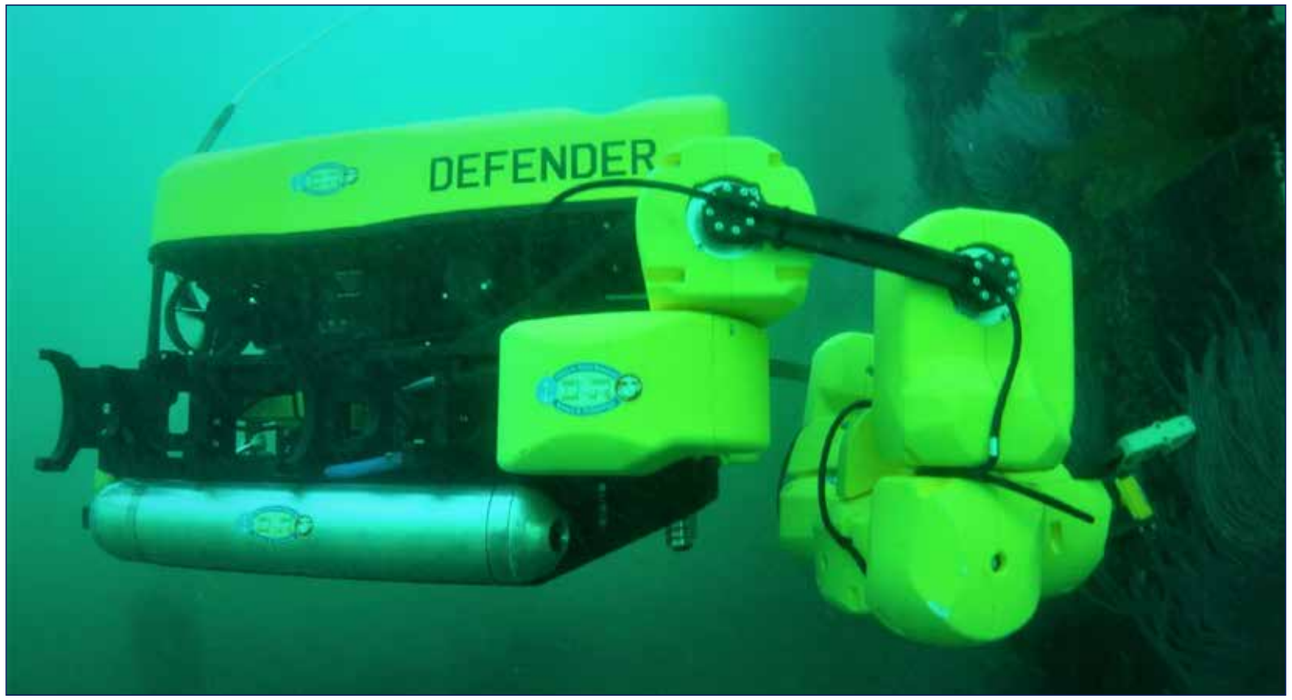
In addition to Sapien Sea Class arms, the M2NS programme will use components, including RE2's advanced computer vision and autonomy software, RE2 Detect and RE2 Intellect, to enable the precise, autonomous, and clandestine neutralization of a target.

SAPIEN ARMS

The Sapien arms are compact, strong, with human-like dexterity (7-function per arm) but the characteristic design feature is that they are neutrally buoyant. The system can be teleoperated, keeping a human in the loop, or operated via autonomous or semi-autonomous control.

The designers say that the electronically driven, energy-saving system prolongs runtime and





Arms on the Defender

frees up subsea UUV power for cameras and sensors to interrogate the environment.

Lightweight, compact design allows for smaller "footprint," or volume, in constricted or precarious environments while the neutral buoyancy ensures system stays balanced and controllable at any depth.

The closed, sealed design protects electrical system from water ingress and grit, reducing system maintenance and downtime. It also has a multi-level corrosion management system, including the use of sacrificial anodes and anodized joints, allows for extended subsea interactions.

The M2NS will use RE2 Detect computer vision software to locate targets underwater, and RE2 Intellect to autonomously and precisely place devices on those targets," said Dr. Amanda Sgroi, director of computer vision and autonomy at RE2.

"We also will integrate new sensors to provide situational awareness and aid autonomy, allowing the system to potentially navigate to extended depths in the ocean."

CLAMS

More recently, RE2 Robotics was awarded it a Phase I Small Business Innovation Research fund to develop a single control system capable of "coupled control" of a remotely operated vehicle (ROV) and its robotic manipulator.

According to RE2, the project, named Coupled Locomotion And Manipulation System (CLAMS), will combine its robotic arms' control system and an ROV control system into one unit that aims to improve coordination of the underwater manipulator and the ROV's movements.

That will then allow operators to control the robotic arms and the ROV simultaneously using one control system, improving the ability for operators to complete complex, underwater tasks.

"Currently, robotic arms and ROVs are controlled with separate control systems," said Jorgen Pedersen, president and CEO, RE2 Robotics, in a release.

"CLAMS will enable both the robotic arms and the mobile platform to be operated with a single control unit. Integrating these platforms will enable users to increase efficiency by eliminating the need for an operator to monitor two separate control stations while completing a mission."

OLYMPIC ARM

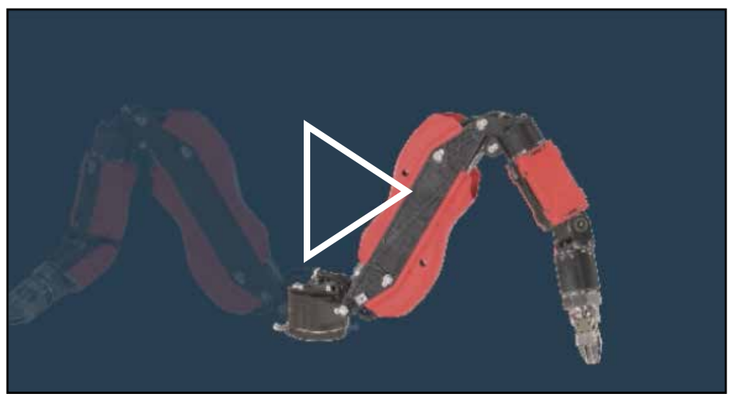
Earlier this year, IKM Subsea selected the Nauticus Robotics Olympic Arm for its subsea resident remotely operated vehicle (ROV) system.

The Olympic Arm is a fully electric work-class manipulator, increases subsea reliability and capability while extending residency dive time. It also boasts the strength, weight, and size characteristics of traditional work-class hydraulic arms without the chronic maintenance needs.

"The shift from hydraulic to intelligent electric manipulators is an obvious and necessary next step in subsea operations technology," said Adam Parsons, Olympic Arm product manager at Nauticus Robotics. "This step change advancement will provide operators greater confidence in more challenging and complex operations."

Nauticus and IKM also plan to implement the Nauticus Software Suite, which can control the Olympic Arm and open the door to more advanced and intelligent ROV automation. IKM Subsea can leverage these increased capabilities to further enhance its winning service offering.

"The Olympic Arm from Nauticus Robotics is completing IKM Subsea's all-electric platform," said Øystein Stjern, executive vice president at IKM Gruppen. "It will aid us in reducing our environmental footprint while enabling the control of ROVs from shore with a reduced number of technicians offshore. Both will help increase our value proposition for our clients."



The Olympic Arm

BACKING THE ASSP

Submarine Technology Limited (STL) is currently working on the development of the an Autonomous Synchronised Stabilised Platform (ASSP) multi-axis robotic arm. It is designed to enable the launch and recovery of underwater vehicles to be carried out from autonomous surface vessels (ASV).

STL will use the experience gained by the development of its Neptune robotic armdesigned for space-stabilised offshore personnel transfer.

Traditionally, underwater vehicles have been launched and controlled form manned surface vehicles. Quite often, those surface vessels had to be onsite already for various offshore support requirements, but equally, some were deployed by dedicate vessels. For ROVs, the vessels would suply the power and would be manoeuvred by pilpts in the vessel's controll rooms. This was notoriously expensive.

When AUVs were required, the manned vessel would often have to stay onsite until it was time to recover vehicle.In recent years, companies have looked for ways to avoid this expense.

Strategies has ranged from making the AUVs large enough to be launched from shore, to house resident vehicles in seabed garages or platforms on a semi-ermanent basis. Another idea was to deliver and launch the unmanned underwater vehicles from unmanned surface vehicles.

And there lies the problem.

Systems for getting a vehicle into the water without manned support are not common. The system bein gdeveloped by STL is employing some of the lesseons already learned with its Neptune 20M+ personnel transfer system.

This light crane was designed for the quick and safe transfer of personnel and equipment between an undulating offshore support vessel and a fixed structure such as wind turbine or hydrocarbons production facility. It was is designed around vessels equipped with dynamic positioning and can cope with a watch-keeping circle up to 3 m radius. Simulations show the system can cope with conditions with a significant wave height (Hs) of 3m. Thanks to its small footprint and low weight, it can be fitted on smaller vessels, e.g., a 54m monohull or 38m catamaran.

The Neptune arm is designed to reach 22m above deck and maintain a stand off of typically 10m. It can carry a 500 kg payload and with secure seating for 3 persons or 2 including a stretchered medical evacuation. In cargo mode Neptune has a lift capacity of 1,000 kg.
In the event of a complete system failure, the fully redundant system has a built-in self-stowing capability.

The maximum compensation ability in each dimension is 5m heave, +/-12° roll, pitch and yaw and +/-2m surge and sway.
To allow the safe transfer to and from the vessel, the system compensates for motion in all 6 degrees of freedom simultaneously (roll, pitch, yaw, heave, surge, sway).

In the future, Neptune 20M+ will be equipped with the ASSP remote sensing capability, enabling Neptune to transfer personnel and cargo between two moving objects such as a vessel and a floating wind turbine foundation, or two vessels, while compensating for the motion of both. The payload will arrive at the moving target without relative motion between them.

In 2020, STL completed initial space-stabilisation and motion-synchronisation tests on the new robotic arm. During testing, the robotic arm was mounted on the ship-motion simulator and a moving-target test rig used to provide a synchronisation target for the ASSP. Hard-wired position and attitude feedback from the ship-motion simulator and moving target were used to automatically synchronise movement of the ASSP with the target.

The current stage of the project is focused on a Remote Sensing System to allow STL's hydraulically actuated robotic systems to achieve 'Synchronous- Stabilisation' without the need for data communication between the moving target and the host vessel. This will add Machine Vision to the robotic control systems and enable the movement of target objects to be tracked.

In addition to evaluating object tracking systems, the work includes trials at in the Ocean Basin at the University of Plymouth COAST Lab with sea trials following in Falmouth Bay.

The next stage of the ASSP development is being supported by the European Regional Development Fund, Marine-I programme.

CURIOUS ROBOT

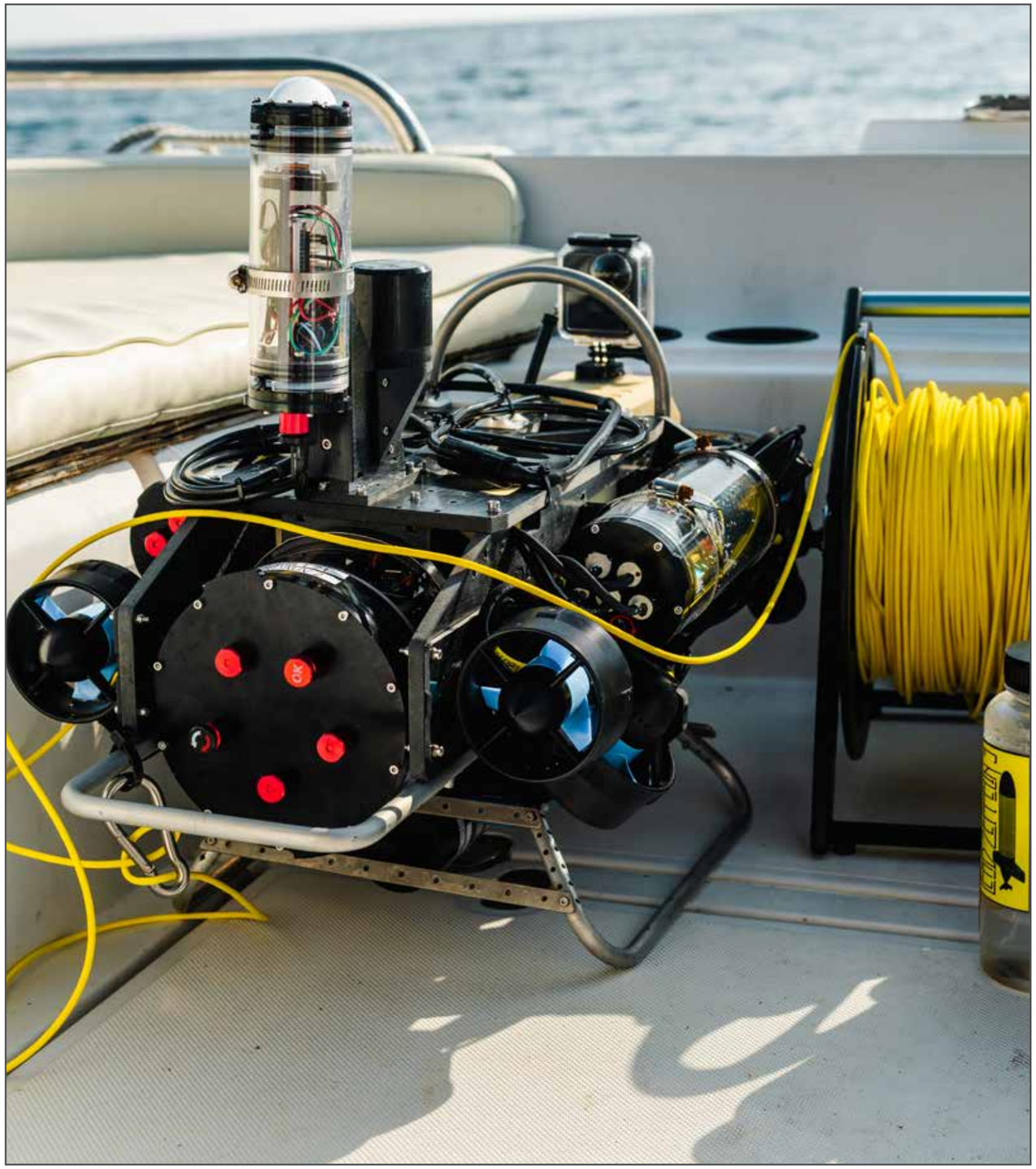
A grant by the National Science Foundation to researchers at the Woods Hole Oceanographic Institution (WHOI) and Syracuse University aims to open new avenues of robotic study of coral reefs by developing autonomous underwater vehicles capable of navigating complex environments and of collecting data over long periods of time.

The team led by WHOI computer scientist Yogesh Girdhar aims to build a robot capable of navigating a reef ecosystem and measuring the biomass, biodiversity, and behavior of organisms living in or passing through a reef over extended periods of time.

Coral reefs support the health of the ocean and support large numbers of people worldwide. About one in four marine organisms relies on reefs at some point in their lifecycle, and hundreds of millions of people derive food, jobs, and protection from storms and erosion from reef ecosystems.

A 2020 report on the status of coral reefs worldwide put the value of benefits reefs provide at $2.7 trillion per year. Despite this, reefs are in decline around the world as a result of rising temperatures, ocean acidification, pollution, and other threats. And scientists are scrambling to better understand complex reef ecosystems and devise ways to deal with a growing crisis.

“The tools we have right now to study coral reefs are pretty primitive,” said Girdhar. “The robots and the sensors we have at the moment can’t capture the spatial and temporal diversity of a reef at the same time. We want to amplify the capability of scientists in the field and the tools they’re using.”



The $1.5 million grant to Girdhar and a team that includes Aran Mooney, WHOI biologist, Frants Jensen, research assistant professor at Syracuse University and former WHOI postdoctoral fellow, and Seth McCammon, WHOI postdoctoral scholar, is entitled *“An Ecologically Curious Robot for Monitoring Coral Reef Biodiversity.”*

It was made as part of the NSF’s National Robotics Initiative 3.0, a program to support fundamental research that promotes integration of robots to the benefit of humans including human safety and human independence.

The robot Girdhar and his team envision will combine two basic methods of observing a coral reef—image collection and acoustic analysis—and use the information it gathers to mimic the curiosity of a trained diver to navigate and explore a reef.

Images enable scientists to positively identify individual species and locations of interest in a complex environment, but have limited range underwater. Acoustic signals can provide an overall assessment of reef health, but often lack detailed, species-specific information. Combining the two, the researchers hope to enable the robot to slowly build a detailed picture of ecosystem function and health, much as a trained scientist would over time.

Another drawback of robotic sensing has been that the presence of a moving vehicle moving underwater can disrupt the behaviour of the animals the vehicle wants to observe, scattering animals to other parts of the reef or causing them to hide.

To reduce its impact on animals’ behaviour, the vehicle will “hop” through a reef, moving for short distances, then setting down on the seafloor to observe and collect data for extended periods.

By only moving for short bursts, the vehicle will also be able to conserve power, greatly extending the length of a mission over a conventional, constantly swimming AUV and allowing it to gradually assemble a picture of where different animals congregate or how they use the reef ecosystem.

“We envision putting the robot in a reef, and having it come back in a week or month with a detailed understanding of how biodiversity is distributed across the reef in space and time,” said Girdhar.

The WARP-AUV is an autonomous robot developed and tested in computer scientist Yogi Girdhar's lab. It is also known as the "Curious Robot," and promises to use artificial intelligence to assess many aspects of reef health. Daniel Hentz/© Woods Hole Oceanographic Institution

COLLABORATIVE UNCREWED SURFACE & SUBSEA VEHICLES

Continuing to enable the use of emerging breakthrough technology, TotalEnergies has partnered with iXblue to demonstrate collaborative uncrewed capabilities for subsea inspection and asset survey operations.

Successful trials were recently conducted off the coast of La Ciotat (South of France), deploying two uncrewed platforms: iXblue DriX Uncrewed Surface Vehicle (USV) and Teledyne Gavia Autonomous Underwater Vehicle (AUV). Both uncrewed platforms were remotely controlled and supervised from iXblue Onshore Control Center, with iXblue DriX USV acting as a communication gateway between the onshore control centre and the Gavia AUV. The two drones were able to successfully communicate together, thanks to the Gaps USBL positioning system installed within the DriX gondola, and that tracked the Gavia AUV.

“With these sea trials, we were able to successfully demonstrate the combination of two light drones working in a collaborative mode, remotely controlled and supervised from the shore. Thanks to the DriX USV, we were able to track the Gavia AUV and send it new mission plans to allow the AUV to closely inspect some defined subsea features, all from the safety of the onshore control center,” explains Mathieu Lardeux, R&D Project Manager at TotalEnergies. “This opens up great possibilities for future multi-energy offshore developments. Replacing the use of conventional large, crewed inspection and survey vessels with uncrewed solutions such as the DriX USV will allow us to reduce offshore risk for personnel, decrease operational costs and lower the carbon footprint of our offshore operations.”

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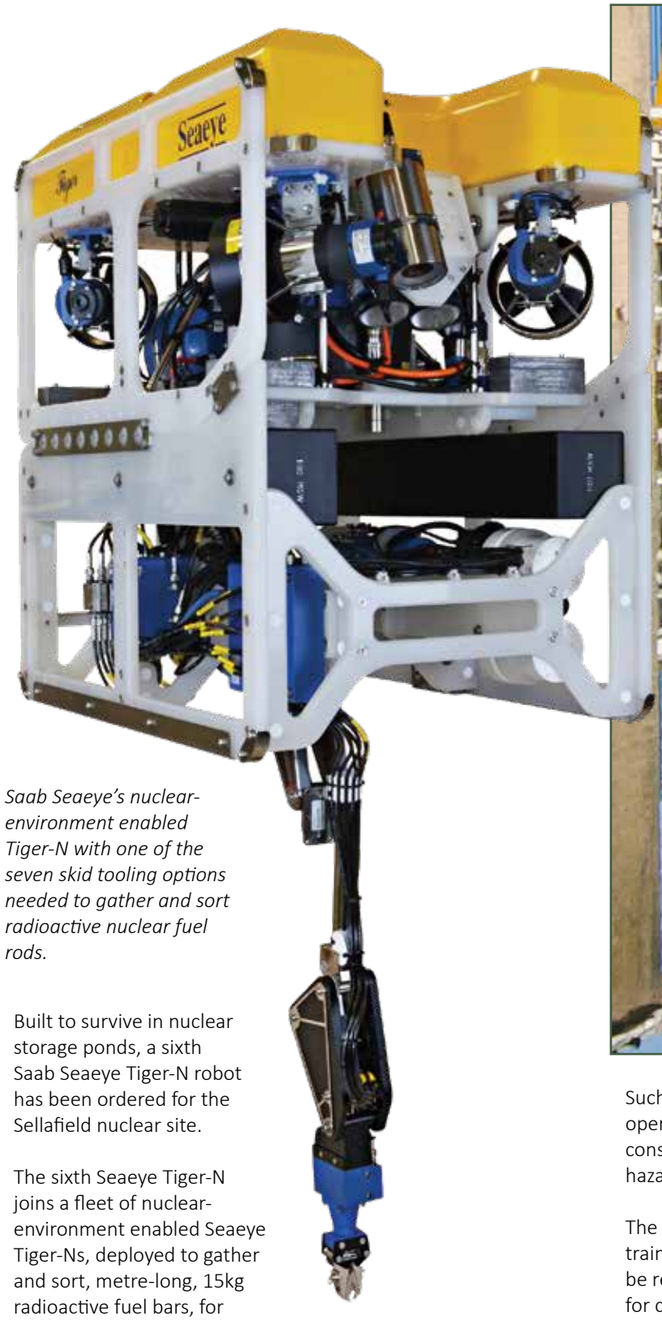


Saab Seaeye's nuclear-environment enabled Tiger-N with one of the seven skid tooling options needed to gather and sort radioactive nuclear fuel rods.

Built to survive in nuclear storage ponds, a sixth Saab Seaeye Tiger-N robot has been ordered for the Sellafield nuclear site.

The sixth Seaeye Tiger-N joins a fleet of nuclear-environment enabled Seaeye Tiger-Ns, deployed to gather and sort, metre-long, 15kg radioactive fuel bars, for removal to long-term storage, among other roles.

Specially adapted by Seaeye and Sellafield engineers for work in one of the most highly corrosive environments on the planet, the proven Saab Seaeye Tiger design was chosen for its reliability in demanding conditions.

Sellafield nuclear waste ponds - a sixth Seaeye Tiger-N joins a fleet of nuclear-environment enabled Seaeye Tiger-Ns, deployed to remove radioactive material to long-term storage.

Such reliability is vital as it limits intervention by operators for maintenance purposes, thereby considerably reducing their exposure to the hazardous environment.

The new Tiger-N replaces the Tiger-N used for training and as an operational spare, which will be redeployed to the Pile Fuel Storage Pond for cobalt cutting operations, a key operational priority for the Tiger-N robots.

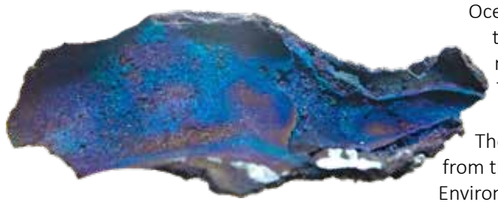
The robust Seaeye Tiger design has a 20-year record of working in challenging conditions around the world and has the thruster power and ability to manoeuvre in tight spaces with agility and precision.

ANOTHER TIGER GOES NUCLEAR

HACON

HOT VENTS IN AN ICE-COVERED OCEAN

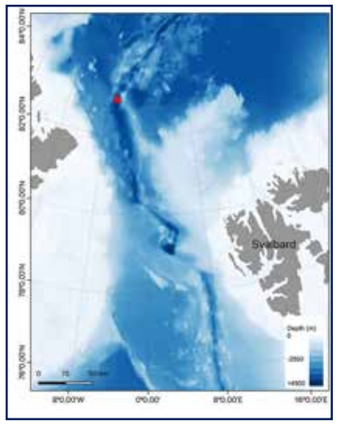
When hydrothermal fluids flow deep under the seafloor, minerals may dissolve into this hot stream. Should these fluids subsequently rise up and vent to the seafloor, any mixing with the cold ambient seawater causes these dissolved minerals to precipitate out.



Precipitated minerals on the seafloor

Sometimes, the minerals gradually accumulate to form chimneys and mounds while others give the appearance of black smoke as they vent into the ocean.

One such accumulation, the Aurora hydrothermal vent field, was discovered in 2014 on a ridge between Svalbard and Greenland during the German AURORA cruise.



Aurora vents

These vents were visited for a second time during the HACON19 cruise. Lying at a 4000m depth and *under permanent ice cover,* no ROV has been able to dive successfully to the vent field. Until now!

This was the motive for taking the vessel *RV Kronprins Haakon*, equipped with REV Ocean´s Kystdesign Supporter ROV, to the Arctic. The ROV was appropriately named *Aurora* and the corresponding TMS, the *Borealis*.

The expedition was led by Stefan Bünz from the Centre for Arctic Gas Hydrate, Environment and Climate (UiT The Arctic University of Norway) and Eva Ramirez-Llodra, from the Norwegian Institute for Water Research.

En Route to the vent field, the *Aurora* ROV carried out preliminary trials into the Molloy Deep, diving 3800m for calibration and sample-taking. The project then crossed into Greenland waters to sail through 1-2m thick ice, looking all the time for 'ice leads' (small openings).

Project planning is challenging in such projects because it is difficult to predict transit times. The extreme conditions can shift very quickly while fog can suddenly make it difficult to see. Despite using the ship's ice maps and ice radar and navigation aids, keeping to an agenda proved challenging.

The plan was to travel north and then drift south on the 0.3kt ice floe speed. The ROV was to be deployed to the Aurora Vent Field ahead of the *RV Kronprins Haakon*. The ship would then drift south, catching up and eventually passing the ROV on the seabed. At a critical time the ROV would then have to return to the ship.

This plan ultimately came to fruition, with the ROV reaching the Aurora Vents providing the first look at the black chimney, taking samples that were given to the chemists, biologists and geologists.

Kronprins Haakon

Smoker

Outside of the Arctic, deep sea water temperatures range from 2-4°C, however, diving to depths of nearly 4km recorded temperatures of-1°C on the vehicle. This was challenging, especially making the hydraulic oil from the ROV flow noticably slower.

The ROV particularly focussed on examining the seafloor communities that live at the periphery of the black smoker vents 4km deep under permanent Arctic ice. Some species thrive in the ambient sea water with temperatures reaching as high as 400° C.

Under pressure 400 times greater than that at sea level, Glass sponges attach themselves to the exposed basalt rock. Their bodies are made of silicon absorbed from the sea water which makes them feel like fibreglass. They grow slowly, and have a long life, possibly hundreds of years.

These deep-sea sponge communities are hotspots of biodiversity and biomass. They enhance nutrient cycles and provide habitat to bottom-dwelling fish and invertebrates.

Kystdesign Supporter

One key objective of the expedition was to retrieve animal samples. The ROV *Aurora* was able to successfully employ a suction sampler to draw the fauna into a chamber at the rear of the ROV. In total, a thousand animals (less than 2cms in length) were taken from three different active vents.

The biologists particularly wanted to understand if these animal communities are unique from those found on the Arctic Mid-Ocean Ridge system, up to 1000 kilometres away, or other sites around the world.

This immediately asks the question- what geological events in the past might have allowed these organisms to develop independently on the Aurora Vent Field below ice? These animals have the potential to reshape knowledge on the biodiversity of vents.

In addition to the suction sampler, the ROV incorporated an additional sampling tool set- a pair of 'biosyringes' capable of collecting volumes up to one litre each. These were deployed to collect microbial mats. Microbial mats are a unique environment, acting as both a scaffold and a haven for a large diversity and abundance of microbes. The scientists even scraped material from the biosyringes into small vials to immediately freeze at-80^{0}C as even a single sample vial contains hundreds of different microbial types.

Other scientists designed a project to try and understand exactly what life thrives and the chemical make up of these fluids. They used Isobaric gas-tight samplers to collect fluids and measure their temperatures directly from inside the hot chimney structures.

ROCK SAMPLES

In total, the HACON 2021 expedition collected 15 samples of several different rock types, including pieces of chimney walls, pieces of old collapsed chimneys, and small iron-rich chimneys constructed by microbes that live near the hot vents.

The scientists plan to analyse the age and composition of the vent deposits to understand:
1) The relationship between the composition of the chimneys, the composition of the fluids and underlying volcano;
2)How long has hydrothermal activity been occurring at Aurora;
3) If and when the location of venting and the composition of the vent fluids might changed over time.

Sample grabbing

SAMS FOR AUV

Credit: UlyX AUV first dives - Autin Timothe (2020). Ifremer

The French Research Institute for Ocean Science, Ifremer, has received its new synthetic aperture sonar (SAS) from iXblue. It will equip the institute's new 6000m-rated Autonomous Underwater Vehicle (AUV) dedicated to deep sea exploration.

This synthetic aperture sonar, the SAMS-150, offers a unique seabed mapping solution perfectly suited to deep-sea autonomous vehicles.

Benefiting from more than 20 years of development within iXblue, this technology is already being operated by world-class navies and scientific institutes. This interferometric SAS sonar allows for simultaneous real-time imaging and high-resolution bathymetric mapping of the seabed.

"With a swath width of 500m for a constant resolution of 6cm, our new SAMS-150 sonar optimises the compromise between the resolution and range of imaging solutions.

Thanks to its interferometric processing, a high-resolution bathymetric model can be generated simultaneously with the production of the imaging data, thus ensuring a coverage equivalent to more than 10 times the height of water under the sensor," explained Bertrand Chemisky, head of civil activities at iXblue Sonar division.

"Our SAS technology, coupled with an inertial navigation system and an acoustic positioning system, will ensure precise geo-referencing of each pixel, thus enabling the creation of homogeneous maps over large areas."

The SAMS (Synthetic Aperture Mapping Sonar) solution as designed by iXblue, responds to the operational objective of significantly reducing the duration of operations at sea and therefore the cost of data acquisition.

Following these same considerations, iXblue Sams sonar aims at optimising the autonomy of underwater vehicles by seeking the best compromise between mapping coverage and energy consumption.

"The UlyX AUV is capable of diving down to 6000m and navigating on mapping profiles or in quasi-stationary flight near the bottom," explains Jan Opderbecke, project manager for the development of the UlyX system at Ifremer.

“It is equipped with a suite of state-of-the-art sensors to produce a set of data on the explored area: high-resolution imagery-bathymetry data with the Sams-150, multi-beam bathymetry, and optical images aided by a laser profiler for photogrammetry.

The AUV also implements a set of modular scientific sensors adapted to the scientific mission: physical parameters, chemical analysis, magnetometry, etc.

Sams-150 was selected based on its specifications for integration and use on the UlyX AUV: size, survey parameters such as altitude, resolution and swath.

The unprecedented performance of the sonar and the data processing software chain are real assets. By combining imagery and bathymetry, the data from the Sams-150 sea trials show a significant potential that will bring scientific exploration to a whole new level.

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