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UNDERWATER VEHICLES

NEWS

MANIPULATORS

RESIDENT VEHICLES

CLEANING

ROVS

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CONTENTS

Front Cover: Deepwater well intervention work west of Malaysia with IKM Electrical Workclass ROV
Image Thinagaran Suppaiyan

Deepocean's T1000
Recovering from another successful dive.
Image: Ashley Bone

TORTUGA

ARAMCO, the Saudi national oil company, has chosen the Subsea Tech's Tortuga ROV to carry out underwater inspections and NDT operations on its offshore infrastructures.

Subsea Tech delivered a multi-sensor Tortuga unit fitted with Blueprint Subsea Oculus M750d imaging sonar and SeaTrac USBL positioning system, Cygnus Instruments FMD and thickness probes, Buckleys (UVRAL) CP probe, altimeter, two-function grabber, cleaning brush, laser defect sizing tool and launch/recovery davit.

The high payload capacity of the Tortuga allowed simultaneous integration of most sensors and tooling, which is a real performance on such compact and lightweight ROV.

Subsea Tech's Tortuga

DIVE TECHNOLOGIES

Dive Technologies has recently completed successful sea trials of a Large Displacement Autonomous Underwater Vehicle (LD-AUV). This is powered by Kraken's pressure-tolerant batteries. Kraken expects further contracts with Dive for additional batteries in 2020 and beyond.

Under the terms of the agreement, Kraken also acquired a license to build two Dive LD-AUVs for use in its growing Robotics-as-a-Service (RaaS) business.

Production of Kraken's first Dive LD-AUV is currently underway with the first unit being manufactured in the United States. The company expects that it will be delivered to its Unmanned Maritime Vehicle Facility in Dartmouth, Nova Scotia for sea trials this spring

XT500 TRENCHER

Forum Energy Technologies has secured an order to supply specialist subsea equipment for a major cable maintenance project in South East Asia.

The contract, which was awarded through Forum's local representatives, will see the company deploy a Perry XT500 trenching system and Dynacon launch and recovery system as well as associated surface power and control installations.

The equipment will be used to support telecommunication contracts in South East Asia and the Indian Ocean.

The XT500 trenching system is ideally suited to cable maintenance projects with a 3000m depth

Forum XT500

rating and 3m ROV burial capability on the ocean floor. It uses Forum's Integrated Control Engine (ICE) and has robust 500HP of power.

The vehicle will be manufactured at Forum's facility at Kirkbymoorside, Yorkshire and installed onboard the client's vessel in early 2021.

As part of the workscope, Forum will also deliver operational and maintenance training for the client's personnel and provide support during the first mobilisation onboard the vessel, including sea trials.

The system is capable of operating in free-fly, skid-based trenching and survey modes.

DEEPOCEAN UK SHUTTING DOWN

DeepOcean is winding down its UK Cable Laying and Trenching (CL&T) business. It will affect 3 companies DeepOcean Subsea Cables Limited and Enshore Subsea Limited.

The process follows an extended period of loss-making operations by the CL&T Group and reflects changes in the industry's procurement strategies and available installation capacity.

There was also a document mismatch between the CL&T Group's contractual commitments and market conditions.

Geotechnical manager Jim Pyrah has put together a valedictory tribute (*above*).

PAN AND TILT

When Kystdesign wished to mount cameras and lighting systems on Pan and Tilt units for its series of underwater vehicles, the company considered many of the existing devices on the market were unsuitable for their vehicle's requirements. Some were too vulnerable, others too low torque or simply had too clumpy a design for the appliction.

This prompted the company to accelerate the development of its own pan-and-tilt.

"The development of our KPA/KPT units has been refined over several years and the result is an extremely compact device with higher accuracy and higher torque at defined speed than most other comparable products in the market," said Managing Director Åge Holsbrekken.

Kystdesign has developed single or dual axis units with high torque that allows heavy payloads to be added. The rugged units are designed for use down to 6000m (20 000 ft). They have ±175 deg angular limits (for both axis) and equipped with absolute position sensors. They are accurate to ±0.1 deg as standard with ±0.01 deg available on request.

They have RS-232, RS-485 (2 wire) or 100 Mb Ethernet Communication interfaces with customer-selectable connectors (Seacon as standard). They operate within a 24 to 48 VDC input voltage range.

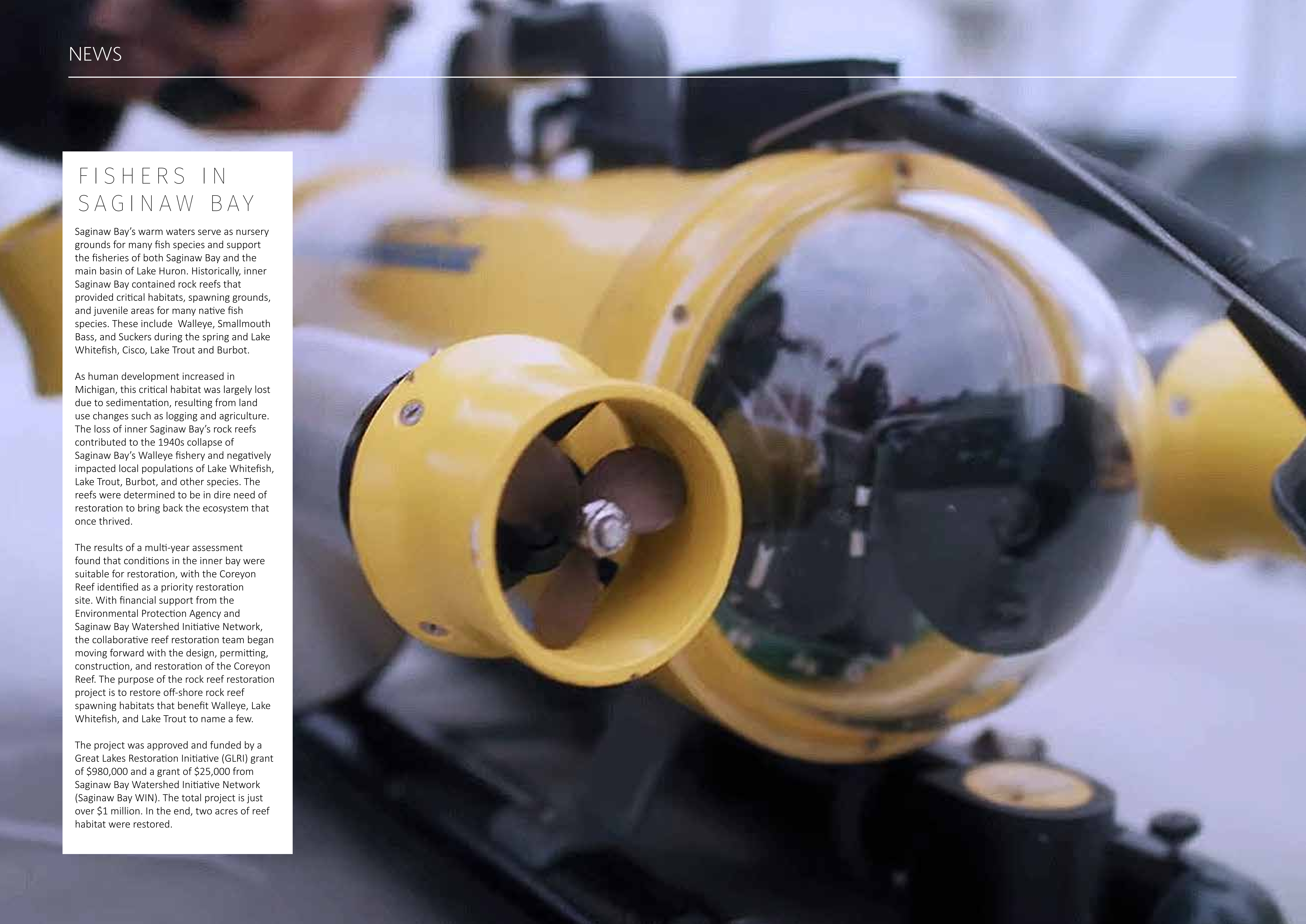
Kystdesign pan and tilt

REMUS 100

Huntington Ingalls Industries has delivered new REMUS 100 Unmanned Underwater Vehicles (UUVs) to the German Navy. The vehicles will be used to expand its current fleet of REMUS 100 UUVs used for mine countermeasure (MCM) operations.

The new REMUS 100 UUVs have advanced core electronics and endurance of up to 12 hrs. Built on the REMUS Technology Platform, the vehicles are open architecture and have enhanced modularity.

The German Navy previously acquired legacy REMUS 100 UUVs after extensive trials by the Federal Office of Defence Technology & Procurement. For the past seven years, the German Navy has been using these successfully for area search, debris field mapping, and topographic ocean floor mapping in water down to 100m. The UUVs are outfitted with side scan sonars.



FISHERS IN SAGINAW BAY

Saginaw Bay's warm waters serve as nursery grounds for many fish species and support the fisheries of both Saginaw Bay and the main basin of Lake Huron. Historically, inner Saginaw Bay contained rock reefs that provided critical habitats, spawning grounds, and juvenile areas for many native fish species. These include Walleye, Smallmouth Bass, and Suckers during the spring and Lake Whitefish, Cisco, Lake Trout and Burbot.

As human development increased in Michigan, this critical habitat was largely lost due to sedimentation, resulting from land use changes such as logging and agriculture. The loss of inner Saginaw Bay's rock reefs contributed to the 1940s collapse of Saginaw Bay's Walleye fishery and negatively impacted local populations of Lake Whitefish, Lake Trout, Burbot, and other species. The reefs were determined to be in dire need of restoration to bring back the ecosystem that once thrived.

The results of a multi-year assessment found that conditions in the inner bay were suitable for restoration, with the Coreyon Reef identified as a priority restoration site. With financial support from the Environmental Protection Agency and Saginaw Bay Watershed Initiative Network, the collaborative reef restoration team began moving forward with the design, permitting, construction, and restoration of the Coreyon Reef. The purpose of the rock reef restoration project is to restore off-shore rock reef spawning habitats that benefit Walleye, Lake Whitefish, and Lake Trout to name a few.

The project was approved and funded by a Great Lakes Restoration Initiative (GLRI) grant of $980,000 and a grant of $25,000 from Saginaw Bay Watershed Initiative Network (Saginaw Bay WIN). The total project is just over $1 million. In the end, two acres of reef habitat were restored.

There are several project partners for the restoration project, but the principals are the Michigan Department of Natural Resources (Michigan DNR) Fisheries Division and the Michigan Environmental and Great Lakes & Energy Department (Michigan EGLE), Remediation Division.

Construction began in early 2019 and was completed by the fall of 2019. The process was recorded and a documentary was filmed featuring the initial post-construction examination work.

Dr David Fielder (Michigan DNR) and his team was a major contributor to the project. Michigan DNR will be evaluating the relative attraction of the new reef to different fishes.

One acre was one type of rock while the second acre was another type of rock, and the differences in productivity can be measured.

Michigan is partnering with Purdue University on the post-construction evaluation of the reef. JW Fishers SeaLion-2 Remote Operated Vehicle (ROV) was also a key part of this project.

The ROV was used as a visual aid to ensure that the rocks were placed correctly and it was also used to monitor the new reef's activity.

Dr. Fielder stated "We did also use our JW Fishers' SSS-dual frequency side scan sonar for additional assessment but unfortunately the filming didn't capture that. On the whole, JW Fishers' equipment played a central role in that habitat work.

We will be going back out there at 'ice out' to take another look (with hopefully better visibility)." Ice out, as Dr. Fielder mentioned, is when the Spring thaw allows for sufficient melting to continue operations.

In most of the onboard footage of the documentary, Dr. Fielder is operating the SeaLion-2 ROV. The person operating the boat is Captain Bill Wellenkamp and the technician launching the ROV is Darren Vercnocke.

Later in 2019, a further $1 million was awarded for further reef work in Saginaw Bay with more to come.

SWEDISH SAFETY SALVAGE AND SURVEY

Peab Marin has selected a Saab Seaeye Falcon as a multi-functional resource to provide support for the company's marine survey, salvage and civil construction operations.

The Swedish marine services company says the Falcon will secure a safer working environment for its divers and will be an 'excellent tool' for surveying.

Importantly for Peab Marin's wide range of construction and maintenance work, the Falcon's quick and easy deployment with ready systems change and expandable systems options, make it a highly adaptable resource.

DIVER SAFETY

Diver safety is paramount and in hazardous circumstances the Falcon can be deployed to work underwater endlessly and tirelessly.

Robert Hedin at Peab describes the important role the Falcon will play in diver safety.

"Some work can offer serious risk for a commercial diver, especially Delta-P situations when the differential pressure between two water columns attempts to equalize, creating tremendous pressure/suction.

"It's a hazard that cannot be downplayed, as in some cases it's just impossible to reduce the suction in case of emergency.

"In situations like this, we prefer to send down the Falcon to either completely replace the diver's work or in order to make a proper safety assessment. It really helps us to create a safer work environment for our commercial divers.

This has been exclusive to the offshore industry for a long time, and we're really glad to see the same application moving into the civil inshore industry in Sweden."

MURKY WATER WORKING

With Swedish waters notorious for low visibility, typically 0.5m and less, and working in a wide variety of water states from open seas to waterway locks, fitting a Bluetooth multibeam sonar to the Falcon was essential.

"It is a must-have for operating an ROV in our underwater environment," said Hedin.

Deploying the Falcon. Image: Peter Steen

SOUTH AMERICAN AQUACULTURE GETS THIRD FALCON

A third Seaeye Falcon has been delivered to Chile-based Underdeep Solutions. This latest Falcon is the second 1000m deep-rated version for the company, which specialises in fish farm inspection and support throughout Chile and the region.

Underdeep's three Falcons are currently working at full capacity in the aquaculture facilities of the major aquaculture company, Salmones Camanchaca.

In addition, Underdeep Solutions has been working for several years in the removal of structures from the Salmones Camanchaca concessions, as requested by current local regulations, thus complying with the continuous plan for the removal of structures for the entire company

Along with inspecting nets and moorings, Underdeep deploy their Falcons, fitted with manipulators, to perform light work tasks around fastenings and buoys, as well as collecting and recovering items.

Their new Seaeye Falcon DR is fitted with a five-function manipulator and soft rope cutter, a Kongsberg HDTV camera, B&W reverse camera, a BlueView multi-beam sonar and an Applied Acoustic high-end USBL- that is now fitted to all Underdeep's Falcons.

Falcon DR undergoing inspection tasks

PILOTS' VIEW

The success of the Falcon in Underdeep's aquaculture work comes from its reassuring reliability, favoured by their pilots for working in isolated locations and its power, agility and steadiness in strong cross currents and harsh conditions whilst heavily loaded with equipment.

The Falcon's world-winning concept comes from having created a highly reliable vehicle packed with five powerful thrusters and Saab Seaeye's iCON intelligent power and distributed control architecture, all fitted into an easily handled metre-sized vehicle that can adopt different tools and sensors for undertaking numerous intricate and demanding tasks.

A Seaeye Cougar XTi is being considered as an addition to Underdeep's vehicle fleet. The 3000m rated Cougar has six powerful SM7 thrusters and Seaeye's iCON control system, making it ideal for handling robust equipment in strong currents whilst manoeuvring around complex structures.

Together with its aquaculture support operations, Underdeep also undertakes a range of other work across South America, including shipwreck recovery, tunnel inspection and offshore support.

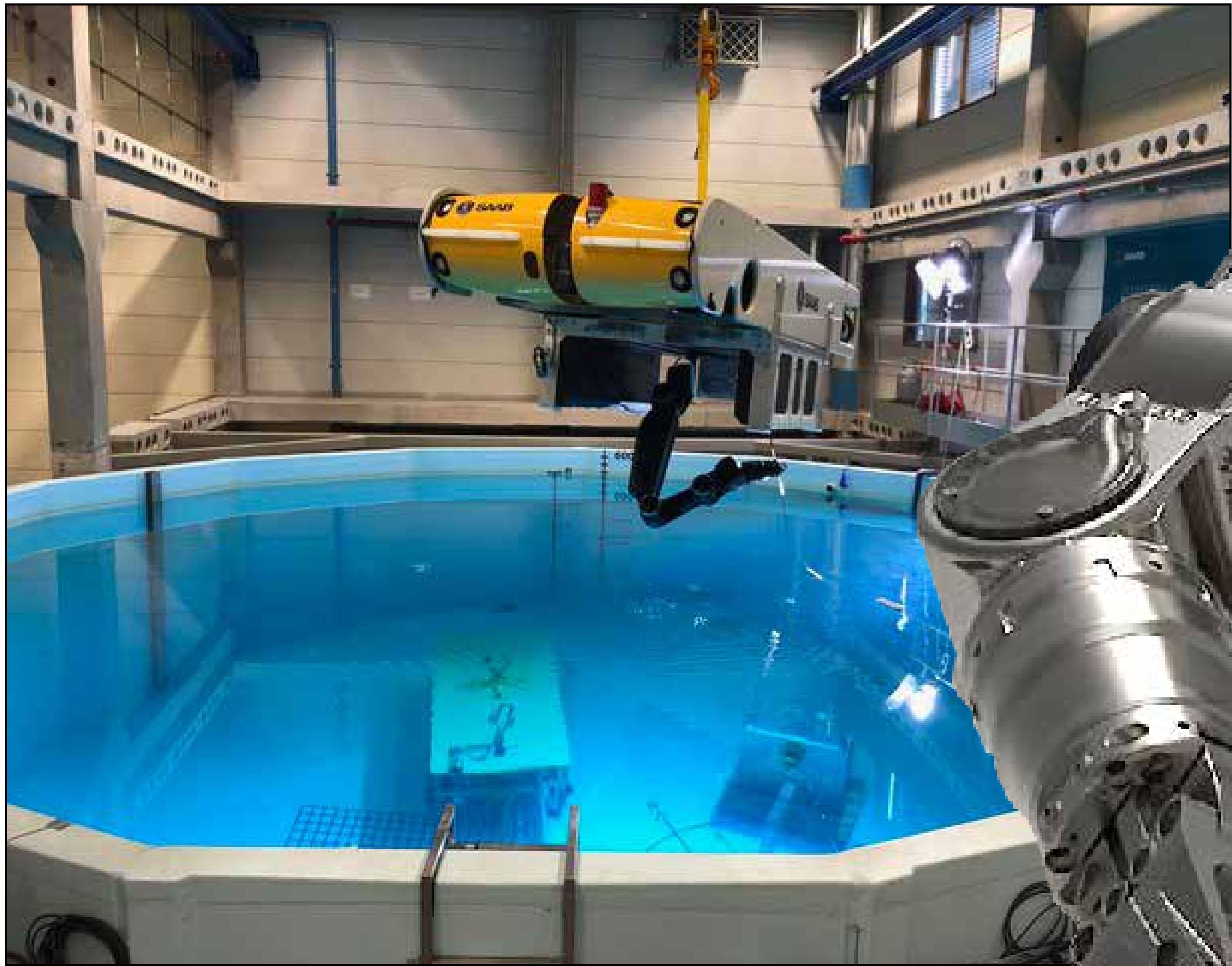
Falcon DR with five function manipulator skid

REACHING INTO THE FUTURE

Emerging technologies are blending functionalities and dissolving the historic concepts of ROV and AUV modes into a new generation of solution-driven robotics.

Advancing this evolution in underwater technology is Saab Seaeye's pioneering breakthrough, with the seven-function all-electric work-class manipulator, named Seaeye eM1-7.

The innovative manipulator advances solution-driven robotics and dissolves pre-conceptions of functionality. As such, Saab Seaeye has fitted the seven-function work-class manipulator to its Sabertooth hybrid ROV/ AUV platform as a technology demonstrator and carried out some initial integration testing.



eM1-7 manipulator fitted to the Saab Seaeye Sabertooth hybrid AUV/ROV System as a Technology Demonstrator

The eM1-7 all-electric work-class manipulator - designed by Saab Seaeye

The concept of work-class manipulation on an AUV is a revolution that vastly expands operational horizons.

The potential has attracted extensive global interest with two manipulators already delivered to a US defence company.

Not only is the manipulator equally powerful, more precise and more intelligent than the hydraulic equivalent used on work class vehicles today, but as the underwater world moves towards an all-electric future, such ecologically friendly, significantly oil-free, all-electric systems have wide appeal, in particular to the offshore energy market.

EXACTITUDE

The combined lift capacity and range of motion of the Seaeye eM1-7 exceeds that of any manipulator on the market, along with its superior accuracy, precise repeatability, high-resolution force and position feedback for greater arm control and path planning.

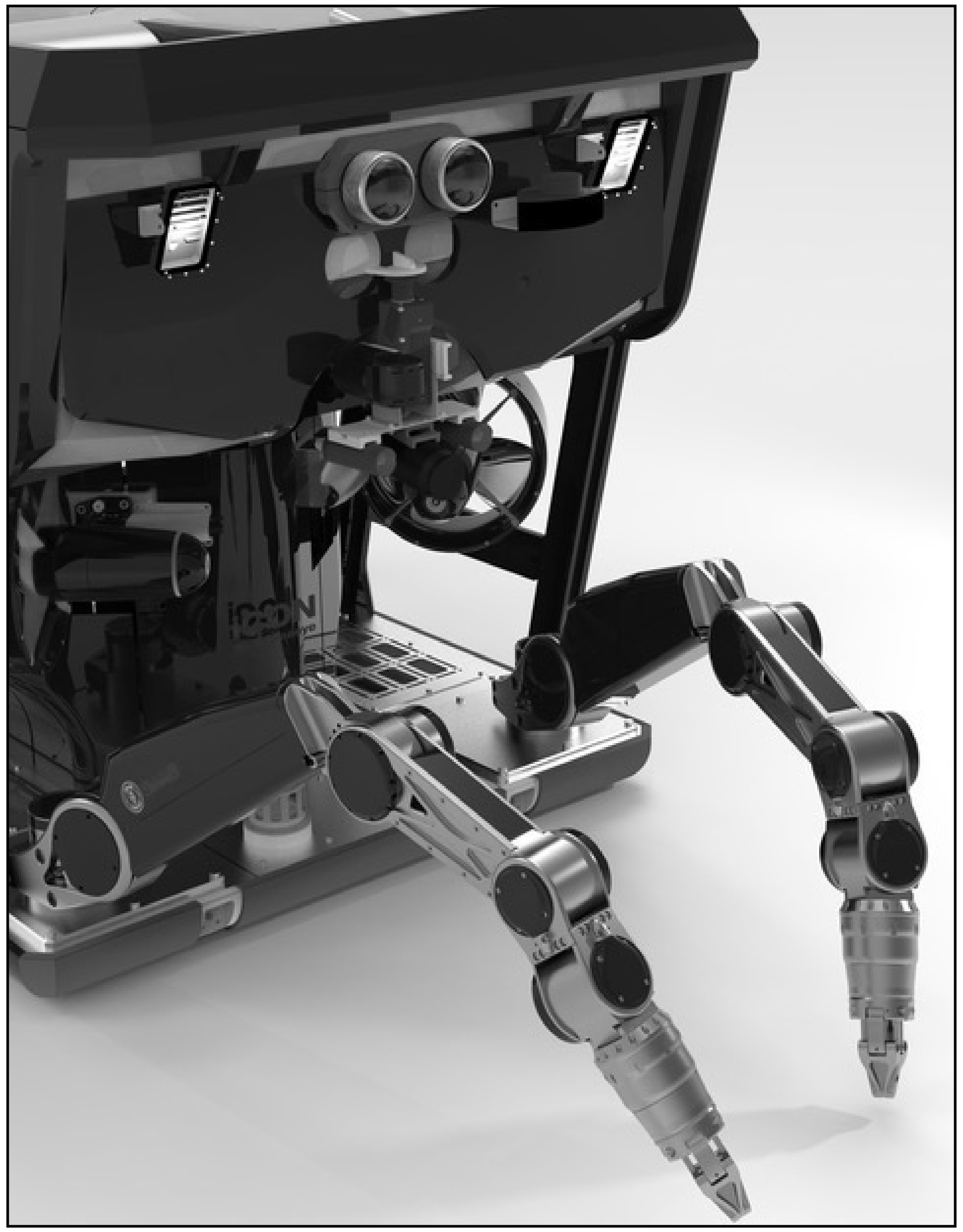
The manipulator's intuitive control simplifies use by mimicking the movement of the master arm. Algorithms predict and manage movement at each joint.

Millimetre precision comes from each of the seven joint modules having their own self-contained smart microprocessors for intelligent, intuitive and precise arm control.

This brings exacting, repeatable precision. The system can predict limb motion paths for self-collision avoidance and adjust movement requests to meet available power, collating joint data for unified control.

Included in the design is an adaptable power input system with advanced power management to limit peaks in power demand and manage regenerative loads.

Tested through many millions of cycles, the manipulator's reliability is expected to reduce operating costs.



Dual eM1-7 manipulators fitted to 250HP Work Class ROV System.

REDUCED MAINTENANCE

Although packed with advanced technology, the work-class manipulator requires far less maintenance compared to hydraulic systems.

Reduced maintenance and reliability through electrification have created a system that, in addition to conventional vehicle deployment, is ideally suited to onshore control with USV deployment or long-term immersion with resident systems.

Designed to be future friendly- the manipulator's advanced technology will enable the transition from manual control to supervised autonomy with advanced perception systems and towards full autonomy.

TWIN MANIPULATORS

SCHILLING ROBOTICS' NEW GEMINI ROV INCORPORATES A REVOLUTIONARY TOOL SELECTION AND CHANGING SYSTEM. MORE TOOLS CAN BE EXCHANGED, QUICKER AND WITH HIGHER RELIABILITY TO INCREASE THE SPEED OF UNDERWATER OPERATIONS

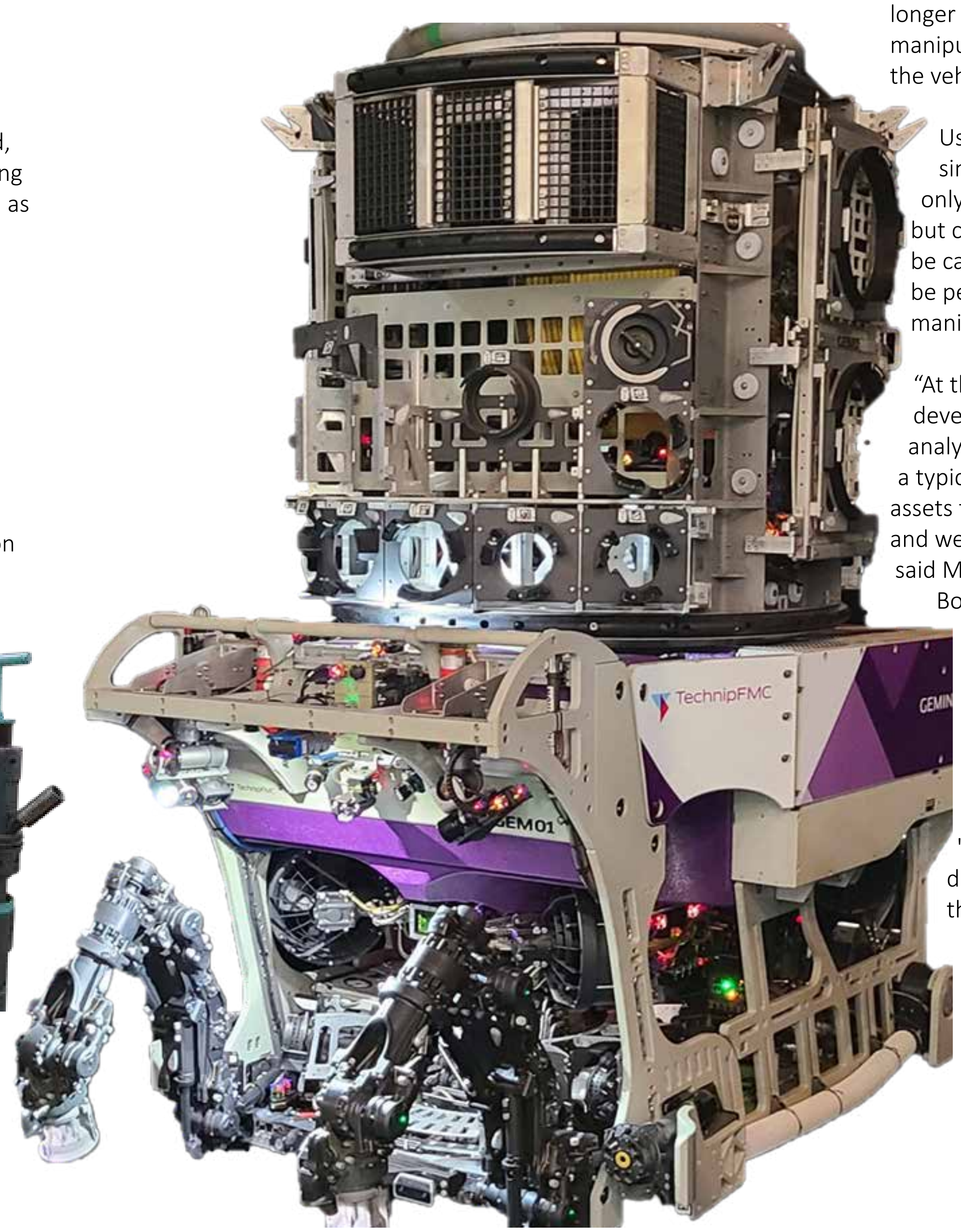
The constellation Gemini is often associated with twins. Schilling Robotics selected this name for its latest ROV to highlight a definitive feature of its design – a pair of ingenious manipulators.

Most workclass ROVs incorporate a pair of arms. The arm the left is almost invariably a strong grabber that can be employed to grip the railing system in front of an interface panel in order to stabilise the entire vehicle. This allows the second, more dexterous, arm to be employed in conducting more precise and delicate intervention tasks such as inserting a tool into a receptacle.

When designing its Gemini ROV system, however, Schilling Robotics took a different approach to carrying out these sort of routine operations.

Over the years, underwater positioning systems have evolved to the point where the ROV can reliably stay in position with a high degree of confidence. Schilling's own system, called 'Stationkeep' is able to maintain the ROV's position within a 1in watch circle, in a 2kt current.

Types of conventional tool handle



With this sort of positioning accuracy, the designers argued that the classic grabber was no longer necessary and instead, TWO manipulators could be installed on the vehicle.

Using two manipulators simultaneously would not only speed up operations, but conceivably, allow work to be carried out that could not be performed using a single manipulator.

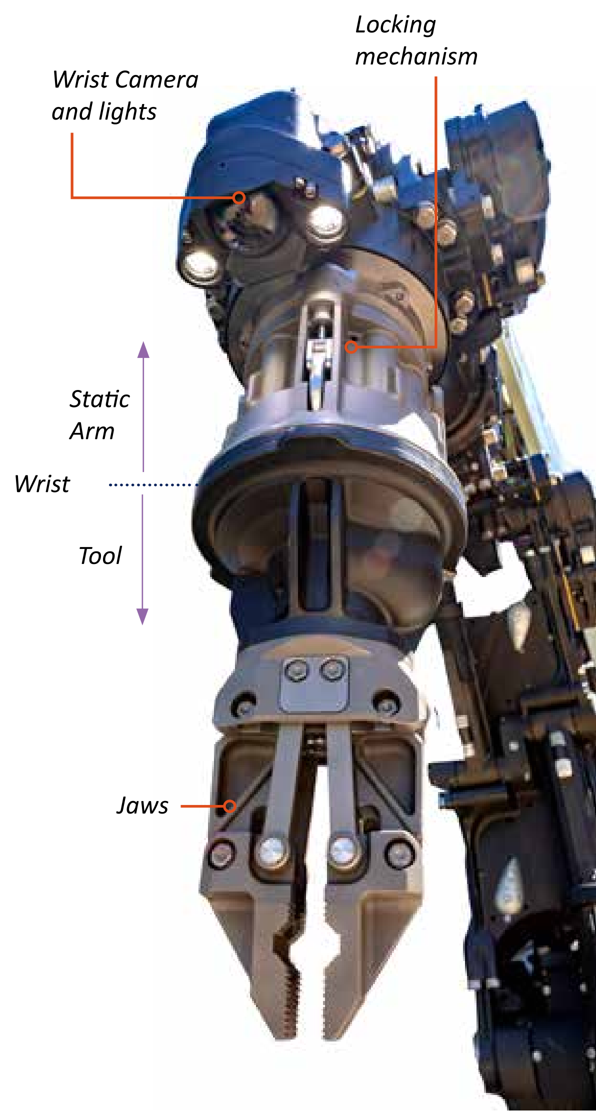
"At the start of the Gemini development project, we analysed the interactions between a typical ROV and the underwater assets throughout a 120 day drilling and well completion campaign, said Mechanical Engineer Mitchell Bosler.

"We then focused on how best to achieve all of those interactions.

"At present, pilots use the manipulator jaws to pick up tools by their handles. "The tool handles are designed to correspond to the manipulator's jaw design or conversely, if the ROV's manipulator has to pick up a tool, it must ensure it has the correct jaw design installed.

TOOL CHANGE

Instead of the jaws picking up the tool by the handle, the designers at Schilling Robotics envisaged a novel tool-changing system.



Video: Manipulator arms exchanging tools prior to intervention. Interfacing with tooling carousel Time 2:14

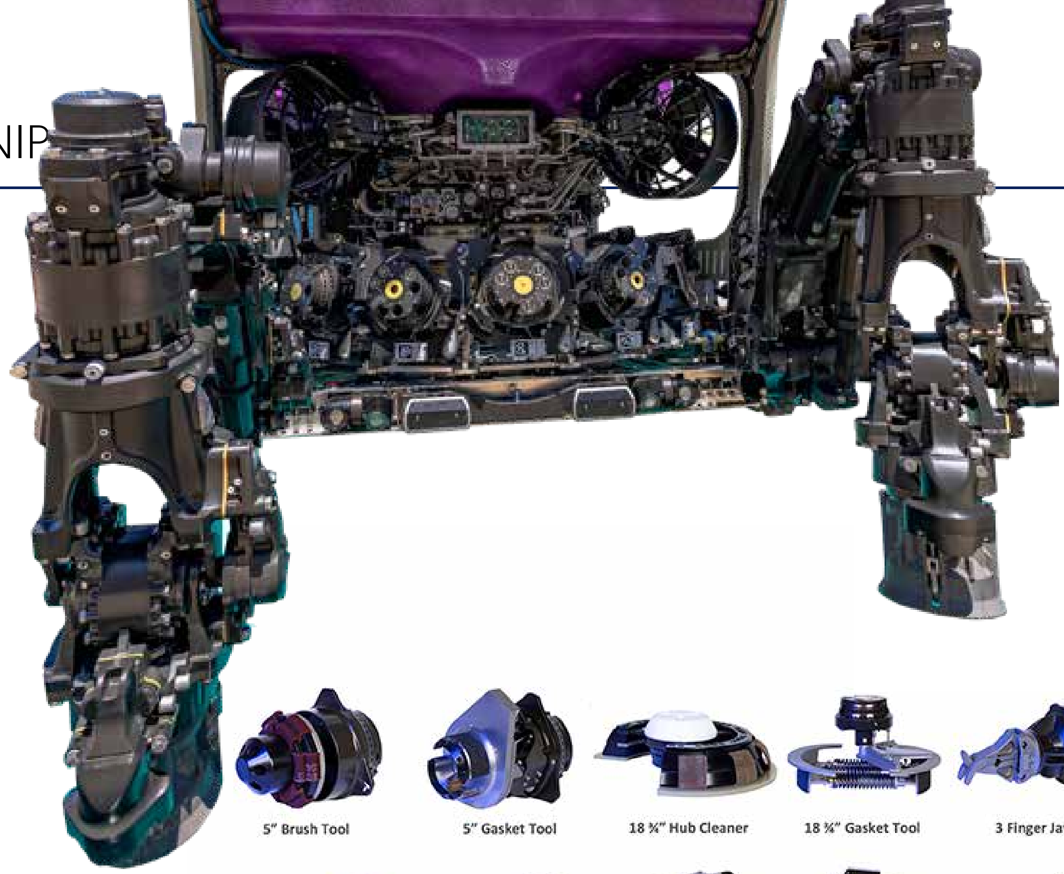
The manipulator arm no longer terminates in a set of jaws, but instead, at the wrist. Meanwhile, the actual tool is integrated into a purpose designed body and obviating the handle entirely. The tooling body and the manipulator wrist are connected via a bayonet-type interface. This allows a *much* more secure attachment.

Over the years, the industry has developed numerous different types of underwater tools to carry out a range of applications. An average 2-4 tools are used on each job.

Clearly, a round-trip to the surface to re-load the tools may take many hours. Historically, this was eliminated by a range of tools being housed in a specialised tooling basket located within the ROV. The action of exchanging the tooling – placing one in the basket and picking up another tool by its handle is a manual process.

For the efficient storage of these tools, TechnipFMC designed a universal

Torque tool



storage receptacle. To allow immediate access to a large number of tools, the Gemini engineers designed this tooling storage system as a rotatable carousel where up to 15 devices can be stored.

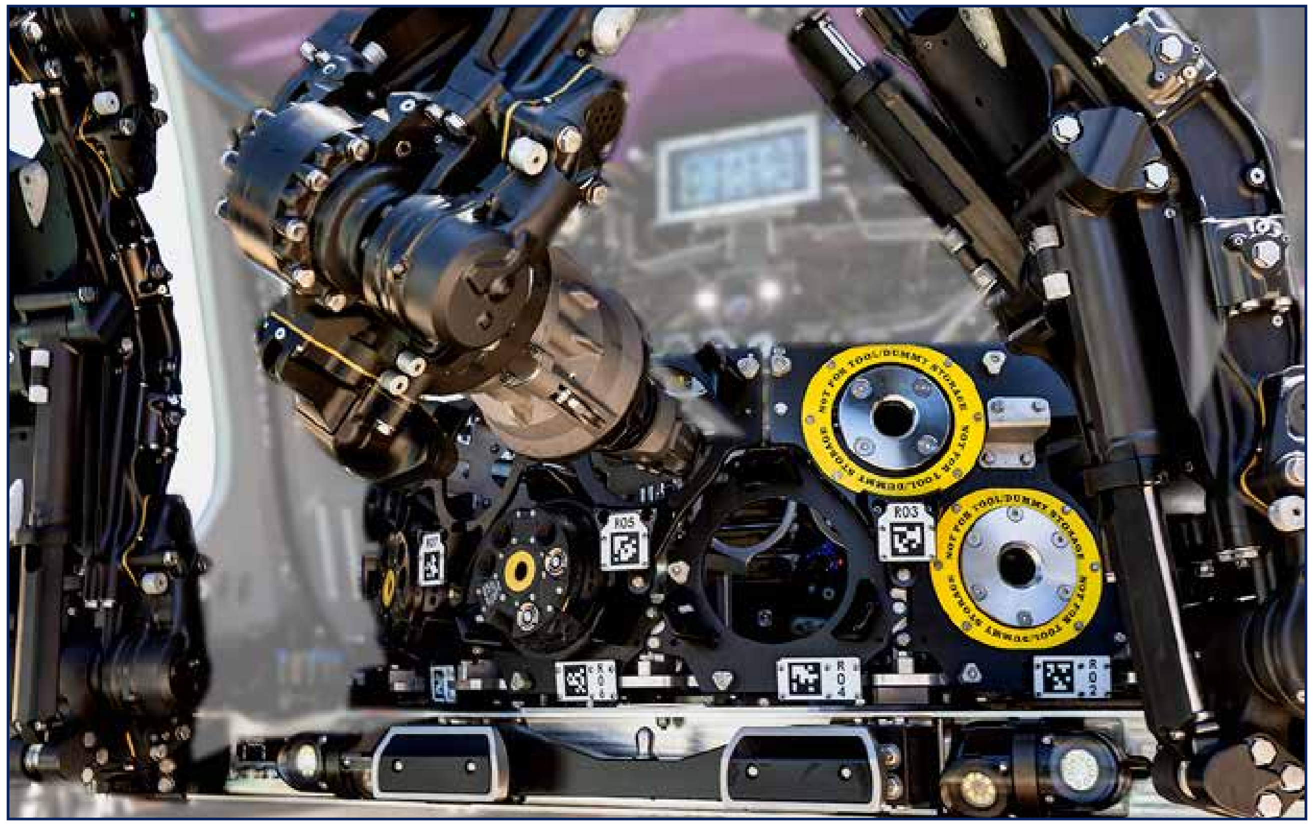
The carousel presents a selected slot to the front of the ROV, The pilot inserts the end of the manipulator into this empty receptacle, unlatches and stows the tool. The carousel then rotates until the desired tool is now presented at the front. The manipulator locks on to this and once it is securely latched, it is the tool is ready to use. The novel part of this manoeuvre, however, is that this process is carried out entirely automatically.

"The Gemini tool-changing wrist was designed to allow access to a large suite of tools with a simple, reliable and repeatable process that any pilot can execute," said Bosler.

Up to 20 more devices including large and odd shaped tools are stored on the tether management system (TMS). The ingenious manipulators can also acquire and replace tools from the TMS with an automated sequence requiring minimal input from the pilot, despite the challenge of TMS motion.

TOOL POWER

Many tools require access to the ROV's power while others such as fluid injection systems need access to a reservoir. Historically, this has been provided by an external umbilical.Despite their robust design, however, these free hanging flexible hoses can get easily damaged.



The manipulators exchanging a tool in a carousel

The Gemini manipulator designers solved this problem by actually running the power and fluid conduits through the inside of the manipulator arm.

"We have spent the last five or six years developing our machining technology to manufacture manifolds with exceptionally long gundrills in Aluminium," said Bosler.

"That ability allowed us to design the fluid conduits into the structure of the manipulator, completely eliminating the need for hydraulic hoses within the arm."

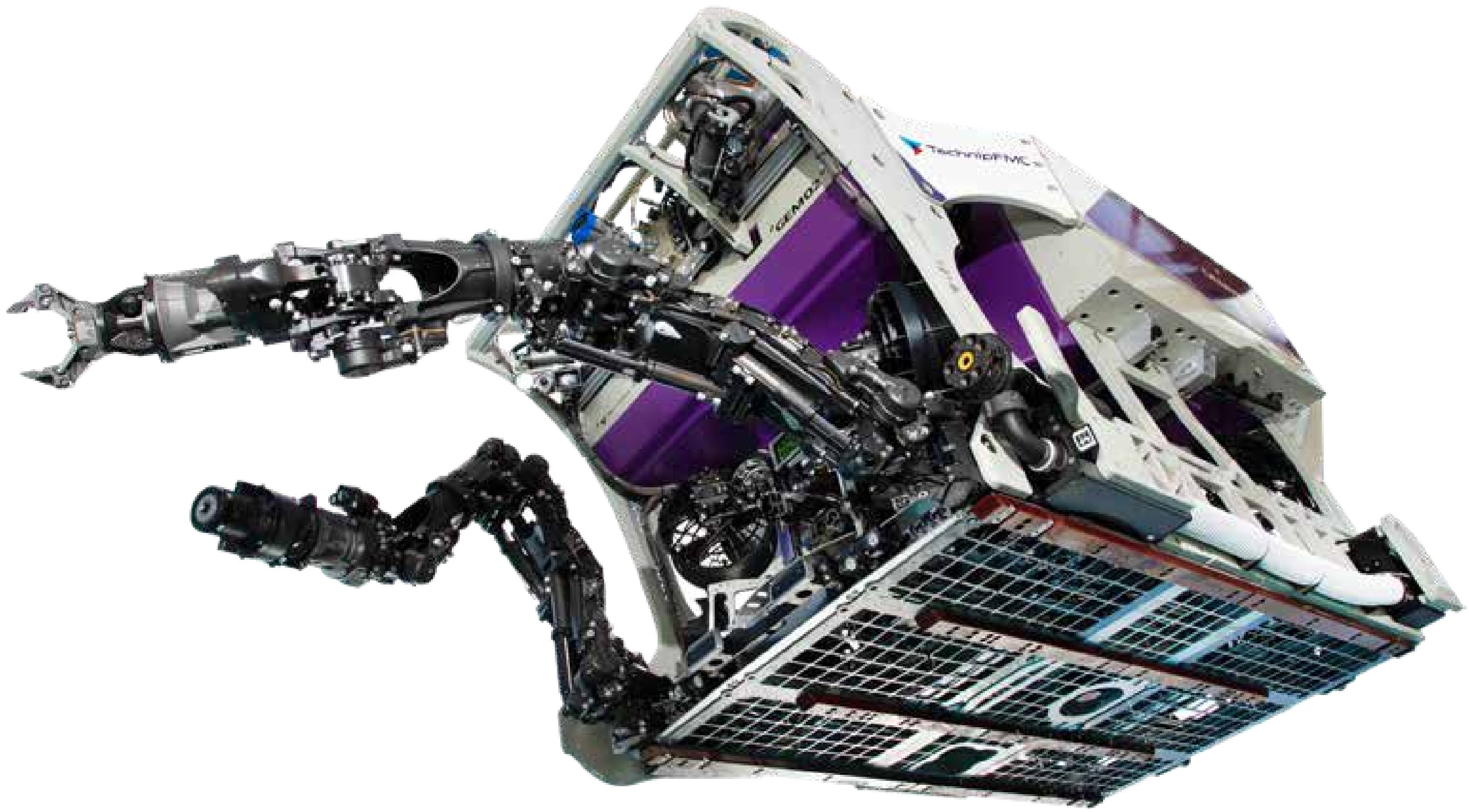
The routing, however, was somewhat challenging.

"Within the manipulator arm, there are nine fluid passages running from the base all the way to the wrist," said Bosler. "Three of these are for the manipulator control actuators, there are another three for the auxiliary tools circuit and a further two are dedicated to the fluid delivery circuit, for example, delivering water/glycol to assets.

"The last one is a maintenance seal drain. There are many places where fluids are routed next to each other through a slip ring or manifold. A seal drain in between prevents cross contamination in the event of a leak."

While enclosing the conduits within the arm affords improved reliability from the elimination of hoses, would doing this make maintenance more difficult?

"Not at all", said Bosler. "The new



design actually makes it much simpler to maintain because we have divided the arm into a number of replaceable units. All replaceable units can be removed and replaced with a single 19mm socket.

“A good example of this is the joint controller unit. In a traditional manipulator, the joint control valves and controllers are gathered together in one location and the position sensors are distributed throughout the arm. In the Titan arm, they are located in the forearm although in most manipulators, the valves and controllers lie within the vehicle itself.

In the Gemini however, the joint controller incorporates the control valve, position sensor and control intelligence all packaged in a single unit and held in place by four fasteners. This makes it easy to remove and replace all of the joint control elements in one operation.

In addition to the fluid and power conduits, the arm also incorporates a high bandwidth Ethernet communication system running through the arm on flexible printed circuits. These snake seamlessly through the arm and are not even visible from the outside.

"In total, 100 Mbps Ethernet communication and 120W of electrical power can pass across the arm-tool interface to provide power, control and bidirectionally pass data between the control system and the tool," said Bosler.

Schilling Robotics is already imagining ways that this interface could be used to communicate with a whole breadth of subsea assets including tree systems.

The power and communication delivery through the arm to the wrist potentially enables the use of intelligent tools such as position sensors for jaw tools or to control a secondary intensification pump in a high pressure intensified hot stab or the new intelligent torque tool.

In the future, this high bandwidth communications system and fluid delivery infrastructure might

be used to communicate with external systems but at the moment is specifically limited to intelligent tooling.

SUBSEA INTERVENTION

“One common underwater operation requires the ROV operator to insert a 'hot-stab' tool into a receptacle within a piece of subsea hardware. It can be when viewing the operation remotely, underwater, with a slight but noticeable latency and in two dimensions through a remote camera.

"Even a slight misalignment prevents the hot-stab from cleanly inserting into the receptacle. Any jamming can possibly push the entire ROV backwards or potentially damage the critical interface. In order to improve the tool/asset interface process, Schilling has developed an advanced force control feature.

"If the tool enters the receptacle at an incorrect angle, sensors located around the periphery of the wrist measure reaction force and moments between tool and asset," said Mitch Bosler.

"Feeding this information into the assisted automation software allows the manipulator to reorient the tool in real time to relieve these forces and allow the probe to slide in freely. This is done without any ROV operator input – it is a completely automatic function."

Another common offshore support operation is to use a torque tool to turn a valve. In traditional systems, torque control usually uses open loop systems with questionable accuracy.

The torque tool that Schilling has designed incorporates highly-accurate closed loop torque control technology that connects to the wrist interface and is integrated into the Gemini control system.

“When you look at many of the actual functions an ROV is providing to a piece of subsea equipment, in many cases, the tool that is currently the interface between the ROV and the asset,” said Bosler. "Now, there is a reliable, wet mateable connection like the Gemini tooling interface that can provide fluid, electrical power and data communications

Schilling say that, at least for the moment, the manipulator arms will be exclusively available with the Gemini system. They are so deeply integrated within the architecture that they could not be simply placed on other ROVs.

ELECTRIC ARMS

Blueprint Lab has extended its manipulator range with a 7-function version.

When small electric ROVs were first tasked to carry out more than just simple observation applications, designers began to install rudimentary and then, more sophisticated grabbers.

Over the years, these small electric vehicles have grown, evolving to carry out operations once the sole domain of large hydraulic vehicles. This intervention work has required more sophisticated and powerful manipulators. Historically, the only way to get sufficient power density was to use hydraulic manipulators.

This required a hydraulic power unit (HPU) to be fitted within the vehicle or on a skid outside. If the vehicle already housed hydraulic circuits, the addition of a further offtake for manipulators would effectively steal capacity from the existing hydraulic system.

Some vehicle operators consequently, began to look at all-electric manipulators as an alternative, although the market has been relatively limited.

Appealing design features of these electric manipulator include the ability to lift as greater weight as practicable, jaws with a high closing to ensure a good grip,high positional accuracy and arm robustness.

In addition, a small size can be a virtue, especially when connected more a more compact ROV while low weight is a universally useful property in any underwater tool.

Another useful feature is dexterity, with the arm being able to carry out sophisticated movements by virtue of having numerous joints.

By far the most important property, however is reliability.

Since Blueprint Lab was formed six years ago, it has already enjoyed considerable success with its Reach Alpha electric manipulator arm.

Looking to further expand its range, however, the company recognised that the current market was

The Bravo 7 seven-function manipulator

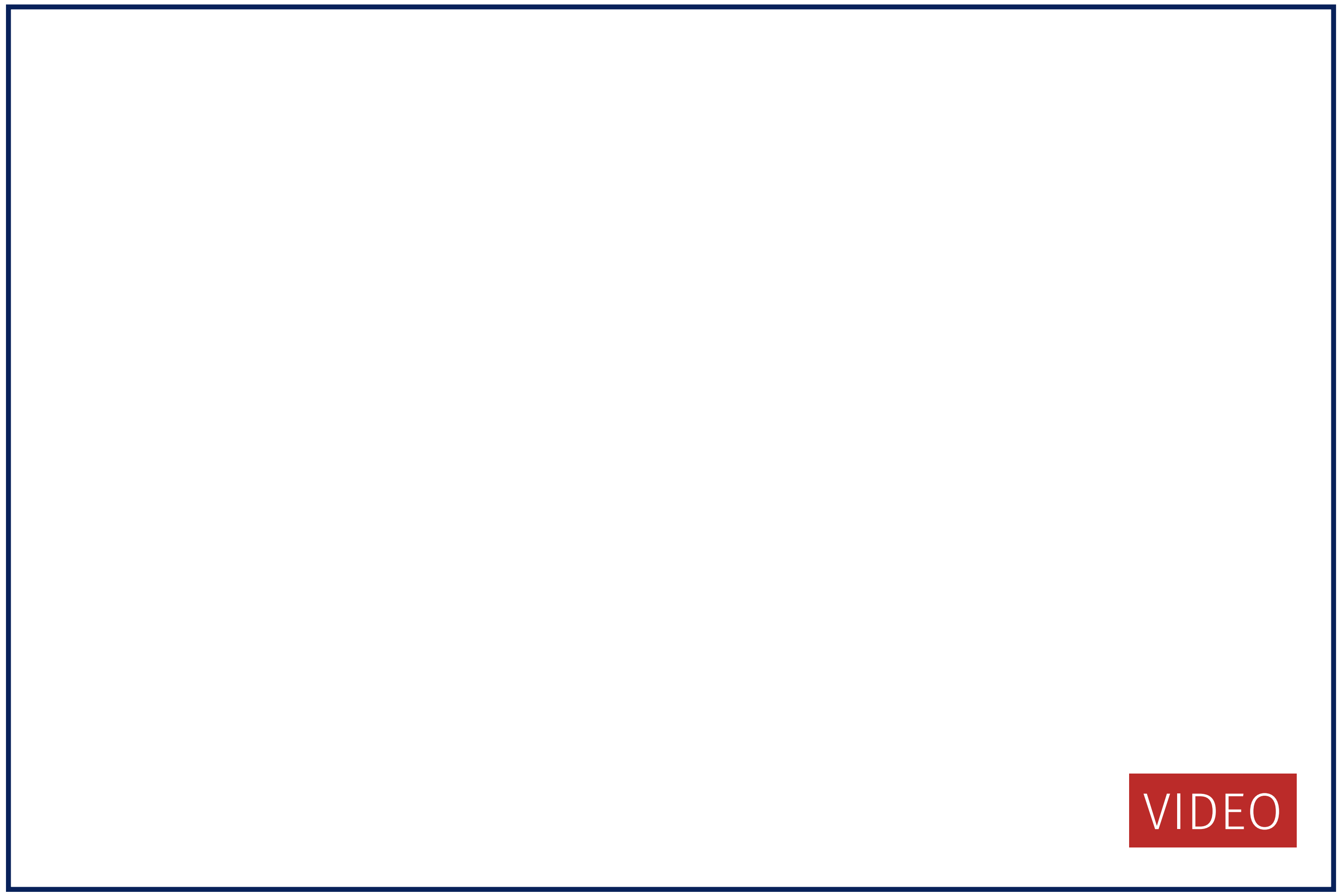
ELECTRIC ADVANTAGES

Being digital, electric manipulators can be move in precise increments within a three dimensional computer model. This means that is always possible to know where any part will be at any time.

This is very useful

It is possible to incorporate exclusion areas within the control software to ensure that manipulators are not allowed to clash with any other part of the vehicle or collide with each other.

Similarly, a digital pan and tilt unit can work in close association with nthe manipulators to always focus on wherever the manipulator jaws happens to be at any given moment.



Blueprint Lab's Bravo 7 arm undergoing tests

looking for something larger, higher powerful and more dexterous. This prompted the designers at Blueprint lab to develop the new the Reach Bravo.

This was formally launched last year.

BRAVO
The Reach Bravo is a lightweight durable compact subsea robotic manipulator typically aimed at the inspection maintenance repair market. It has a high positional accuracy of 0.1deg. The arms have a maximum outer diameter of 90 mm and the system is rated to 300m water depth.

There are four models in the Reach Bravo range, with selection largely depending on the application and the number of functions required.

The smaller 2-function Bravo 2 arm would typically rely on the vehicle to provide the lift and, therefore, can boast an axial load capacity of 200 kg. As with all lifting devices, however, as the reach increases, the lifting capacity normally decreases.

Nevertheless, other end of the range, the 7-function Bravo 7 has a reach of 0.9m and yet can still lift 10 kg.

"The manipulator has been designed ostensibly to execute tasks usually


The Bravo 2 grabber arm is -33m long and has a load carrying capacity of 200kg


The Bravo 3 Three-function manipulator arm has a 0.41, reach and can lift 15kg at full extension.


The Bravo 5 Five -function manipulator arm has a 0.67 reach where it can lift 12kg

reserved for human divers," said Anders Ridley-Smith, Business Development Manager at Blueprint Labs.

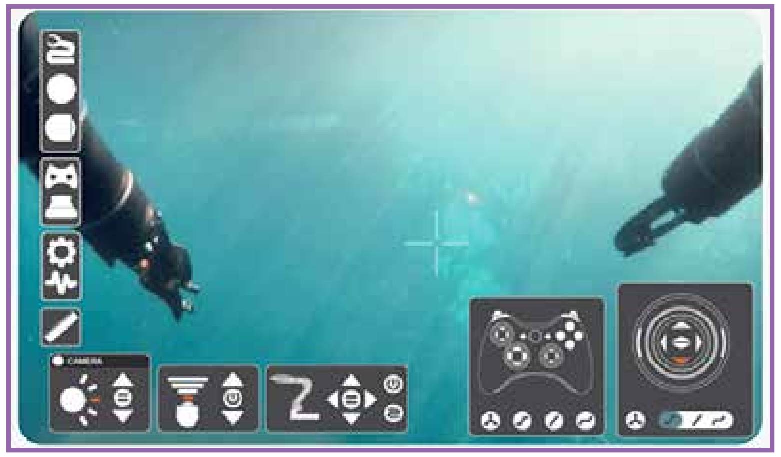
“In order to emulate their dexterity and natural handling ability, we have gone to great lengths to make made the end effector as responsive as possible.

The adjustable grab force is delicate enough to be able to pick up sea fauna. Alternatively, it can impart sufficient force necessary to cut a wire cable.

"We have also designed a number of mission-specific end effectors such as parallel quad or interlocking quad jaws that can be interchanged easily on site. Other end effectors include grabbers, probe handlers, cutters or customer supplied devices.

At the end of the operation, when the vehicle has to return to base, the arms can assume the stow position with a single click of the control button.

Any ROV manipulator system, however, is only really as good as the method of controlling it. Blueprint lab offers two options.



The reach control system incorporates an advanced tablet based human machine interface (HMI) in which the centre of the screen is taken up by the image from the front facing camera on the vehicle.

Around the periphery are icons and digital control buttons that allow the operator to not only move the manipulator, but regulate various parameters such as velocity and force. It can display the XYZ cartesian coordinates of the end effectors.


Interlocking Quad


Parallel Jaws


Wide Quad jaws

The tablet also incorporates diagnostics and status monitoring information. The tablet is connected to the manipulator using TCP/IP, cereal or UDP links.

For more precise control, Blueprint Labs have also developed a novel master arm joystick-type control system. This allows the operator to carry out quite sophisticated operations such as attaching hooks and shackles.

The joints on the master arm controller directly match those on the main manipulator arm itself. The joint mapping means that intuitively moving or turning the controller will cause the main arm to move exactly in the same orientation.

At the end of the arm is the master arm handle with a number of buttons to pause deploy or stow the manipulator. A joystick button is used to work the jaws.

In order to improve operations, especially intervention with a subsea target, a camera may be strapped on to the wrist. This allows the operator to lock onto the target more easily.

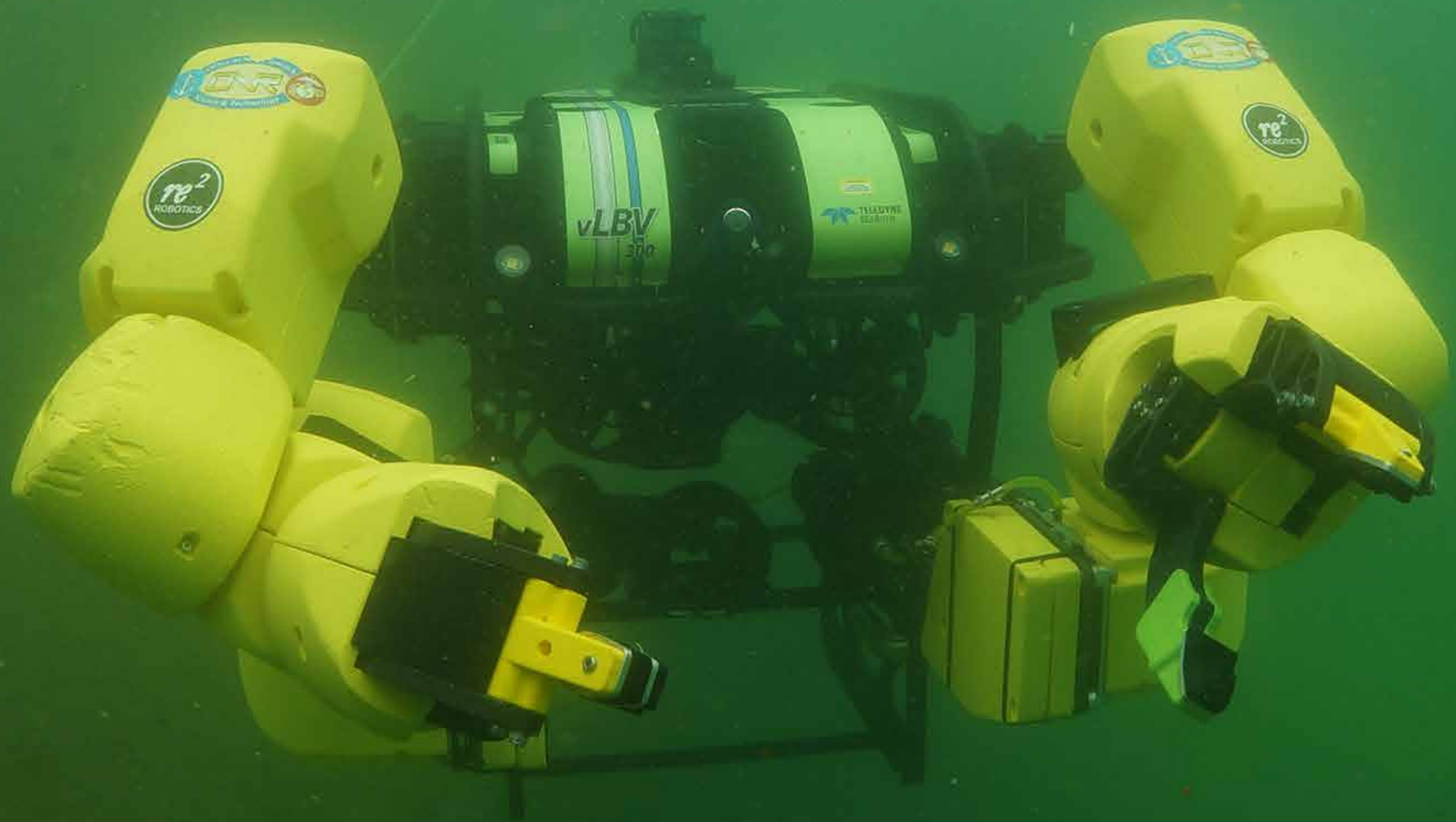
ELECTRIC DEXTEROUS ARMS

RE2 ROBOTICS UNDERWATER AUTONOMOUS MANIPULATION

RE2 Robotics has been developing outdoor mobile manipulation systems for commercial and military customers for nearly twenty years. Recently, the company reached a new technical milestone with the successful testing of its underwater electric dual-arm manipulation system's autonomy capabilities.

Called RE2 MDMS (Maritime Dexterous Manipulation System), the system completed numerous US Naval tasks autonomously.

"Although the Naval tasks cannot be publicly disclosed, the arms demonstrated sophisticated capability analogous to commercial tasks, such as turning a valve, painting a surface, threading a pulley, and precisely inspecting seams," stated Jorgen Pedersen, CEO of RE2 Robotics.



RE2 MDMS Maritime Dexterous Manipulation System

Buoyant arms on a VideoRay ROV

MDMS features a human-like electric seven-function robotic arm that offers neutral buoyancy, corrosion protection and pressure compensation for use on inspection-class ROVs.

“Its small footprint allows it to access confined, precarious spaces that bulkier systems cannot, enabling the ROV to perform tasks that are often identified as too dangerous, complex, or remote for humans said VP of Project and Product Management Jack Reinhart.

"Naval tests proved that the system can operate much deeper than its standard operating depth of 300m."

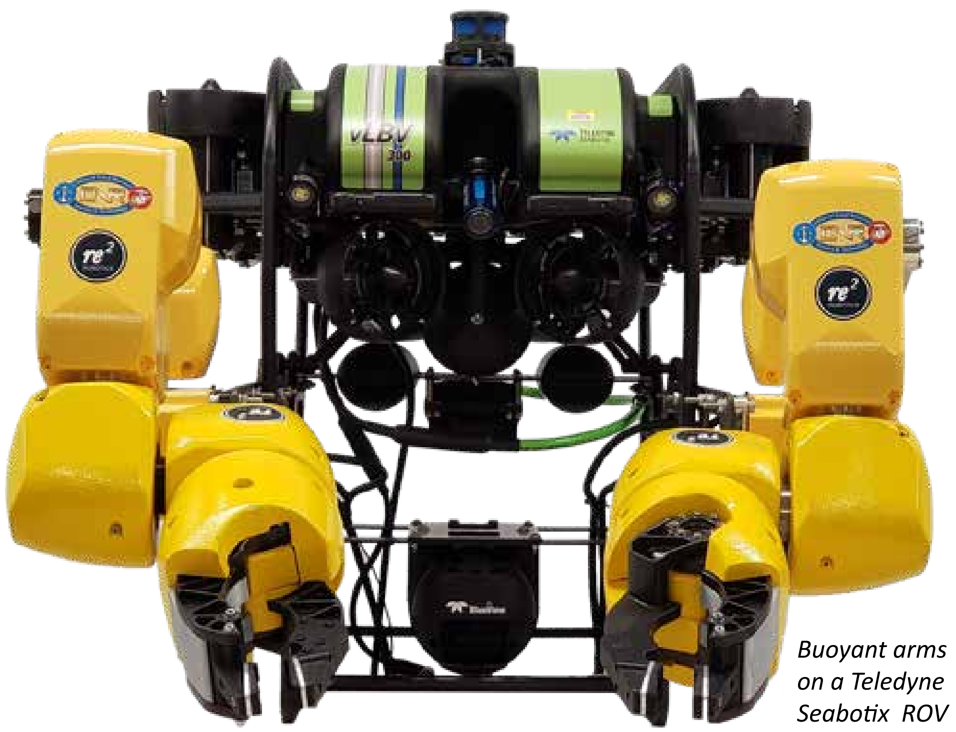
MDMS’ pioneering design has been tested to withstand and counteract the corrosive effects of extended saltwater exposure, which means a longer service life for the arms.

The system’s positive-pressure, sealed design protects the electrical system from water ingress and grit, reducing system maintenance and downtime.

In addition, its multi-level corrosion management system, including the use of sacrificial anodes and anodised joints, allows for extended subsea interactions.

“Because of these differentiating system features, MDMS boasts unprecedented reliability, dependability and incredible up-time statistics," said Reinhart

“The Navy testing proved that MDMS could be used in a variety of inspection, maintenance, and repair applications across a wide swath of industries while protecting divers from dangerous tasks,” said Marcus Kolb, CTO of VideoRay. “The arms can continuously rotate at the wrist joint, allowing for easy winding or screwing tasks and can be used to measure distance, weight and load – much more than divers can do without specific tools.”



Buoyant arms on a Teledyne Seabotix ROV

Another key feature of the system is its electromechanical design.

“Without the added bulk of a hydraulic power system, when at human scale, MDMS is more lightweight and power efficient than a hydraulic arm,” said Pedersen.

MDMS’ dual electric arms use only small amounts of oil to achieve greater depths and to compensate for the pressure of depth. Since the system does not have as many surfaces to seal, it offers greater reliability and requires less maintenance while reducing the risk of seal failure, contamination, and downtime. Less oil also means that there is less risk to the environment.

Because the system draws less power, a simple electrical battery can serve as the power source. In addition, electric arms only use power when they are in use, allowing the system to remain dormant on the ocean floor for long periods of time and then quickly be “awakened” and ready for use.

Overall, electric drive systems eliminate or significantly reduce many of the mechanical problems that occur with hydraulic systems, enhancing productivity and reducing costs. As a result of its electric design, MDMS is a power-efficient system with a high strength-to-weight ratio.

BUOYANCY

Since neutral buoyancy maintains the system at a specific depth, there is less impact on an ROV. This ensures that the system stays balanced and controllable at any depth, especially when grasping objects. This feature is critical to achieving dexterous, coordinated manipulation while underwater, whether the system is being teleoperated, through supervised autonomy, or is fully autonomous.

Reinhart continued, “The MDMS arms use specialised foam to help stabilise the system in ocean depths. Designed to withstand its rated depth without compression, the foam prevents the system from oscillating too abruptly in the water, especially when grasping, carrying, or transporting objects with the ROV.”

FLEXIBLE CONTROL

In tests, the RE2 was able to successfully demonstrate autonomy using its RE2 Detect and RE2 Intellect autonomy software, explained Pedersen.

“RE2’s arms operate using multi-modal 2D and 3D imaging sensors and algorithms that can adapt to various lighting and environmental conditions,” he said. “RE2 Detect perception software can detect and track objects in just about any outdoor environment, including a complex subsea environment.”

RE2’s autonomy algorithms fuse traditional machine learning and computer-vision-based techniques to provide human-like decision processing. While traditional autonomy algorithms rely on a single method and only work in structured environments with controlled lighting, RE2 Intellect can handle anomalies that are common in unstructured underwater environments, similar to the way human brains perceive and process information.

“The RE2 Intellect software reasons what is being perceived by RE2 Detect, generates trajectories and grasp plans, and then translates those plans into synchronised actions between two robotic arms to autonomously manipulate the environment according to its mission,” explained Reinhart.

“Additionally, we successfully demonstrated the ability to autonomously grasp and use different tools based on the task at hand. This was an exciting milestone for our team.”

The MDMS is a flexible, dual-arm system that is designed to seamlessly transition from a teleoperated system to a fully autonomous one. For operations that still require a human in the loop, the system can be teleoperated or controlled using supervised autonomy. For teleoperation, the system is controlled using the RE2 Imitative Controller, which can be stand-mounted or chest-mounted for portability.

The Imitative Controller allows the user to mimic the desired movements of the robot’s manipulators from the safety of a remote location either on ship or shore. The easy-to-learn technology allows operators to control an underwater vehicle remotely with the same dexterity and accuracy of a diver.

“We measure intuitiveness in two ways—training time and time to proficiency. First, the training time for new Imitative Controller users is typically less than one minute. Second, usually within an hour of training, an operator becomes proficient at simultaneously controlling 14 functions across two manipulators,” stated Reinhart.

“With its seamless control scheme, the intuitiveness of the Imitative Controller allows operators to use MDMS as a true extension of themselves.”

Manipulator control system

I N T E R S U B

BEFORE THE ROV WAS THE MANNED SUBMERSIBLE

The opening up of the North Sea hydrocarbons industry in the mid 60s and early 70s fuelled a boom in the need for the subsea intervention and inspection of the new offshore production assets.

The Southern North Sea fields were characterised by gas finds in shallow waters located relatively close to shore. This allowed numerous fields to be tied into a gas gathering system which could be largely inspected using divers, typically from Naval backgrounds.

It was when the pioneers pushed North into more inhospitable waters of the Central and Northern North Sea that the problems emerged. Diving in these much deeper waters became more challenging with time at depth becoming limited.

Saturation diving became technically achievable in the late 60s in the Gulf of Mexico. It was in its infancy when these techniques began to slowly spread across the globe and particularly to the North Sea. Reaching the seabed was typically carried out from the rig/platform by diving bell, with the first dedicated saturation diving DSVs not appearing until much later.

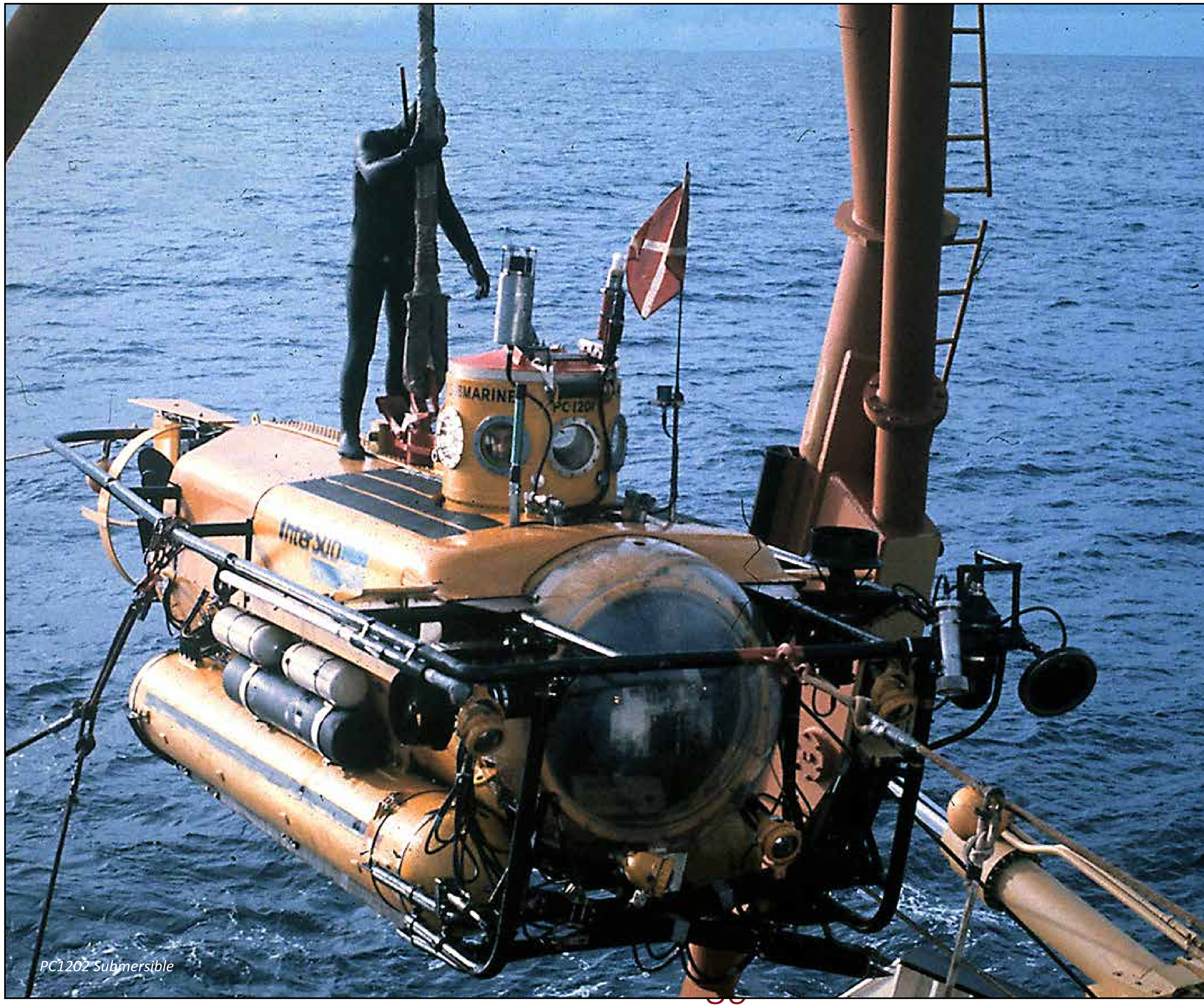
Looking for an alternative to using divers for conducting observation tasks, manned one-atmosphere submersibles, sometimes called deep submergence vehicles started to become increasingly advantageous.
At the time, various vehicle models existed, typically designed by North American companies to serve the military, recreation and oceanographic markets.

Two main designs soon dominated the offshore sector. One was the Pisces range developed by Hyco-International Hydrodynamics of Vancouver, Canada and was adopted by Vickers Oceanics for their underwater surveys. The second was from Perry Submarine Builders of Florida, USA, with its PC range of submersibles. Both vehicles were noted for their robustness, being manufactured in steel.

A third company, appeared later, a furniture-to-aeroplane manufacturer called Slingsby, of Kirbymoorside, North Yorkshire in the UK, who recognised the technical similarity between a pressure cockpit and a pressure hull, and carried out pioneering work manufacturing deep submergence vehicles in glass reinforced plastic (GRP).

In order to service the burgeoning offshore industry, Maurice Pinto, co-founder of Sea Containers, a London based container leasing company, established Northern Offshore Limited (NOL) as a leading company supplying offshore services. It had already established a joint ventures

HISTORY



PC1202 Submersible

Left: PC 1201. Below PC 1202 with dive lockout

Images: Nick Messinger

with Bugge Supply Ships of Tonsberg in Norway- originally a whaling company that had diversified into offshore business around the time that Statoil had started up- and was keen to add deep submergence vehicles into its portfolio.

NOL was approached by the new French company InterSub, which had been started by the charismatic young French engineer Jean-François Durand, and soon began to offer manned observation vehicle services to the industry.

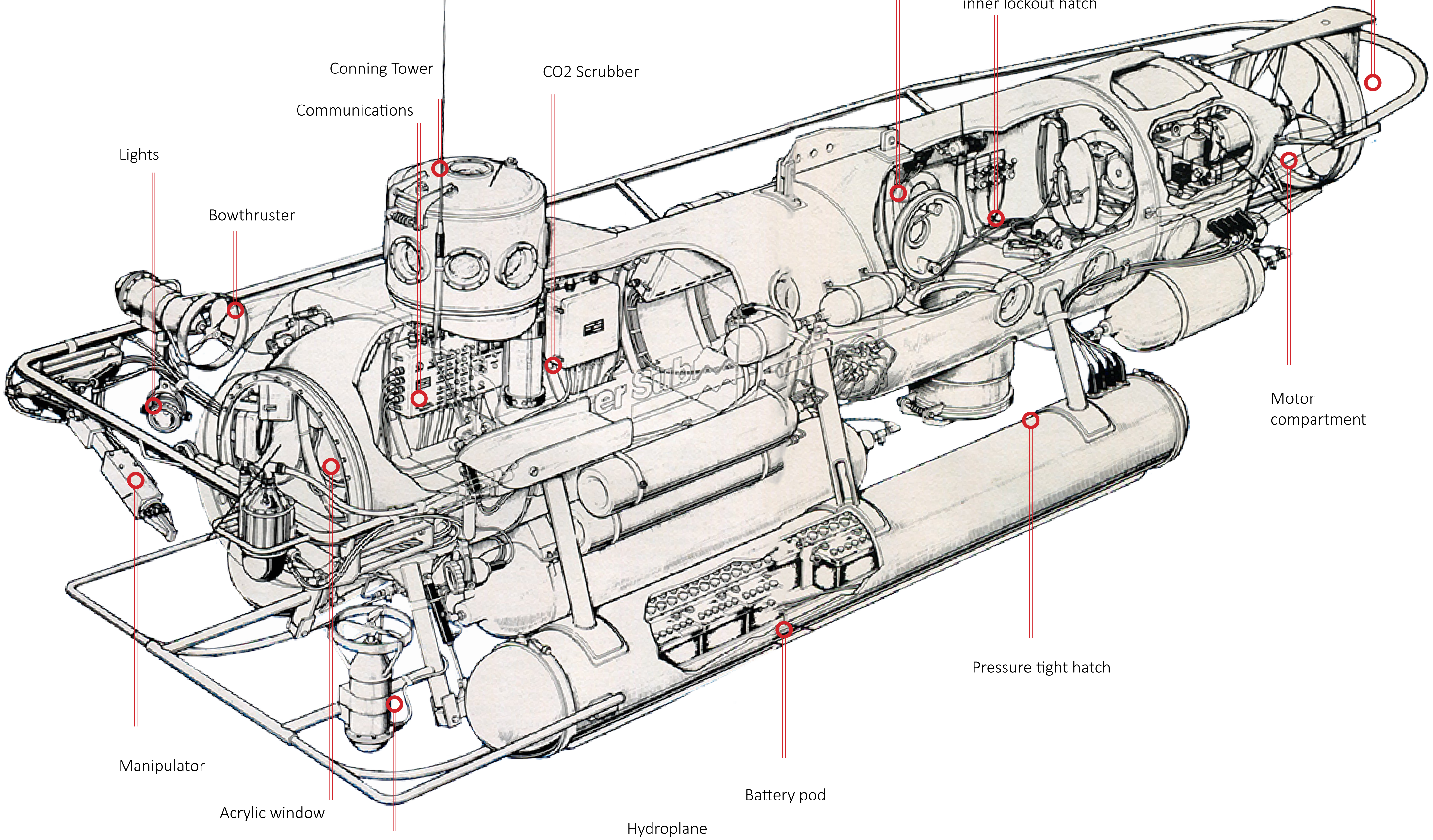
"I was doing a Research Fellowship at Plymouth and came up to London to give a talk in BP's Britannic House headquarters on 'Subsea Completions and Dry Transfer of Personnel into Subsea Habitats," said Nick Messinger, who was later to become InterSub's Operations Manager. "I met Jean-Francois and by the end of the evening, he had convinced me to work for a season on the ***Le Nadir***, a vessel incidentally designed by Jacques Cousteau.

"This vessel carried a single Perry PC8 submersible and we spent the summer of 1974 carrying out bathymetric surveys for Total Oil Marine and Elf. My job was to help with the navigation of the submarine and plotting the bathymetric data."

The following year was a memorable year for Messinger for many reasons. He was contacted by Durand to join InterSub full time, flew to the South of France, caught Scabies in a Marseilles hotel, and joined the ***Le Nadir*** as supervisor, later being promoted to operations manager, and spending the whole of the non-operational winter months writing up technical proposals for companies requiring manned submersible intervention.

"In no time, we had five mother ships and ten submersibles operating pretty much across the globe , from carrying out support work off the Nova Scotia coast for the drill ship ***Ben Ocean Lancer*** to setting up an operation in the Middle East. We established a local joint venture company with Swire called Swire Pacific Offshore."

At the start the new season Messinger went to Egypt to join ***Intersub 1***, an old supply boat originally called ***Sea Stork*** which was converted to carry a small submersible.



PC1202 on Intersub 3

From working off Qatar and Bahrain the company won a contract to fly the submersible over the pipeline between Kharg Island and the Iranian mainland. The trip also included being dragged off an aeroplane flying from Abadan up to Qom and Isfahan- and being locked up for a day and a half with passport confiscated and no explanation given.

"An important operational landmark project was the support work involved in laying the Mediterranean pipeline between Tunisia and Sicily which would bring Algerian gas to Italy. The new and highly advanced dynamically-positioned lay barge Castoro Sei laid the pipe in 3,000ft perhaps the deepest waters ever to be crossed at the time.

"We used a deepwater Perry PC 16 submarine , with its interesting tri-sphere configuration to monitor the touchdown point of the pipe coming off the back of the lay barge. We became the eyes that guided the pipe through the subterranean mountain ranges, occasionally installing brackets underneath the pipe to correct free span and generally photographing and checking out the cathodic protection."

SUBMERSIBLES

Altogether, Intersub operated five vessels. ***Intersub 1*** and ***2*** were a small and slightly larger rig boat, while ***Intersubs 3*** and ***4*** were large high seastate German freezer stern trawlers that were converted into very well equipped submersible support ships at Bremerhaven.

Each of these larger vessels were capable of handling 2 submarines. The ***Intersub 2, 3*** and ***4*** all had saturation dive systems installed. From these four vessels, Intersub could employ a variety of different submersibles, depending on the application.

Amongst its vehicles were a PC8, PC1201, PC1203, PC1204, PC1205 observation vehicles as well as PC1202, PC1801, PC1802, PC1804 diver lockout submersibles and a 3,000ft-rated PC16 Deep Observation and Dry Transfer Submersible.

InterSub also rented a Pisces submersible from Hyco for support work for the ***Ben Ocean Lancer,*** operating off Nova Scotia.The PC1202 was initially installed on Intersub 2 but later transferred to the larger InterSub 3 so it could be used alongside the smaller PC1201, back-to-back from the same mother ship.

After working alongside a Paris company that manufactured garbage compacter trucks, Durand developed an innovative hydraulic A-frame which was used to swiftly launch and recover these heavy vehicles in sea states up to and including Force Six.

The smaller vehicles were used for inspection and basic manipulator intervention- but notably, PC1202 incorporated a diver lockout facility.

Later ***InterSub 5*** joined the fleet.

She had originally been a supply boat that had sunk, been salvaged and then converted to carry a new TROV remotely controlled vehicle.

Like the others, it had an A-frame but the operators soon decided to cut a moon pool in the hull for better handling of the large ROV.

DIVER LOCKOUT.

The underlying principle of deepwater diving is that if the diver spends time at depth and surfaces, it is important to do so at a controlled rate so that dissolved gases (mainly nitrogen) do not come out of solution in the form of bubbles and inflict decompression sickness. The deeper the dive and the longer time spent working at depth, the more time necessary for decompression.

At the time, conventional bell diving was carried out from an often-congested rig or platform in the form of a tiny 2-man bell. The bottom door would be closed and the divers taken down to the worksite at a 1 Atm surface pressure.

Once at depth, the bell would be blown down with the correct gas mix, the bottom door would drop open at ambient pressure. The designers of the manned submersibles reasoned that the bell functionality could be emulated by a modification to the submersible in the form of a diver lockout compartment.

The Perry PC102 consisted of a cylindrical hull. By dividing the hull into two interconnected compartments by a pressure resistant hatch door, it could establish a diver lockout (DLO) system.

"Inside the 1202's pressure hull, the pilot sat on a stool with his head inside the conning tower looking outwards. This was particularly important when launching or recovering the boat. At the very front , a large Plexiglass window allowed the observer to view the target while controlling the manipulators and plotting the navigation. We had emergency life-support for seven

Top to bottom: Cutting the ties, the buoys reach the surface, taken away on supply boat

days from the external O2 banks, CO2 scrubbers, lithium and sodasorb.

In addition to the 2-man crew, the PC1202 could also accommodate a dive supervisor and two divers. The submersible would fly down to the worksite, whereupon one diver might crawl into the forward dry observation area to see what needed to be done- or have the job explained, while viewing through the plexiglass front window. The diver would then return to the lockout compartment and the interconnecting watertight door would be shut.

The chamber would then be blown down with a gas mixture appropriate to the correct operating pressure. One diver would exit the boat on a 75ft umbilical that provided the communications, gas and power as well as providing a safety link with the other back in the Diver lockout (DLO) In order to complete the job, the two divers might switch roles.

"One problem we had was heating the divers. Using mixed gas, the divers were very vulnerable to any change in temperature and it was vital to keep them warm. These electrically heated under suits and hot water tubing could quickly drain the boat's batteries.

Once a job had finished, the divers under pressure would re-enter the diver lockout compartment and then the boat would ascend to the mothership while the divers immediately commenced decompression in the diver lockout compartment, before transferring under pressure to the ship's decompression chamber, situated on the deck below.

This technique was known as bounce diving. It was vital to get the task done quickly and move the divers back into the DLO (or bell) as soon as possible. The divers often performed numerous short-duration dives with minimal time to recompress. The rates of sickness and injury proved to be very problematic.

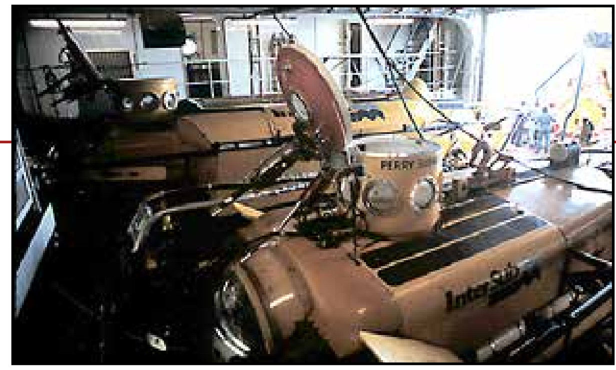
This eventually led to the establishment of stricter guidelines and the establishment of saturation diving. In this, the saturation commenced in a safe environment on the mothership, under strict observation and control, and with far greater safety. The divers were then transferred to the DLO under pressure. As a result, the number of diver pressure related incidents fell away sharply.

"Ever the master of innovation, Jean- François Durand invented a stainless steel and hydraulic bellows - type configuration that connected the saturation system directly to the diver access hatch in the underside of the submersible," said Messinger. "Thereby enabling divers to transfer into the DLO- and back into the saturation dive system, in complete safety."

OPERATIONS

Submersibles were used for a variety of operations. Typical of these involved flying along a pipeline, recording video, monitoring cathodic protection, looking at free spans and any damage to the pipe, such as buckling. If required, the subs two manipulators could be used to collect sandbags, lowered down from the surface, manoeuvring them into position under the pipe for support, where there was free-spanning.

"One operation involved assisting with

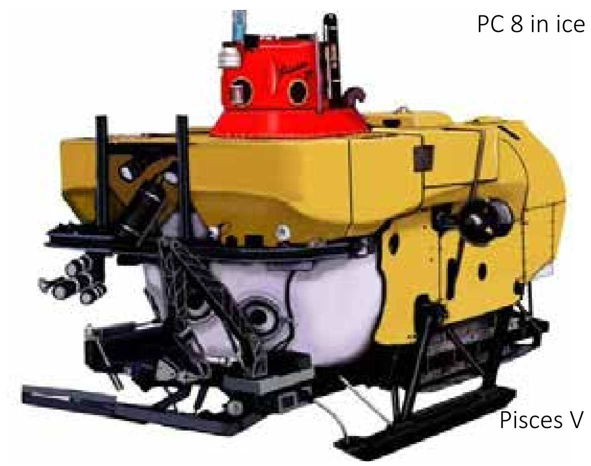


PC 1202 and 1204

PC 18

PC 1804

PC 8 in ice



Pisces V

the 34in concrete-clad gas pipeline as it was laid from the ETPM1601 laybarge. Severe buckling of the pipe as it came off the stinger was a problem- easily solved by the attachment of floatation devices attached to the pipe at intervals. Well before the days of plastic or syntactic buoyancy, the flotation consisted of pairs of giant inter-connected hollow metal spheres, similar in appearance to a giant yellow-painted dumbbell.

"Once the pipe was laid, our job was to cut the metal straps and release the flotation spheres," said Messinger.

"Initially, we experimented with shaped charges to cut the steel wire lashings, but these were expensive and didn't always work. Once again, Jean- François Durand, the amazingly innovative engineer, came up with a simple and effective solution: A rotary cutting disc, connected by flexi-drive to a spare thruster motor, solved the problem- saving the company a great deal of money on expensive explosives, while providing a more efficient service to the client – Total Oil Marine.

The newly unrestrained buoyancy spheres would shoot upwards through the 500ft water column, like Polaris missiles. They would then be collected by a supply boat, and returned to the laybarge for further use.

"Of course it was necessary to give a warning to the local traffic and unconfirmed rumours often circulated of the rising spheres once hitting the stern transom of an anchor handling supply boat, completely removing both propellers, the rudder and most of the backend."

Looking for more work in the Norwegian Sector, InterSub formed a joint venture with Kvaerner Engineering of Oslo, with Nick Messinger as General Manager, aimed at promoting submarine operations for Statoil, Esso and various other companies operating out of Stavanger and Bergen, while working with the Kvaerner team on underwater systems development.

A tragedy, however, was about to unfold. In March 1978, Jean François Durand, along with technical director Marc Henry, and the company's newly appointed finance director, were killed in a plane crash in Milan.

Before long, many of InterSub's assets were taken up by British Underwater Engineering an umbrella company consisting of Vickers Oceanics and Vickers Slingsby, with many personnel joining the new company.

"The demise of InterSub was due to a number of factors- the principal one being the lack of Jean Francois' driving force, charisma and foresight, coupled with the tragic, sudden deaths of his Marseille-based senior management team," lamented Messinger. "

The company was a unique, close-knit, international family and went into deep shock. It's misfortune also coincided with the emergence of ROVs as reliable tools for observation and intervention. Its end compounded by the fact that the financing of InterSub was very highly geared and when revenue decreased, debt quickly mounted."

PC 1202

Archive: Dick Winchester

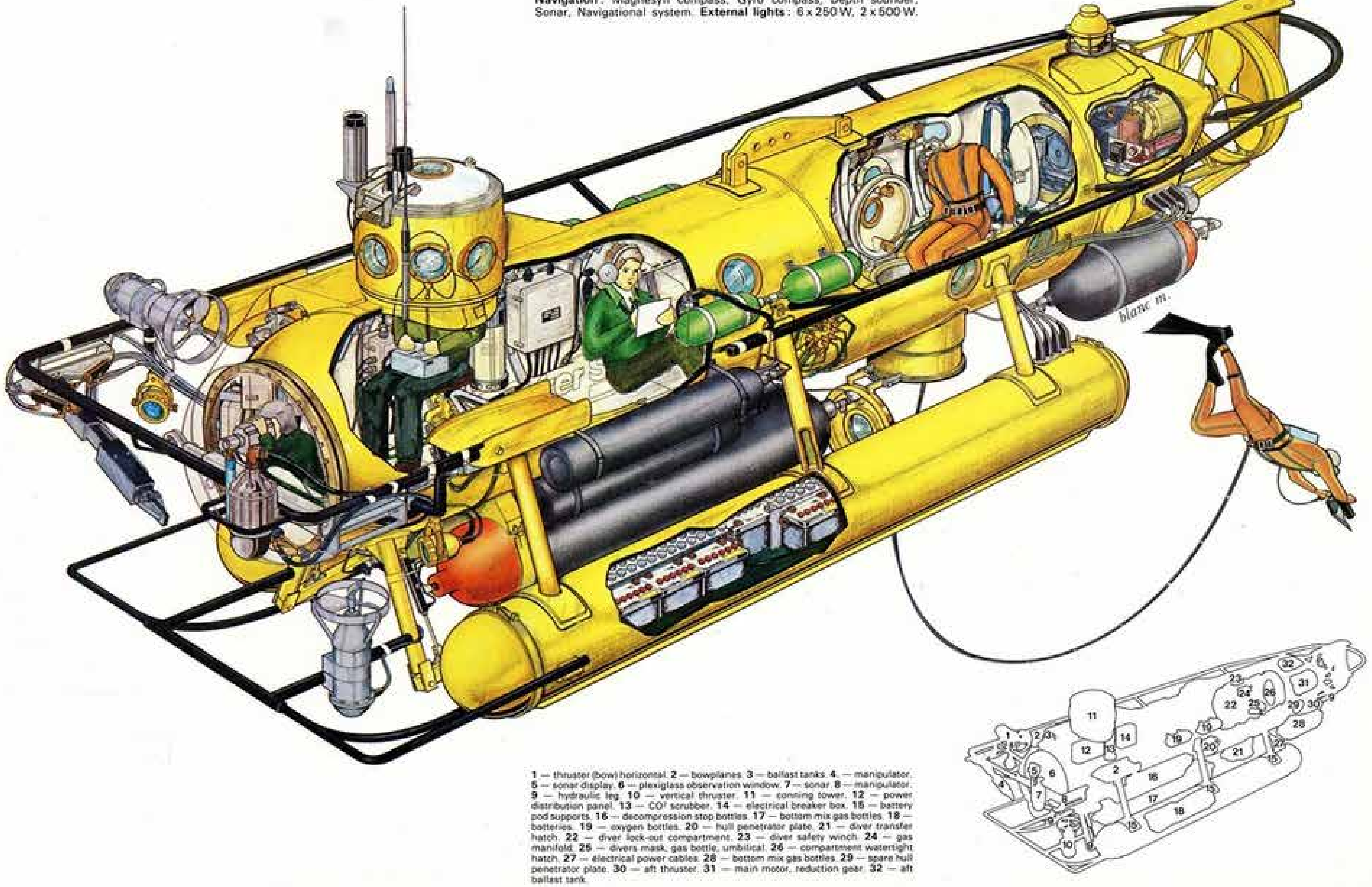
SPECIFICATIONS

Manufacturer Perry Oceanographics ABS classified. Overall length 31'. Height 9'. Beam 8'. Operating depth 1000'. Weight 15 tons. Payload 1500 lbs. Crew 2 + 3. View ports 9" x 6" in conning tower plus forward spherical segment 36". 2 x 6" in diver compartment. Power 53 KWH. Main propulsion 10 HP motor. Auxiliary thrusters 2. Top speed 2.5 knots. Mission duration max. 6-8. Life support (per crew member) 3 days.

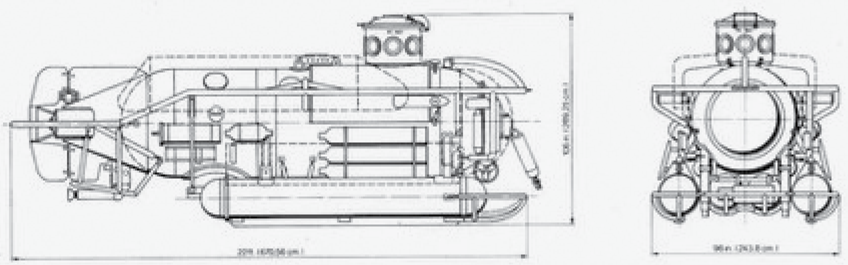
EQUIPMENT

Communication : Underwater telephone Citizen Band radio. **Navigation :** Magnesyn compass. Gyro compass. Depth sounder. Sonar. Navigational system. **External lights :** 6 x 250 W, 2 x 500 W.

Television : Video tape recorder and camera with audio track. **Manipulators :** 2,75 lbs capacity. **Lock-out facilities :** Gas storage : — on the submersible : approx. 8,000 scf of three different gases. — on board the vessel : approx. 200,000 scf of gases. **Environmental controls :** O2 and CO2 monitors Lindbergh Hammar CO2 scrubber. **Decompression chambers :** two, 950' double-lock chambers, 60" dia. Independently controlled from console.



1 — thruster (bow) horizontal. 2 — bowplanes. 3 — ballast tanks. 4. — manipulator. 5 — sonar display. 6 — plexiglass observation window. 7 — sonar. 8 — manipulator. 9 — hydraulic leg. 10 — vertical thruster. 11 — conning tower. 12 — power distribution panel. 13 — CO² scrubber. 14 — electrical breaker box. 15 — battery pod supports. 16 — decompression stop bottles. 17 — bottom mix gas bottles. 18 — batteries. 19 — oxygen bottles. 20 — hull penetrator plate. 21 — diver transfer hatch. 22 — diver lock-out compartment. 23 — diver safety winch. 24 — gas manifold. 25 — divers mask, gas bottle, umbilical. 26 — compartment watertight hatch. 27 — electrical power cables. 28 — bottom mix gas bottles. 29 — spare hull penetrator plate. 30 — aft thruster. 31 — main motor, reduction gear. 32 — aft ballast tank.



PC 1801 - 1802 - 1804

DIVER LOCK-OUT SUBMERSIBLES

SPECIFICATIONS

GENERAL DATA

Length 21' (6.4 m)
Breadth 8' (2.4 m)
Height 8'9" (2.7 m)
Weight 24,000 lbs
Payload 1000 lbs (454 kg)
Crew 2 + 2 Divers
Life Support 7 days per crew member
Max Depth 1000' (300 m)
Diver lockout 650' (200 m)
Max Speed 2.5 knots
Duration 8 hours (observation)
Power 120 V DC 37 kwh
Main Propulsion 10 hp
Direction Thrusters 2 x 70 lb (32 kg)

CONSTRUCTION

- Built by Perry and classified by the American Bureau of Shipping.
- Pressure hull is of pressure vessel quality carbon steel, meeting impact test requirements for low temperature service. Inside diameter is 54" (1.37 m) with internal ribs.
- Battery pods are cylindrical 20" (50 cm) O.D. with removable closures at both ends for ease of access.
- Main propulsion motor is in a pivoting pod for steerage.
- Through hull fittings via removable penetrator plates, four basic types of penetrators are used with several blanked spares for additional equipment functions, a medical lock with internal and external hatches is fitted in lockout compartment.
- Viewports : All viewports are 8" (20 cm) major diameter, eight equally spaced in conning tower for horizontal viewing plus one upward looking in hatch, intercompartment hatch, D.L.O. inner and outer hatch each have a central viewport. The Pilots compartment has one 35" major diameter hemispherical viewport. The viewports are of acrylic plastic.
- D.L.O. compartment has quick disconnect hub for mating to a deck decompression facility and is adaptable to a dry transfer facility.
- Retractable legs to permit diver egress/ingress whilst on sea bed.
- Conning tower hatch has 20" (50 cm) freeboard in normal surfaced state.
- All external equipment and fittings protected by heavy duty fender rails.

SYSTEMS

BUOYANCY
External ballast tanks of 800 lbs (363 kg) total capacity with H.P. air system for blowing the tanks for surface stability and buoyancy.

TRIM
Internal variable buoyancy trim system of 200 lbs (90 kg) tank forward and 500 lbs (227 kg) tank aft in D.L.O. with H.P. overboard discharge and transfer pumps.

AIR
The high pressure air system of 740 scf at 3600 psi in two externally mounted cylinders for use in conjunction with ballast tanks and emergency equipment.

LIFE SUPPORT
One-atmosphere-pressure system consisting of carbon-dioxide removal and oxygen make-up capable of supporting 4 persons for 176 hrs (8-hr mission and 168-hr reserve).

DIVER BREATHING GAS
For the divers and pressurisation of the D.L.O. compartment is carried in three sets of externally mounted cylinders with total volume of 6000 scf.

HYDRAULIC
Electrically powered hydraulic system for motor housing, planes and extendable leg functions. In addition, externally mounted, a D.S.W.P. (Deep submergence work package) with internal controls described below.

CONTROLS
Portable control box with joystick-type control for motor housing and plane position, control for main power and direction, and thruster controls ; indicator meters for propulsion voltage, propulsion current, and main motor position.

STANDARD EQUIPMENT

- Magnesyn compass digicourse.
- Humphrey gyro compass.
- Wesmar SS140 scanning sonar.
- Depth gauges.
- Autopilot.
- Communications : Mesotech underwater telephone, Helle diver phones with unscramblers. VHF radio (surface communications).
- External lights 6 x 250 W and 2 x 500 W Quartz Halogen iodide.
- Television : Sony AV 3420 CE videotape recorder and camera with audio track.
- DSWP (Deep Submergence Work Package) consisting of :
  - . 2 Manipulators :
    Wrist rotating 360 degrees
    Wrist extension 18"
    Jaw open 4"
    Max lift (fully extended) - 150 lb.
  - . Diver tools :
    Two quick-disconnects for impact wrench or grinder.

SAFETY FEATURES

- Droppable Battery Pods : Two released individually by means of self-contained hydraulic actuator.
- Leak Detector System : Indicates presence of salt water in each battery pod and motor housing.
- Emergency Breathing System : Built-in emergency breathing system, masks and life vests.
- Pinger : Acoustic pinger locator/marker.
- Self powered flashing strobe light, smoke flare and flashlight.

F R E E D O M

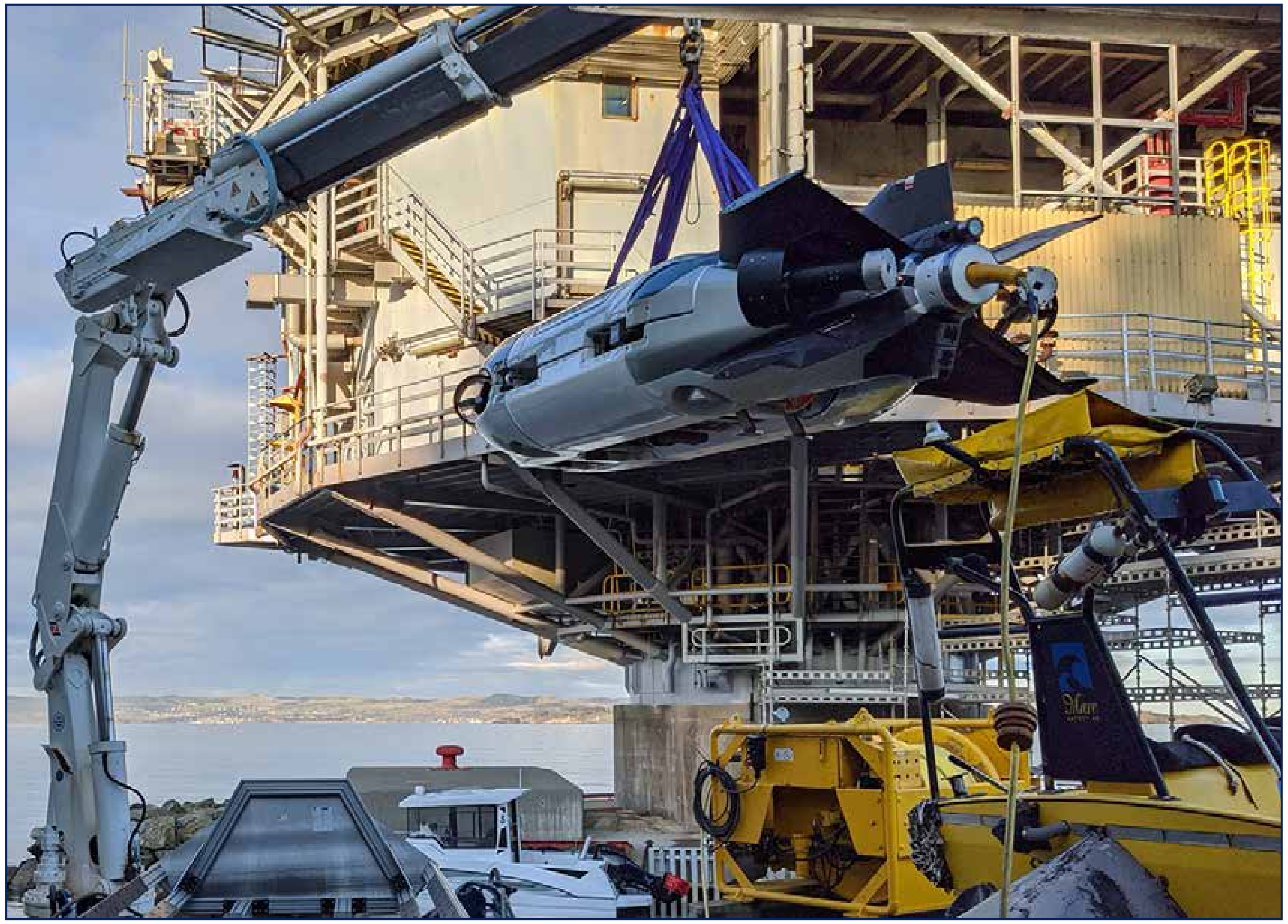
RESIDENT VEHICLES

This April, Oceaneering will commence the next-stage testing of its new Freedom ROV. For a considerable time, the company had been conducting inshore and shore-based tests and planned to conduct deeper water trials last November. The schedule has since slipped, both due to Covid and the desire to learn more and increase confidence. Plans now envisage the vehicle experimentally tracking an offshore pipeline along the Norwegian coast in the winter months.

Freedom is Oceaneering’s newest underwater vehicle, effectively combining the functions of an ROV with the speed, range and manoeuvrability of an AUV. It can operate in two modes: either remotely via a tether or optical through-water comms, and thus possibly allowing a land-based a pilot to control the vehicle, or fully autonomously with no real-time human interaction whatsoever.

The ROV has a working range of about 200km per mission, a depth rating of 6000m and a maximum speed of 6kts. It carries out a typical survey at nearer 3kts, depending upon the data resolution required.

“The basic Freedom platform allows many operational variations," said Subsea Robotics Product Manager Steffan Lindsø. "It can be used to support inspection, particularly pipeline, light intervention work and general survey. At present, much of this work is typically carried out by AUVs and ROVs. How the Freedom approaches this task, however, illustrates the difference between it and many other conventional underwater vehicle alternatives.



A typical AUV flies around 6m over the seabed when carrying out a survey. A key design feature of the Freedom is for it to operate MUCH closer, maybe to fly only 1m above the pipeline, in order to attain a much greater imaging resolution.

"This brings its own set of challenges,” said Lindsø, "mainly because it increases the possibility of colliding with other pipeline structures and appurtenances such as crossings, T-pieces or protection frames. Encountering a sudden obstruction, at speed, requires quick reaction times to manoeuvre the vehicle away and avoid impact.
In order to navigate so close proximity to the pipeline, the vehicle controls require assistance from machine learning and collision avoidance algorithms running constantly in the background of the control system."

The Freedom has sophisticated supervisory software to allow enhanced situational awareness. It is assisted by input from an array of sensors directed 360° around the vehicle.

These are principally used for operational reasons such as to recognise pipeline features, detect free spans, look at depleted anodes, focus on alerts or anomalies, and identify crossings with the mattresses suddenly rising above the pipeline profile.

"Freedom can recognise a problem through machine vision" said Lindsø. "The vehicle can hover over the identified target and acquire detailed information such as high definition imagery."

SUBSEA RESIDENCY

An important feature of the Freedom vehicle is that it is designed for underwater deployment over extended periods of up to 6 months. This means that the vehicle requires intermittent battery recharging and the ability to upload/download data and instructions. This, in turn, necessitates either a subsea garage or docking station.

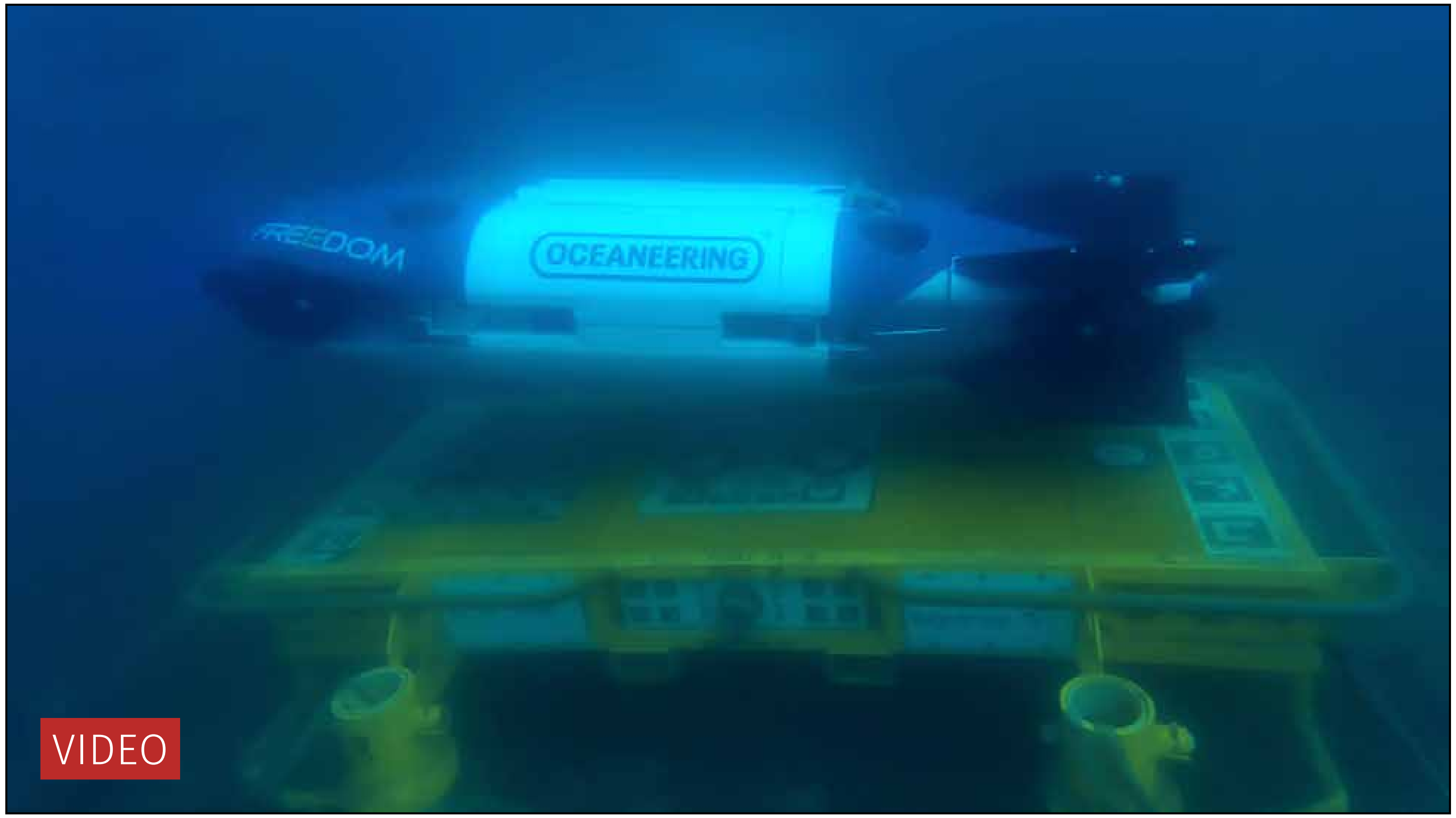
Oceaneering has been carrying out routine docking exercises for over a year, in particular, in association with Blue Logic and their charging platform (see separate story).

"There are three different mechanisms that allow Freedom to navigate towards the docking station," said Lindsø. "The initial approach employs a long-range acoustic beacon which allows discovery of the target's rough position. Once within visual range, cameras on the vehicle take over, locking onto and interrogating the ArUco codes displayed on the deck's side and surface.

"This provides identification information but as Freedom slows to a hover, the machine vision software continually calculates its exact position relative to the marker as the vehicle moves across the platform, measuring the apparent angular change and converting this into a position.

There soon comes a time where the downward-facing cameras get so close to the deck, that it is no longer possible to recognise the markers. At this point, other sensors on the vehicle start to pick up the magnetic field emanating from the dock's charging connector. This allows the final and highly accurate homing-in of the vehicle and allowing the Freedom to be positioned over the landing cone with tolerances of less than 2cm.

"Latching such an expensive vehicle on top of a small ring on a flat deck and leaving it there for a couple of months requires a lot of confidence," said Lindsø. "A simple flat deck would be necessary for a universal charging station, but we have also purpose-designed a garage system to offer our vehicles more protection.



VIDEO

CAGES

“In recent years, we have invested a considerable amount of time and money upgrading our entire underwater vehicle fleet, including developing an enhanced ROV called Liberty,” said Lindsø. "This has its own subsea garage system and has been in operation since 2019.

“While these cages were designed for Liberty, they are equally applicable for Freedom, and we have been carrying out docking procedures using the two vehicles. The ability for both Oceaneering vehicles to use the same facilities is a good example of commonality across the platforms.

"The thrusters, batteries, computers will all be the same as will the supervisory control software” said Lindsø. "The machine learning or intelligence packages and operating software can support a variety of mission types. Furthermore, software upgrades can be easily rolled out to the entire fleet.

FREEDOM TESTS.

Oceaneering has been performing in-water tests on the Freedom for nearly 2 years. The initial phase saw this trialled in a protected underwater environment. On the seabed, we have an exact replica of what we would encounter in a live offshore environment,” said Lindsø."

It soon became apparent that the autonomy we sought takes a tremendous amount of programming and adjusting algorithm. Even now this is at an advanced stage. A continuous development programme will seek to improve efficiencies as more data is captured.

UNDERWATER GARAGE

"The underwater garage that houses Liberty and Freedom has a specially-designed launching system. As the structure is lowered into the water using a crane whereupon, a hinged horizontal tube rotates 90deg point upwards,” said Lindsø.

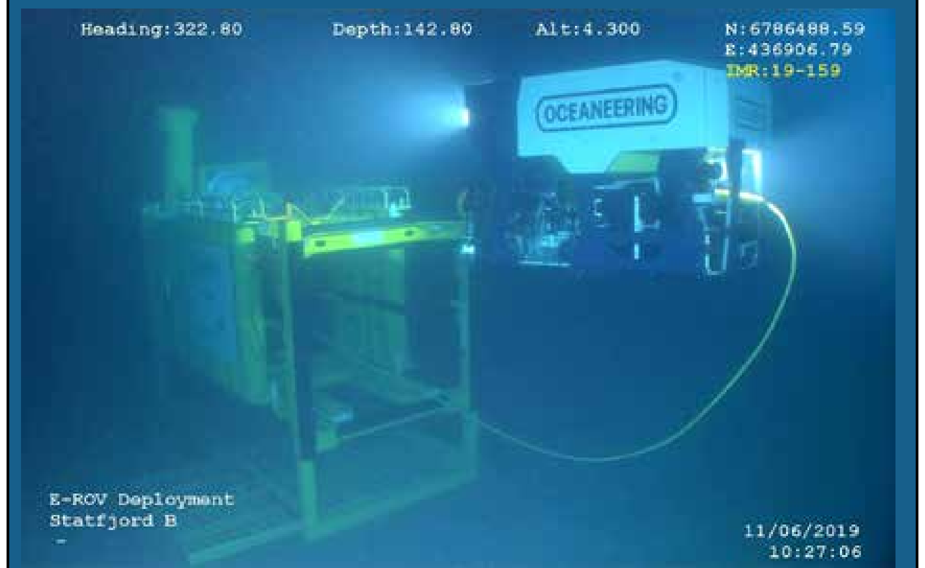
"Within this tube is a flotation buoy. As the cage descends, the buoy escapes from the tube and rises to the surface, taking with it a communications cable. The float doubles as a 4G cell tower, allowing data and instructions between the underwater enclosure and remote pilot control facilities, possibly from a local support vessel or at shore facilities in Morgan City, Louisiana, or in Norway.

"This is quite adequate for offshore regions such as in the North Sea with offshore assets relatively close together, but we have been equally looking at its application in other areas with more distributed and remote assets such as Africa and the Gulf of Mexico. Due to their location they cannot support 4G broadband signals and rely on over-the-horizon satellite communication to transmit control and data signals.

"There have been numerous advances in such communication over the years and at present, we communicate with high-orbit satellites. These require a perfectly aligned, relatively large dish. This demands a stable platform.

"We are, however, looking at the next generation of low earth orbit satellites. These could provide enough bandwidth while also being much cheaper to offer, particularly because they do not require a large dish. They are also much easier to align. That opens up the opportunity to install such an antenna on a Liberty buoy that can exchange messages even when rotating or gyrating,” said Lindso.

"The first phase of these satellites will cover equatorial and tropical areas such as Africa and the Gulf of Mexico, in which the fields are much more remote and separated. They will hopefully be operational sometime in 2021."



Using the same garage

ON TRIAL

The verdict of the ONS committee was that this year's Innovation Award should go to Blue Logic for the development of a new subsea docking station for underwater vehicles.

IN THE DOCK

SUBSEA DOCKING STATION

Underwater vehicles have become an integral component of observation or light intervention operations within the offshore industry. Conventionally, these remote vehicles have been physically or electronically tied back to a floating mother vessel, both to receive power and exchange data.

These surface vessels, however, are extremely expensive to maintain and generate a large carbon footprint. For many years, operators have looked to reduce costs by finding different ways of reallocating their prime functions of the vessel to other agencies.

It is now possible to control and communicate the underwater vehicles not from the vessel, but from remote facilities from land possibly thousands miles away. This property is particularly beneficial during the current travel restrictions due to the Covid 19 pandemic. The underwater vehicle's power demand has been harder to supply.

A number of underwater vehicle developers have recognised the operational advantages of expanding into the autonomous workspace but these too need to recharge. Others have begun to explore ways charging remote vehicles (and carrying out data exchange) from nodes housed within bespoke underwater garages. This is especially appealing for servicing remote subsea fields or supporting a space-congested surface platform.

Equinor was instrumental in driving this revolution, announcing its desire to use these subsea resident vehicles and willing to invest in the technology to develop them. The company suggested that by 2020, every new greenfield development they operate should be prepared for a docking station in the design.

Interface designers Blue Logic has taken the step of developing a universal docking platform. Any underwater vehicle or drone can use the platform to recharge and download information before continuing to its next assignment.

"We are probably better known as a developer of subsea hydraulic, electrical, communication and mechanical interfaces," said Blue Logic's Business Manager Helge Sverre Eide, "so this wireless platform represents a progressive extension of this technology.

"Many of us worked with Ifokus and when we were bought by Oceaneering, we started looking for a new venture. We were interested in developing underwater electrical and mechanical interfaces for subsea equipment. We were probably better known for developing hydraulic connectors, but we also had one of the first inductive power transfer systems. This development coincided with the growing demand for underwater electric actuators and control systems and the latest generation of underwater vehicles that were slowly coming to market.

GARAGES

While underwater vehicle developers were concentrating on using custom-designed underwater garages to supply their own vehicles with their precise power requirements and interface with their own systems, Blue Logic, decided a better strategy might be to develop a universal station allowing recharging and data transfer to any vehicle

"An important part of our business strategy was that the station could be used by vehicles of all sizes and shapes and to do that , we had to develop open standards and open interfaces," said Eide. "We worked closely with major developers such as Saab, Oceaneering , Subsea 7 and Saipem and in the US, with DeepStar to incorporate the fundamentals into the next edition of the API 17H."

CHARGING STATION

The station consists of a framework structure with a flat roof on which the underwater vehicle lands. This structure measures 2.586m x 2.856m (8.484 ft x 9.370 ft) but the design is fairly fluid and it is quite possible that other dimensions and layouts will emerge in future. These garages are lowered to the seabed and securing using a range of methods depending upon the seabed condition. It can lie on the seafloor as a gravity structure and especially over a standard API 17 D guidepost, either on top of a suction anchor or piled into the seabed.

Underneath the framework roof lies the recharging and wireless data transmission equipment, transformers and control systems. The design consists of up to 22 ports distributed across the, top, sides and corners lined to a fibre optical communications and power connector. The power can be supplied by an umbilical link from the surface but alternatively, may also be fed from local wind or wave energy generators.

The station roof and other parts of the structure house a number of AruCo markers- better understood as QR -type codes.

These are positioned so that when approaching, vehicles of various dimensions are able to recognise an navigate in 6 degrees of freedom. When the drone cameras focus on these, machine vision software can calculate the angle and position relative to that marker and interpret the relative position.

One novel feature of the Blue Logic structure is a magnetic homing system that can work in parallel with the markers. This allows the vehicle to navigate, possibly in total darkness, by

Blue Logic station

Trials of a Saab Seaeye vehicle docking onto a Blue Logic station

Markers on the platform used for positioning

locking into the residial magnetic field that the electric induction system naturally emits.

“The magnetic waves used in the power transfer system adopt a mushroom-like shape and the vehicles coming in for landing can use this phenomena,” said Eide.

“A detector coil housed within the free-flying vehicle can sense this magnetic field and use it to home in on the landing target. The two-way communication allows the ,vehicle to assume the correct position in relation to the charging station. It is possible to navigate the drone down to 1mm accuracy using only the magnetic field.

“We own the patents the copyright but rather than stopping anyone else using it, our open interfaces business strategy allows others charging stations to adopt it but at a different price point.

“The power interface is broadly analogous to a charger on a mobile phone,” said Eide. “On average, a typical drone has a battery size of around 30 and 50 kWh. A typical charging capacity, however, is around 5 kW, so for a deep charge, this takes around 10 hours.

"There can be considerable waiting time between operations. The system we have developed is adheres to inductive standards but we have incorporated a specialised charging algorithm developed in-house.”

COMMUNICATIONS

The wireless communications systems are based on by a full duplex 100 megabit ethernet link.

“There are three main methods of wireless communications underwater,” said Eide. “On behalf of the subsea wireless group (SWIG) we has developed the inductive standard in addition to the original acoustic, the third, free space optics, is seen as the next area for standardisation. The open standards mean that any device will be able to connect their equipment, however proprietary systems already exist.

While the developers of the established systems will want to protect their superior bandwidth, etc, it is equally likely that there will be applications that don’t have a bandwidth requirement, that an alternative to free space optic could be good enough.

But why is underwater communications so important on a charging station? If an underwater vehicle has to take 10 hours recharging, then surely it doesn't really matter how slow the data rate is, because the vehicle has to be on station anyway.

“Not so,” said Eide. “A large AUV can return from a survey with 2 TB of data. Transferring this at 100 megabits/sec can actually take 36 hrs. and the upload bandwidth, therefore forms the bottle neck. One solution might be to use free space optical systems that can transfer data at rates of 1 to 4 GB of data gigabit per second of data and we are currently looking at a fibre-optic tether connection. Once this has been perfected, the then the bottleneck then returns back to the power system.

TOOLING

Blue Logic say that the design of the charging stations are not only about power, but also about tooling.

“In order to maximise the use of an underwater drone, especially one resident on the seabed, it has to have access to as wide a range as possible to sensors and tooling to perform different tasks.

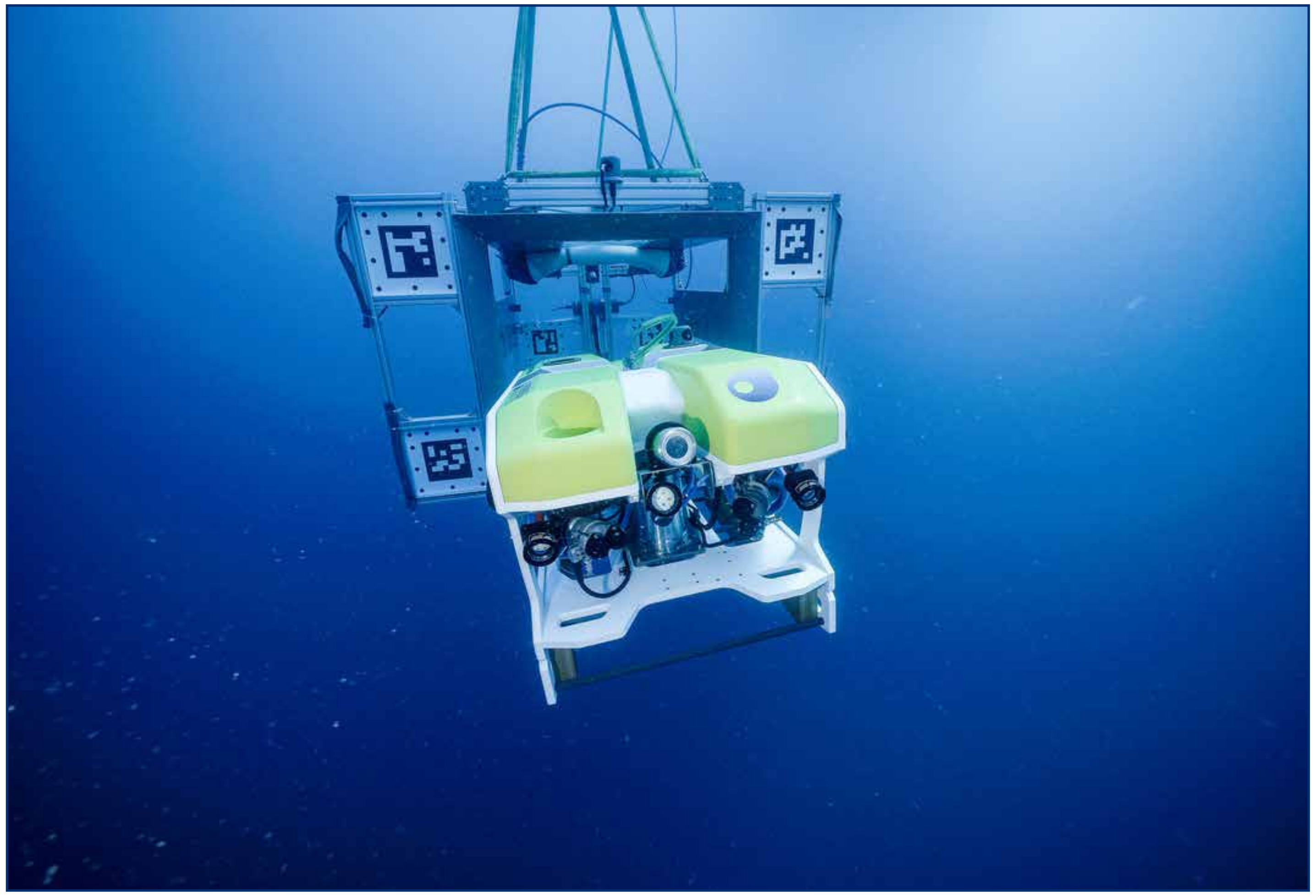
Instead of the power-critical vehicles having to carry these tools around, another option is for the removable equipment items to be stored subsea and the vehicle to simply access them on demand from a seabed bin or carousel.

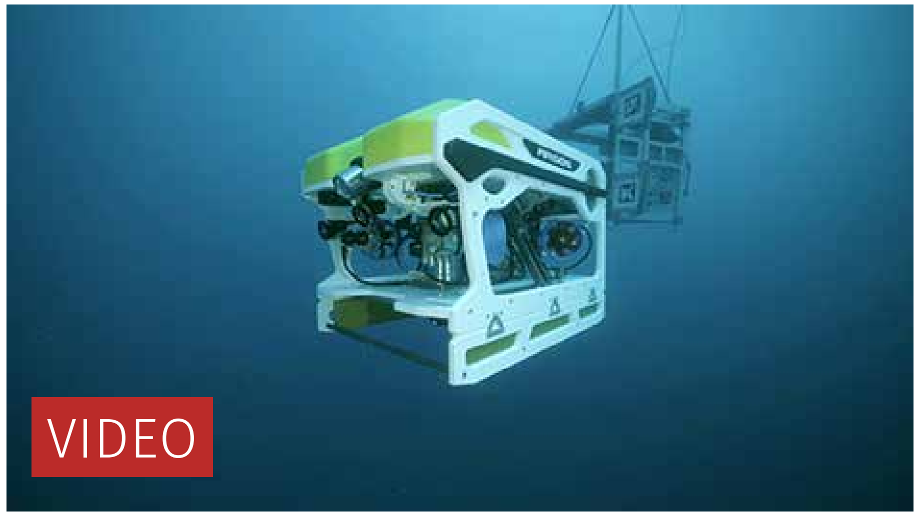
These subsea stations, therefore, can double as an equipment depositary although once again, this will require a standard interface.

At present, Equinor has ordered 5 docking stations. Two are in production, one is installed in Trondheim at the University, One is being used for testing in Sweden and Italy, and the last should have already been installed but this has been delayed due to coronavirus.

A R G O S

Forssea has developed a new inspection and light workclass ROV. Called Argos, this can be seen as an intermediate step to developing a fully autonomous vehicle





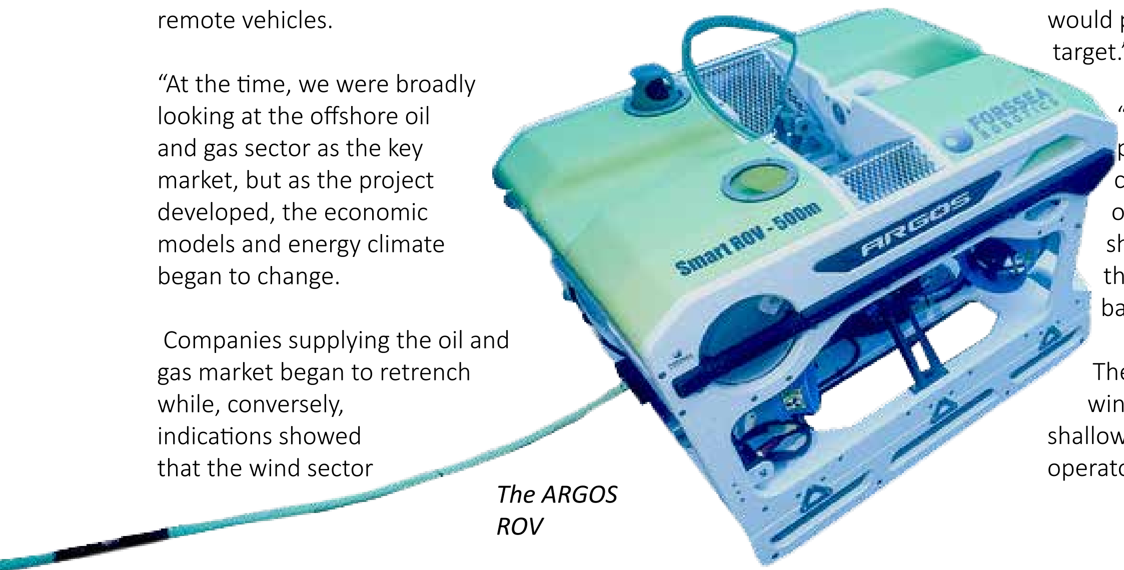
A few years ago, Forssea Robotics made a splash in the underwater market with Atoll, its novel observation ROV. At the time, the company was also developing a novel ethernet-based camera system. This was able to recognise QR codes on underwater structures.

Today, the machine vision image recognition technology has become more advanced to the point that in order to derive the maximum potential benefit for the technology, the company reasoned that it needed a free-flying ROV.

“We could have selected any one of a number of ROVs” said Gautier Dreyfus, “but we decided a better direction would be to develop our own because we envisaged that during the journey, we would learn more the practical aspects of about how our cameras worked with remote vehicles.

“At the time, we were broadly looking at the offshore oil and gas sector as the key market, but as the project developed, the economic models and energy climate began to change.

Companies supplying the oil and gas market began to retrench while, conversely, indications showed that the wind sector was set to grow dramatically. This would provide a far more appealing target.”



The ARGOS ROV

“The wind market requires powerful, compact ROVs to carry out light intervention operations in high velocity shallow waters. Satisfying these demands formed the basis of the Argos design.

The present generation of wind turbines are in relatively shallow waters , however, many operators are also promulgating floating designs for deeper waters.

The Argos ROV was designed with 500m depth rating, however, with relatively simple modifications, the vehicle could be re-engineered for work in 1000 m water depths.

“With the Argos, we are also looking at a different business model,” said Dreyfus. “ We envisage not only providing a powerful vehicle, but also the whole extended package that goes with it. The client will, of course, require training on how the systems work but we envisage a model of working closer together with a survey or maintenance partner together on a lump sum contract.

“The ROV is now fully built and field-tested. We were supposed to carry out its first deployment looking at a gas line in the North Sea, but this has been postponed until next summer because of Coronavirus. We have, however, been organising a series of tests in south of France and are planning to conduct shipwreck surveys. The French Navy have been part of these tests.

QR CODES

From the start, image recognition has been one of the most important tools of Forssea’s technology armoury.

At the time, simply being able to calculate distance was the sole domain of the subsea laser. Visually locking onto the image, however, the camera can recognise the code and interrogate a database to provide more information.

More importantly, machine vision software developed as part of the camera system, can now image the various shapes and particularly, the angles and straight lines that the QR code presents.

From the relative differences in perspective, it is possible to look at numerous tracks and calculate the distance to the target as well as its orientation and declination using trigonometry.

“An example we often use is when installing a structure on a pile,” said Dreyfus.

“Stabbing one structure onto another underwater is difficult to accomplish in three dimensions. With a QR code on the pile and another on the structure, however, it is possible for a cameras on the ROV to view both simultaneously and provide information on one moving relative to another.

"The software can automatically detect the location of each. It can tell the exact orientation pitch heading and role of all structures in 6degrees of freedom. By triangulation, calculate the distance between the

The user-screen during docking

two in real time as the vehicle and the pile closes together.

"In theory, the image doesn't even have to be a code; it can be any identifiable item on the structure such an identity marker for valve. One concept that Forssea are working on is called 'Polar X' which is based on combining smart cameras working in polarised light in order to achieve better visibility.

QR codes are also useful during an underwater survey. Vallourec, FORSSEA Robotics and iXblue have developed a pipeline inspection solution combining subsea drones and the use of visual markers, removing the need for surface vessels.

Traditionally, the inspection of subsea pipelines and structures requires the use of a surface vessel (manned or unmanned) with acoustic positioning used to monitor the deployment of Autonomous Underwater Vehicles (AUVs) or Remotely Operated Vehicles (ROVs).

These subsea vehicles then collect the required information – such as a pipeline's general aspect and route, anode consumption, free span, burial and crossing areas – using observation sensors.

In order to reduce pipeline inspection operational costs, visual markers are integrated directly onto subsea pipelines. These passive positioning reference barcodes, logged with their own coordinates during the laying operation, will remain accessible throughout the life of the field.

When the pipe is laid, the markers can be used as navigation aids for subsea drones equipped with FORSEEA cameras and iXblue's inertial navigation system. These relay the pipelines' locations to the operators thus removing the need for acoustic positioning systems and costly mother vessels. They remain visible to divers and subsea drones throughout the project's lifespan.

Another application for QR Codes is for their use in underwater garages. Subsea resident ROVs are becoming an increasingly interesting feature of many subsea projects, bringing a number of cost-effective advantages.

This requires the autonomous visual docking of the vehicle for recharging and data transfer. The use of subsea markers can provide great assistance in the docking process.

"It is more than just nice to have," said Dreyfus. "It is quite challenging for a pilot to land a ROV in or on a docking station and many ROVs benefit from some sort of software-driven stationkeeping. QR codes can further assist the pilots so that it is possible to move 1-2 cm at a time and even deal with latency.

"We carried out the testing programme in 2019 in Egypt and elsewhere in the North Sea. Since then, we have carried out more testing in the Congo and Australia last year.

We had trials in which the Navy was invited. Military work comes along in 5-10 year cycles and it is a long-term strategy to be part of that.

" Our ambition is to develop a hybrid ROV. We have been developing the software. Next year, we will replace a battery pack and while this will be a challenge, it is far from insurmountable" said Dreyfus.

ROV WINCH

While probably better known for its patented 100kpa suction dredge systems, Vortex has been looking to other areas of underwater tooling development for use with ROVs and divers.

One project that Vortex was planning demanded the purchase a dedicated subsea ROV mounted winch. Looking at the market, however, the company struggled to find a suitable device. This made Vortex pair up again with integrated subsea technology and services provider Ashtead Technology to specify and build its own line of heavy duty winches.

A small smaller version is presently in the final stages of manufacture in New Zealand.

Ashtead Technology has a number of Vortex winches on multiyear hire in the wind farm sector running survey packages on foundation piles.

The operational compatibility of these winches covers a vast array of potential operations operated from topside or on a host ROV.

This includes the new Vortex Heavy duty ROV camera winch. Constructed from stainless steel and Acetyl, with oil filled Gearbox,it has a 180kg capacity for operation at 3000m depth.

The gear train consists of worm drive gearbox to stainless chains and sprockets. The load holding via the worm gearbox, provides controlled lowering and full load holding – with no brake being required.

The winch is recommended for tooling packages and down hole cameras, survey packages, laser scanning inside well heads, power extension cable for subsea tooling and lifting weights.

The winch has a rated line pull of 180 kg / 442 lb at 11th layer of cable with the motor running at 1000psi. This gives a line speed of 6.8m/min at first layer of cable using minimum hydraulic flow of 16 litres/ min and minimum operation pressure of 70 bar/ 1000 psi.

Although it can accommodate custom cable sizes, it has a with the standard recommended cable size of 9mm +/- 0.1mm.

HD Winch

Using 9mm diameter cable and a theoretical wrapping of 18 wraps per layer, the drum capacity t would achieve approximately 146m.

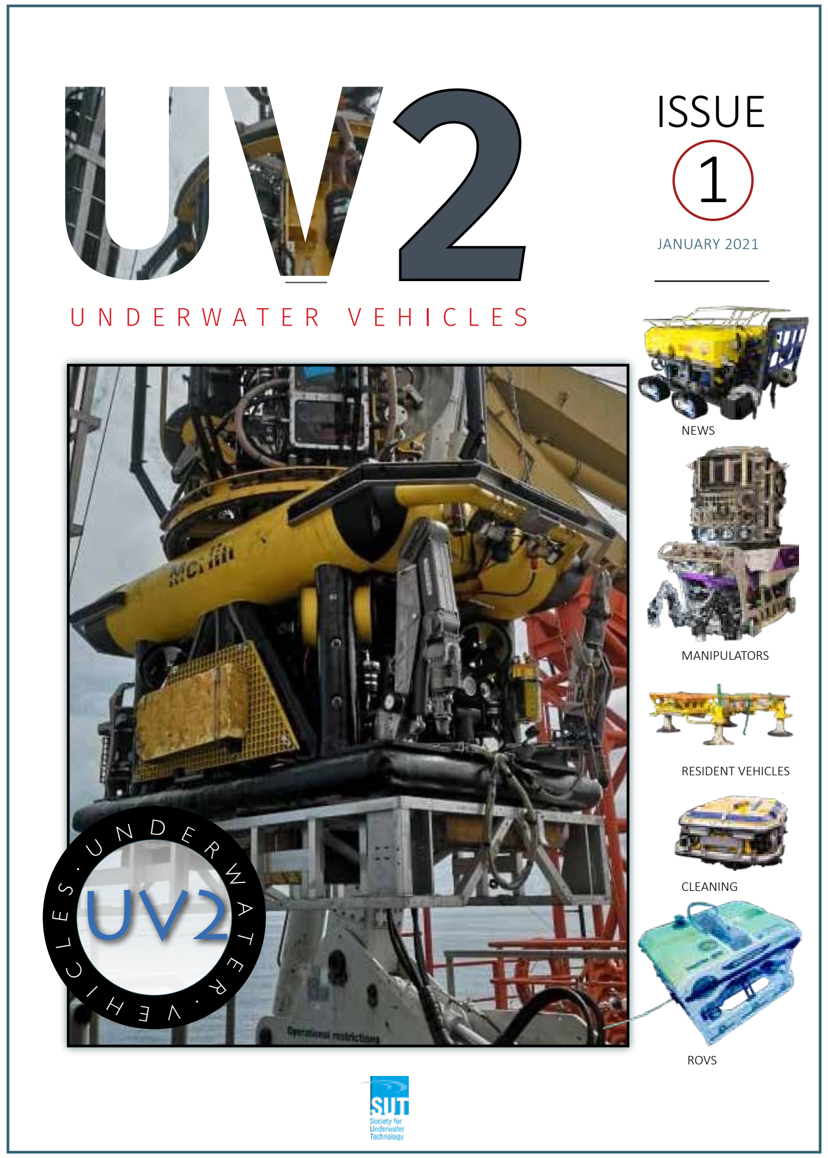
Winding the cable onto the winch is carried out using a stainless diamond bar with integral fairlead These have oil filled slip rings .

The weight of the winch in air is 59kg but this decreases to 39kg in water. Its dimensions are 650mm L x 550mm high x 528mm wide.

HD Winch on tool

Next Issue

- News
- Gliders
- Thrusters
- History



2Q 2021

OFFSHORE CLEANING TOOLS

When a structure is launched or placed in seawater, it comes into contact with is in contact with A variety of different organisms from slime and algae to macro fauna.

For more information on Biofouling, see UT2 Issue 6 2020

BIOFOULING

Jotun's HullSkater vehicle

When biofouling is are attached to the hull of a ship, it can impart drag resistance which Increases the power required to move the vessel by up to 85%. It can accumulate on floating structures such as buoys, oceanographic sensors or even underwater vehicles.

Coatings are the first line of defence but biofouling Is often removed by divers using high-pressure water jets. For planar surfaces, cleaning vehicles are the tools of choice.

Coating manufacturer Jotun has developed a hull cleaning device called a HullSkater.

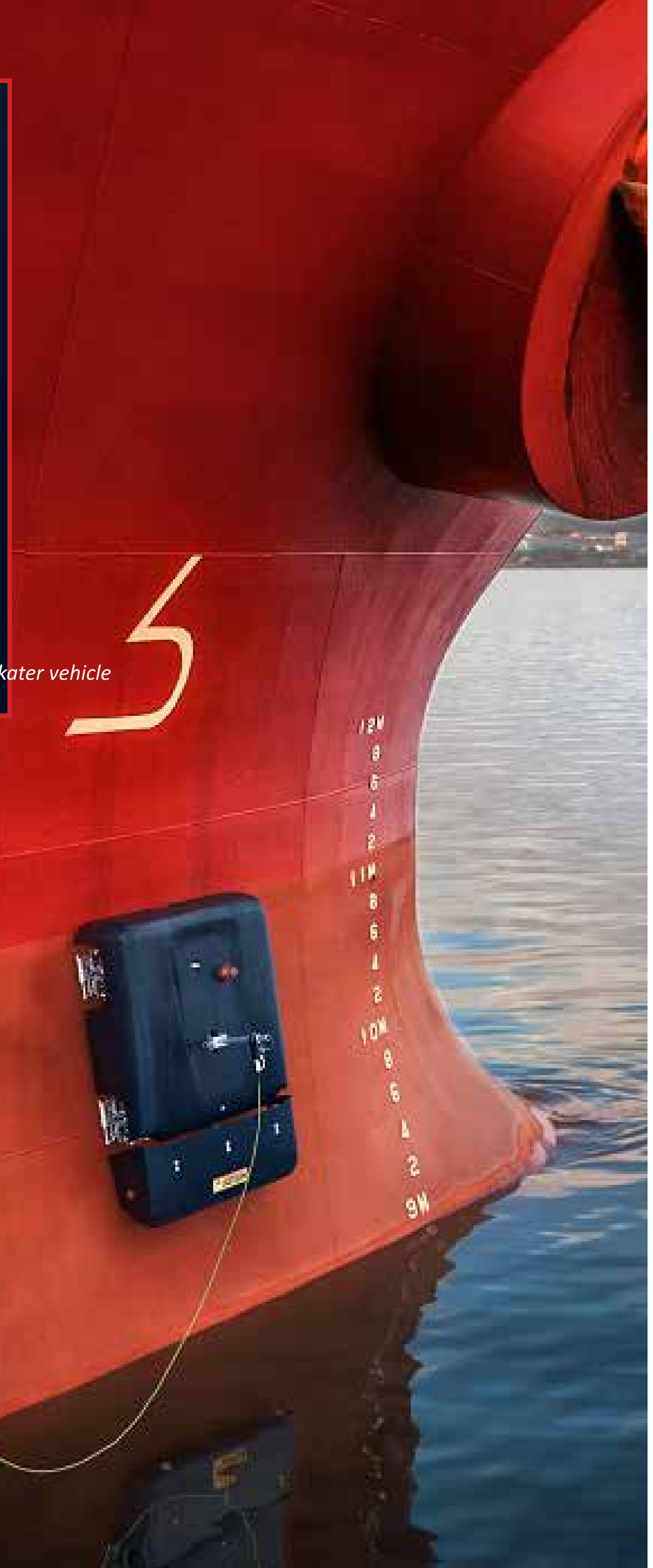
The key difference between the HullSkater and conventional underwater hull-cleaning crawlers is that the latter are employed to remove fouling that has already taken place for one reason or another.

"Removing fouling in its advanced stages requires harsh mechanical action," said Jotun's Global Marketing Manager Tan Keng Khoon

"This action can often abrade the vessel's antifouling coating, shortening the remaining protection lifespan. Furthermore, with the mechanical removal of the biofouling, the profile of the remaining underlying coating becomes rougher, making it more prone to future fouling attachment and an increased drag resistance. Jotun's HullSkater, conversely, provides proactive cleaning.

The HullSkater has been specifically developed together with the SeaQuantum Skate coating, with no observed erosion of coating or brush during cleaning mission, documented through laboratory and in-service testing.

The HullSkater starts by inspecting the hull using 4 high resolution video cameras, three front facing and one rear-facing, the target being illuminated by 4 LED lights with low beam peak intensity



As soon as early stage slime is detected, the cleaning part of the operation is conducted. This uses a 900mm wide brush rotating at 220 revs/min. The 227mm diameter brush is driven at 450W.

Behind the cleaning systems is the control electronics housed in a pressure container, and the propulsion system. The Skater is self-powered by Lithium ion battery packs supplying 4kW of power. These can be totally charged in 2 hours.

The drive line is capable of moving the HullSkater at high speed. It has a total of 4 drive lines for propulsion, 4 for steering and one for actuating the brush. The drive lines consist of a permanent magnet motor, encoder, gearbox and motor driver.

The vehicle is attached to the hull by means of a magnet, however, in the event of a malfunction, there is also a mechanism that allows controlled release from the vessels hull.

A Durable polyurethane tether Allows the pilot to keep command of the skater, delivering feedback of all sense of signals and simultaneous video streams.
And acoustic nude enables in cryptic communication with the skater.

The HullSkater is kept on the board vessel in a portable unit Which includes its own launch and recovery ramp. As it is not deployed by divers, it can not only used when the ships in the harbour but also when it is at anchor.

Jotun's in-house analysts can, through proactive condition monitoring, make fouling predictions based on big data trends, algorithms and analyses, and then advise customers on when to carry out hull maintenance.

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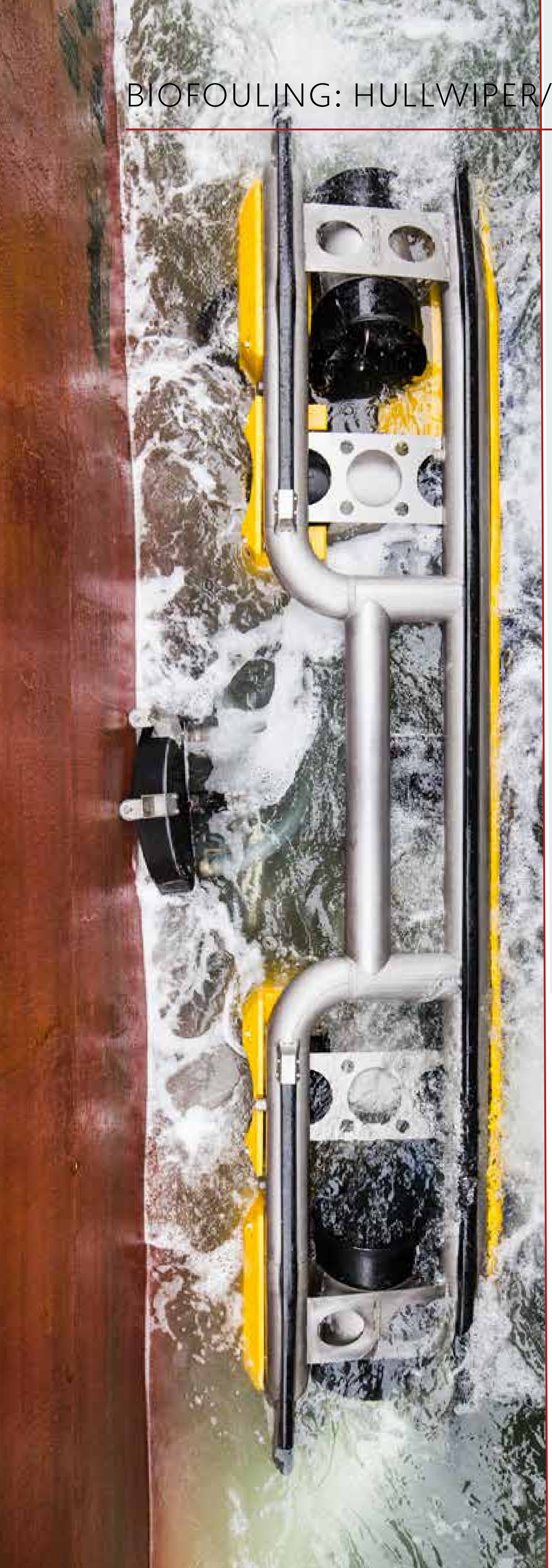


HULL WIPER

The HullWiper is a purpose designed Remotely Operated Vehicle (ROV) hull cleaning machine capable of working in water depths down to 40m. The body measures 330 cm (L) x 170 cm (W) x 85 cm (H) and weighs 1275 kg, and lies neutrally buoyant in water because of its solid cell syntactic foam structure that is attached to the main stainless steel tube frame.

The ROV is connected to the surface support facilities by a 350m long, 24mm Kevlar outer diameter armoured umbilical. The umbilical delivers 690VAC, 3-phase and 230VAC, single phase power to the vehicle through its conductors. It also has eight single mode fibres and a ¾in HP 300bar water hose.

On the front of the ROV are a pair of 250W LED light banks controlled by a 3-channel dimmer. These lamps illuminate the target for the vehicle's camera system. They are equipped with removable IR-cut filter for day and night function effective up to 15m distance, and have a resolution of 1280 X 800 pixels.

The imaging system has a built-in MicroSD/SDHC memory card slot for onboard storage. At the surface control room, the live images can be viewed from a pair of 32in monitors. The viewing screen has an overlay facility for data presentations including depth, date, time and heading. It has the capability to superimpose text and there is also a video grabber.

The vehicle's management system has a 4bar depth sensor, a 160 bar oil pressure sensor, a Magnetic 5 level oil sensor with automatic shut down (with 25% oil level) and a 600 bar high water pressure sensor.

LAUNCH

Once lowered into the water by crane, the HullWiper ROV uses eight hydraulic thrusters to adhere against the side of the hull which allows it to move across the hull as required. It can move horizontally at 2kts and vertically at 0.7kts.

The propulsion is driven by a hydraulic system. From its 40-litre reservoir, fluid is pumped at 195 l/min at 130 bar, compensated with an overpressure of 0.5 bar.

"HullWiper works by spraying seawater through its adjustable jets, directly onto a ship's hull at a very high pressures (50–450 bar 80 lit/min) which is powerful enough to dislodge waste materials without using scrubbing, harsh chemicals or abrasive materials," says Simon Doran, Managing Director of HullWiper.

"This ensures that the vehicle does not damage the ship's expensive antifouling coatings."

The water system has a pump capacity up to 635 lit/min. The actual cleaning unit consists of three discs, each 480mm giving a total cleaning width of 1,460mm. Each disc has 4 nozzles (12 in total).

Rather than polluting local port water and risking the spread of harmful invasive marine species, HullWiper collects marine fouling from hulls using a 38 m³ / hour waste suction pump. Captured residues are pumped into an onboard filter unit and deposited into dedicated drums onshore for safe disposal. These are collected by a locally approved environmental waste disposal company.

The effectiveness of HullWiper's filter system in cleaning biofouling from vessel hulls has been verified by AMT Environmental, an environmental analysis and consulting professional.

ECOSubsea

There are considerable efficiency and environmental savings to be made by cleaning ship's hulls of biofouling. A number of companies have taken up this challenge by designing intelligent and sophisticated cleaning devices

One such is the Norwegian company EcoSubsea. The company originally worked out of Southampton but the Dutch national regulatory body, Rijkswaterstaat recently gave permission to start offering hull cleaning services to vessels at all Dutch Ports including Rotterdam, a move that is helping the firm solidify its position in Europe following similar agreements in Antwerp, Zeebrugge and Ghent.

The cleaning robot they have developed measures around 3m long and stands 2m in height. It can remove biofouling at a rate of up to 3000m2/h.

"Picture an underwater vacuum cleaner or an automated lawnmower," said Tor M. Østervold CEO of ECOsubsea. "The technology shares qualities with both of them. "It is based on a remotely operated underwater vehicles with patented "soft jets" that ensure effective, non-abrasive cleaning gently remove all organic matter without damaging vessel coatings.

The debris is sucked along a 200m vacuum hose and into a collector unit which amasses everything that is removed from the hull. The material is taken for collection, filtration and used for biogas (under a project with waste and energy management company Veolia).

The entire hull-cleaning process takes an average of 8.5 hours, but this can be carried out during normal port-based cargo operations.

CLEANING TECHNOLOGIES

Marine growth cleaning is a key component of any hull, riser or mooring inspection operation, especially when class certifications are due or asset inspection, maintenance and repair (IMR) management programmes are to be undertaken.

Ashtead Technology’s in-house asset integrity management specialists use ROV-deployed underwater measurement technology to support routine integrity management, damage assessment, fitness for purpose evaluation, and asset life extension. Our proprietary cleaning technologies enable thorough and effective visual inspection, measurements and NDT; removing months or years of marine growth to uncover the true condition of assets underwater.

Traditionally, seafaring vessels will drydock for hull inspections to maintain Class compliance. When a hull inspection is required for permanently-installed production assets every 2.5 or 5 years, Underwater Inspection In Lieu of Drydocking (UWILD) surveys via ROVs are the preferred approach.

This requires ROV cleaning methods and NDT technologies to measure cathodic protection, hull plate thickness among other requirements.

Chain cleaning

Similarly, subsea risers and moorings require inspection to ensure fitness for service. Mooring chains are designed with specific corrosion allowances to account for corrosion and wear throughout their service life. Design corrosion allowances are generally 0.2-0.4mm per year, but often higher in tropical waters.

This often amounts to as little as 4-8mm total corrosion allowance for a typical FPSO mooring system with 20-year design life. Chain diameter is a de facto performance standard for every mooring system and the accuracy and precision of measurement tools is critical when corrosion allowances are so minute.

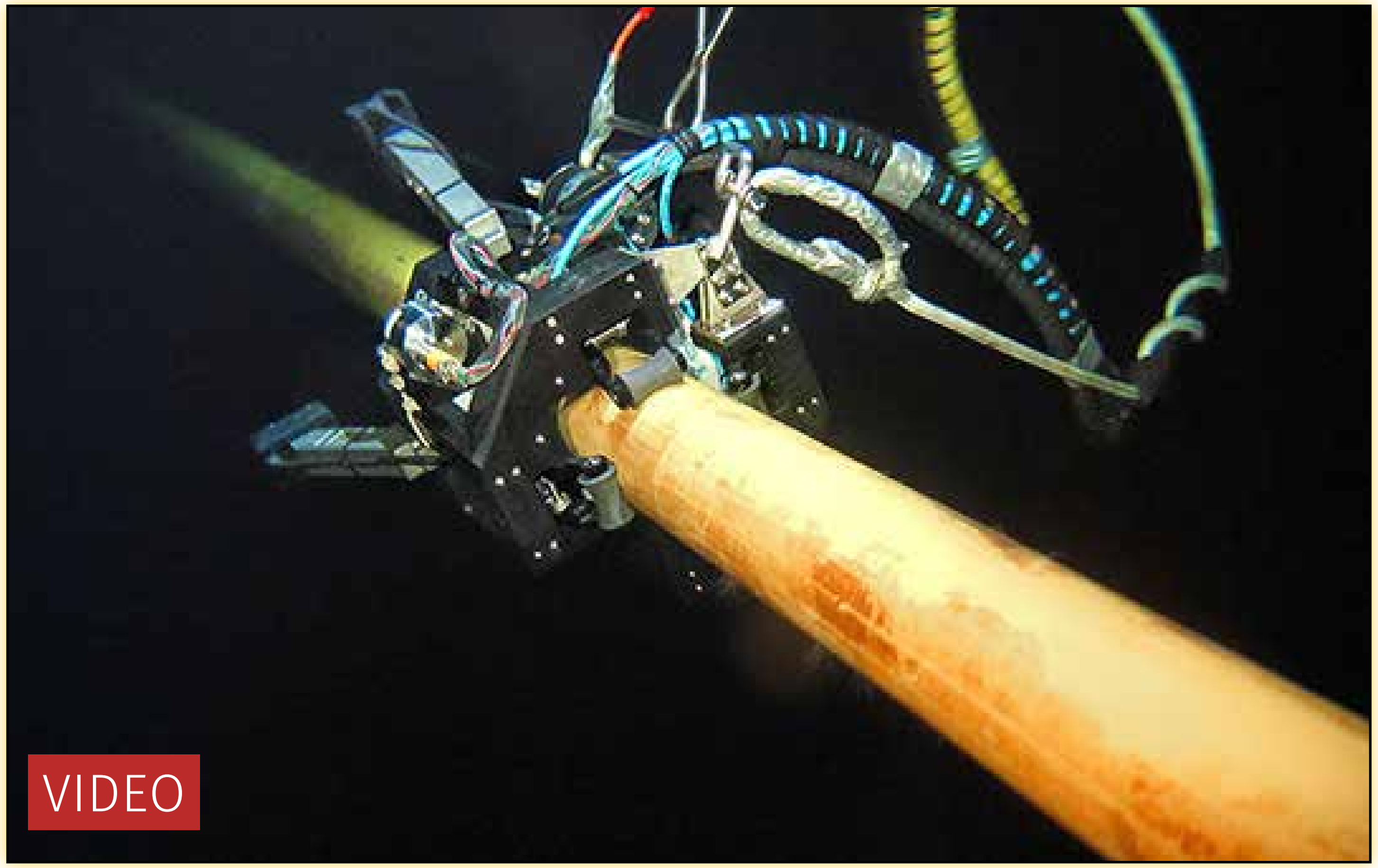
Ashtead’s Subsea Cleaning Tool (SCT) is a low-cost yet highly effective tool to remove difficult marine growth from subsea components and vessel hulls.

It comes with two cleaning heads: 1) flexible rods for soft marine growth or coated components, and 2) a brass chain flail head for hard marine growth and calcareous scale. ROV cleaning time can often exceed the time to inspect hulls and mooring chains.

The SCT dramatically reduces cleaning time, saving operators both boat/ROV time and associated costs for inspection preparation. The SCT can be used by both Class II and Class III ROVs, allowing hull cleaning operation to be performed by ROVs launched from the production asset.

The Welaptega Riser/Rope Cleaning and Inspection System (RCIS) cleans and inspects the surface of flexible risers, marine power cables, umbilicals and fibre or wire moorings. The RCIS frame is towed by a ROV, efficiently cleaning both soft and hard marine growth.

An optional module consisting of four cameras performs a full 360-degree close visual inspection of the riser or rope surface.



Tailored to the exact requirements of the scope, the RCIS can also be outfitted with an inclinometer to measure line angles or depth sensor for precise position referencing.

The RCIS enables rapid, safe and thorough cleaning of subsea tubular components supporting your inspection and riser weight/fatigue management requirements. The RCIS is also used to clean risers prior to decommissioning, as it is faster than topside cleaning on the support vessel and reduces onshore disposal costs.

Brush cleaning

FLEXICLEAN

For a number of years, the Norwegian company Lateral has been using its FlexiClean system to remove marine growth and debris on underwater structures and equipment. Earlier this year, the company extended this to smaller electrically-driven vehicles.

In order to carry out successful underwater inspection, especially in shallower waters, it is likely that at some stage, a biofouling covering will have to be removed.

Seven years ago, Lateral entered the market with its patented FlexiClean. The original system consisted of a cross-shaped rotary brush and work by each of the four arms or fingers physically impacting against the target in turn, using a slapping mechanism.

The force that this imparts on the target depends on parameters such as the length and number of fingers, the mass and elasticity of the material and the rotary speed. It cleans along the entire length of the sweeper arm as it drags along the surface after impact. The arm then flicks the fouling out of the way.

“Importantly, unlike brushes, this system doesn’t clog and has an extremely good endurance” said Lateral’s co-founder Keith Robertson. We have experience of over 150 hours of cleaning using a single head.

"It also has advantages over some water jetting systems which are depth sensitive. Unlike jetting, the FlexiClean is not impaired by dislodged debris present in the water absorbing jetting energy and standoff distance is not critical. Importantly, it does not damage any underlying surfaces and produces quick results.

"When a third party tested the FlexiClean head for upwards of 4 million impacts on a flexible riser outer sheath, it showed no evidence of damage."

The standard unit, used on work class ROVs, consists of three layers of cruciform plastic blades measuring 600mm across, arranged as a stack. A further development saw a field-configurable lower-vibration head geometry option.

The arms are hydraulically-driven from the ROV’s tooling power circuits using motors, specifically designed to withstand the punishment taken by the system during cleaning operations.

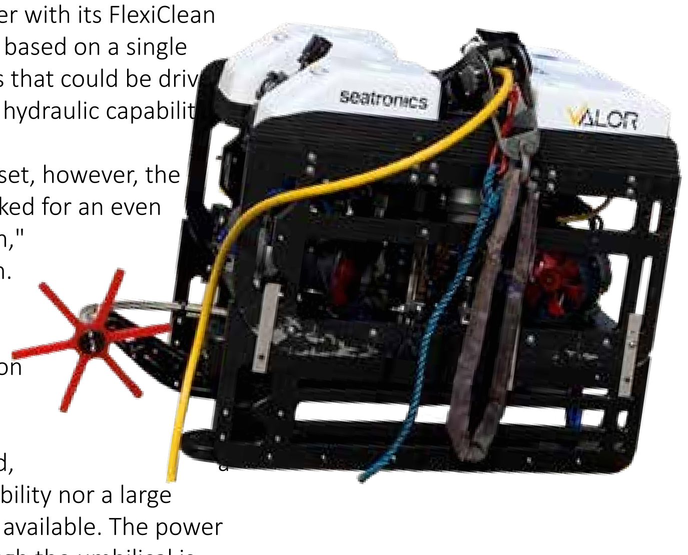
The company then extended the technique to smaller ROVs with less hydraulic power with its FlexiClean Mini. This was based on a single layer of fingers that could be driven with a smaller hydraulic capability.

"From the outset, however, the market had asked for an even smaller version," said Robertson. "The problem with this was that observation class vehicles neither have a large payload, hydraulic capability nor a large power budget available. The power supplied through the umbilical is sized to satisfy the vehicle’s imaging and thruster requirements, with only a small part allocated for any tooling demand."

This drove Lateral to look at a battery-powered design. The lithium battery-based system would have to be large enough to make cleaning possible, but not so large or powerful that the vehicle would be incapable of physically handling the payload or be incapable of counteracting the forces imposed on it by the cleaning action.

“We arrived at a smaller-diameter' six-fingered tool driven by battery and able to run at full speed for about 30 mins,” said Robertson.

“Called the Micro, it has a diameter of approximately half that of the standard system, and is powered completely independently of the ROV.
"The sole requirement is a trigger signal from the ROV. Once triggered, the system’s internal control takes over, self-checks and then starts up on demand.



A Seatronics Valor ROV with a Flexiclean tool

“We considered a good additional feature would be to incorporate trickle charging, taking only a small amount of power from the vehicle when available, thus allowing the battery to be recharged when the tool was not running.

"When on deck, it takes around an hour to charge the battery although on the vehicle itself, it will take nearer 6-7hrs from flat. By working in a set routine, however, say, doing cleaning for 10 minutes and then inspecting for 15 minutes, the battery could probably last a full 12hr working shift.

“The prototype was well received in principle and remains the standard solution, however, some clients recognised the relatively short battery life as an operational constraint and requested a system able to be powered from the ROV. In addition, shipping lithium batteries by air is a painful process and should be avoided where possible. We minimised the issues around this by utilising a widely available and locally sourced battery pack.

"In order to be commercially viable, we had to develop a generic power supply solution able to fit on maybe 20 target ROVs, each with its own individual power architecture, rather than tailor it around each specific system.Currently, we have solutions that are applicable to common ROV candidates.

“Once we developed the prototype, we contacted some regular customers and arranged to install it on their vehicles for tank tests as we really didn’t know how it would behave on smaller vehicles. The cleaner generates significant torque and we wanted to ensure that the tool would rotate, not the vehicle.
"We followed this by three problem-free integrations and tank tests and field operations on three electric vehicles, (Seatronics VALOR, Saab Seaeye Tiger and Ocean Modules V8 M500). Other vehicles are being added regularly to the list

But exactly how small could the mother ROV be, while still being able to operate the device efficiently?

Lateral had been speaking to a local company, Norwegian Tunnel Inspection,whose business was principally inspecting hydroelectric tunnels using their Saab Seaeye Falcon. The Falcon was less powerful and physically smaller than the others we had tested but being produced in significant numbers made the ROV an appealing candidate.

Tank-testing proved to be very successful, the vehicle handling the system with ease.

"Taking the opportunity of having the Falcon in the test tank, we swapped the standard head for that of a different geometry to gauge the vehicle reaction and again, this was very successful," said Robertson.

A Saab Seaeye Falcon testing the Flexiclean

"Looking to the future and recognising the advances being made in the areas of all-electric and resident ROV’s, we are looking at two developments.

"One area is to drive the FlexiClean by water instead of hydraulic oil. We have already delivered a custom-built FlexiClean Mini based system using water hydraulics and are looking to provide this on a wider basis.

"Conventional hydraulic circuits have a flow and return which is not necessary in water-based circuits. This design immediately eliminates any undesirable oil leakage to the environment.

"In addition, we are looking at the direct electric drive of a standard configuration FlexiClean. The combination of high torque and low speed in a sensibly priced and sized package presents significant challenges but we believe it is achievable," said Robertson.

FLEETCLEANER

Delft-based Fleetcleaner has designed a hull cleaning ROV that uses high-pressure water jets for cleaning the vertical sides and bottom of a ship's hull. Depending on the coating type, condition and fouling severity, it is possible to can continuously regulate the water pressure to ensure suitable cleaning result without damaging the coating.

The Fleetcleaner ROV is attached to the ship's hull by magnetic force This keeps the attachment and locomotion of the robot independent from the cleaning.

"It enables us to clean in all weather conditions and in places with strong currents such as the Scheldt river in Antwerp," said a spokesperson. "On such places where the visibility is near zero, we can use our inhouse-developed localisation and navigation software.

"This sophisticated software enables us to clean on places where divers or other underwater contractors cannot operate. It ensures a full semi-autonomous cleaning coverage of the vessel.

"The ROV size is approx. 2m by 1.8m and stands 0.8m tall. It weighs around 800 kg out of water. In operation it is possible to cover over 1300m^2/hr.

"All fouling is captured and transported to our support vessel.

This is based on a 20ft container fully equipped with advanced filter equipment to ensure only clean water is released back into the ports, thus complying with the most stringent environmental regulations.