UT TWO

UNDERWATER TECHNOLOGY

ISSUE 5 2021

SURVEY
IRM

SUT
Society for Underwater Technology

SUT
Society for Underwater Technology

SOCIETY FOR UNDERWATER TECHNOLOGY

HQS Wellington,
Victoria Embankment,
London WC2R 2PN

Vol 15 No 5

Editor: John Howes
John@ut-2.com
+44 7859905550

Editorial Assistant:
Trudy Keyhole

Production:
Sue Denham

Advertising:
Zinat Hassan
UT3subsea@gmail.com

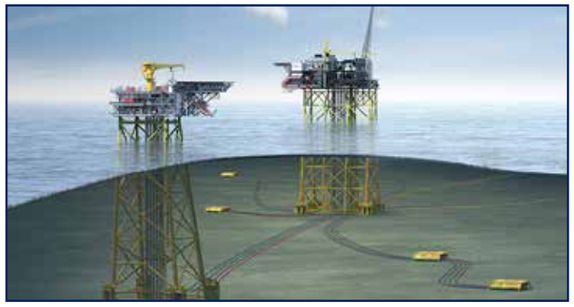
Tel: +44 (0) 845 6522 483
Mobile: +44 (0) 781 1200 483

ORMEN LANGE

OneSubsea has awarded Subsea 7 a contract for engineering, procurement, construction and installation of the subsea flowline system on Shell's Ormen Lange field as well as the installation of OneSubsea's multiphase compression system.

NOA FULLA

Subsea 7 was also awarded a front-end engineering and design (FEED) study from Aker BP for the NOA Fulla development project, offshore Norway. The awarded is required to finalise the technical definition of the proposed development prior to Aker BP and its partners making the final investment decision (FID) late 2022. The FEED study will begin immediately.



NOA Fulla

DOF CONTRACT

TechnipFMC and its joint venture partner DOF Subsea has been awarded a long-term charter and services contracts by Petrobras for the pipelay support vessels *Skandi Vitória* and *Skandi Niteroi*. The Brazilian-built and flagged vessels are owned by DOFCON Navegação, a 50/50 JV between TechnipFMC and DOF Subsea. Each contract is for three years, with an option to extend.

TROLL PHASE 3

Equinor has started production from its Troll phase 3 project in the North Sea. The project has a break-even price below $10 and CO_2 emissions are less than 0.1 kg per barrel oil equivalent. The new wells are tied in to the Troll A platform and the development will extend the platform's life past 2050.

Recoverable volumes from Troll phase 3, which will produce the Troll West gas cap, are estimated at as much as 347 billion m^3 of gas. Converted into oil equivalent this amounts to 2.2 billion barrels. Investments are approximately NOK 8 billion.

C-KORE CONTRACTS

Over recent months the UK based company C-Kore Systems has added Angola, China, Canada and Israel to the list of countries where their tools have been successfully deployed.

Customers in more than 20 countries are now benefiting from the robust performance of the devices which were developed to help oil and gas operators and contractors reduce expensive subsea intervention time.

The most recent deployments have involved both C-Kore's Cable Monitor tool which tests the insulation and continuity integrity of subsea circuits, and their Subsea Time Domain Reflectometer, which can pin-point the location along the cable where the fault has occurred.

Building on a position in their domestic market as the leader in subsea cable test equipment, C-Kore has seen its export markets flourish in recent years and the company won its second Queen's Award for Enterprise in 2021, this time in the international trade category.

At a time of a global pandemic and severely restricted international travel, the simplicity of operation has made the tools an obvious choice for time-critical interventions in all corners of the world. The comprehensive training provided by C-Kore prior to the subsea mission, together with the intuitive user interface, has enabled customers in all countries to use the tools efficiently and successfully without mobilising specialist personnel from the UK. This has resulted in both a significant cost saving for the customer and a reduction in carbon footprint.

FUEL CELL

SEA-KIT has won funding to install an innovative PCB-based hydrogen fuel cell, engineered by project partner Bramble Energy, on its 12m USV *Maxlimer* and demonstrate zero emission maritime operations.

The project, funded by the Department for Transport (DfT) working with InnovateUK, will showcase a successful diesel to hydrogen conversion of SEA-KIT's USV design and demonstrate a route to fulfilling the UK's Clean Maritime Plan Strategy commitment of reducing greenhouse gas emissions from shipping by 50% by 2050.

This project will replace one of the diesel generators with new hydrogen fuel cell technology from Bramble Energy. Bramble will design and manufacture a marinised, customised version of its printed circuit board fuel cell (PCBFC).

12m USV 'Maxlimer

The use of PCBs, as opposed to metallic or graphite end plates, makes the technology more suited to rugged, marine environments. Bramble Energy's PCBFC system will sit inside an enclosure within the USV to prevent sea water ingress and corrosion. Data gathered from bench testing and sea trials will be utilised for the design and build of similar USVs, as well as for larger uncrewed vessel builds in the near future.

JANSZ-IO CABLES

Nexans has been awarded a significant turnkey contract to supply and install a groundbreaking deep-water high voltage dynamic cable solution for the Jansz-Io Compression (J-IC) project operated by Chevron Australia.

The Jansz-Io gas field is part of the wider Chevron-operated Gorgon development, which has been operational since 2016 and delivers natural gas to customers across Asia and Australia. The J-IC project will use world-leading subsea compression technology to maintain long-term natural gas supplies to the Gorgon liquefied natural gas (LNG) and domestic gas facilities on Barrow Island.

As part of this, Nexans will deploy a power and communication transmission system from the shore to the offshore compression facilities, which will sit at a water depth of 1,400m.

A 145kV deep-water dynamic cable will provide power from shore to an offshore floating facility that will subsequently power and control the subsea compression.

Nexans will use its new cable-laying vessel, the Aurora, to install the cables for J-IC. The 135km long high voltage subsea power cable will also be manufactured, tested and installed in one continuous length.
To date, Nexans has invested more than €500M in high voltage st manufacturing and installation assets.

THIALF RETURNS TO GOLDENEYE FIELD

Heerema's *Thialf* has safely removed Shell's Goldeneye wellhead platform after installing the structure in 2003. The operations included removing the 1280 metric ton topside and the 3019t jacket before transportation to the AF Environmental Base in Norway for recycling and reuse.

GOLDENEYE PLATFORM

The Goldeneye platform was located in the Central North Sea, in the United Kingdom Continental Shelf, around 100 km northeast of the Aberdeenshire coast. The platform included five platform wells in 120m water depth with a direct tie-back via the Goldeneye pipeline to the St. Fergus onshore facility. It was operational as a gas-producing field from 2004, and cessation of production was granted in 2011.

The Goldeneye platform was removed using Heerema's reverse installation method, starting with removing the 1280t topside in a single lift. After removal, the topside was transferred to *Thialf's* deck for transportation.

The Goldeneye jacket involved cutting skirt piles using Deco Subsea's internal abrasive water jet cutting techniques at-3m below the seabed. After which, the 3019 metric ton jacket was safely removed and remained suspended in *Thialf's* cranes for transportation to Vats, Norway.

The Goldeneye platform has been safely set down at the AF Environmental Base yard in Vats, Norway, to be dismantled for reuse and recycling. It is anticipated that over 97% of the material will be recycled. *Thialf* will now undergo yard maintenance, including modifications to the vessel's A-Frame to enable *Thialf* to expand its service area and deliver solutions in the Baltic and the Black Sea regions.

GEO OCEANS

As a global underwater services company, Geo Oceans is committed to adding industry-leading robotic vehicles to its fleet for deployment over a wide range of tasks.

Such tasks include non-destructive testing, high-definition visual inspection, 3D modelling and photogrammetry, high pressure water blasting and numerous maintenance undertakings.

1000 DIVES

Earlier experience with a loaned Falcon proved its worth, says Geo Oceans. The Falcon completed 1000 dives during a challenging seismic survey project in Southeast Asia, with zero incidents and no loss of productivity. The company says that the Falcon gives it the versatility, power and control intelligence to perform the vast array of tasks needed.

At the heart of the Falcon's success is Saab Seaeye's iCON future-flexible intelligent control architecture, a concept that pioneered distributed control technology.

Geo Oceans ROV

Together with five powerful thrusters, the metre sized, 1000m rated Falcon, makes it a highly manoeuvrable, multi-tasking vehicle that can be packed with cameras, sensors and tools, while holding steady in strong cross currents.

Geo Oceans says that it looks to bring innovative solutions to the subsea and environmental markets with the aim of reducing cost and time whilst increasing safety efficiency. Supporting the sale was Saab Seaeye distributor, BlueZone.

HYBRID CABLE-

NOVACAVI has specially developed a hybrid underwater cable with optical fibre for the first sea-scale prototype of floating energy archipelago, an innovative idea for a sustainable use of marine renewable energy of CNR-INM (Institute for Marine Engineering).

With a reinforced configuration, this cable has been designed for the first laboratory at sea, in Italy at the port of Naples (co-managed by CNR-Diitet and Unicampania university).

It will integrate the transmission of electricity from land to platforms at sea, the of electricity generated at sea to land and the digital signal transmission while at the same time, it will guarantee excellent resilience to the forces to which it subjected

NEXUS 8

THE NEW NEXUS 8 IS SPECIFICALLY DESIGNED AND DEVELOPED TO MEET THE MARKET'S DEMANDS FOR TECHNOLOGY AND DATA ACQUISITION NOW AND IN THE FUTURE. IT COULD BE THE MOST ADVANCED, COMPACT AND VERSATILE PRODUCT OF ITS GENERATION.

Continuing MacArtney's long tradition of developing products in consultation with the marketplace, the NEXUS 8 is the result of considerable customer and end-user input to ensure the product will fit the need, as explained by Lars Jørgensen, Head of Product Management:

"Naturally, we have our own opinion on what a multiplexer should be able to do, but what's more important is what the customer and end-user expects and needs. We specifically wanted customer input on what they wanted from a new generation multiplexer, and their requirements for new, advanced subsea telemetry systems when developing the NEXUS 8."

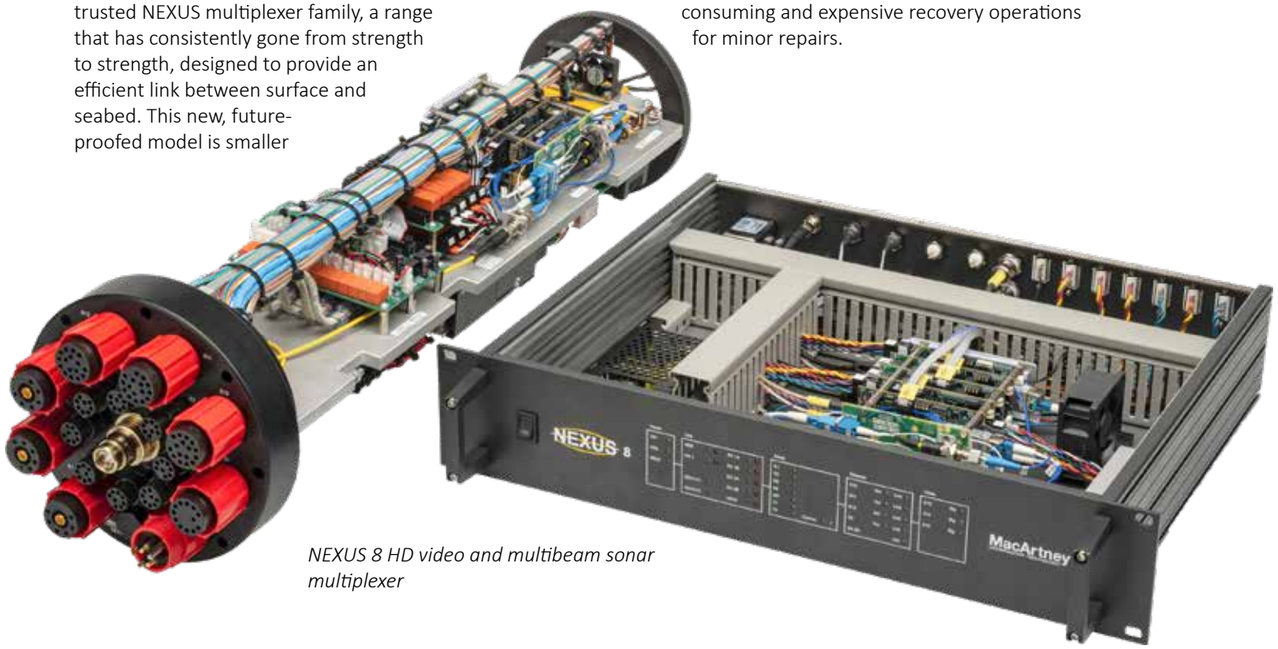
TRIED AND TRUSTED

"NEXUS 8 is the latest addition to the tried and trusted NEXUS multiplexer family, a range that has consistently gone from strength to strength, designed to provide an efficient link between surface and seabed. This new, future-proofed model is smaller and lighter than not only its predecessor, but also its competitors, specifically designed for environments where space is at a premium and to fit into virtually any existing subsea system."

NEXUS 8 is an HD video and multibeam sonar multiplexer, with ultra-high bandwidth and three full HD video interfaces for up to 3 HD cameras, able to provide real-time monitoring without any latency, and to run instruments and sensors for measurement, surveys, sonar, manipulation and control.

eFUSES INCORPORATED

The NEXUS 8 features intelligent programmable eFuses for dynamic performance and to save space. eFuses are ideal for subsea systems, offering flexible, dynamic programming, and avoiding time-consuming and expensive recovery operations for minor repairs.



NEXUS 8 HD video and multibeam sonar multiplexer

SUBSEA MONITORING

ClampOn has received a contract to supply subsea erosion monitors and sand detectors for the Kristin Sør development operated by Equinor.

The non-intrusive subsea erosion monitors will be installed in pipe bends and will be an effective tool in helping monitor for any wall thickness loss.

Included in the scope of supply from ClampOn are non-intrusive subsea particle monitors / sand detectors. These will be installed in funnels and clamped to the outside of the pipe about two pipe diameters after the bend. Any particles in the flow hit the inside wall of the pipe and generate a noise.

This noise is picked up by the sensor which, based on the noise signal, also quantifies the amount of sand produced. This gives the operator early warning of any sand production, so is an important measure in monitoring pipe condition and maintaining optimal safe production. The contract is worth close to NOK 10 million.

The Kristin Sør development consists of Lavrans and Kristin Q, with satellites to the existing Kristin platform. It is a high-pressure, high-temperature gas-condensate field, located off the coast of mid- Norway.

Aker Solutions won the contract for the subsea templates, subsea trees and manifolds. ClampOn has previously supplied topside and subsea instrumentation to Kristin for both sand monitoring and pig detection.

AMAZON

Following an upgrade to its ultra-deepwater capabilities, McDermott's *Amazon* will support a subsea contract for the Whale Development in Alaminos Canyon.

Under the contract's scope, McDermott will provide engineering, procurement, construction, installation and commissioning (EPCIC) for 30 miles (50 km) of pipeline and approximately nine miles (15km) of umbilical to connect five drill centres to a new offshore platform. The project will commence immediately and is expected to be completed in 2024.

The Amazon's upgraded specifications enable highly automated operations, the production of hex joints from single or double joints using an onboard multi-joint facility and a pipe hold capacity of 10 000t.

Its increased level of automation also enables a significant reduction in the crew numbers required to safely perform pipelay operations—boosting its operational resilience.

SOLVEIG CONSENT

The Norwegian authorities have granted consent for start-up of Lundin's Solveig field in the North Sea.

Solveig (PL 359 LINK) will produce from subsea production facilities tied into the Edvard Grieg field, 15km away. The oil and gas will be processed there before further transport.

Phase 1 consists of three wells for oil production, along with two wells that will be used to inject water. The field is expected to produce up to 2041.

The investment decision for Phase 2 will come later, based on experience and information from Phase 1.

The Plan for Development and Operation (PDO) estimated recoverable reserves from Solveig at 9.2 million m^3 of oil equivalent in Phase 1. This is distributed between 6.98 million m^3 oil (44 million bbls), 1.44 billion m^3 sales gas and 0.42 million tonnes NGL.

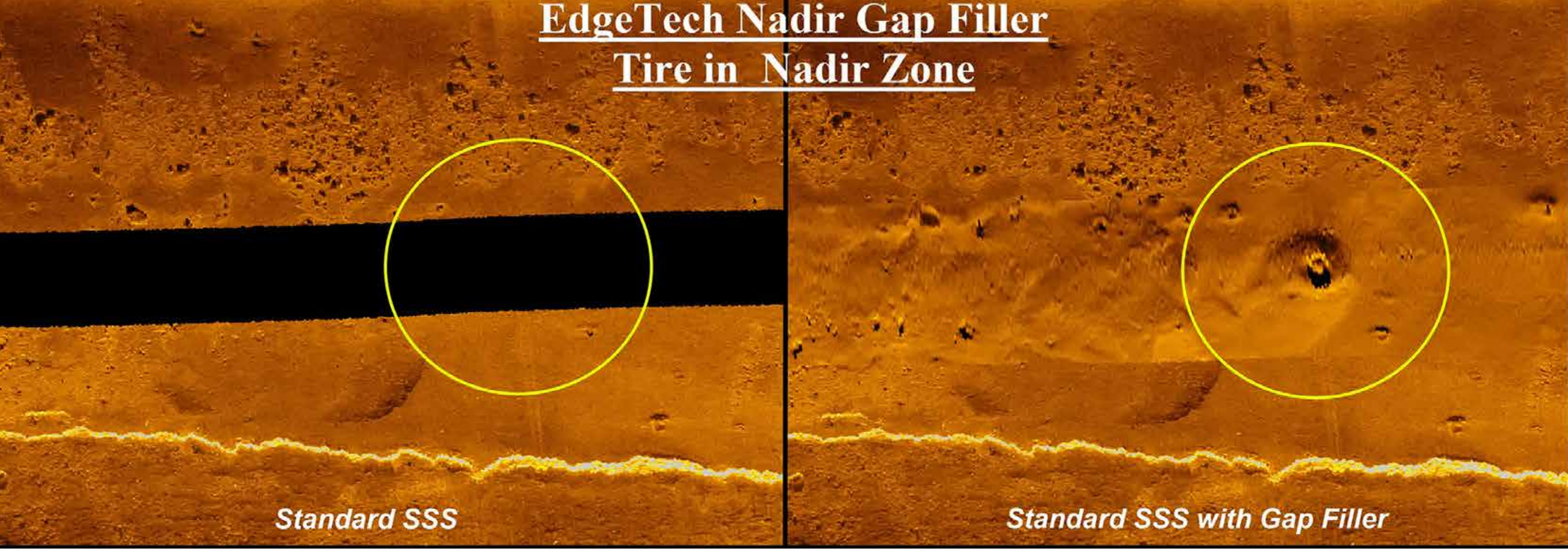
McDermott's *Amazon*

ACOUSTIC FIELD VERIFICATION

Earlier this year, Seiche was selected by ACSM to provide pre-survey modelling, underwater acoustic verification for two pieces of equipment (Sparker and SBP) to verify how they would affect marine mammals in the area along with continuous Acoustic and Visual Marine Mammal Mitigation services.

This project represented a full cycle of environmental support for an offshore survey – from the pre-survey modelling done in-house with the team of its acoustic scientists, through acoustic field verification with Seiche bespoke equipment, survey design by the BioScience's team to full marine mammal mitigation scope with its consultant MMOs and PAM operators and in-house build PAM system designed to acoustically detect various species of resident marine mammals.

ACSM Pre-survey modelling



NADIR GAP-FILL SONAR

EdgeTech has recently introduced an innovative method to provide nadir gap coverage on the EdgeTech 2205 sonar platforms. Complementing this new technology is SonarWiz from Chesapeake Technology that provides a software solution to support the processing and mosaicing of the new gap fill solution.

The 2205 system with gap-fill technology was designed specifically for hosted platforms operating in shallow water or within close proximity to the bottom and is ideal for Unmanned Surface Vehicles (USV) and Unmanned Underwater Vehicles (UUV/ AUV).

The new 2205 system is available in a number of dual and tri-frequency configurations and the gap fill technology is available in a number of frequency options.
The most popular frequency set, the 850kHz and 1600kHz dual frequency combination, is ideal for high resolution side scan sonar surveys where the nadir gap can now be filled with data while the vehicle performs single pass survey operations.

Unique to EdgeTech's gap-fill solution is the ability to "see" the nadir gap from both the left and right sides, providing shadows from either direction, as well as in a three-dimensional aspect in the nadir gap.

Gap fill shadows are perpendicular to the vehicle's path and consistent with traditional side scan methods enabling easy interpretation of data.

The 2205 system

Additionally, gap fill data in the 2205 system is coincident with the side scan data and is therefore geospatially the same, unlike other solutions that look forward and across the vehicle path making target positions between the side scan and gap fill data less robust.

The area directly below the vehicle, until now often lacking in coverage, can now be viewed with the gap data mosaiced right into the main sidescan sonar display using SonarWiz.

EDGETECH 2205

The EdgeTech 2205 is a compact, flexible and configurable sonar system for integration on third party underwater and surface vehicles. This modular unit can be configured, based on the customers' application, to collect side scan sonar imagery, sub-bottom profiles and bathymetric data, singly or in concert with one another.

The system is available either as packaged 2205 electronics enclosed in a pressure vessel, or alternatively the core electronics can be provided as boards mounted onto a chassis so the customer can integrate the system into their vehicle's dry electronics area.

Two transducer arrays, one on each side of the vehicle, provide side scan sonar, gap-fill and bathymetry. An optional sub-bottom profiler is also available.

The system can operate independent of the hosted platform by simply storing the data, or it can be configured to autonomously interoperate with the vehicle during its mission.

CORROSION

Corrosion within the marine and subsea environment can have a dramatic impact on offshore assets The engineering consultancy Frazer-Nash recently considered the importance and types of corrosion and mitigation.

“Corrosion is a chemical reaction that transforms a material into a different compound, usually with inferior material properties,” said Calum Ferguson, Senior Engineer at Frazer Nash.

"This newly transformed material may no longer have the ability to satisfy the requirements it was original specified to fulfil, leading to structural failure. The weaker material may also be removed by erosion, possibly adding to critical failure."

The cost of corrosion can be very high. An impact report by the National Association of Corrosion Engineers released in 2016 estimated the cost of corrosion to be around 3 to 4% of each nation's GDP, equating to a global yearly cost of US$2.5 trillion.

While offshore energy has recognised this problem for many decades, the nascent renewable sector is gradually entering a period where the long term effects of corrosion on older assets are starting to become apparent.

A report from The Welding Institute estimates the total cost of remedying coating failures to be 50 to 100 times higher for offshore compared to onshore assets. A recent coating failure on a wind farm off the coast of Ireland cost over £2 million to rectify, which was twenty times the cost of installation.

Most corrosion systems are based on classic electrolytic cells in which an electric current flows between two dissimilar metals forming an anode and a cathode. These need to be surrounded by a conductive solution for the diffusion or migration of ions. This is typically water or seawater. There also needs to be an electrical connection between the anode and cathode for electron transfer.

The anode and the cathode can be spatially separated by centimetres or even metres. In the case of pitting and crevice corrosion, the anode is at the tip of the crack, while the surrounding metal surface is the cathode.

In addition, there needs to be a driving force. Some metals are more reactive than others. These can be ranked in electrochemical series tables. At the top are active metals such as zinc and aluminium which have a large driving force for oxidation in seawater. Conversely, more noble metals such as copper and gold have a smaller driving force.

When steel is exposed to moisture in the atmosphere, it acts as the anode and oxidises. Iron in the steel is oxidised to form iron oxide, which gradually breaks off into spalls as it thickens; it a weak oxide that does not bond well to the underlying steel. However, not all metals have weak oxides.

A feature of stainless steels is that they naturally form a stable chromium oxide film. This film adheres well to the underlying steel, preventing water from coming in contact with unreacted metal, protecting the metal surface from further corrosion. The process of forming this oxide film is called passivation.

Aluminium also forms a protective oxide film in response to water or moisture in the air which protects the underlying metal from further corrosion. The passivating oxide layers may only be a few nanometres thick, but prevent oxygen from reaching unreacted metal below.

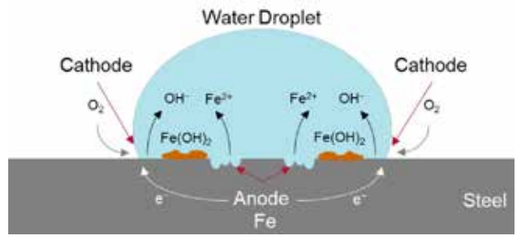
Not all metals passivate, however, including mild steel which does not have chromium to form the protective chromium oxide layer.

MECHANISMS

There are a number of mechanisms which are prevalent in the marine and subsea industry. These include:

1. UNIFORM OR GENERAL CORROSION

This is the most prevalent form of corrosion. For steel, this oxide scale is colloquially known as rust.



Uniform corrosion

Uniform corrosion can occur on any exposed steel surface in contact with water, be it condensation, precipitation, splash or submerged.
In the presence of seawater, the corrosion rate of metals is faster as the presence of salt increases the conductivity.

The corrosion rate depends on the environment. Splash zones can show very high corrosion rate due to the increasing salinity as droplets evaporate. Submerged components are particularly affected where dissolved

oxygen concentration controls the corrosion rate.

Another critical factor is temperature – as a general rule of thumb, the rate approximately doubles as the temperature increases by 10°C.

The material loss is gradual – it may take up to 10 years until the remaining material can no longer support the applied stresses.

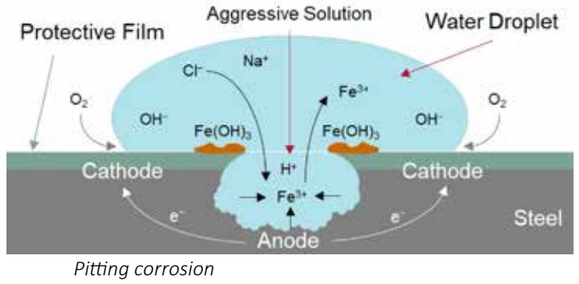
Aluminium oxide adheres very well to the base aluminium. This is not the same for Iron. The rust will grow quickly but crumbles and falls off from the steel, exposing fresh surfaces for further corrosion.

2. PITTING CORROSION

Pitting is a form of localised corrosion, common on metals that form passive oxide films in marine environments. It is an insidious unpredictable form of corrosion because the surface area of the anode is often very much smaller than the cathode. This makes it much harder to observe the propagating pits while the high corrosion rate focused in a small anode area can lead to very deep pits. Once initiated can cause failure between 2-5 years.

Pitting can initiate when a protective film is removed or damaged, exposing the metal. This corrodes forming a metastable pit, usually a dish or hemispherical depression. Usually, a large number of such initiation events occur forming metastable pits that grow then repassivate until one grows to a critical size and becomes stable.

"The chemical reaction of metal ions with water to form



Pitting corrosion

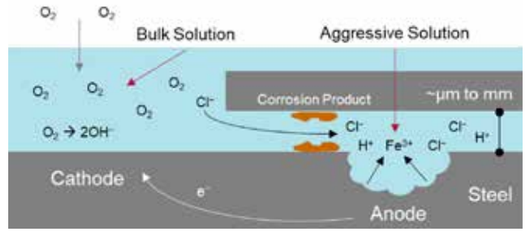
metal hydroxides generates positive hydrogen ions in the pit which attracts negative chloride ions to maintain charge neutrality," explained Ben Daymond, Consultant at Frazer-Nash, "A highly acidic environment is produced within the pit. As this promotes further corrosion, the process is said to be autocatalytic. This will continue until the pit chemistry is changed to allow passivation."

Surface defects, scratches or local changes in composition can initiate pitting. Temperature and chloride concentration are key environmental parameters in addition. Other anions in the environment can inhibit or promote pitting corrosion.

CREVICE CORROSION

Like pitting, this is a form of localised corrosion that occurs at a joint or under solid debris. It is caused by a concentration cell due to limited mass transport between the bulk solution (eg surrounding seawater) and the solution in the crevice. This means that crevice corrosion is a threat mainly in the zones that are continuously whetted by the environment or submerged. This allows water to penetrate under and remain in the crevice.

There are many situations where crevice corrosion can manifest eg, under gaskets, clamps, between joints and washers. They can also form in disbanded coatings, surface deposits and under insulation or biofouling.

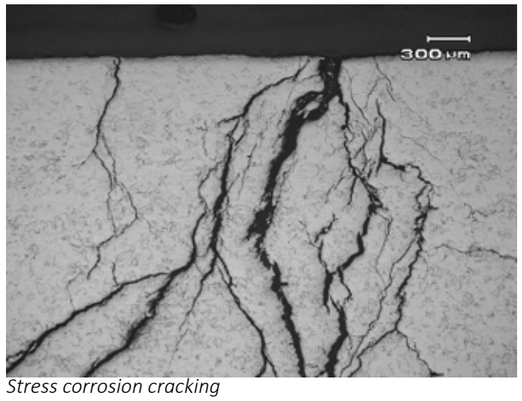


Crevice corrosion

"The mechanism starts by electrochemical reactions on the metal (eg uniform corrosion or passive film growth) within the crevice, consuming the dissolved oxygen deep in the crevice" said Daymond.

"The restrictive geometry causes oxygen to be depleted with the corrosion reaction occurring within the crevice (anode) and the proportionally much larger surrounding metal surface becoming the cathode. The formation of metal hydroxides releases positive hydrogen ions in the crevice.

"This imbalance attracts chloride ions which can react with the iron to form ferric chloride and creates a highly acidic environment, which continues to corrode the metal. This is another example of the corrosion being autocatalytic."



Stress corrosion cracking

STRESS CORROSION CRACKING

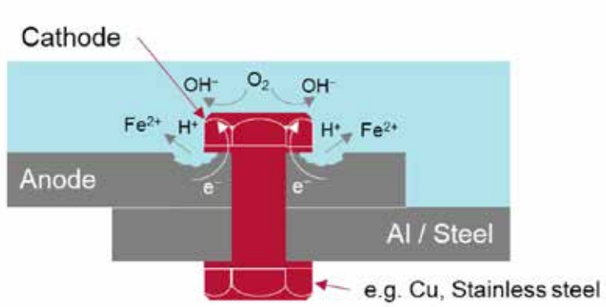
When stress is added to a corrosive environment, these interactions can result in stress corrosion cracking (SCC). On an offshore wind turbine, a typical location would be the high stress states near the top of the monopile or at sea level.

"Specific requirements to generate an SCC threat are susceptible material, a suitable corrosion environment and sufficient tensile stress," said Calum Ferguson. "As a result, SCC only occurs under specific conditions. In the marine environment, this could be where high strength austenitic stainless steels are exposed to chloride and temperatures above 63oC.

"SCC can occur in three ways. When accelerated corrosion forms along an active path such as grain boundaries, hydrogen generated from cathodic reactions penetrates into the metal and diffuses into the crack tip causing embrittlement. Cracks initiate in a brittle film as a result of corrosion propagating into the metal.

Crack propagation is usually inter-granular as the grain boundaries are a weak point, however, it can also be transgranular. For a particular alloy and environment, there is a critical crack length to initiate SCC. Thus if cracks below this size can be detected and repaired, SCC is unlikely to occur.

If the stress experienced by the metal is cyclic rather than constant then corrosion fatigue will occur.



Galvanic corrosion

"All metals show some decrease in their fatigue life if they are exposed to corrosion" said Ferguson. "However, there is no fatigue limit for corrosion fatigue meaning failure can occur at any stress amplitude.

"Corrosion can either help the crack grow faster or reduce the cyclic stress required for the crack to grow. The crack growth rate per cycle tends to increase with low frequencies as the environment has more time to interact with the crack tip.

"The rate of corrosion fatigue depends on the corrosion resistance of the alloy, the surface profile and microstructure. "

GALVANIC CORROSION

Some metals may be individually resistant but corrosion happens if two different metals come into electrical contact while immersed in a solution.

The conductive pathway may be a bulk solution (seawater), a condensed film or damp solid such as salty deposits or corrosion product. The severity corresponds to their relative positions in the electrochemical series.

The more active metal corrodes while the more noble metal supports the cathodic reaction. In most cases, the larger the difference in potential, the greater the corrosion rate.

The surface area ratio is an important factor. A small anode : large cathode ratio has a much greater risk of acid failure than the opposite. The time to failure once started can be about two years.
In a wind turbine, corrosion threats are often evident near the base of the monopile due to aggressive corrosion environment and the attachment of secondary steel structures.

Care is taken to avoid contact between mismatched metals and to protect these structures using cathodic protection and/or coatings. Due to the mechanical complexity and large number of different metallic components used, galvanic corrosion could be a significant threat in the nacelle.

Complex alloys can suffer from self-corrosion and this is termed selective phase corrosion. Nickel Aluminium Bronze (NAB) is a good example of this problem.

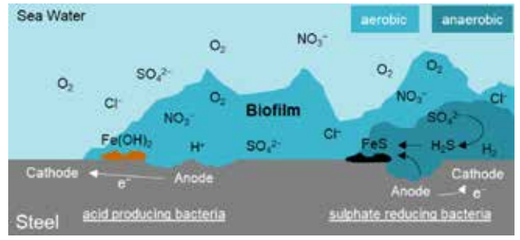
MICROBIOLOGICALLY INDUCED CORROSION (MIC).

Within a few minutes to hours of metal service being exposed to sea water, a biofilm will form on the surface. This is made up of various microbial colonies and is called microfouling. This threat extends from between the high and low water marks to the sea floor.

Over days and months algae can grow and larvae can attach and grow into barnacles and mussels

The key corrosion threats from biofouling is the radical alteration in the environmental conditions at the metal surface including pH, dissolved oxygen, organic and inorganic species.
The biofilm is not uniform on the surface and both aerobic and anaerobic conditions can arise. Different conditions can be set up to promote the anodic or cathodic reactions. This can cause localised corrosion forming pits in the metal surface.

Biofouling



One of the main threats to steels are sulphate reducing bacteria (SRBs). These can be found globally in marine and estuarine waters.

They reduce sulphate in the sea water to hydrogen sulphide that corrodes steel. This threat is referred to as accelerated low water corrosion.

Accelerated low water corrosion can result in corrosion rates of up to 1 mm/year perforating steel pilings within 2 years. MIC rates are usually an order of magnitude lower. And all of this occurs under a biofilm and hidden from visual inspection.

Biofouling on a hull

STABBING PAINS

THE TRADITIONAL METHOD OF MEASURING CATHODIC PROTECTION OF A SUBSEA STRUCTURE IS TO USE AN INSTRUMENTED PROBE TO MAKE PHYSICAL CONTACT WITH BARE METAL. SOME SYSTEMS, HOWEVER, CAN MEASURE THIS CONTACTLESSLY FROM UNDERWATER VEHICLES.

When two dissimilar metals are immersed in an electrolyte, this sets up an electrochemical cell causing ions to move the cathode from the anode. In practical terms for metals jackets or pipelines located underwater, with the seawater medium acting as an electrolyte, the resultant galvanic reaction means that the steel pipes – the anode component- become slowly corroded.

One universal solution is to coat the bare metal and prevent it coming in contact with the seawater in the first place, but because of defects or damage that can occur such as during manufacture or when laying the pipe, this in this barrier layer can become compromised while platform jacket legs often remain uncoated.

Most pipelines and jackets systems, therefore, employ some sort of cathodic protection. This is based on attaching sacrificial anodes to the metal pipe which are designed to be depleted instead of the bare metal. It is vital, however, that these systems are periodically surveyed to ensure that the corrosion protection system operates as planned.

There are 4 main ways in which this survey can be conducted.

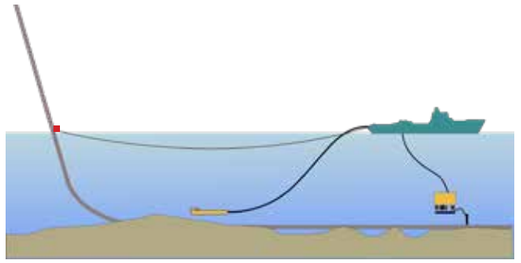
PROBE STABBING

Perhaps the most common is to periodically based on making physical contact with the bare metal of the pipe using a 'stabber'. This allows the potential of the metal to be measured in comparison to a reference cell. It is a very simple and effective method although high salinity often shows an increased negative potential within the reference cell and the results may be misleading.

Because the system depends on bare metal being available on which go stab onto, the system cannot be used for buried pipelines.

TRAILING WIRE

The trailing wire technique is particularly suited to use in shallow water. One end of a wire reel is connected to the pipeline.

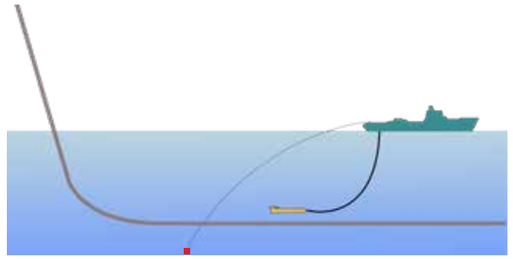


Trailing Wire *After CorrOcean*

The reel is then attached to an ROV or towfish. This vehicle also contains the reference cell. The vehicle then flies along the pipe,taking a continuous reading while paying out the wire behind it. When reaching a maximum length of 10 km, the wire is cut and the weighted reference cell dropped as close as possible nearby. One practical problem is that the wire can snag and at the end of the survey, lengths of wire left on the seabed

CELL TO CELL

The ROV flies over the pipe, grasping the CP probe in the vehicle's manipulators and periodically lowering it down to make contact with the bare pipe. This measures the potential difference between the probe and a remote cell (that is usually towed far away behind the mother vessel).



Trailing Wire weighted drop cell *After CorrOcean*

Sensor survey CorrOcean

All these CP systems, require frequent stabs and calibrations , thereby slowing down the survey process. They may not work if some or all of the pipe is buried or lies in areas normally out of reach. They also provide an instant snapshot, requiring the operator to return at fixed intervals (e.g. every 3-5 years), unless they happen to be in the area.

FIELD GRADIENT SENSOR

In recent years, the industry has been looking at a fourth system- the Field Gradient sensor. Normally mounted on an underwater vehicle, it is based on two measuring reference cells located within 0.5m to each other with the gradient being a function of the flowing current.

It works by measuring the potential drop between two cells (Ag/AgCl), to determine anodic/ cathodic activity. The downside is that cells will drift over time and require calibration every 1 km pipeline or every hour. This requires stopping the ROV to do a calibration stab, backtracking 100m for overlap, before continuing the survey.

A traditional field gradient plot is rarely aligned with the relative position/burial condition as function of time with distance from pipe and burial condition and as such, it cannot be used to calculate accurate anode current outputs or life expectancy. This is why it cannot be used for modelling.

Any life expectancy will then be a best guess made by visual depletion of the anodes. Similarly, if the

ROV-Mounted sensor

survey height is not the same in repeat surveys, the field gradient plot cannot be used to check any changes or development.
This prompted , Norwegian company FORCE Technology Norway AS, developed a novel FiGS FG sensor. Like the Field gradient sensor, its has to cells

but these are mounted on a rotating head around an axis parallel with the pipeline which provides direction of the electric field. The rotating head measures the potential drop from with the same cell as it is physically moved from one side of the disk to the other (eg. 12-6 o'clock position), and this effectively cancels any drift of the reference cells and produces less noise.

This in turn means there is no need for calibration of the sensors along a pipeline survey saving a lot of time.

This produces a very high resolution non-contact system , with a practical detection limit of 0.07 µV/cm. The sensitivity is about 50-100 times higher than conventional FG probes. This method can measure both current from anodes and cathodes

Whiles traditional FG surveys are done from 50cm above pipeline, FiGS surveys can be conducted from up to 5 m above pipeline using an AUV. By conducting the inspection faster (12km/h max) than conventional methods (800m/hour) there is a significant savings in vessel time/ cost.

Even with conventional working class ROVs and a very conservative inspection speed of 2km/h, the vessel time is cut in more than half. FIGs has carried out several inspections with working class ROV's at 3-5km/h reducing the vessel time with 75%.

By aligning the FiGS data with accurate relative position, burial conditions combined with CP modelling, it can deliver an accurate anode current output (+/-5-10% tested by 3rd party). The anode current output effectively provides information on how hard the anodes are working while providing information about the status of the CP system.

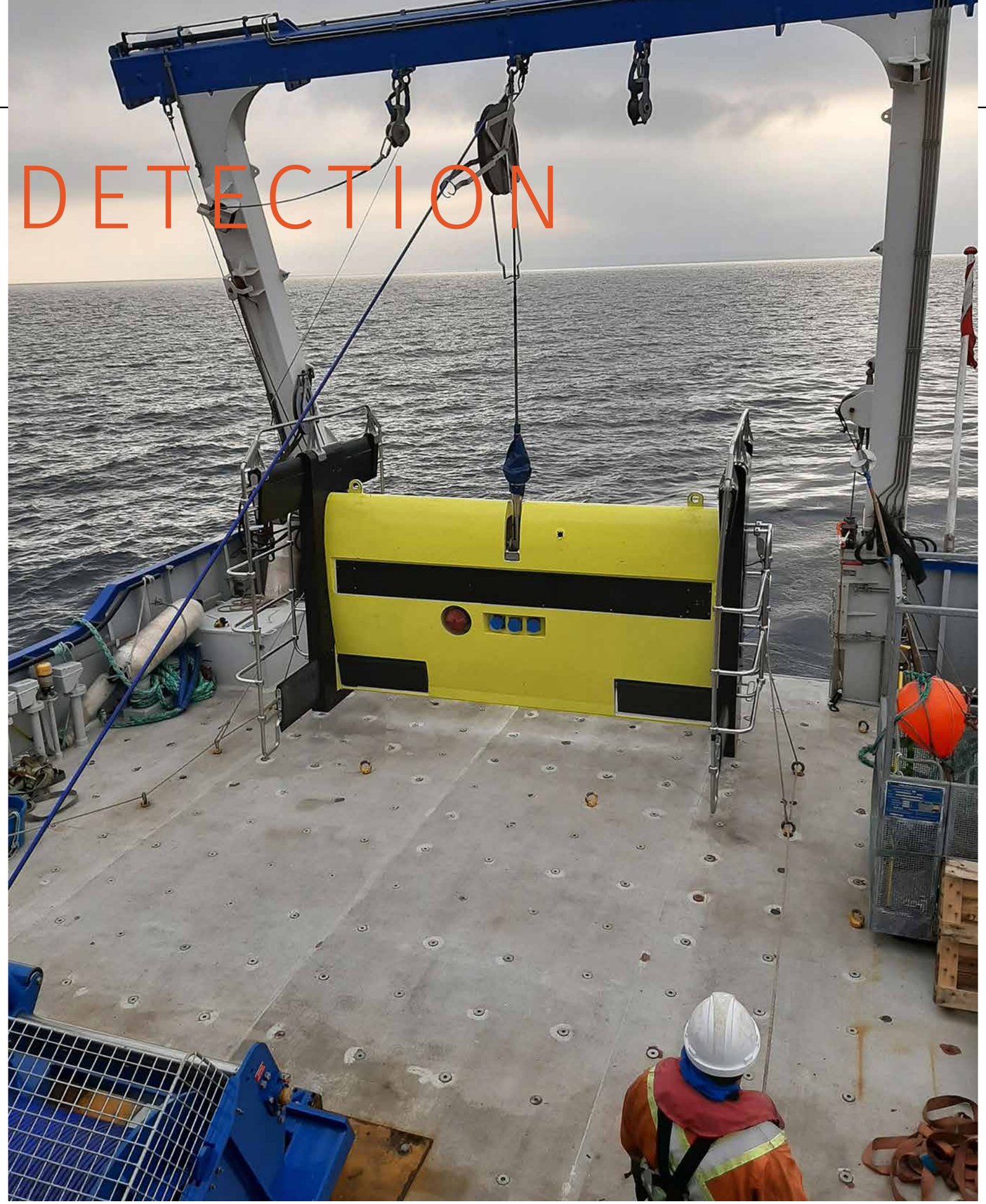
FIGS sensor

It is a repeatable and qualitative unit to monitor development of drain to other structures, coating defects and coating breakdowns over the years and is used to calculate remaining life.

"FiGS measures both strength and direction of the electrical field," said Leiv Erling Grytten (sales Manager at FORCE Technology.

"Unlike traditional sensors, they do not need to be kept perpendicular to the pipeline. Where traditional FG probes will produce faulty readings if not kept vertical over the centre of the pipe or perpendicular to the side, FiGS vector feature will always produce correct readings unaffected by position over pipe.

UXO DETECTION



PanGeo is currently perusing the data produced from the most recent run of its latest UXO detection system. This merges 3D acoustic data imaging with magnetometry. The tool combination not only produces more reliable data but it can also be collected at a speed considerably faster than using many traditional systems.

When an operator wishes to install an array, export or interconnector cable, it will normally subcontract the work out in a turnkey basis. The contract value,however, may be artificially inflated because the contractor does not know the subsurface conditions and, therefore, how many kilometres of cable the company's installation equipment can lay on any given day.

"They might have a rough idea because they may know the type of lithology from working in similar areas," said business development manager Chris Almond. "Knowing information about whether the seabed is composed of sands silts, clays etc, along the planned corridor as well as the hardnesses and the homogeneity of the rocks, it is possible to develop a trenching plan required.

"One potential problem,however, is understanding the conditions below the surface. Buried boulders may require the use of various excavation tools or re-routing the intended path to avoid such obstacles.

"A useful tool to image subsurface structures is a 3D sub-bottom imager which uses a sonar system to send acoustic pulses that penetrate into the seabed and then record the reflection. These not only show sedimentary layers but any anomalies such as buried boulders quickly stand out."

This survey is often carried out by mounting the 3D acoustic device on an ROV. About 18months go, however, PanGeo incorporated it into its SeaKite remotely operated towed vehicle(ROTV). Being towed at a speed of 6-7kts, this had significant advantages over the 0.5–1kt speed of an ROV.

UXO

The other main obstacle to cable route surveying , particularly in the shallow offshore/ nearshore waters of the North Sea, is Unexploded Ordnance (UXO).

In the last century, international conflicts have caused ships to be sunk, aircraft to be shot down and munitions to be released into the sea. In times of peace, unwanted ordnance has been discarded into waters located well away from populations.

"When establishing offshore energy installations from oil platforms or wind turbines, it was sometimes necessary to route cables through these ammunition dumps and ensure that all the local seabed is explosive-free," said Almond.

"As most munitions are ferrous, one useful detection method is to tow magnetometers across the seabed from a boat."

Magnetometers normally detect and measure the weak magnetism of minerals within rocks and any magnetism induced by the earth's magnetic field. Objects containing iron or steel, however, can be highly magnetised and can cause large local anomalies.

The downside of a magnetometric survey it is not possible to differentiate between a munition or any other ferrous object and the corollary is that this list can be very large. Each target would require intervention by an ROV at a rate of around 5-7 per day.

"In practice, over 95% of these targets often turn out to be pieces of metal or other false positives due to an error in the magnetic readings. When excavated, these

This munition was located during a SeaKite survey. Located at 3.1m burial depth it was observed using the 3D acoustic Sub-Bottom Imager (SBI) mounted into the ROTV SeaKite.

locations are found to reveal nothing substantive."

COMBINATION

In June, PanGeo decided to combine the two techniques by towing magnetometers from its SeaKite.

“We can use the acoustics to image the munitions and accumulate geophysical data to plot changes in lithological units. With the addition of magnetometers, however, we can consolidate the target listing. Instead of carrying out two separate campaigns, we can carry out a single campaign which provides a far more concise list.

And the results have been promising with a success rate averaging 70%. This immediately reduces 1000 targets to 300.

"There are other benefits. The traditional acoustic survey of known targets was previously carried out from an ROV support vessel ahead of excavation.

The combined acoustic/magnetic systems, however, can be carried out from a much smaller vessel, maybe 20-30m shorter, perhaps 20 fewer people and much cheaper to operate. This also shortens the overall UXO mitigation process by carrying out all survey works ahead of the ID&C phase using smaller, cheaper vessels. "It has been a great success so far" said Almond. "We carried out separate surveys with the magnetometer and this verified that it was suitable for UXO operations, and confirmed that the magnetometers were close enough to the sea bed and stable.

"It is important to get the magnetometers as close to the sea bed as possible, but without the bottom of the ROVT scraping on the seabed.

"The steel body would adversely affect the magnetometer, so we run it from the SeaKite as a towed system.while being weighted so they sit below the platform at their optimil altitude.

"The survey has also discovered a number of LMB mines, one of which was in pristine condition. Because of the aluminium case, it didn’t have a and didn't have a magnetic trace but was recorded in the 3D acoustic data."

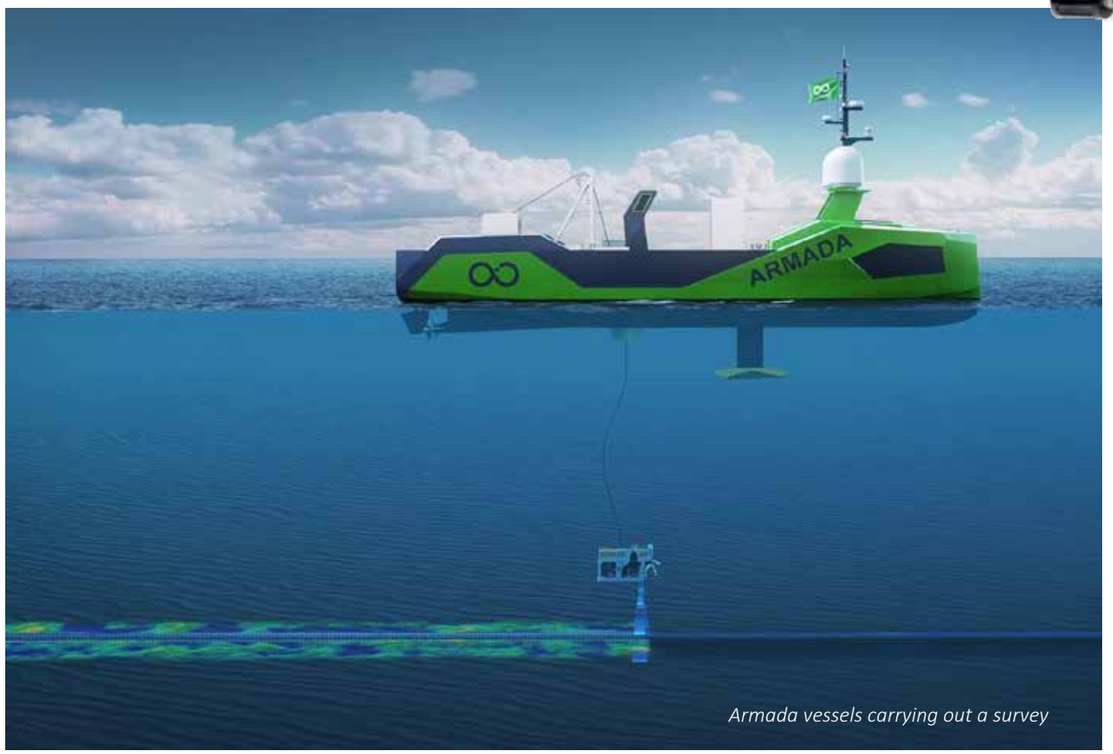
VALEPORT ARMADA

Valeport sensor technology has been selected by Ocean Infinity to provide sound velocity and bathymetric data for its pioneering Armada fleet of ocean-going robotic vessels.

Integrating a suite of Valeport’s sensors and profilers to a selection of the fleet’s uncrewed vessels will provide important data to support operations for Ocean Infinity.

Valeport’s miniSVS will be mounted on the vessels beside the multi-beam echosounder in the sensor gondola, to provide surface Sound Velocity correction.

Through the water column, the Midas SVX2, powered by the vessel, will deliver the Sound Velocity data of an SVP with the Salinity and Density data from a CTD.
The Midas SVX2 has also been combined with the VA500 altimeter to provide range data for the vessels. Selected to interface with the Edge Tech side scan sonar and Saab Seaeye Leopard ROVs, the Valeport uvSVX will be integrated onto the vessels to deliver Sound Velocity, Temperature and Salinity combined with range data from the VA500 altimeter and precision depth from the miniIPS2.



Armada vessels carrying out a survey


Valeport sensors

The compact and robust instruments will be fitted across a selection of six vessels in the fleet including the 21m and 36m vessels, to assist their offshore data acquisition and ROV work in both shallow and deepwater operations.

Valeport has already delivered the first instalment of instruments to Ocean Infinity’s facility in Southampton UK and further deliveries will be made throughout 2021 and 2022.

The robotic vessels in Ocean Infinity’s Armada Fleet use low emission technology, with an Armada robotic vessel emitting 90% less CO_2 than a conventional survey vessel. The Armada Fleet will serve a wide range of industries by being fully equipped to perform a multiplicity of offshore data acquisition and intervention operations down to a depth of 6000m.

SENTINEL

Sonardyne has been chosen to protect a string of naval facilities and critical national infrastructure in the Middle East. Their Sentinel Intruder Detection Sonar (IDS) will be deployed across a number of fixed and floating assets to provide perimeter and mobile protection from threats, including unauthorised divers and unmanned underwater vehicles (UUVs).

More than ten Sentinel sonar systems will be used across the naval sites as part of a 360 degree NiDAR surface and sub-surface waterline surveillance system, developed and supplied by Sonardyne's long-term maritime security partner, MARSS Group. Integrated into the NiDAR C2, the Sentinel arrays, create some of the largest ever fully integrated underwater security shields around marine infrastructure, delivering a security layer covering in excess of 8 sq km.

In addition to this significant order, a further order for multiple Sentinel sonar systems will also be supplied via MARSS Group in the third quarter of 2021 to protect a vital piece of coastal-facing national infrastructure. A further separate order, with an undisclosed client, will see another Sentinel system used on a vessel for the protection of offshore infrastructure.

Sentinel sonar

SONAR

SeeByte and Raytheon Technologies are working together to bring Raytheon's AN/AQS-20C advanced minehunting sonar system data into SeeByte's SeeTrack v4, multi-domain command and control system.

The AN/AQS-20C's combination of sidescan, forward-looking, and gap-filler sonars enables the sonar to detect and classify mine-like objects from the seafloor to the near surface in a single pass.

This data can now be brought into SeeByte's SeeTrack for mission analysis. The AN/AQS-20C has built in Automated Target recognition (ATR) and identification level contacts can now be displayed in SeeTrack in near-real time.

The AN/AQS-20C is an advanced minehunting sonar system that has been designated as the minehunting sonar for the U.S. Navy. It is the most advanced and capable mine warfare sensor system, fully integrated with and effectively operated from the Littoral Combat Ship.

SeeTrack's post-mission analysis tools provide an intuitive user interface and streamlined workflow for ease of use in operational situations and its open architecture means it can be integrated with different sonars, sensors or behaviours for specific operational needs.

GAPS USBL RENTAL

Unique Group has purchased an iXblue Gaps M7 Ultra Short Base Line (USBL) acoustic positioning and communication system. This new addition will be placed in Unique Group's rental pool of equipment and made available to clients across the Americas.

The company says that USBL positioning systems have been highly sought after by clients due to the increase in geophysical projects in the US. Such projects push the vertical-horizontal tracking range and accuracies to extremities.

The Gaps M7 is an integrated solution that makes USBL underwater positioning extremely simple to operate from any vessel of opportunity, using a portable and truly pre-calibrated USBL head coupled with internal INS (Inertial Navigation System) and GNSS.

Offering horizontal tracking capabilities and very high-precision geo-referenced positioning performance from extremely shallow water depths to 4000m, the Gaps M7 can be used for various applications such as ROV, AUV, gliders, tow fish tracking and dynamic positioning to name a few.

Easy to install and operate thanks to its compact size and light weight, Gaps M7 can be deployed from small vessels of opportunity with a reduced crew onboard or on instrumented buoys.

Embedding its own inertial navigation system, Gaps M7 does not require any on-the-field calibration, making it ready to use right away and translating into operational time savings and efficiency on the field.

Name: Power ARK 100
Length: 100.5m
Width: 21.9m
Draft: 5m
DWT: 2200t
Range: 100-300km electricity
Speed Cruise: 7kts, Max: 14kts
Power Capacity: 222MWh

Power ARK 100

For many years, floating storage and offloading has been a popular in the oil and gas industry. One company is looking to employ a similar system for the renewable s sector.

In the very early days of the North Sea oil developments, the only method of getting oil to shore was to store it onsite and periodically offload it into tankers which sailed it to a terminal. Before long, pipeline infrastructure began to cover the North sea and in the same way, inter-array and export cables have become a feature of the current wind sector. Key similarities also remain.

Today, FPSOs and shuttle tankers are used if the cost of the pipelines makes the oil or gas development prohibitive. This is particularly true for remote resources that require very long, specialised pipelines and especially those that lie in very deep water. A similar argument can be made for the wind sector.

Trenching cables, like pipelines, can be expensive, especially if the path has to be cleared of explosives and debris, both natural and manmade. The cable itself is expensive and even when laid correctly, sometimes fails.

JAPAN

Japan is surrounded by deep coastal waters, which limits the potential range for subsea cables. Japanese company PowerX, offers an innovative development solution. The company envisages a power storage and transmission system based on using a Power Transfer Vessel to carry electricity from offshore wind farms to shore instead of a cable.

PowerX will build automated Power Transfer Vessels each with a massive battery payload to transport offshore wind power to shore.

"An undersea power cable typically requires expensive construction that comes with substantial environmental impacts," said a source. "The Power Transfer Vessel , however, is resilient to natural disasters, requires less time and cost for development, leaves minimal impact on the environment, and is able to expand the potential of offshore wind power significantly."

The very first model of the Power ARK series, *Power ARK 100* is a 100TEU trimaran specially designed for transferring renewable energy in Japan's coastal waters. Upon its completion in 2025, Power ARK 100 will carry 100 grid batteries, or 200MWh of power (equivalent to the total electricity consumption by 22,000 Japanese households in a day.

The vessel can travel up to 300km when running only on electricity and will be able to unlock long-distance, intercontinental clean power transmission when it is powered by both electricity and sustainable biodiesel fuels.

PowerX also plans to build a giga-scale battery assembly facility in Japan to mass-produce batteries for the Power Transfer Vessel. .

DRIX

A MULTI-FACETED SOLUTION FOR OFFSHORE US WINDFARMS

The US offshore wind industry took a major step forward in May last year following approval for the construction and development of the Vineyard Wind 1 – the 800MW windfarm off the coast of Massachusetts. This marks the first such large-scale project in the country although many more offshore wind development proposals from Maine to Virginia. are in various stages of planning and development.

The US is now poised for a potentially massive growth in offshore wind which , in turn, will eventually drive down costs. At present, one such major cost is from the areas of site investigations, pre-construction/cable route surveys and environmental assessments.

Geotechnical and geophysical surveys are typically conducted using large survey vessels deploying large work class ROVs to acquire critical seabed information. Nearshore surveys are particularly challenging given heavy vessel traffic near ports, harbours and coastal communities.

The Northeast is both a busy shipping channel and a historically robust and active area for fisheries. It is also a habitat for endangered species such as the North Atlantic right whale. This adds layers of complexities to any offshore operations. Entanglement with fishing lines or collision with large mammals is potentially a risk.

Protection of human life and preservation of the environment is of utmost importance across all these activities. Although necessary, stringent permitting processes often contribute to project delays.

In order to meet all these challenges, the US offshore windfarm initiative can rely on new – and proven – marine technologies, such as Uncrewed Surface Vessels (USV), that bring greener, safer and efficient solutions to the market.

CHALLENGES

iXblue DriX is a highly reliable, multi-faceted USV, putting humans away from risky offshore operations. It provides an ultra-low-carbon footprint option that protects the environment without interfering with fishing activities or equipment and poses no threat to endangered species.

With its unrivalled speed, intelligent obstacle avoidance system (OAS), stability and reduced noise radiations, DriX offers the integrated sensors a safe and exceptional data gathering environment compared to traditional survey methods.

Consequently, it adds significant efficiency, endurance and safety across many different survey operations including nearshore activities in shallow waters, especially in high vessel traffic areas.

Conceptualised, designed and developed at the iXblue shipyard in La Ciotat, France, the DriX USV is RL9 certified as per NOAA NAO 216-105B (RL9: System, process, product, service or tool deployed and used routinely). With over 15 000hrs in operations around the world and more than 75 000nm sailed during missions, demonstrations and tests, the DriX, along with its safe and efficient launch and recovery system, is a proven solution for offshore and coastal operations.

It has gone through a rigorous certification process with Bureau Veritas (BV) and is designed, surveyed, and certified as per BV Malta Cross Hull special service and reviewed as per an agreement of principle regarding compliance with BV Marine and Offshore NI641.

A STRONG TRACK RECORD

The DriX has a key role to play in today's US offshore wind farm development, having already proven its mettle in European renewables activities – starting with multibeam (MBES) surveys for site investigations, pre-construction surveys for monopiles and cable routes, all the way through to the construction phase during trenching operations and as-laid surveys.

Other domains would also prove DriX relevance, such as post-construction operation and maintenance (O&M) to include scheduled inspection maintenance and repair (IMR) as well as fisheries and biomass assessment.

DriX conducted scour surveys in Gwynt Y Môr offshore wind farm, operated by Innogy Renewables UK LTD. The 576MW offshore wind farm is in a tidally-challenging area off the North Wales coast and was at the time the *fourth* largest operating offshore windfarm in the world.

PROVIDING EXCEPTIONAL DATA QUALITY

The development of offshore wind farms demands highly accurate seabed mapping data. Today, a vast majority of geophysical and geotechnical surveys are being conducted in Atlantic waters using traditional survey vessels, navigating in and out of some of the busiest cities and ports in the US.

The seabed also proves treacherous with the presence of boulders as well as potential UXOs. Cable route surveys require nearshore operation and accurate survey data, which is extremely difficult (if not impossible) using traditional methods.

DriX is capable of operating in less than a metre of water depth- an enhanced stabiliser option gives the operator flexibility, not only to survey where most ROVs and AUVs cannot venture, but can also assist in station keeping and in zero speed U-turn manoeuvres.

DriX can operate all the way from the coastline (starting around 4m)

DriX USV control room

to the offshore regions. It can be equipped with a whole range of sensors, including the possibility of deep rated MBES to collect data to 3600m water depths which could be extremely beneficial for pre and post cable lay routes.

DriX can also be equipped with iXblue Gaps Ultra Short Base Line (USBL) system, an excellent solution for accurately (and autonomously) tracking subsea assets such as trenchers and ROVs where traditional acoustic methods can be challenging, especially when operating in a noisy environment with long lay backs.

The DriX USV offers the possibility of force multiplication along with improving the overall survey operation efficiency (such as by operating in areas not easily accessible by traditional methods, faster acquisition of higher quality multibeam data eliminating the need for re-runs and reducing data post-processing time).

UNMATCHED SITUATIONAL AWARENESS

DriX can be relied upon to operate safely and efficiently near shore, in coastal waters and in areas of heavy marine traffic and fisheries activities. It operates at a high level of autonomy under the supervision of a human operator, providing flexibility in terms of concept of operations as well as operational layout.

It can be controlled autonomously under the supervision of a DriX supervisor or directly by a DriX pilot using remote control.
The supervised autonomous operation can be performed either in Line of Sight (LOS) or Over the Horizon (OTH), relying on a proprietary software framework developed by iXblue. The vehicle safety implements an intelligent obstacle avoidance system (OAS).

The software framework continuously monitors the vehicle health and defines warnings and alerts which are displayed in real time to the DriX supervisor. Depending on the level of criticality, the warnings and alerts are also deployed at the vehicular level to adjust DriX behavior.

The OAS, when activated in autonomous mode, can automatically replan DriX's trajectory to avoid the obstacle while minimising the impact on the overall mission. More importantly, the DriX supervisor has continuous access to a comprehensive overview of situational awareness in terms of surrounding obstacles and how they may impact the vehicle trajectory.

There are multiple redundant communication systems on-board DriX that constantly ensure proper control and supervision. The software framework enables the supervisor to define communication preferences while continuously monitoring the quality on the communication channels. There is also built-in (priority-based) communication bandwidth management that ensure communication reliability as well as minimum service level quality on a low bandwidth communication link.

DriX is equipped with internal and external sensors that provide the data used to establish and monitor complete 360deg situational awareness. External sensors include radar (for long range detection of marine vessels at high speeds), 3D LIDAR, 360deg optical (camera) coverage, Inertial Navigation System (position/attitude), GPS (position), Automated Identification System (AIS) and a forward-looking Infrared Camera (IR).

A 3D volumetric sonar such as iXblue SeapiX that is capable of providing real-time full 3D biomass assessment and bathymetry from shallow to deep waters and provides fish classification results for demersal or pelagic species, can also be integrated, adding yet another layer of awareness capable of rapidly detecting and avoiding large mammals in the general vicinity.

This combination of sensors creates the multi-sensor, multi-spectral DriX USV perception that provide extensive situational awareness in variable weather conditions and at night.

These multi-layered system and vehicle level supervision together with a 360deg situational awareness and multi-modal communication makes DriX an attractive option for pre-construction surveys, UXO and cable route surveys, as well as for post-construction operations and maintenance within a continuous 24-hour operational envelope. In fact, in a recent OTH survey conducted off the coast of France, the DriX was the first to detect a group of students learning

DriX USV working safely near offshore installations

to sail and automatically re-calculated its route to a safer one, avoiding any hazard.
The remote operator, located hundreds of miles away in an onshore location, simply monitored the situation as DriX maneuvered its own way out of potential danger.

DATA QUALITY

Hydrographic survey data using DriX is compliant with the standards outlined within IHO S-44, 6th Ed, Exclusive Order to depths of 20 m and Order 1a to 200 m.

An 8m-long USV with a highly hydrodynamic monohull constructed out of composite and Kevlar reinforcement, DriX is lightweight yet extremely tough and generating very low self-radiated noise. The USV is an open data gathering platform offering sensors to be integrated within a retractable “universal gondola” located 2m below the surface.

The specially designed gondola is large enough to integrate a wide variety of sensor combinations, such as MBES, Inertial Navigation System (INS), Ultra Short Baseline (USBL), Sub-Bottom Profiler (SBP), Sound Velocity Profiler (SVP), Magnetometers, etc. and provides a bubble-free environment – optimum conditions for high quality data acquisition.

DriX off the coast of Bakou

iXblue has also designed and developed a positively buoyant, actively controlled (altitude or depth, pitch, roll) Remotely Operated Towed Vehicle (ROTV) called FlipiX – constructed out of composites to minimize interference, extending the possibility of additional sensor payload integration and enhancing efficiency during geophysical (single side scan plus mag), UXO (up to four mags), pre-lay, trenching and as-laid surveys (using a single side scan and video camera).

The DriX gondola also offers flexibility to mission planners and surveyors, increases mission efficiency and reduces downtime- sensors can be swapped very easily and operators can either replace the payload directly within the existing gondola or swap out the complete gondola assembly with another one pre-fitted with different sensor payload.

An embedded high grade IMU (iXblue Phins Compact C7 INS) avoids any bias or mechanical decoupling between the acoustic antennas and the measurement of the motions.

Data quality is further enhanced by the DriX's outstanding line keeping, with a track record in high sea states (up to sea state 5 on the Douglas scale) and in cross current situations, as experienced in the waters of Gwynt Y Môr offshore wind farm.

The highly hydrodynamic monohull and drop keel of the DriX offer exceptional stability and balance to the overall platform. It can pierce through waves and will not capsize, even at high sea states and can maintain high stability by keeping movements to a minimum, thus expanding the onboard sensors operation window.

The tumblehome bow cuts through the incoming waves, adding to minimize the wave induced motions on the vehicle. The shape and stability allow high operational speed (up to 14 kts), reducing transit time and providing optimal data quality at high survey speeds (7 – 10 kts), at a fraction of the time compared to traditional survey methods. In fact, DriX has proven to be several times more efficient than a traditional survey vessel conducting multibeam surveys in offshore windfarms.

DriX has exceptionally high endurance at sea – it can sail for 6 days at 7kts. It can maintain continuous operations for 24 hours at a top speed of 14kts, with a 10-day mission operating at 4kts.

DriX being deployed from NOAA's Thomas Jefferson hydrographic survey vessel

Adding the fact that the DriX is capable of conducting a 180deg turn with a turning diameter under 40 yards at 14kts, this powerful combination of speed, endurance, manoeuvrability and low noise with an ultra-low carbon footprint, makes DriX an extremely stable and efficient yet cost-effective solution for nearshore and offshore multibeam surveys, UXO and cable-route surveys, monitoring endangered species and conducting environmental assessments (integrating PAMS – Passive Acoustic Monitoring Systems – and SeapiX 3D volumetric sonar), scour detection and other routine operational and maintenance operation.

CONCLUSION

When it comes to the full life cycle of offshore windfarms, DriX USV is an asset every step of the way, from site investigations, construction and cable lay to operations and maintenance.

A green USV, with a very limited fuel consumption and CO2 footprint, DriX is also a very safe asset capable of operating in restricted areas and in rough meteorological conditions with unmatched accuracy compared to any traditional asset. Its zero re-run history and the flexibility it offers in swapping payloads according to mission requirements make it the perfect tool for conducting different survey operations in challenging environments.

When it comes to long duration wind measurements in greenfields for future windfarm development, DriX also proves to be an attractive mobile alternative to static buoys. It has indeed proven to be thoroughly equipped to perform autonomous planned, routine survey operations in and around wind farms: scour detection, environmental assessment, fisheries and aquaculture monitoring to name a few.

Overall, DriX intelligence, speed, endurance, agility and quiet data gathering environment, that all benefit from continuous enhancements, make iXblue's USV the best-fitted technological solution for efficient operations during each phase of wind farms projects development.

DRAGON CLASS

Marine energy developer Minesto has introduced a new range of power plants – the Dragon Class – an upgraded design of the company's Deep Green technology for predictable renewable electricity generation from tidal and ocean currents.

Featuring increased performance and decreased manufacturing costs, the Dragon Class will be delivered and installed in all of Minesto's ongoing projects as well as in the build-out of the company's first array projects.

"The Dragon Class evolves from the systems we have installed and operated in our Faeroe Islands' project said Minesto CEO Dr Martin Edlund. "Its increased customer value is to maximise yield and minimise costs. This is the backbone for our ongoing commercial scale-up",

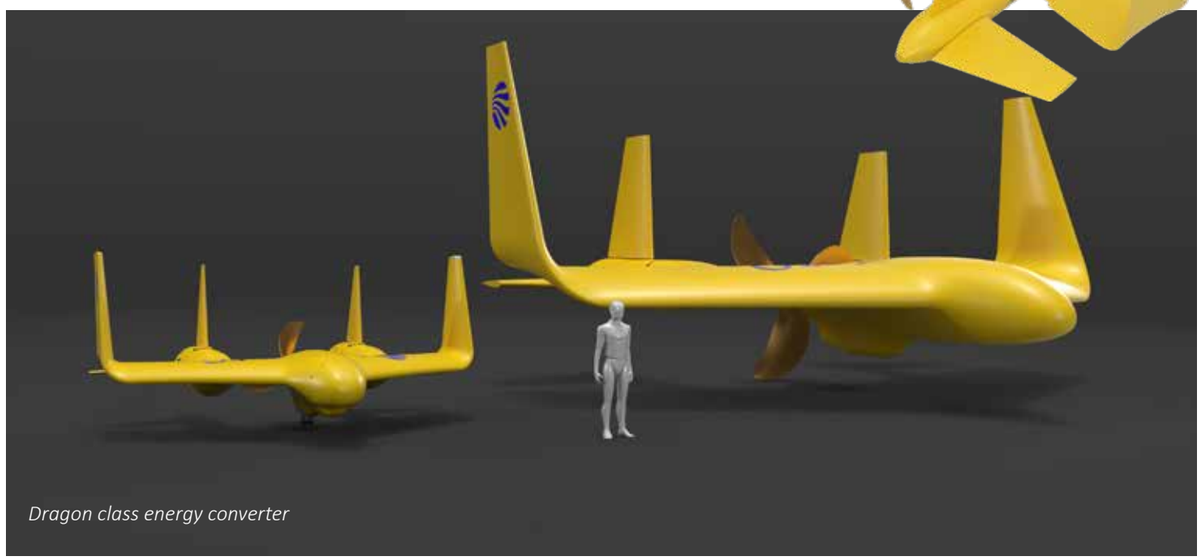
Using extensive Computational Fluid Dynamics (CFD) modelling, ocean scale model testing and operational data from the grid-connected DG100 units in Vestmannasund, Minesto's technology development team has been able to improve the energy conversion and at the same time refine the power plant by reducing the number of power plant subsystems and components.

With the Dragon Class, Minesto also strengthens its patent portfolio as innovations related to the upgraded design have resulted in new patent applications.

"The Dragon Class design results in significantly higher power production performance and by reducing the number of components we also decrease costs for manufacturing and assembly. In addition, it simplifies handling during installation and maintenance, which is crucial when we now scale up the technology to megawatt-sized power plants for commercial installations", said Martin Edlund.

The Dragon Class design scales effectively and will thus be available in different sizes and rated power tailored for maximum yield depending on site conditions such as water flow rate and depth.

Minesto are in the procurement and manufacturing phase for five Dragon Class power plants for utility-scale (1.2 MW) and smaller microgrid installations.



Dragon class energy converter

ARTEMIS HMD

Blueprint Subsea has developed a head-mounted display for its Artemis Diver Navigation Systems.

When underwater, it can be very difficult for divers to be fully aware of their position, particularly in three dimensions, with any accuracy. They often have to rely on rudimentary orienteering techniques. As a consequence, Blueprint Subsea launched its portable Artemis diver navigation aid. The current range has been in development for over 5 years.

This compact hand-portable console can provide the diver with vital navigation information as well as sonar imaging and acoustic communication capabilities. It is aimed at the Search And Rescue market but is equally suitable for military and special forces.

It comes in three configurations, the Artemis Pro, Artemis HHS and Artemis Lite depending upon the level of sophistication required.

Blueprint subsequently reached an agreement with subsea propulsion manufacturers, SUEX, to mount the Artemis on a battery-powered diver delivery vehicle. This gives the otherwise 'dumb' underwater propulsion system a very useful navigation facility. The diver can interface with the Artemis by means of a large screen and clearly see the information in an easily digestible format.

This large bright display screen may be very useful for any other divers within the group, effectively providing a guiding beacon allowing them to follow the 'lead' diver.

Artemis system on a SUEX propulsion unit

While this bright screen has many advantages, the same feature can be a detrimental for covert operations in which the diver might wish to be as inconspicuous as possible.

This has prompted Blueprint Subsea to develop a novel head-mounted display (HMD) which allows only the diver to see the output from the Artemis. This is enabled by means of a small visual display unit.

"The Artemis HMD provides a mask-mounted full colour binocular display reproducing the Artemis interface for tactical operations," said Sales Coordinator Cindy Mercier.

"It effectively replicates this Artemis display at eye-level for improved visibility in turbid water. It is an ergonomically designed, optically correct binocular display suitable for all operators."

"Compatible with all Artemis diver navigation systems via the user port, the binocular display can be easily moved in and out of operator's field of view by use of a pivot, slide and quick release mounting. It is compatible with a range of dive masks".

ARTEMIS

The Artemis unit incorporates a compass, sonar, camera and light. There is also a Doppler velocity log to track movement.

The HMD weighs 370g in air and only 200g in water. It has a resolution of 800 by 600 pixels per eye with interpupillary distance optimised lenses. It is constructed of anodised aluminium and has a depth rating of 100m.

Artemis HMD

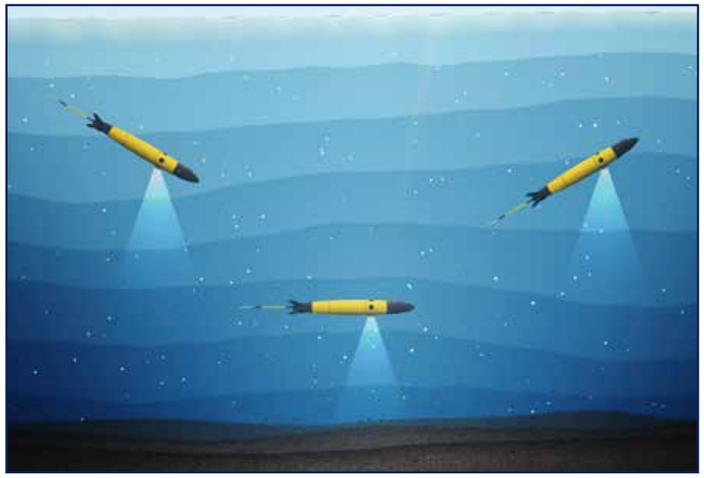
GLIDER ADCP

Alseamar has been able to produce accurate data plots of current profiles from large swathes of the water column. A combination of tailor-made algorithms, underwater gliders and a high-performing ADCP from Nortek has helped break new ground for the oceanographic community, making high-quality data more accessible for a multitude of stakeholders.

Acoustic Doppler current profilers (ADCPs) have revolutionised the ability to record ocean current movements. The downside is that they can only measure what they can "see" and that is largely determined by what they are attached to- normally a surface buoy or a frame on the seabed.

The Nortek ADCP's small form and low profile enabled Alseamar to fit it to the SeaExplorer with little impact on the glider's hydrodynamic properties

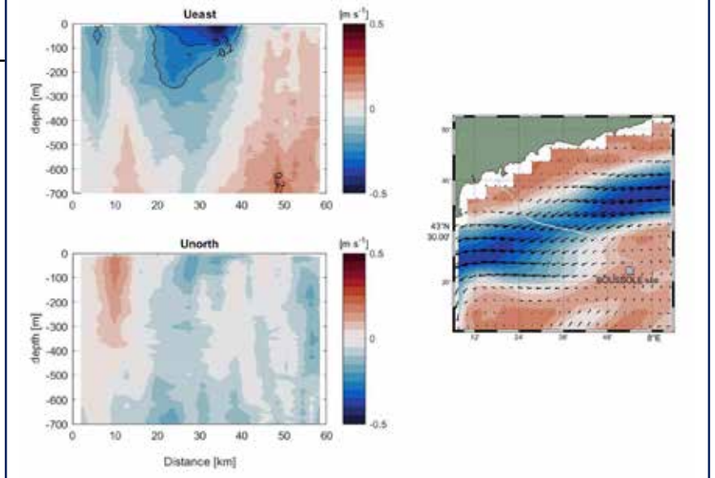
When seeking information on movements of currents across a large swathe of ocean, then mounting an ADCP on a moving surface vessel is a good option. A better option, however, may be to incorporate the tool on a battery-powered glider that is capable of cruising through the oceans for months at a time.



Accurate analysis of currents across tens of kilometres of ocean is now possible due to Alseamar's successful integration of the Nortek ADCP into its SeaExplorer glider. This provides a opportunities for measuring full ocean current profiles, whether the vehicle is ascending or descending.

Typically, these gliders move in a sawtooth pattern between the top of the water column and depths of around 1000m. An ADCP fixed to a glider, therefore, would provide a cost-effective way of profiling a huge volume of water in a relatively short period of time.

That possibility prompted researchers at French marine tech company Alseamar to investigate how an ADCP could be combined with its SeaExplorer glider. The detailed analysis of current movements made possible by the Nortek ADCP, combined with data from the glider's other instruments, gives users access to highly accurate data on how our oceans work.



Current profiles acquired by a SeaExplorer glider equipped with a Nortek ADCP in the northwest Mediterranean, crossing a well-known geostrophic current. The left figures represent depth-resolved water currents acquired along the glider transect (the gray line on the right figure). The colour indicates the velocity of the currents.

"Glider missions contribute to the international efforts of the Global Ocean Observing System (GOOS)," said Orens de Fommervault, the Alseamar oceanographer leading the ADCP glider integration project. The UNESCO-led GOOS programme coordinates observations in the ocean globally, focuses on three critical themes: climate, operational services and marine ecosystem health.

Some academic institutions are able to estimate water currents from a glider, but this service this will now be available from a private company. Alseamar will be able to estimate water currents from its glider and provide this service to other companies, organisations and researchers.

Accurate analysis of currents across tens of kilometres of ocean is now possible which provides unprecedented opportunities for measuring full ocean current profiles, whether the vehicle is ascending or descending.

"Glider-mounted ADCPs offer the ability to collect high-resolution, dense-data water velocity measurements at an unprecedented spatio-temporal scale resolution without the constant use and expense of support vessels," said de Fommervault. He continued that Nortek's 1 MHz current profiler was an attractive option for Alseamar due to a multitude of reasons.

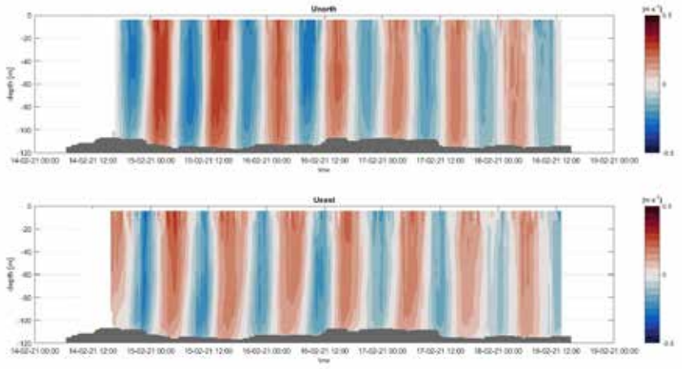
"The relatively small size and low power consumption of Nortek's ADCP are 'plus points' when you are seeking to pack as much instrumentation on to a glider as possible and get the most out of its on-board battery. In tests, the ADCP-equipped glider has proved its accuracy in a number of different environments.

"We have already taken current profiles using the ADCP on the SeaExplorer across 60 km in the Mediterranean Sea off southern France. It is possible to correlate with temperature, salinity and chlorophyll measurements taken by the glider at the same time.

The ADCP was also able to measure tidal currents in considerable detail through the depth profile in the Atlantic off northwest France.

But configuring the ADCP-equipped underwater glider to gather vast amounts of usable oceanographic data is not the end of the story.

"One big remaining challenge is to get access to as much of that data as possible in real time – something that is vital for our customers in the oil and gas industry, for example," said Orens de Fommervault.



Tidal current in the Atlantic off Brittany, northwest France, over a 12-hour period, measured by the Alseamar SeaExplorer glider equipped with the Nortek ADCP glider current profiler. Source: This data was acquired in the framework of the MELANGE project (ASTRID MATURATION) in collaboration with the SHOM and the CNRS (Perpignan University).

SafeWAVE

The Marine Renewable Energy (MRE) sector, particularly ocean wave energy (WE), yields many unknowns about its potential environmental pressures and impacts. Regulators and other stakeholders perceive this as high risk and this can sometimes also lead to opposition within intended communities, creating a critical obstacle in granting of ocean WE projects.

This prompted the launch of SafeWAVE, a project intended to overcome non-technological barriers that could hinder the future development of one of the main pillars of the EU Blue Growth strategy.

Since 2019, the SEM-REV (The Central school of Nantes Offshore test site) has been hosting GEPS Techno's prototype, WAVEGEM, a hybrid platform for wave energy recovery. Environmental monitoring operations of the SafeWAVE project have been conducted around this platform. In order to collect data, SEM-REV has joined forces with RTsys.

In June 2021, RTsys deployed its COMET-300 AUV. This two men portable and enduring autonomous underwater vehicle (more than 20 hrs) was equipped with a dual frequency Side Scan Sonar (Klein UUV3500) to collect the widest covering area of data on the underwater landscape all around WAVEGEM.

A second vehicle have also been deployed during the

WAVEGEM

measurement campaign – the NEMOSENS µAUV which is much more compact and light (0.9m / less than 9kg) but nevertheless with a high ratio power/autonomy (10 hours endurance, speed from 3 to kts). NEMOSENS micro AUV equipped with an experimental acoustic sensor was enabled to collect acoustic data for noise monitoring purpose.

The data will now be analysed and compared with those obtained at the other sites to give an overview of the activities' impact on seabed integrity and underwater acoustic environment. A new operation will take place after the departure of WAVEGEM to compare the data.

ARTEMIS VCOMPACT

TSC Subsea has designed a new ROV-deployed automated scanning tool which addresses the issue of carrying out tight access field joint inspection through difficult to penetrate pipeline coating.

The ARTEMIS vCompact, a smaller, lightweight, more-flexible version of the standard ARTEMIS, was designed, developed and built by TSC Subsea's engineers to work in tandem with inspection class ROV for the remote inspection of pipelines and structures.

It was designed and built in a turnaround time of less than six weeks to meet the precise requirements of a project for Beach Energy in Australia's Bass Strait, to carry out wall thickness inspection on the 20in Otway pipeline near the Thylacine A platform.

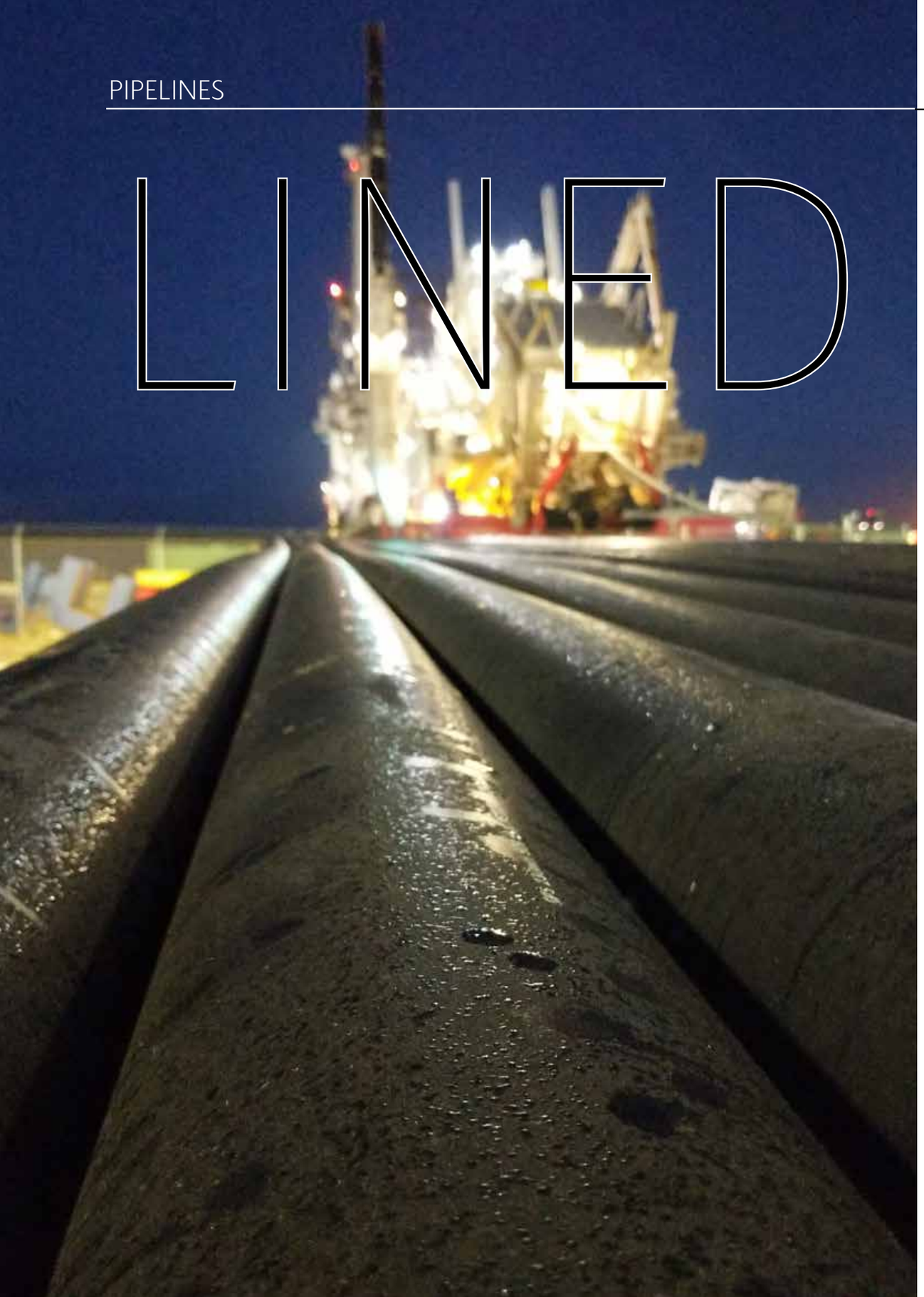
The location of the pipeline joints required the inspection to be conducted remotely within a very narrow field joint section which was too confined for the standard ARTEMIS. The solution is the ARTEMIS vCompact.

Its design incorporates TSC Subsea's Acoustic Resonance Technology (ART). ART is the only high-resolution technology that penetrates and inspects through thick subsea coating with lightweight, high-precision 3-axis scanning to produce high accuracy wall thickness measurements and corrosion mapping.

Strong magnetic feet fix the scanner firmly in position. The ROV then detaches and stands off, negating the need for it to hold station accurately for long periods of time. The tooling utilises motorised and encoded manipulators which enable the probe to accurately follow the areas to be inspected. Inspection data is transferred to a topside computer and can be analysed from anywhere in the world.

The ARTEMIS vCompact on a pipe

LINED PIPE



One traditional technique employed by the water industry to solve the problem of leaking infrastructure has been to internally line corroding or fractured carbon steel pipework with a polymer pipe.

The oil and gas industry adopted this corrosion mitigation solution in the North Sea in mid 1990s. Since its first use, polymer lining has been widely used to provide greater service life assurance to subsea pipelines by providing corrosion protection. Not only that, the polymer liner system can potentially offer other additional benefits for both flowline and now riser applications.

One area where liner technology has been regularly deployed in the oil and gas sector, is the relatively benign environment of water injection service.

Preventing host pipe corrosion is a key benefit for water injection applications. At the start of the pipeline service life, the flow performance of a polymer lined pipe is comparable to that of a conventional steel pipeline. However, as corrosion occurs over time, the performance of the steel pipe deteriorates whilst the polymer liner remains unchanged.

Subsea 7, a global leader in delivering offshore projects and services, specialises in the design and installation of polymer lining systems for pipeline and riser systems. It's Swagelining polymer-lined system technology supports the energy industry by eliminating internal pipeline corrosion, the main cause of pipeline failure.

Allan Feeney, Swagelining Product Director at Subsea 7, explained cost savings are another advantage: "We recently completed a product value study, with client support, which demonstrated we could potentially provide savings over a standard carbon steel solution."

The study looked at both the Capex

LINER THICKNESS

The wall thickness of the liner is a function of a variety of design considerations which mitigate risk, provide compatibility with the operational environment and ensure the integrity of the liner from its manufacture to the end of service life.

The liner wall thickness can also assist optimisation of pipeline design criteria such as the U-value of the system whilst considering the impact of any resulting increased liner wall thickness on hydraulic deliverability over the operational lifetime.

Butt fusion welding of polymer liner pipe

and Opex costs and showed that considerable savings for each were possible.

Part of the traditional pipeline design includes an allowance for corrosion. If corrosion is no longer an issue, the steel wall thickness can be reduced. This provides a reduction in pipe weight that could result in a reduced number of vessel trips, lower vessel top tension and lower platform hang off weights.

The addition of the Swagelining polymer-liner system could also mean a reduction or removal of the chemical injection process, a reduction in pipeline maintenance activities, fewer pigging operations, accelerated product recovery and greater life assurance for the pipeline.

In a previous study, it was noted by decommissioning engineers removing an offshore facility, that the polymer liner system used to provide corrosion protection for the water injection pipeline looked almost unaffected after 13 years of continuous service. This was confirmed by testing as the mechanical properties and liner thickness remained relatively unchanged.

Subsea 7 has now qualified a polymer liner system for use in riser applications with one major International Oil Company and is currently working on a similar qualification scope with another.

In addition, following the successful outcome of an internal test programme, Subsea 7 has now attained DNV Technology Certification for use of its polymer lined systems in water injection riser applications.

LinerBridge being installed on the firing line

These qualification exercises will result in a probable industry first polymer lined riser delivered by Reel-Lay.

There are also opportunities for the technology to be employed within other similar applications such as Enhanced Oil Recovery. Testing to demonstrate polymer lining's suitability for EOR service has been successfully executed by Subsea 7.

Subsea 7 is also in the advanced stages of development of polymer lining for production or multiphase fluids. This means that not only could this new product be used in production flowlines and risers, but there may also be opportunities for use in Water Alternating Gas and in newer energy applications such as transportation of hydrogen and CO2 flowlines for carbon capture and storage.

SWAGELINING

By 2016 around 250- 300km of polymer lined water injection pipelines had been successfully installed.

To date, the Swagelining polymer lined system has been used to protect individual subsea pipeline lengths of up to 46km.

For the Swagelining polymer lined system, discrete polymer liner stalks of up to 1500m are produced by welding shorter, more manageable liner lengths together. The Swagelining polymer lined system process relies upon the principles of cold die drawing. An oversized polymer liner pipe is pulled through a reducing die under tension in order to reduce the diameter and allow for entry into the carbon steel host pipe.

Once the liner pipe has exited the far end of the steel host pipe, the pulling tension is removed. As the liner pipe is kept within its elastic limits during the lining process, on removal of the tension, the liner attempts to revert radially and axially back to its original size. It's this reversion process that gives the Swagelining product it's unique tight fitting liner.

Once the desired number of discrete steel stalks have been lined (i.e. to suit the overall project pipeline length), pipe to pipe tie-ins are completed using either the corrosion resistant alloy (CRA) based WeldLink connector or the simpler, more cost effective, all polymer LinerBridge connector.

Having a track record of more than 25 years, the WeldLink connector is welded to the steel stalks prior to polymer lining. Once the liner is installed, the liner is trimmed and a CRA compression ring is inserted.

It is this compressive force on the liner that flows the polymer liner into grooved features of the WeldLink® body providing a leak tight seal and liner securement. Once the liner is terminated, CRA welding procedures are used to join lined steel pipes together on the firing line ready for reeling on to the vessel. To date, WeldLink connectors have been used in commercial projects in pipe sizes from 4in to 24in and currently qualified up to 1293bar (g).

Developed by Subsea 7, polymer LinerBridge connector is the world's first all-polymer lining connector that removes the need for costly Corrosion Resistant Alloy (CRA) welding. The innovative connector offers an alternative to conventional CRA connectors and the opportunity to create a robust and fully integrated polymer barrier within the pipeline.

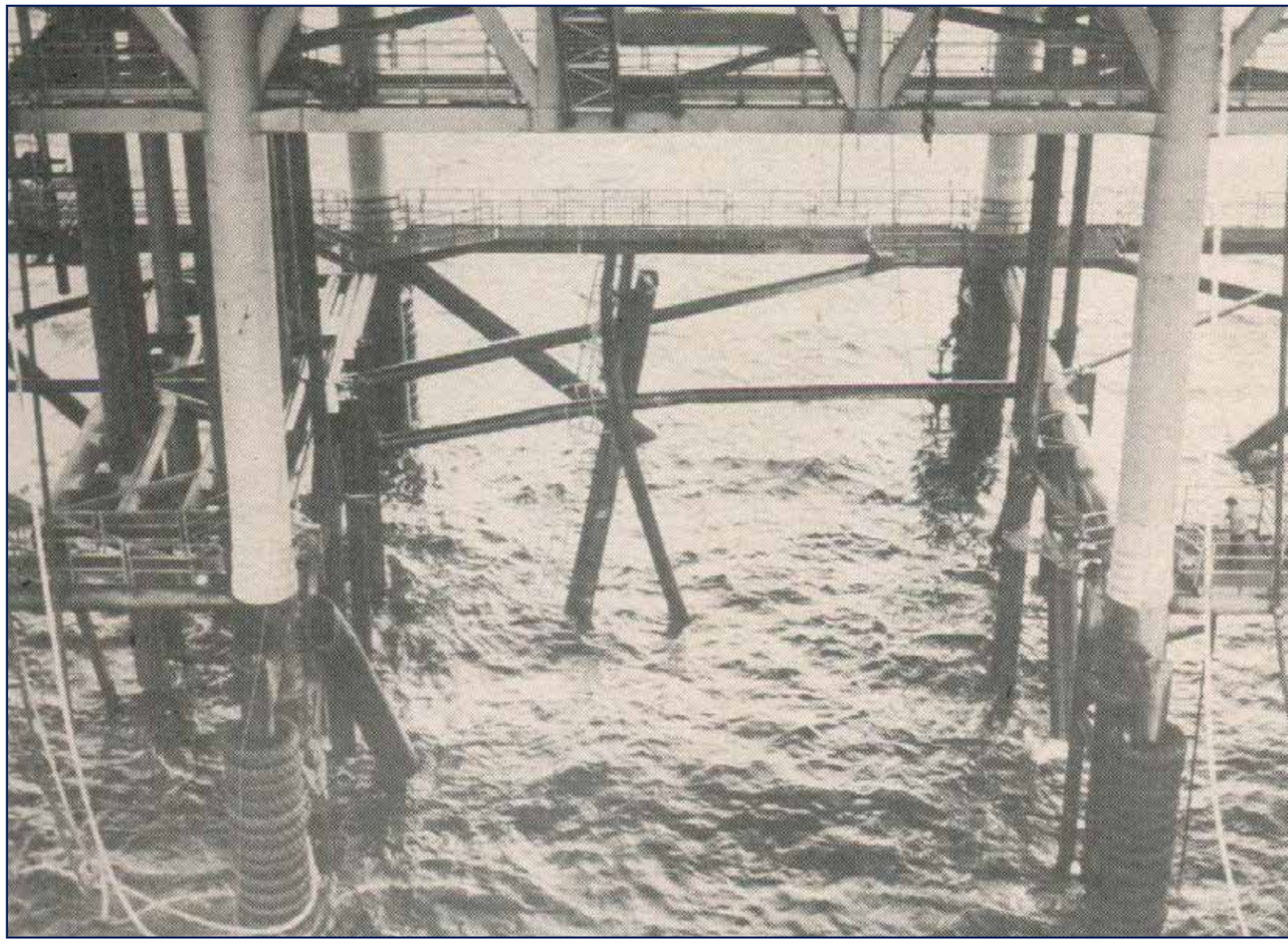
The technology increases the cost-effectiveness of polymer lining systems, enabling a step-change in the mitigation of internal corrosion for pipelines and risers. LinerBridge connector is currently available to suit pipe sizes 8" to 16" and is qualified to 850bar (g).

For water injection service, the liner system is normally manufactured from Polyethylene based materials; however, this depends on various factors including pipeline design temperature and fluid composition.

For pipelines where the fluid composition is suitable for a Polyethylene liner, two material variants are possible; one material for temperatures up to 60°C and another for temperatures up to 80°C. For those applications where the temperature or fluid composition are not suitable for Polyethylene, alternative materials such as Polypropylene, Polyamides or Polyvinylidene Fluoride can be used.

Spoolbase

AUK



The boat Star Sea rammed into the Auk jacket in thick fog, bending the horizontal member.A diagonal and outer horizontal member were torn away

Auk the first trip as WSPE at Shell, the wooden accommodation and a drill-floor the size of a football pitch. But a galley very small and groups came in on rota because it was too small?

My first offshore visit was to AUK.

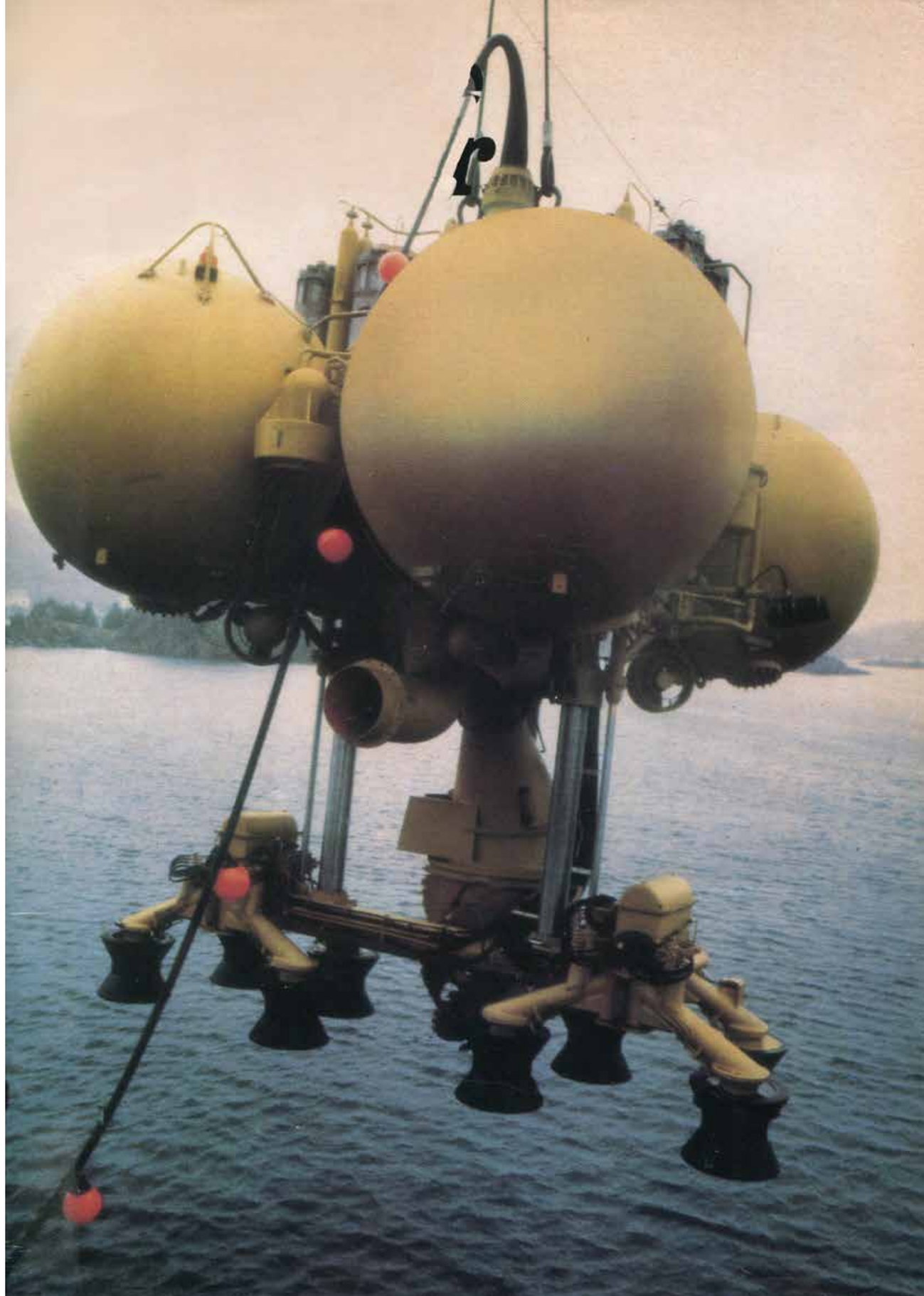
Was it “A” UK or a bird?!
I recall three braces failed at the ends- the welds were so brittle. Times have changed.

GULLFAKS | TRENCHER

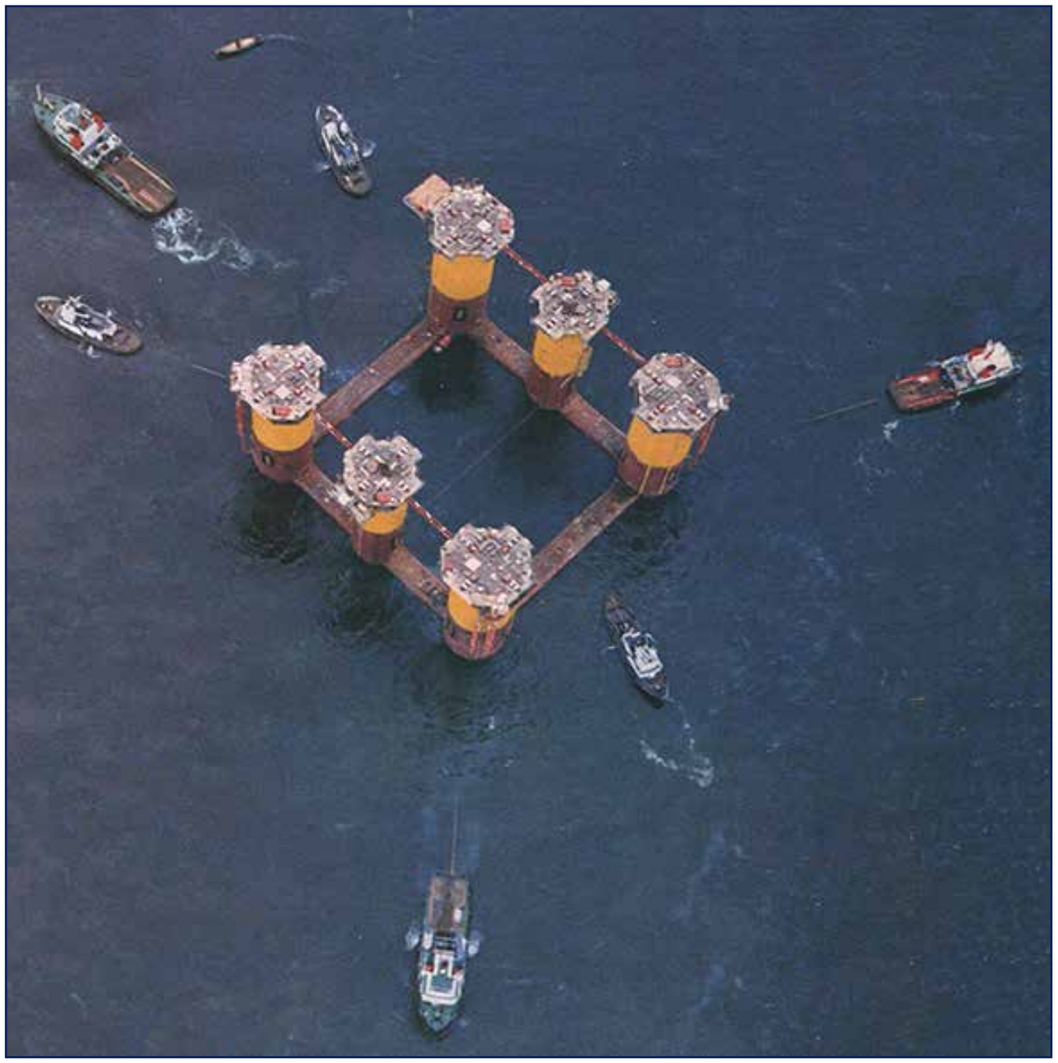
Kvaerner Stord Yard in Norway

Trencher design 1979 developed by Kvaerner-Myren and launched in 300m of water. This deepwater trenching system was part of Statoil's Statfjord Transportation System Project to prove the feasibility of laying and maintaining a pipeline which any line from Statfjord to the Norwegian Coast would have to cross.

The company rejected the idea of jetting in factor of a mechanical cutter.



HUTTON 1984



The first TLP hull moves out through the HiFab gates at Nigg and prepares itself for mating with the deck. The topside was built at McDermott's Ardersier yard.

MPP

In 2001, KCI Multi Purpose Platforms (MPP) was installed on the Dutch P6-D field. This MPP had previously been producing from the P2-SE field since 1996 and proved that the designs could be re-used.

The self-installing MPP was originally developed as a concept that allowed short-duration production , unmanned operations and could be maintained inshore prior to reinstallation.

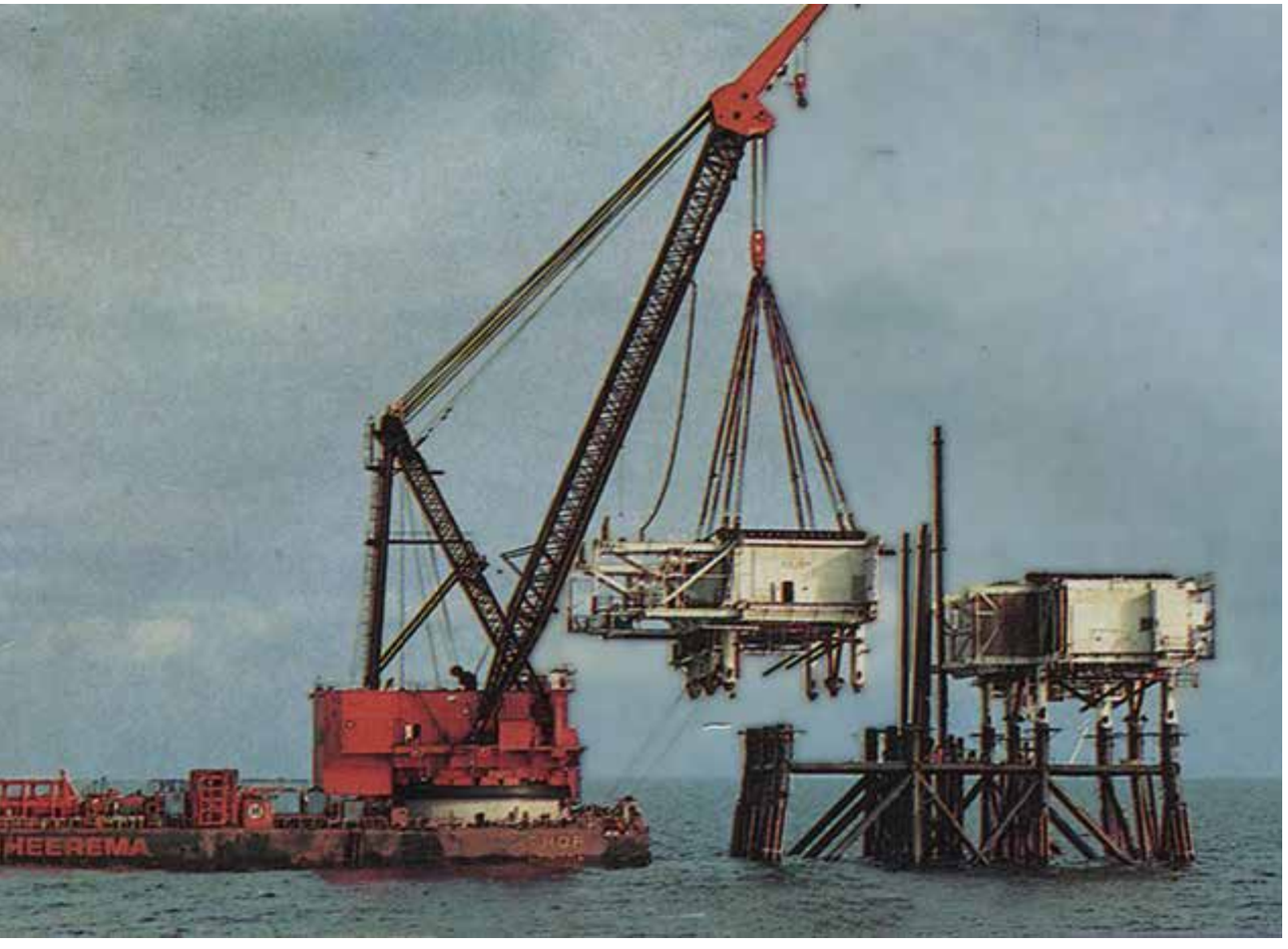
BRUTUS 2001

Shell's 5th TLP. It was built at GMF's Ingleside yard to be moored in around 1000m of water. The hull was taken directly from Mars and Ram/Powell while the tendons were taken from Ursa.

VALHALL

The field complex consists of five separate steel platforms that are bridge-connected. In addition, there are two unmanned flank platforms.

FORTIES 1974



GR Heerema Thor featuring a 2000 t Gusto offshore crane. Former oil tanker Veedol was converted into a crane vessel in Rotterdam in 1974. In 1984 the crane capacity was upgraded to 3000 t. Vessel retired in 1994 then named McDermott DB 52.

Most of these modules Built by Grootint. Zwijndrecht at the time. Too long ago!

DS I was a teenager when founder Pieter was in Aberdeen and he came by my grandfathers farm to visit him as the were at Uni together- some of the stories they told were amazing. Those 2 pioneers sparked my interest in the patch.

ROCKY

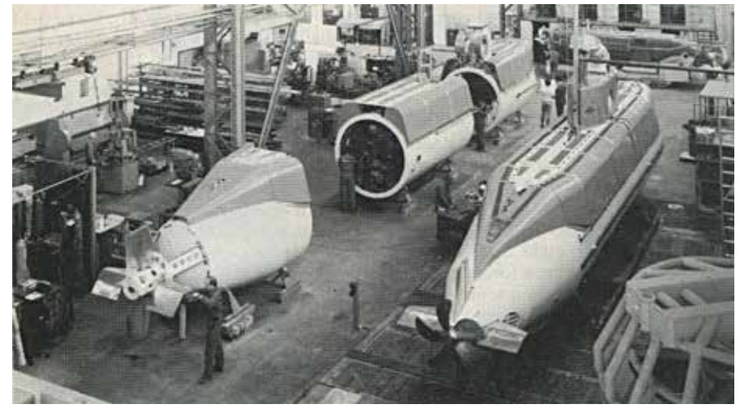
The thruster suite or dungeons never to be forgotten on both vessels

v Deepwater 1 and 2 in my day, I think 4 hulls were built 2 for 2W 1 for India, not sure where the 4th went

I think the Swedish Navy still has it (Belos)

SEAHORSES

1988
In the Broker Meerestechnik facilities, West Germany. On the left is the experimental Seahorse KD and on the right, the autonomous research and inspection submarine Seahorse 11B.

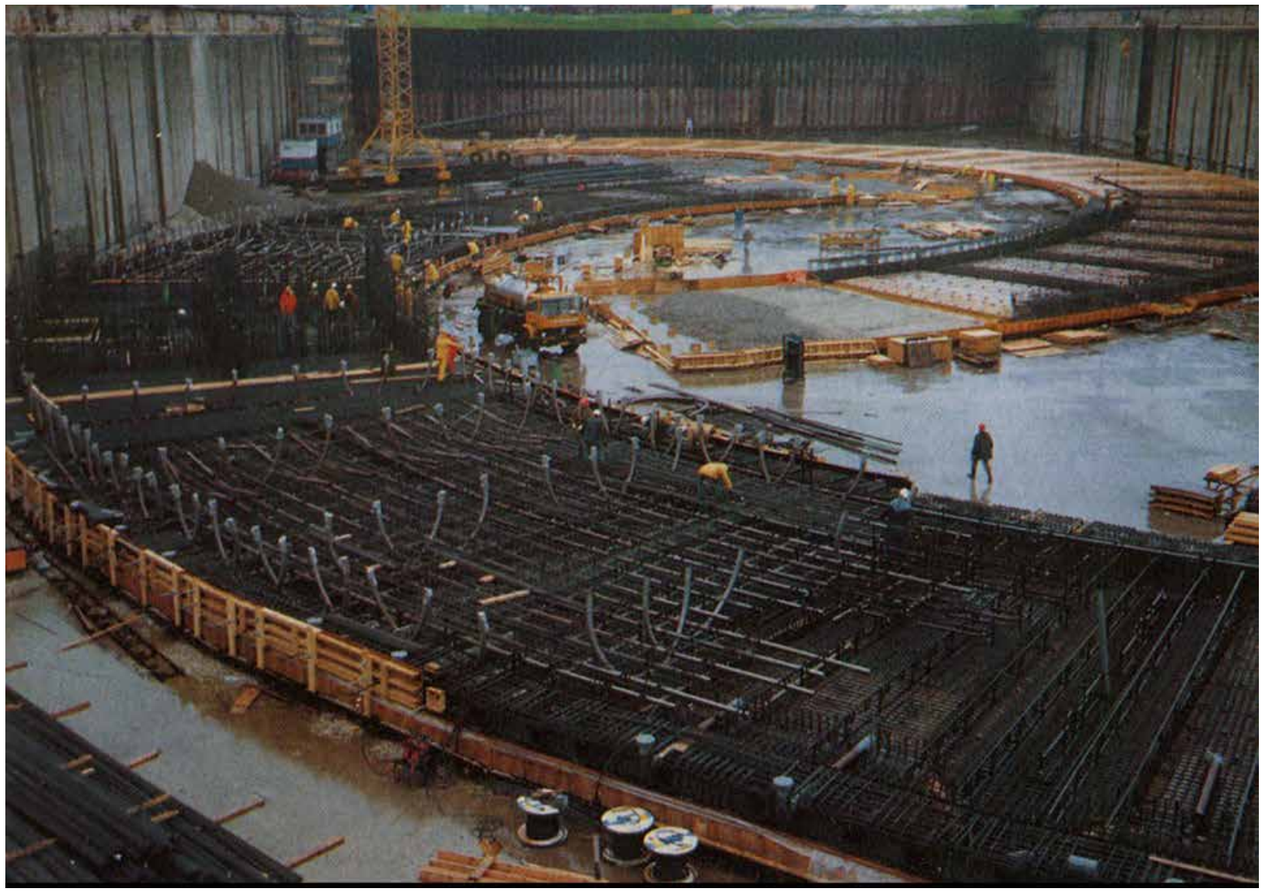


SPRINT 1993

HENRY GOODRICH

Emerald Producer 1996

Below the floater were 16 wellheads and subsea structures connected to the FSU Ailsa Craig.The field was relatively short lived but being a floating system, the abandonment was relatively simple. The work removing the floating system and subsea arrangement went to Coflexip Stena in a £10 million lump sum contract.



Ekofisk

The concrete tank being built in a dry dock in two sections

Glomar Moray Firth 1985

The CFEM type T2600 rig that was a commonly used in the central and southern basin of the North Sea

GULLFAKS A 1986

A few weeks ago, we had a picture that may or may not have been the Gullfaks A float out.
Well here is a better picture

Evo Logics®

SMART SUBSEA SOLUTIONS

Delivering data in most adverse conditions: underwater acoustic modems with advanced communication technology and networking

Accurate USBL and LBL positioning of underwater assets

Modem emulator and other cost-saving developer tools

Autonomous surface vehicle for bathymetry, monitoring, search & rescue, and AUV support

Meet us at

OCEAN BUSINESS

12-14 October 2021
Southampton, UK

STAND M4 and online
evologics.de/OB21

sales@evologics.de

EvoLogics.de