

VALIDATING NEW SUBSEA TECHNOLOGIES

DEVELOPMENT OPTIONS FOR
SUBSEA FIELD OF THE FUTURE

FIELD DEVELOPMENT GROUP

Demonstrating the value
of new technologies
through digital screening

FLOWLINE SYSTEMS

Setting new standards
in thermal performance
and corrosion resistance

PIPELINE BUNDLES

Innovative dynamic
temperature control to
extend production life

DEEPWATER RISER VERSATILITY

New free-hanging riser
configuration eliminates
buoyancy modules

LIFE OF FIELD ACCELERATION

Enabling predictive
digital Asset Integrity
Management

subsea 7

JOURNEY
THROUGH
THE PAST
PRESENT
AND FUTURE

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WELCOME TO DEEP 7

Olivier Lodeho

HEAD OF TECHNOLOGY GROUP

“With our clients, we derive great satisfaction from seeing these technology propositions realise value.”

ARTICULATING THE VALUE OF NEW TECHNOLOGIES

Our commitment to developing effective new technologies in key areas of subsea field development continues to gain momentum.

During the last year alone, we have brought to market ground-breaking innovations in high-performance heated flowlines, free-hanging deepwater risers, dynamic thermal management systems and digital Asset Integrity Management.

The scope of the technological developments described in this magazine – and the pace at which they are being successfully commercialised – is based on our willingness to collaborate with specialist partners both within our industry and through Open Innovation (OI) networks.

Over the last five years, we have successfully established a wide-ranging and highly productive OI technology ecosystem which we access through our 7INNOVATE digital toolkit.

This gives us access to 45 million solution providers, many of them from leading academic and research institutions who relish the challenge of generating effective cross-industry technology solutions. We are already benefiting from OI solutions to five specific subsea pipeline technology challenges which we set – and which, in the process, also generated resolutions to other issues which we were not expecting.

Subsea 7 can draw on decades of specialist in-house technological knowhow but our fruitful experiences with OI are now enabling us to acquire specialist technological knowledge from diverse external sources and pull it efficiently and rapidly back into our organisation.

QUANTIFYING THE BENEFITS

One particularly significant development during the last year was the adoption by our Field Development Group (FDG) of advanced digital toolsets to screen

our new technology products and demonstrate their quantifiable economic and environmental value when compared with ‘traditional’ market-ready solutions.

Based on early client engagement, FDG has developed robust and convincing business cases for a number of our pioneering energy lifecycle solutions, most notably Electrically Heat Traced Flowlines (EHTF).

EHTF is now in its project delivery phase in both the North Sea and the Gulf of Mexico, and we can demonstrate high-value costed benefits in OPEX, CAPEX, TOTEX and reliability through its adoption.

As well as enabling the screening of comparative technologies, our major investments in digitalisation are also underpinning a comprehensive Asset Integrity Management programme to enable the delivery of actionable full Life of Field insights of real value to clients.

In terms of engineering technology innovations, we are about to qualify GluBi[®] Corrosion-Resistant Alloy (CRA) lined pipe for Reel-lay applications and during 2019 saw the project debut of Swagelining’s LinerBridge[®] connector, the world’s first all-polymer connector.

At OTC Brasil, we successfully launched our Gimbal Joint Riser, an ingeniously simple mechanical concept which allows cost-effective free-hanging rigid riser configurations with no requirement for additional buoyancy.

With our clients, we derive great satisfaction from seeing these technology propositions realise value. We will continue to invest in bringing to market innovative products and systems which uncover fresh opportunities for the industry.

We look forward to working with you on the journey.

Olivier Lodeho
Head of Technology Group

CAPEX

OPEX

ENVIRONMENT

UPTIME AND RELIABILITY

ADDITIONAL RECOVERY

ACCELERATED RECOVERY

These six elements comprise Subsea 7's Technology Value Framework and are individually assessed to enable us to deliver optimal outcomes for our clients.

COMPARATIVE ASSESSMENT OF FIELD DEVELOPMENT TECHNOLOGIES

DARREN CORMELL
Vice President Field Development

VALUE

CAPEX

OPEX

ENVIRONMENT

UPTIME AND RELIABILITY

ADDITIONAL RECOVERY

ACCELERATED RECOVERY

COMPARATIVE ASSESSMENT OF FIELD DEVELOPMENT TECHNOLOGIES

Subsea 7's Field Development Group (FDG) plays an increasingly important role in helping clients to assess how both new and existing technologies can unlock value for their development plans.

Formed in 2016, FDG's multi-discipline teams comprise engineering specialists who support client projects throughout the energy lifecycle from concept development to project sanction and beyond.

The FDG teams draw upon cohesive experience from across Subsea 7's business units and collaboration partners to combine advanced field development planning capabilities with execution and delivery know-how.

Some of Subsea 7's core engineering strengths are in:

- Production assurance
- Systems engineering
- Pipeline materials
- Geotechnics
- Subsea processing
- Flowlines and risers
- Pipeline Bundles

By engaging with clients at an early stage, FDG can fully understand project drivers and use advanced digital toolsets to develop a robust business case for energy lifecycle solutions.

"Our production of studies has grown threefold in the last two years, of which around half are early-stage concept selections," says Darren Cormell, Subsea 7 Vice President Field Development.

"We have an efficient service delivery framework in place which not only conveys our range of front-end capabilities but also shows clients how supplier-led solutions designed in this way may be quite different from what traditional approaches can deliver."

A recent project illustrates the strength of the integrated FDG approach. A detailed study was prepared for a multinational client comparing the merits of subsea compression with conventional topside operations.

The feedback revealed that the client not only greatly valued the technical capability and impact of the study but also appreciated the valuable insights which it afforded into the management of logistics and shutdown planning.

The study tackled both technical and delivery challenges of the project which could have been a key blocker in considering the subsea approach and in the process gave the client confidence to consider a supplier-led solution.

FIELD ARCHITECTURE SCREENING TOOL

One of the notable FDG achievements during 2019 was the development of a robust Field Architecture Screening Tool (FAST) which allows valuable early-stage access to Subsea 7's comprehensive digital product library for new technology screening.

FAST uses the same field development planning user interface to screen conventional field architectures against new technology products in the library and enables the development team to deliver costed alternative field architecture designs based on new technologies.

"FAST allows us to use our value framework to assess the value of new technologies when deployed in a development setting," says Darren Cormell. "Being able to make these assessments for early-phase technologies and through the entire development process is a transformative capability."

"Using the same front-end visualisation layer, we can analyse proposed conventional field architectures and, out of this understanding, screen suitable new technologies from our library which can displace the old to create real value."

"The really exciting thing about FAST is its ability to articulate the true value of our technology," continues Darren Cormell. "There is already significant industry interest in linking digital twins with concept planning, but FAST allows us to use a digital representation of the field to combine technology screening and system innovation within a digital planning environment."

This digital representation enables value generation for Subsea 7 and for our clients through early engagement, rather than just being a deliverable at the end of the process.

"Although it is a relatively new tool, FAST already has universal application and can be used to screen our new technology products to demonstrate

the value of their economic and environmental benefits," says Darren Cormell.

"Based on this unique capability, we can not only assess a traditional market-ready solution but also model an alternative approach, compare the economics and deliver a quantifiable business case for using new technology."

FLOWLINE SYSTEMS

We recently delivered a far-reaching value framework study on deploying our Electrically Heat Traced Flowline (EHTF) product in comparison with traditional topside architecture for both oil and gas installations.

The alternative approach for the gas development would be to install a large, power-hungry MonoEthylene Glycol (MEG) injection solution on the platform for continuous injection. For the oil system, we have replaced Low Dosage Hydrate Inhibitor (LDHI) chemical injection facilities and requirements.

With an EHTF system on the flowline, however, we have demonstrated a number of high-value costed benefits:

- Reduced CAPEX on topsides plant
- Reduced OPEX through drastically decreased use of chemicals
- Extended production life, increased oil production and deferred decommissioning.

The gas study revealed further value realisation:

- Fuel gas available for sale due to lower power demand
- Greatly reduced CO₂ emissions
- Substantial savings on carbon tax.

Both studies confirmed a net value of the EHTF approach in excess of \$500 million on each project.

RISERS AND PIPELINE BUNDLES

FAST allows FDG to screen many other Subsea 7 technologies for quantifiable value assessment.

In our flowline and riser portfolios, we continue to reduce CAPEX by developing new cost-effective pipeline materials and welding technologies. Lining technologies boost incremental recovery with the potential to improve production profiles. Monitoring and low-cost sensor advances are improving flowline performance and integrity and we have identified major environmental benefits through using sustainable pipeline materials.

We are extending the range of our unique Pipeline Bundle products into wider markets as a cost-effective flowline solution.

Pipeline Bundles can provide infrastructure to support subsea intervention and monitoring to drive improved operability outcomes and fibre-optic sensors ensure operation to high environmental standards.

Our market-ready reusable Pipeline Bundles provide a new, highly inventive approach to field development, enabling incremental recovery by unlocking marginal fields and accelerated recovery through all-year weather-independent installation and accelerated project schedules.

"All our FDG studies are value-driven," emphasises Darren Cormell. "We now possess a framework that allows us to articulate not only the OPEX and CAPEX impact of our technology solutions, but also their environmental effects and reliability over the full production lifecycle."

"This in turn allows us to demonstrate attractive benefits to clients in terms of incremental recovery, extended production life and accelerated recovery. This holistic approach is an invaluable platform from which we can demonstrate the underlying value of new, disruptive technologies to our clients."

"A framework to articulate the impact of our technology solutions."

"Delivers a quantifiable business case for using new technology."

"Supplier-led solutions designed in this way may be quite different from what traditional approaches can deliver."



FLOWLINE SYSTEMS

OLIVIER LODEHO
Head of Technology Group

MICHEL RICHARD
Product Director EHTF

RICHARD JONES
Pipeline Production Team
Technology Manager

VALUE

CAPEX

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ENVIRONMENT

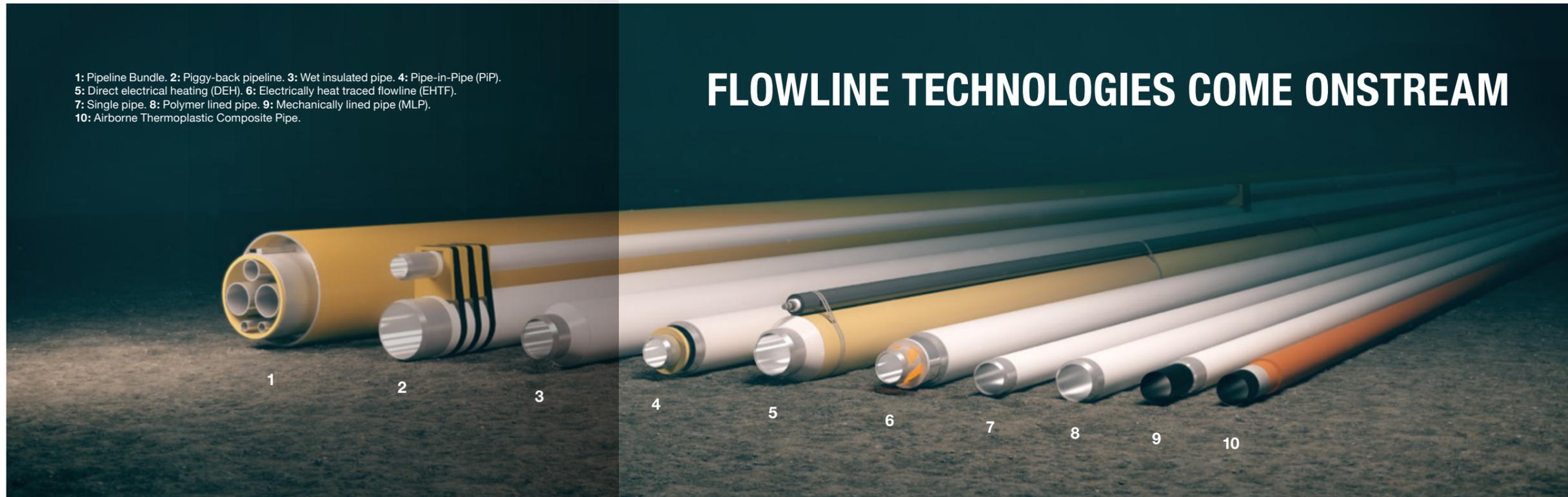
UPTIME AND RELIABILITY

ADDITIONAL RECOVERY

ACCELERATED RECOVERY

1: Pipeline Bundle. 2: Piggy-back pipeline. 3: Wet insulated pipe. 4: Pipe-in-Pipe (PiP). 5: Direct electrical heating (DEH). 6: Electrically heat traced flowline (EHTF). 7: Single pipe. 8: Polymer lined pipe. 9: Mechanically lined pipe (MLP). 10: Airborne Thermoplastic Composite Pipe.

FLOWLINE TECHNOLOGIES COME ONSTREAM



“Developing a new active heating flowline system which combines the heat efficiency of EHTF with the simplicity of DEH.”

“The focus of our flowline technology development is to ensure the reliable and economic flow of well streams over increasing distances without costly host modifications,” says Olivier Lodeho, Head of Subsea 7’s Technology Group.

“To support the market’s increasingly disciplined approach to subsea development CAPEX, we are establishing new standards in flowline performance.

“New pipeline systems are under development which are capable of delivering game-changing flowline performance by enabling future tie-backs of up to 150km, reducing pipeline weight by over 40% and utilising polymer linings to deliver a design life of 50 years in even the most corrosive environments.”

Having installed over 6,000km of rigid flowlines and risers on a global basis, and executing around 60,000 welds per annum, Subsea 7 has established one of the strongest portfolio of pipeline systems in the industry to meet the challenges of cost constraints, thermal performance and corrosion resistance.

Key strategic development of new pipeline materials and welding

processes is delivered through our Pipeline Group Production team with its unique research and development facilities near Glasgow, Scotland.

This is supported by one of the industry’s most capable and versatile pipelay fleets and extensive state-of-the-art onshore fabrication capabilities.

EHTF TECHNOLOGY

Our Electrically Heat Traced Flowline (EHTF) technology delivers market-leading standards of thermal efficiency based on a unique combination of ultra-high-performance flowline insulation and low-voltage electric heating to mitigate flow assurance challenges.

EHTF moved into its project delivery phase during 2019 following several cycles of development and refinement.

The system uses low-voltage (<1.5kV) resistive wires inside a highly insulated Pipe-in-Pipe (only around 10W/m to maintain non-blocking temperature). The high thermal insulation performance leads to low thermal exchange, which enables the use of low-voltage power to reduce the topside footprint, lower the use of chemicals, extend production availability and decrease the scale of subsea hardware.

EHTF technology allows operators to install economic ‘neighbourhood’ tie-ins or greatly extend the length of heated flowlines and is therefore a key enabler in the move towards long-distance tie-backs as a cost-effective alternative to FPSO or customised host facilities.

Following an extensive development programme in conjunction with manufacturer ITP INTERPIPE and other collaborators, EHTF was recently qualified at Technology Readiness Level (TRL) 5 following test fabrications at our Vigra spoolbase in Norway in 2018/19.

A new EHTF fabrication line was installed at Vigra including a helix machine and tensioner system, and this successfully fabricated two 100m EHTF Pipe-in-Pipe (PiP) stalks which were welded, spliced and reeled on-board our pipelay vessel *Seven Oceans*.

Following the integrity tests, fabrication started at Vigra of a 20km 10”/16” EHTF flowline for the AkerBP Ærfugl Project for installation later this year, followed by an 8km 8”/12” EHTF flowline for BP’s Manuel Project in the Gulf of Mexico.

The Ærfugl product comprised a 10” inner pipe with a 16” carrier pipe (PiP), incorporating 16mm Izoflex™

insulation. This results in good insulation performance (0.4w/Km²) with limited power requirements for heating.

The configuration enables topside arrival temperature at 45°C in steady-state mode and maintains the production fluid at minimum 25°C during shutdown.

The EHTF system demonstrates high flexibility in the configuration of its electrical architecture. The low voltage at which it operates enables high numbers of smaller long-life cables to be used, which are more flexible for winding round the pipe, especially at connecting elements such as Y- and T-connectors.

This results in more efficient cold-spot management and reduces overheating which can contribute to the unnecessary ageing of components and degrading reliability of the overall system.

With this highly efficient thermal performance, EHTF not only reduces the viscosity of the fluid to enable production but also maintains the temperature during shutdowns for efficient restarting of production.

The system can operate in either a passive or active functionality. The heat-traced technology can be applied with

all pipe metallurgies, at high temperatures and in permanent operation.

OTHER HEATING TECHNOLOGIES

Subsea 7 is the only subsea contractor with extensive experience in three different active flowline heating technologies: hot water circulation within a Pipeline Bundle, EHTF and its complementary Direct Electrical Heating (DEH) system. DEH is based on piggy-backing an electrical power cable from a topsides-located current generator onto a wet-coated insulated pipeline.

Subsea 7 has been successfully installing electrical heating systems since 2007 including the world’s deepest open-loop DEH system in 2015 for Chevron’s Lianzi Project in water depth of 1070m. Current developments are focused on using low-frequency current in DEH for very long tie-back distances.

We continue to extend the applicability and competitiveness of our current flowline heating products by introducing performance-enhancing new components, and plan to complete



“The next generation of flowline systems will transform the economics of field development.”

our product portfolio by developing a new active heating flowline system which combines the heat efficiency of EHTF with the simplicity of DEH.

In collaboration with Subsea Integration Alliance, a non-incorporated strategic global alliance between Subsea 7 and OneSubsea®, the subsea technologies, production and processing systems division of Schlumberger, we have developed Subsea Electrical Power Distribution Units (SEPDU) which allow increased step-out distances for EHTF by powering and controlling not only the new flowline section but also other subsea components, in the process simplifying the electrical/control architecture.

The SEPDU supplies power via an umbilical at different stages along the EHTF flowline, heating sections of the flowline as required while simultaneously maintaining system reliability.

“EHTF moves the industry away from historical solutions involving storage of large volumes of blockage-preventing chemicals, high-power heating and complicated procedures for managing start-ups,” says Olivier Lodeho.

“Following multi-cycled integrity testing, we have achieved a quantitative estimation of EHTF design life to validate 30-year usage. This process gives us flexibility in developing next-gen

EHTF both for longer tie-backs of up to 50km and also for lower-performance applications to meet market demand where required.”

(For a detailed value proposition on EHTF, see Field Development Group article on page 9)

HIGH-PERFORMANCE STEEL PIPELINES

Our Pipeline Group Production team is currently engaged in the development of high-strength carbon steel linepipe solutions which reduce weight and top-tension installation requirements for deepwater production.

The move into deeper water fields is now driving pipeline designs towards the use of higher-strength steels in order to achieve reductions in pipeline weight. To meet this anticipated demand, Subsea 7 has successfully performed a linepipe and welding qualification for reelable X80 for both flowline and riser applications, including sour service.

A study to assess the value creation of using X80 for a deepwater Steel Lazy Wave Riser (SLWR) configuration demonstrated that pipeline weight reductions of up to 18% and fabrication and installation cost reduction of up to 11% are achievable relative to similar riser configurations in X65, mainly derived through a reduction in buoyancy module requirements.

Subsea 7 has also worked with linepipe manufacturer BUTTING to demonstrate the feasibility of manufacturing Corrosion-Resistant Alloy (CRA)-lined X80 pipe as a mechanically lined product. The girth weld of this pipe required a novel approach involving internal welding of the CRA liner followed by external welding using carbon steel weld metal in order to achieve the overmatching weld strength properties needed for successful pipe reeling.

Looking to the future, we see further added value through the use of even higher-strength steels beyond X80, although welding these steels poses challenges.

Alternative welding technologies giving less rapid cooling rates may be required, such as Friction Stir Welding (FSW), a solid-state one-shot joining process which offers high joint completion rates with minimal personnel requirements.

FSW is well established for the welding of aluminium in other industries but the welding of steel pipelines presents unique technical challenges due to the high temperature strength of the steel material.

We have already successfully test-welded plates from X52 up to X100 grade in different thicknesses and are currently optimising new FSW tool and equipment design to enable us to move on to pipe welding.

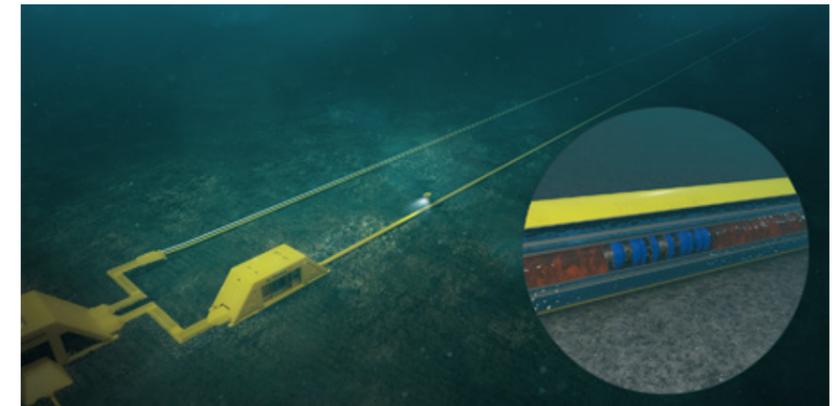
We now aim to proceed to a client JIP in 2020/21 to qualify a prototype FSW machine which will successfully control the thermal cycle of the joining process.

MECHANICALLY LINED PIPE

Working closely with manufacturer BUTTING, Subsea 7 has pioneered the Reel-lay installation of mechanically lined BuBi® pipe as a highly cost-efficient alternative to metallurgically clad pipe for corrosion-resistant applications.

Now well established for both fatigue and non-fatigue sensitive zones in production flowlines and risers up to 16" OD and Pipeline Bundles, BuBi® has been joined by another BUTTING product which eliminates the need for internal pressurisation during reeling.

GluBi® avoids pressurisation with an application of adhesive between the CRA liner and the carbon steel pipe. The adhesive results in an enhanced grip condition that prevents wrinkling during reeling, with a range of adhesives available to provide the required shear



strength and high temperature resistance. Qualification for Reel-lay is imminent for uncoated pipe, and GluBi® will deliver many of the benefits of BuBi® applications but with the enhancements of reduced spooling times, shorter installation schedules and simpler installation procedures.

POLYMER-LINED PIPE

Completing Subsea 7's market-leading capabilities in corrosion-resistant flowlines is our in-house Swagelining® polymer-lined system.

Recognised as the most cost-effective corrosion-resistant pipeline solution for water injection service, recent development has concentrated on expanding Swagelining's application to multi-phase sour hydrocarbon service, dynamic steel catenary risers and S-lay installation.

Swagelining's LinerBridge® connector, the world's first all-polymer connector, was deployed for the first time during 2019 for four clients.

LinerBridge® uses robust and proven electrofusion welding technology adapted from the onshore gas industry to provide a continuous polymer corrosion barrier end-to-end for the pipeline system.

This reduces connector procurement costs and schedule and allows for standard carbon steel welding procedures to be utilised for pipeline tie-ins, with the connector including insulation to prevent damage to the underlying polymer material during welding.

NEXT-GENERATION SUBSEA FLOWLINES

Despite the growing capability of our flow-line heating technologies, subsea processing based on Cold Flow fluid transportation is regarded as a more

competitive option for the economic development of long-distance tie-backs beyond 50km for oilfields and 100km for gas.

Cold Flow technologies are particularly effective in the development of remote fields which lack significant subsea architecture.

To mitigate wax deposition in our flowline systems, we are developing a subsea Wax Control System (WCS) based on our Pipeline Bundle technology in combination with cooling water pumps and remotely controlled pigging.

The temperature of the flow is cooled to ambient seawater, causing wax to precipitate and accumulate on the flowline wall. A pig flows continuously around the cooling loop to scrape off the wax inside the flowline. No further reduction in temperature takes place beyond the heat exchanger, so no further wax deposition is expected on the pipe wall.

Based on a collaboration with the Norwegian University of Science and Technology (NTNU), a prototype WCS underwent successful testing during 2019 to demonstrate the proof of concept and scale the wax deposition model. The ongoing qualification testing is expected to be completed by June 2020, resulting in a new process that will enable long-distance flow in simple, uninsulated and cost-effective flowlines.

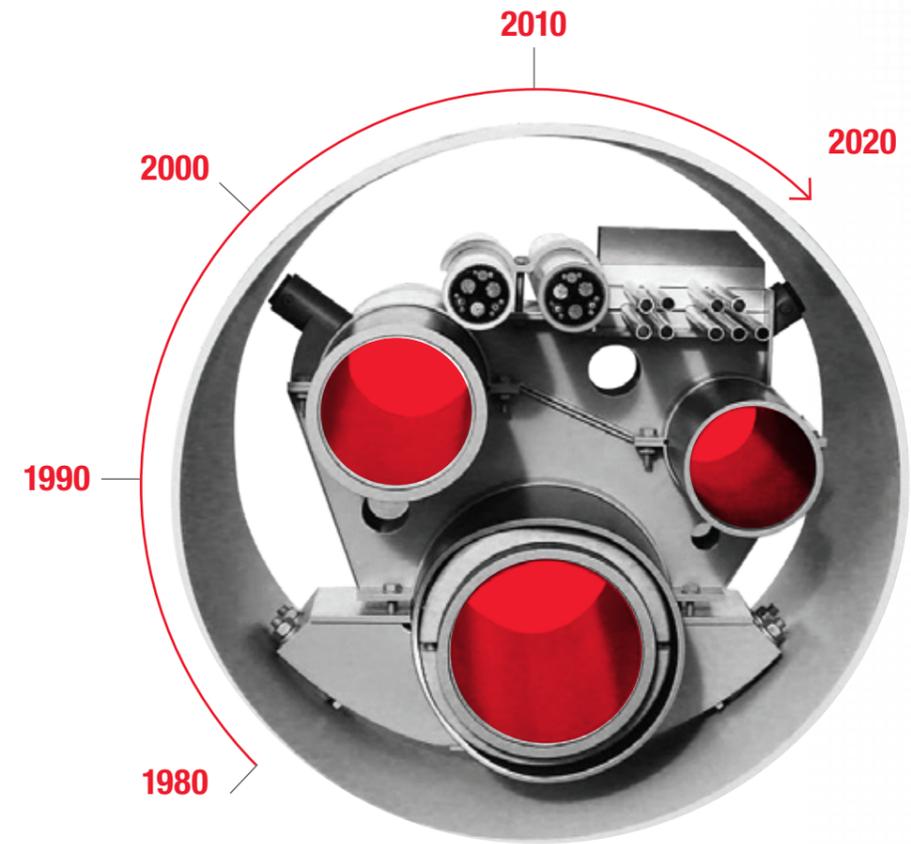
“In terms of flowline technology development, we are building on many years of expertise in adapting innovative solutions to meet specific market demands,” says Olivier Lodeho.

“The next generation of flowline systems available to clients will enable longer tie-backs, tie-ins and other subsea architecture which will transform the economics of field development.”



Right: Installing EHTF heating cables at our Vigra spoolbase.

**HIGH-PERFORMANCE
COST-EFFECTIVE
SOLUTION**



A NEW ERA OF SERVICE LIFE

Subsea 7's prefabricated Pipeline Bundles are entering a new era of technological advancement to build on their remarkable history across four decades of offshore field development.

A unique product based on a tried and tested concept of full onshore assembly and testing followed by cost-effective, low-fatigue towed transportation and installation, Pipeline Bundles have demonstrated their versatility and durability during 40 years of continuous development in over 80 challenging projects.



40 YEARS

1980

1980
First Pipeline Bundle (Murchison)

2000

1997
Actively Heated Pipeline Bundle (Åsgard)

2020

2020
HPHT > Deepwater > Length > Flexibility > Migration

A SELECTION OF PIPELINE BUNDLES INSTALLED

1990

2010

2014
West of Shetland (BP Clair Ridge)

THE FUTURE

Thermal Performance Management System
Reusable Pipeline Bundles

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MARTIN GOODLAD
Strategic Technology Manager
Pipeline Bundles R&D

RICHARD JONES
Pipeline Production Team
Technology Manager

The capability of the field-proven concept is now greatly enhanced by a number of new technologies which open up significant areas of new opportunities for operators:

- Dynamic arrival temperature, an innovative thermal performance management system which can greatly extend production and field life
- Reusable Pipeline Bundles which unlock previously uneconomic small pools by significantly reducing both CAPEX and decommissioning costs
- New capabilities in High Pressure High Temperature (HPHT) performance, enabling operators to recover previously undeveloped reserves.

DYNAMIC TEMPERATURE CONTROL

Dynamic arrival temperature is a unique flowline insulation performance system developed by Subsea 7's Towed Solutions engineering team and qualified during 2019 for both normal pressure and HPHT applications.

By managing variable heat loss in a Pipe-in-Pipe (PiP) system, it allows operators for the first time to actively control and adjust the arrival temperature of the production fluid.

"The beauty of dynamic arrival temperature is its simplicity," says Subsea 7 Vice President of Strategy and Technology Thomas Sunde. "The operator can improve the thermal performance of any PiP flowline by a factor of ten or more by using simple topside technologies to adjust the flowline U-Value."

The system is based on adjusting the pressure in the annular gap between the production and the sleeve pipe either through an umbilical from the topside facility or by connecting a downline from a vessel.

Nitrogen is injected to increase the pressure and heat loss or reduced by vacuum pumping for applications where heat conservation is required.

By using established topside control equipment to manage the flowline temperature, dynamic arrival temperature avoids the deployment of complex measures to mitigate downstream flowline buckling. The technology delivers further environmental and economic benefits by reducing chemical usage and topside energy consumption.

"The key benefit of dynamic arrival temperature is its flexibility," says Thomas Sunde. "It manages uncertainty

over the required thermal performance during FEED, compensates for slowing flow-rates towards the end of field life and enables the addition of future tie-backs."

REUSABLE PIPELINE BUNDLES

The reuse of subsea infrastructure is the key to unlocking many challenging or marginal fields, stranded reservoirs and longer tie-backs by significantly reducing both CAPEX and decommissioning costs. In addition, reuse of existing structures makes a major contribution towards environmental sustainability.

Pipeline Bundles have considerable remaining integrity at the end of their design life, and, by applying our world-leading expertise in refloating and dewatering the structures, we can design Pipeline Bundles capable of future reuse, either in whole or in part.

Subsea 7's innovative new multibore connector, currently being developed by Subsea Integration Alliance, our non-incorporated strategic global alliance with OneSubsea®, enables the diverless connection of multiple Pipeline Bundles and is the key to their flexible reuse for long-term subsea service with different duty cycles.

Pipeline Bundles can accommodate

a wide range of high-performance pipeline materials and control systems to cater for the most onerous duties in these multiple lifecycles.

Reusable Pipeline Bundles are of particular interest to marginal field operators who have a number of reservoirs in close proximity to an existing host. In such circumstances, they enable multiple marginal developments within a licence block using a single suite of reconfigurable subsea equipment.

"Some marginal fields may have potentially short lives, but operators can transform the economics of recovery by deploying a reusable Pipeline Bundle combination to exploit pools in succession," says Strategic Technology Manager Martin Goodlad.

"Being able to design Pipeline Bundles for cost-effective refloating, reconfiguration, reuse and even removal is a high-performance concept that greatly reduces capital cost amortisations and makes a substantial contribution towards environmental sustainability."

Reusable Pipeline Bundles are available with on-board performance and condition monitoring to verify continued safe use and life extension

or alternative duty reassurance. This includes electrical and fibre-optic lines in preparation for the use of Underwater Intervention Drones or Autonomous Underwater Vehicles.

Subsea 7's new multi-bore connector enables the serial connection of multiple Pipeline Bundle sections to create longer tie-backs of any desired length without intermediate towheads and tie-in spools.

"Although the commercial model for the reuse and reconfiguration of FPSOs is widely appreciated, our new reusable Pipeline Bundle technology creates a completely new and inventive way of thinking in terms of field development," says Martin Goodlad.



"A completely new and inventive way of thinking in terms of field development."

VALUE

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ACCELERATED RECOVERY

“Allows operators for the first time to actively control and adjust the arrival temperature of the production fluid.”

HPHT APPLICATIONS

With their capability to operate at pressure and temperature limits beyond conventional tie-back options, prefabricated Pipeline Bundles represent a cost-effective solution to the challenge of recovering oil and gas from HPHT reserves in temperatures to 220°C/428°F and pressures to 1379 bar/20,000psi.

Especially when used in combination with our new dynamic arrival temperature technology, Pipeline Bundles deliver active control of the arrival temperature across the production life.

Five Pipeline Bundles are currently in operation in HPHT applications, including Chrysaor Jasmine and Total's West Franklin in the North Sea, at production temperatures of 160°C.

Typically, such installations allow the production fluid to flow at full temperature, optimising the arrival

condition for processing. Fully pressure-rated fortified Corrosion-Resistant Alloy (CRA) production pipelines can be utilised within 500m zones, and no global buckling mitigation is required.

As with all Pipeline Bundles, the product leaves a minimal seabed footprint as all flowlines are incorporated within the carrier pipe.

THE PIPELINE BUNDLE CONCEPT

Prefabricated Pipeline Bundles greatly reduce the design complexity of wellhead platforms or, especially when used in combination with Towed Production Systems (TPS), can offer a cost-effective subsea alternative to the platform.

The TPS enables conventional platform functions such as separation and High Integrity Pressure Protection Systems (HIPPS) to be integrated into the towhead manifold structures,

delivering significant project acceleration and CAPEX savings for small tie-back developments.

The subsea HIPPS can be interchangeable with a retrofit boosting pump for re-tasking the towhead and enhancing late-life production.

Pipeline Bundles are a smart, simple solution, incorporating all the structures, valve work, pipelines and control systems for field operation contained in a single, large-diameter carrier pipe.

These can include multiple production pipes, including high-performance thermally insulated PiP and CRA mechanically lined pipe, and well stimulus pipes, including water injection pipes with our unique Swagelining all-polymer, corrosion-resistant, long-life lining system.

Subsea 7 has a strong track record of innovation within the Pipeline Bundle concept.

The first CRA pipe was incorporated in ConocoPhillips' HPHT Embla development in 1992, followed by mechanically-lined BuBi® pipe on BP's North Sea Cyrus field in 1995.

Active heating in a Pipeline Bundle was first installed on Equinor's Åsgard field in 1997, and Swagelining deployed on BP's Machar development in 2008, both in the North Sea.

More recently, the Apache North Sea Callater tie-back was developed using a hot-water-heated Pipeline Bundle system as an extension to the existing Skene Bundle system installed in 2002, with the extended heated tie-back measuring 18.8km in total.

Equinor's Snorre field is currently being developed with all-electric valve actuation and prepared for future hosting of AIVs.

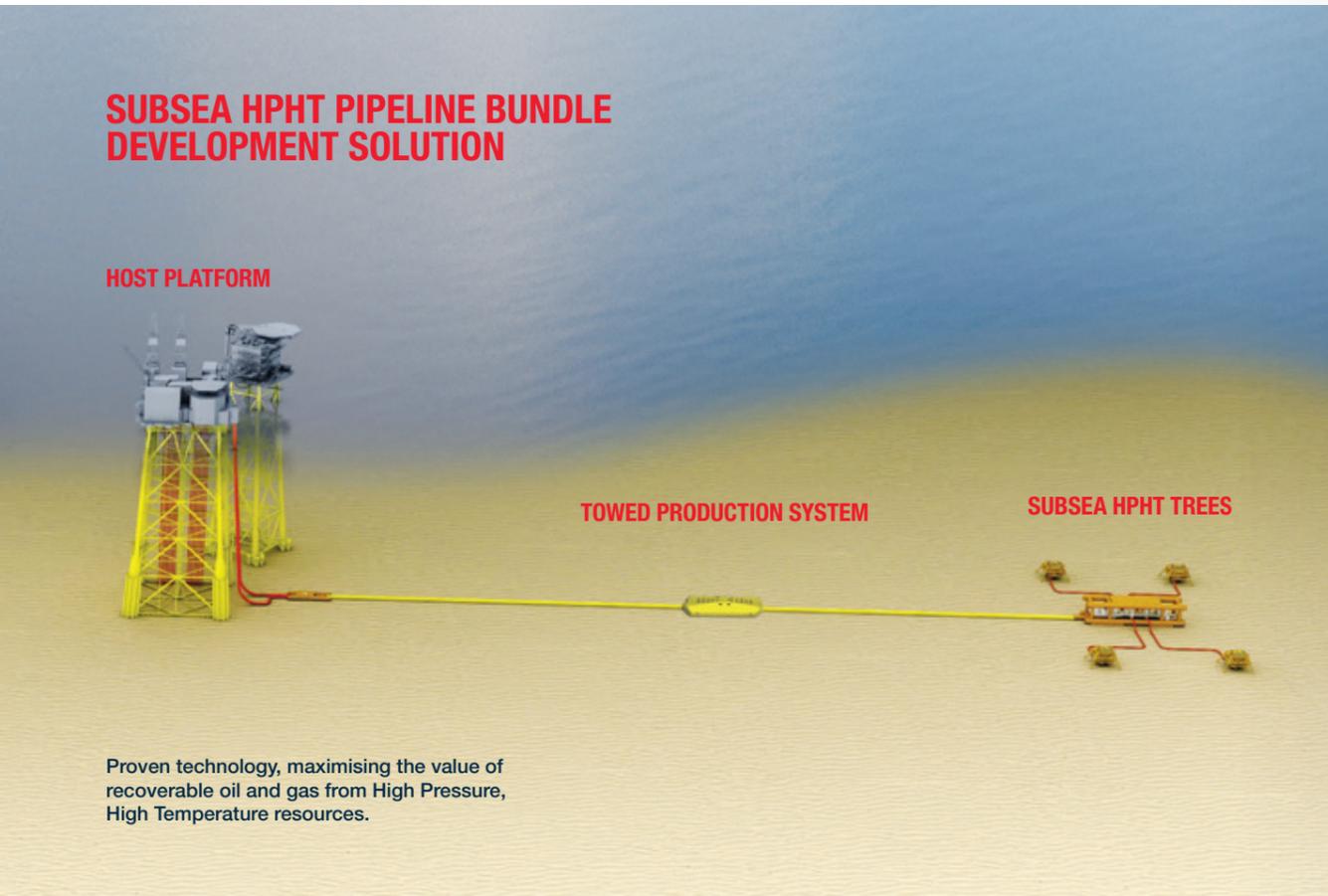
The onshore fabrication and testing of Pipeline Bundles allows all-year installation with simplified campaigns

and eliminates the need for specialist pipelay or heavy construction vessels.

The Pipeline Bundles, up to 7700m in length, are transported and installed in position by the efficient Controlled Depth Tow Method (CDTM), a low-stress and low-fatigue process using local anchor-handling tugs.

“As well as its benefits of cost reduction and project acceleration, the reusable Pipeline Bundle is environmentally sustainable,” says Thomas Sunde.

“There are very few subsea concepts which combine a strong track record with such outstanding potential for meeting fresh technological challenges.”



SUBSEA HPHT PIPELINE BUNDLE DEVELOPMENT SOLUTION

HOST PLATFORM

TOWED PRODUCTION SYSTEM

SUBSEA HPHT TREES

Proven technology, maximising the value of recoverable oil and gas from High Pressure, High Temperature resources.

INSTALLED PIPELINE BUNDLES: NORTH SEA

84

Number Installed

7,681m

Longest: ConocoPhillips Enochdhu

4

Most Pipe-in-Pipes: Equinor Snorre East

12,371t

Heaviest: Equinor Snorre East

547t

Heaviest Towhead: BG Knarr

58 inches

Largest Diameter: Equinor Snorre East

410m

Deepest: BG Knarr

42m

Shallowest: Maersk Dan

1,000km

Longest Tow: North of Wick

160°C

Highest Design Temperature: Total West Franklin

28.7km

Longest in Series: BP Andrew

650km

Longest Tow: South of Wick

VERSATILITY IN DEPTH

Selecting the optimum riser system at an early stage in field development planning is the key.

//////
YANN BROUARD
 Riser Technology Manager

IVAN CRUZ
 Senior Technology Manager

RICHARD JONES
 Pipeline Production Team
 Technology Manager

VALUE

- CAPEX
- OPEX
- ENVIRONMENT
- UPTIME AND RELIABILITY
- ADDITIONAL RECOVERY
- ACCELERATED RECOVERY

“The GJR allows free-hanging rigid riser configurations which are more cost-effective than high-performance SLWRs.”

“Over many years of innovative product development, we have demonstrated that selecting the optimum riser system at an early stage in field development planning is the key to unlocking economic hydrocarbon production,” says Subsea 7 Riser Technology Manager, Yann Brouard.

After designing, constructing and installing one of the widest and most adaptable ranges of riser systems in the industry, Subsea 7 is refining our established riser technology portfolio to meet the challenges of the future. The principal drivers in this programme are developing advanced capabilities to lower the installed cost, enhance fatigue performance, reduce loads on the host and improve corrosion resistance properties.

We are also looking to the near future when lightweight non-metallic pipeline materials will transform riser performance.

Our established riser portfolio consists of both coupled systems (for direct connection to the floating host facility) and hybrid decoupled systems with flexible jumper connections which are suitable for deepwater applications with large hang-off loads or strong dynamic motions.

The use of decoupled risers has diminished in recent years for cost reasons, although they are still deployed in specific cases where the field development is based on using refurbished FPSOs with limited payload.

We are currently focusing on several key technology innovations in both categories:

- Gimbal Joint Riser (GJR) – to allow free-hanging rigid riser configurations which are more cost-effective than high-performance Steel Lazy Wave Risers (SLWRs) and require no buoyancy
- Tethered Catenary Riser (TCR) – the consolidation of several field-proven decoupled riser designs into a new cost-efficient TCR assembly suitable for fabrication and installation on a global basis
- Advanced riser materials – the successful introduction of high-strength steel and non-metallic materials into riser systems, in particular Corrosion-Resistant Alloy (CRA), polymer-lined and Thermoplastic Composite Pipe (TCP).

THE GIMBAL JOINT RISER

Launched at OTC Brasil 2019 in an award-winning presentation, this ingeniously simple concept is based on the insertion of a multiple hinged joint within the suspended catenary which absorbs the dynamic movements coming from the floating host.

The mechanical joint acts as an exoskeleton, providing added strength and maintaining flexibility in an area which is subject to continuous repetitive, fatigue-inducing motions.

The GJR comprises multiple tubular elements with a number of articulated rigid sections which transfer tensile, compressive and torsion loads and permit degrees of pivoting motion. These armoured elements decouple the dynamic excitation transferred through the riser from vessel motion and protect a pliant inner riser pipe which supports high curvatures.

This mid-riser solution addresses the problem of fatigue at the touchdown point (TDP), which is conventionally overcome through local material thickening with possible constriction of the internal diameter.

“Platform dynamics are the main driver in the industry quest to develop free-hanging riser configurations which require no expensive distributed buoyancy modules,” explains Senior Technology Manager Ivan Cruz of the GJR development team.

“In deepwater regions, operators are converting cargo vessels for redeployment as spread-moored FPSOs, and these vessels can experience hang-off upward and downward velocities of 5/6 metres per second in harsh weathers.

“Such conditions make standard Steel Catenary Risers unfeasible, and traditionally require the deployment of expensive buoyancy modules in an SLWR configuration.”

Already two years under development in collaboration with several leading operators, the Gimbal Joint Riser is now heading for full-scale prototype testing to Technology Readiness Level (TRL) 4.

As well as removing the costs of added buoyancy modules, the GJR also delivers significant cost savings by reducing the length of the riser lines compared with SLWR solutions. This cost benefit increases with multi-riser applications lined with expensive Alloy 625.

“A common configuration is to have all the risers in Brazilian FPSOs on one side of the floating facility,” adds Cruz. “Deploying GJRs could also allow operators to physically locate an FPSO nearer the TDP, potentially saving hundreds of metres of flowline sections in addition to the length reductions in the suspended catenaries.”

THE TETHERED CATENARY RISER (TCR)

This new market-ready concept pulls together up to six riser lines into a buoyant midwater arch, which prevents clashing. The riser lines can be accessed individually and, as with other decoupled risers, the buoyant assembly reduces the combined weight imposed on the floating host by the risers.

The TCR has a lower installed cost than other hybrid riser designs while still delivering excellent dynamic and fatigue performance. By grouping multiple risers within a single assembly, the TCR concept benefits from economies of scale over a conventional Single Hybrid Riser design.

The TCR design allows for reductions in riser components, including mechanical joints, bottom spools, Pipeline End Terminations (PLETs), monitoring systems and buoyancy tanks.

The assembly can be pre-installed in advance of the FPSO arrival on site and is compatible with all field types and regional conditions anywhere in the world.

NEW RISER PIPELINE MATERIALS

Using higher-strength steel to decrease pipe thickness is an effective way to lower material and fabrication costs and significantly reduce installation costs.

Subsea 7 has performed material and welding qualification for X80 installed by Reel-lay including CRA mechanically lined pipe. A recent study by Subsea 7’s Pipeline Production Team identified a potential 20% reduction in the weight of SLWRs and an 11% reduction in buoyancy material costs by replacing X65 riser steel with higher-strength X80.

It is non-metallic materials, however, that could become serious game-changers in the next generation of riser design.

Subsea 7’s Swagelining® product is currently progressing the qualification of its first polymer-lined water injection SCR, which, with its inherent fatigue-resistance and lower weight, offers a

highly cost-effective corrosion barrier for riser applications.

With its 50-year qualified design life, reduced weight and improved flow assurance, the Swagelining® product has the potential for greater system simplicity, potentially avoiding the need for the complex integration of flexible risers with the rigid pipe flowline.

Looking further to the future, the industry is anticipating substantial benefits from the deployment of Thermoplastic Composite Pipe (TCP) in riser configurations.

Subsea 7 has made a strategic investment in leading TCP manufacturer Airborne Oil & Gas, who have already presented a detailed business case for free-hanging TCP catenary risers in deepwater developments. This deployment would require no external buoyancy and would deliver significant reductions in topside tension.

Airborne commenced its TCP Riser qualification programme in 2018, and its solid pipe structure is impervious to corrosion, resulting in outstanding performance in H₂S and CO₂ corrosive environments. It has an inner fully bonded, smooth-bore polymer liner that ensures the best attainable flow properties.

Yann Brouard believes that TCP represents the future of deepwater riser design.

“TCP is beautifully simple, suffers no corrosion or fatigue issues and is thinner, lighter and more spoolable – that’s what makes it the key to the future,” he says.

“Indeed, TCP may be the only possible solution for the most challenging ultra-deepwater installations.”

“Ingeniously simple concept based on the insertion of a multiple hinged joint which absorbs the dynamic movements from the floating host.”



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HUGH FERGUSON
 Digital Services Strategy Director

VALUE

CAPEX

OPEX

ENVIRONMENT

UPTIME AND RELIABILITY

ADDITIONAL RECOVERY

ACCELERATED RECOVERY

INVESTMENT IN DIGITALISATION: DATA IS OUR LIFEBLOOD

At i-Tech 7, we significantly accelerated our digitalisation programme throughout 2019 to ensure that we deliver actionable full life of field insights of real value to clients.

As one of the leading Inspection Repair and Maintenance (IRM) specialists in the industry, data is, by definition, i-Tech 7's lifeblood. We are currently implementing a transformative digitalisation programme in collaboration with leading IT company Leidos, with whom we forged a strategic five-year partnership in April 2018.

Leidos' global experience across defence, air transport and other adjacent industries gives us ready access to market-tested solutions in Machine Learning, Data Federation (aggregating data from disparate sources), Dynamic Visualisation and Augmented Intelligence, all of which are currently being adapted for the specific challenges of subsea asset management.

Automated vision recognition in challenging subsea conditions of sediment, water movement and poor lighting has been one of our successful early deliverables. With Leidos we have developed advanced Artificial Intelligence (AI) based on algorithms to recognise objects, changes in objects

and other relevant data from video inspections.

Machine Learning is used to classify these events and objects – a time-consuming phase while the machine is 'trained' to recognise objects. Once it achieves a critical mass of knowledge, however, it begins 'learning' on its own and becomes increasingly robust, looking for and identifying patterns in very large amounts of video footage.

We are currently deploying these advanced digitalisation technologies on our offshore campaigns as part of an ongoing development, initially with pipelines and moving on to structures and risers.

This new system enables and accelerates the processing of data from

new high-speed inspection sensors, which can increase the pace of pipeline inspections from a manual speed of around one knot to between 4–6 knots. Although the process creates a huge amount of data, our automated AI workflow reduces processing time by over 50%, delivering major benefits for clients who want efficient inspections without being swamped with extraneous data.

Based on this success, we are now starting field testing of Automated Pipeline Eventing to deliver event and anomaly detection. This will eliminate time-consuming, resource-heavy manual video reviews and deliver automated damage assessment reports and predictive analysis to clients in near-real time from on board the vessel.

DYNAMIC VISUALISATION

The visualisation of data is the key to enabling clients to benefit from the data's value and acquire valuable insights. Visualisation techniques are now considerably more sophisticated than a single dashboard, and we are developing a range of devices to cater for varying levels of client interpretation of data.

We are currently building various levels of data display technology ranging from interactive apps for hands-on technologists to Geographic Information System (GIS) displays for senior engineering decision-makers who need immediate, high-fidelity access to core data.

AUGMENTED INTELLIGENCE

The value of Artificial Intelligence extends beyond the cost of investment, in particular when it is applied in Augmented Intelligence in an assistive role to enhance human intelligence to go beyond automation of existing processes and create new ways of working.

This hybrid of human and machine capabilities allows humans more time to apply expertise, experience, intuition for new solutions and enhanced decision-making. The strength of AI in culling massive amounts of raw data and delivering focused information enables highly effective creative human problem-solving and future planning.

In practical terms, this has particular relevance for the offshore oil and gas IRM sector. Highly knowledgeable inspection engineers are empowered

with superior AI tools to bring integrity management to the front end of the offshore business.

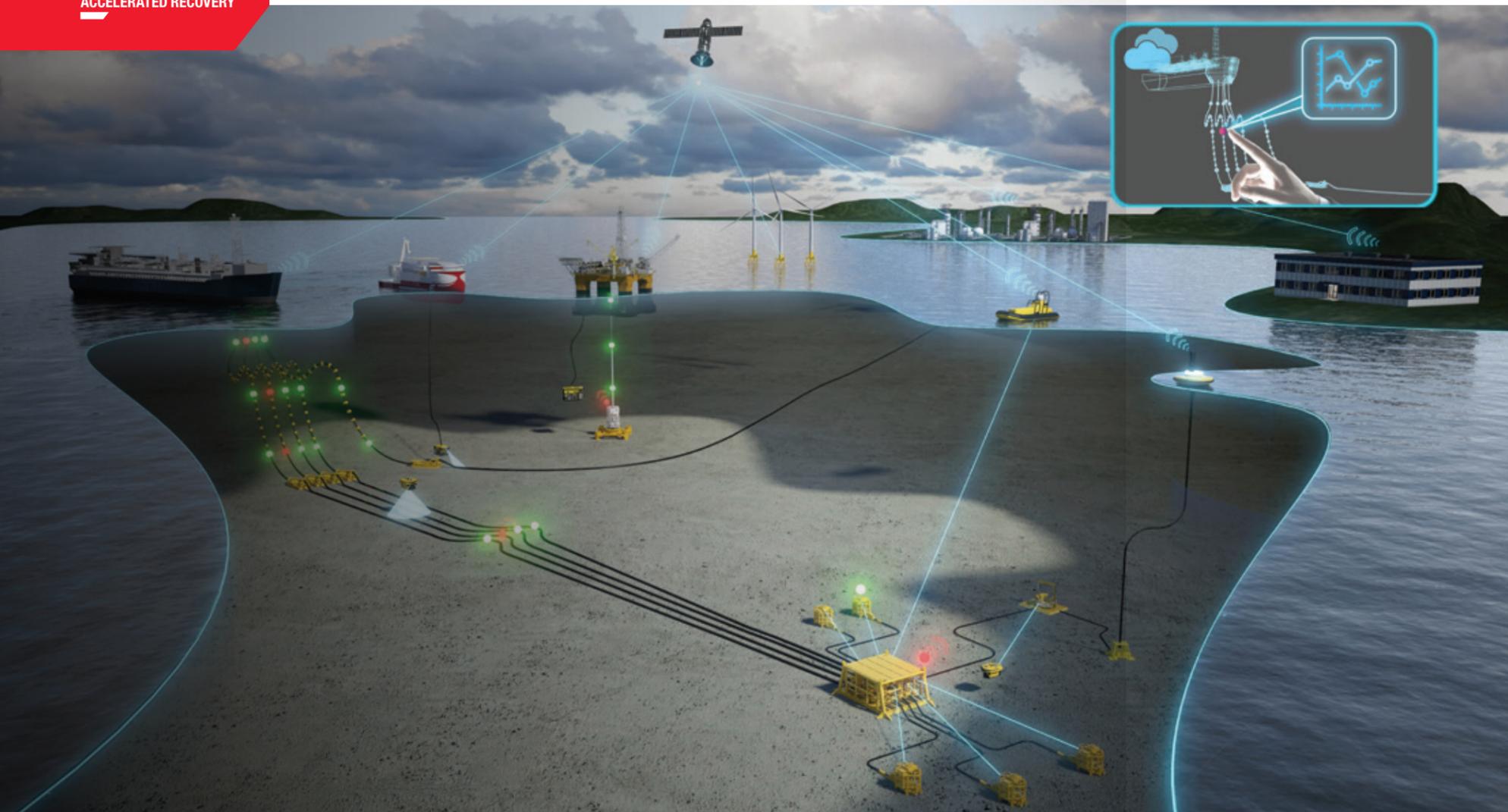
Moving workloads closer to the source of the data creates a highly effective collaborative autonomy ('Interoperability'), which gives human experts improved accessibility to near- and real-time information while simultaneously creating cognitive capabilities for networks and machines to self-diagnose and self-heal data anomalies.

WIDER VALUE

Although i-Tech 7 has pioneered digitalisation in our specialist activities, we are working within a comprehensive digitalisation programme throughout the entire Subsea 7 organisation.

A joint project is already underway between Subsea 7 and 4Subsea towards the monitoring of key operational data on Subsea 7 vessels. This programme will use advanced algorithms, Artificial Intelligence and digital twins to enable the digitalisation of wide-ranging marine operations across the organisation.

“Automated AI workflow reduces processing time by over 50%. This new system greatly accelerates the pace of pipeline inspections.”



HIMANSHU MAHESHWARI
Director of Integrity
Engineering, i-Tech 7

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“This game-changing technology is planned for market delivery in mid-2020.”

DATA-DRIVEN DECISION-MAKING IN AIM

Subsea 7 is leading the industry transformation towards digital Asset Integrity Management (AIM) by building on our 40 years’ experience in global Inspection, Repair and Maintenance (IRM) project execution.

i-Tech 7 is driving Subsea 7’s strategic initiative to be the first one-stop shop in digital AIM, delivering real-time insights through a powerful combination of integrated inspection, monitoring, data management and integrity analytics technologies.

“The subsea AIM market is fragmented and rich in niche technologies,” notes Himanshu Maheshwari, Director of Integrity Engineering with i-Tech 7. “We are well positioned to become a market-leading system integrator leveraging innovation through collaboration with clients and specialist partners across the supply chain.”

i-Tech 7 has moved rapidly into providing decision support services, not only helping clients to identify the data they need, and how they can manage it, but also reducing reliance on traditional inspection by introducing advanced monitoring and analytics.

BUILDING THE FOUNDATION

2019 was a critical year for Subsea 7’s Life of Field business unit in building a foundation for digital AIM. During the year, we brought in the majority of the competence required for digital AIM, with a central element being 4Subsea and Xodus joining the Subsea 7 group.

4Subsea is a Norwegian market leader in delivering digital twins and integrated digital solutions across offshore energy infrastructure including risers, pipelines and subsea infrastructure in both brownfield and greenfield developments as well as offshore wind.

Xodus, now wholly owned by Subsea 7, has strong integrity engineering capabilities, with competence in risk-based integrity planning and flow assurance. It also brings environmental engineering expertise allowing Subsea 7 to address the market need for carbon footprint management.

“Subsea 7 in combination with i-Tech 7, 4Subsea and Xodus now offers the industry’s most comprehensive digital

AIM solution,” notes Himanshu Maheshwari. “The focus will be on the integration and scaling of these capabilities to maximise the value for clients.”

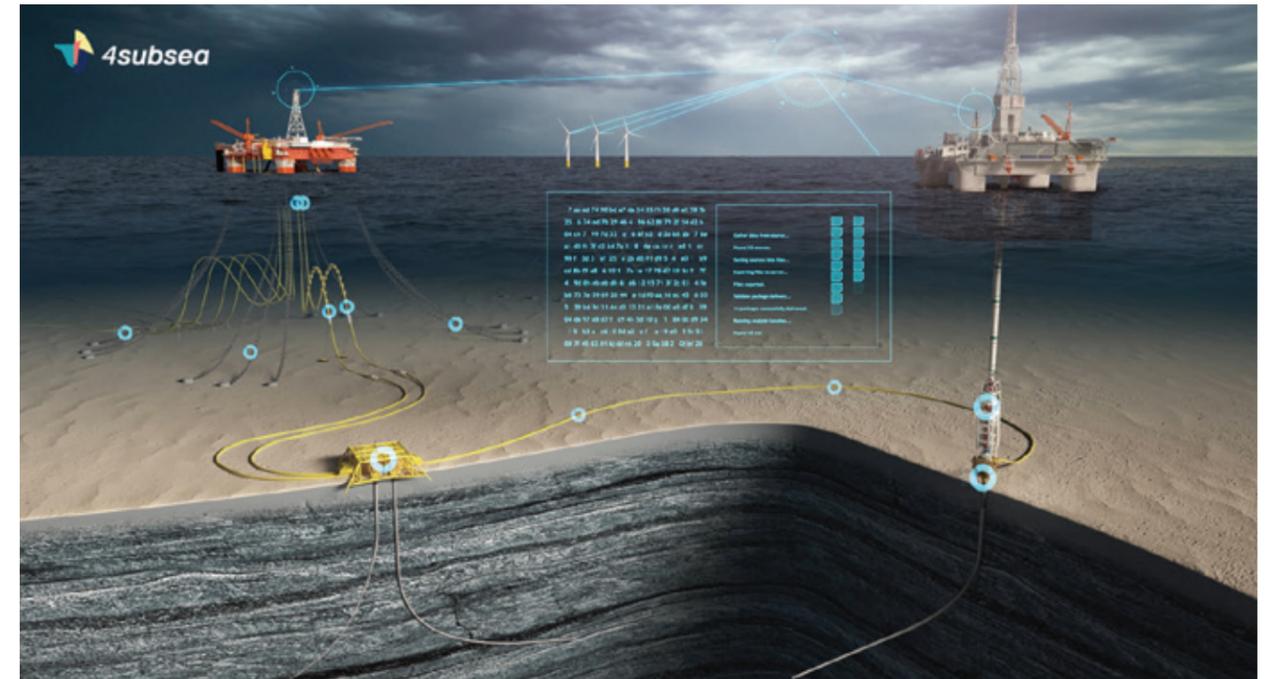
SENSING THE CHANGE

A key technology challenge in tracking the condition of dynamic subsea assets is the high cost and low reliability of sensors, since effective predictive lifecycle management requires access to critical data for the health of subsea infrastructure.

To achieve this goal, Subsea 7 has licensed an award-winning nanomaterial-based sensor technology from the Massachusetts Institute of Technology (MIT). This sensor technology, developed for aircraft, tracks key failure modes at a fraction of the cost of traditional sensors and without maintenance requirement throughout the asset’s lifecycle. This game-changing technology is planned for market delivery in mid-2020.

“When it comes to digitalisation and automation, the subsea industry can learn from adjacent industries such as aerospace and defence,” says Himanshu Maheshwari. “The nanomaterial-based sensor is one such example where we are taking existing aerospace technologies and adapting it for the offshore energy infrastructure”.

“A network of interconnected data filtered through analytics.”



CLONING THE SYSTEM

Digital AIM represents a system-based approach to managing asset health using data-driven decision-making.

Historically, subsea AIM was schedule-based, using key enablers including vessels, ROVs and discrete IRM tools and technologies on a regular calendar basis.

The last decade has seen an era of condition-based integrity management, where inspection has been augmented with proactive continuous monitoring and advanced analytical models.

i-Tech 7’s new digital capabilities reduce the scope and scale of reactive

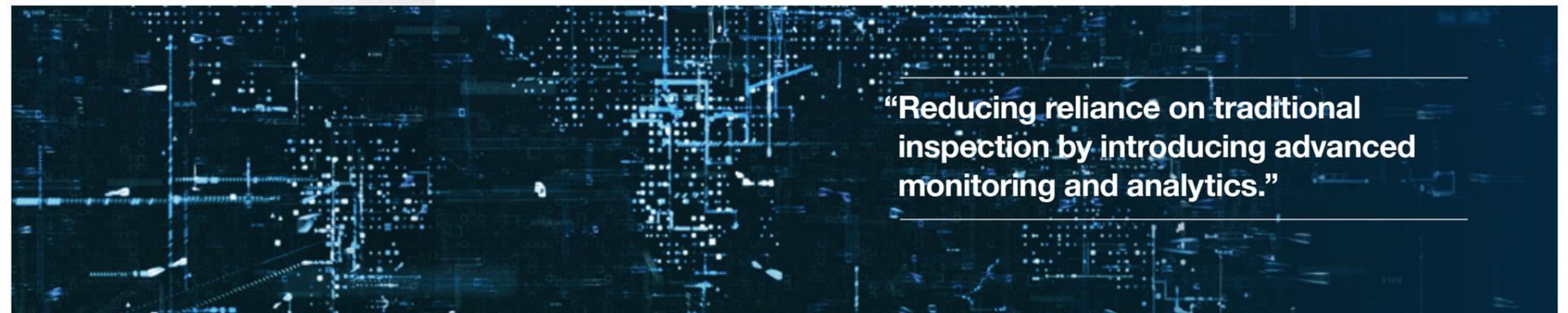
inspection and, building on advanced data analytics, enable highly effective predictive integrity management.

In particular, we use ‘digital twins’ to give a live quantitative view of what is happening to operational assets based on data from our own permanent sensors, third-party sensors and targeted inspections.

Specific digital twins are built for given equipment and failure modes, such as risers, pipelines and subsea infrastructure, and in the future will all work together in a common data environment to form a complete picture of the asset. This will transform the

nature of ongoing IRM operations, replacing expensive field inspections with data-driven decision-making.

“The term ‘digital twin’ is currently widely misused,” notes Himanshu Maheshwari. “It’s not just an eye-catching visualisation, it’s more a network of interconnected data filtered through analytics to enable insights for optimal asset management throughout the Life of Field. The comprehensive ‘digital twin’ does not yet exist in the industry, but that is our goal.”



“Reducing reliance on traditional inspection by introducing advanced monitoring and analytics.”

JIM JAMIESON
Strategy and Technology
Manager, i-Tech 7

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**THE ROADMAP TO
SUBSEA AUTONOMY**

“The disruptive potential of introducing autonomy into underwater vehicle services is a genuinely exciting prospect,” says Jim Jamieson, Strategy and Technology Development Manager with i-Tech 7. “After decades of experience in pioneering development we understand that the real key to successful technology implementation is managing when and how it is applied.

“Shiny new technologies can become radical game-changers – but only if they are developed incrementally to meet current and near-market requirements. Demonstrable early successes, followed by timely instalments, are important to reinforce the benefits over established ways of working.

“A road map has been devised to help navigate the technical and commercial milestones, along with key stakeholder requirements in this new business landscape.”

The change in market demands, with an increased focus on environmental and cost-driven solutions, is driving the industry search for innovative solutions with the potential to enable a step-change in service provision.

“The resultant increase in autonomous development activity creates significant industry ‘noise’,” Jim notes. “Every success in this sector, regardless of its significance, seems to attract prominent industry media coverage.”

The approach favoured by i-Tech 7 is therefore highly strategic: applying a development roadmap to filter the noise and identify the high-value technology needed to progress along the route to

the next destination as an incremental, controlled and deliberate process.

“The market is always wary of step changes,” Jim notes. “Drawing on over thirty years’ experience in the industry, we ensure that every technological step we take is market-led and heading us in the right direction.”

REMOTE PILOTING

A recent major achievement for i-Tech 7 has been the successful commissioning of two beach-based Onshore Control Centres (OCCs) in Stavanger and Aberdeen to deliver remote piloting of ROVs in the field.

One of the challenges in remote subsea operations is the ability to maintain robust communication links, and we have tackled this problem in several ways.

We have introduced high-quality, low-latency image compression for

transmission across available high-bandwidth offshore communications networks. The video/data compression methods utilised, sourced from cutting-edge industry providers, ensure that the live ROV operations are seamless and robust with no constraints on operations.

The introduction of our ‘Autonomy Engine’ to the remote-control architecture enables the wider use of globally available communication networks that may have less bandwidth or increased transmission latencies. If bandwidth issues begin to interfere with remote operations, the engine automatically introduces autonomous modes to maintain safe vehicle control. To use a comparison with mobile telephones, when signal strength drops from five bars to one and only emergency calls are permitted, the autonomy engine ensures that safe vehicle control is maintained.

A shared control system, which can be used with multiple ROVs or autonomous vehicles, ensures optimum operational versatility and flexibility. A generic Autonomy Engine can be plugged into any ROV or autonomy hardware to allow switching between ‘human-in-the-loop manual’ and fully autonomous control. In planned autonomous operation, the engine can reintroduce ‘human in-the-loop’ control when communications channels become available.

This shared control system, which can be used with multiple ROVs or autonomous vehicles, ensures optimum operational versatility and flexibility.

AUTONOMY MILESTONES

i-Tech 7 has a long and distinguished track record in the development of autonomous vehicles for subsea inspections.

Our first model was a result of collaboration with Southampton University and long-term software partner SeeByte which produced the torpedo-shaped vehicle ‘GEOSUB’ which successfully executed the world’s first autonomous pipeline inspection for BP in the West of Shetland area in 2006.

GEOSUB’s shape presented a limitation on use cases, and a form factor change to a hovering platform led to the development of the Autonomous Inspection Vehicle (AIV). This change enables us to perform close inspection

of infield subsea infrastructure and to track vertical risers and structures as well as horizontal pipelines. The development also extended and strengthened our relationship with our long-term partner.

One of the key challenges for the AIV, the capability to carry out safe close inspections, was the development of a method of merging long-range vehicle navigation with close-up positioning around subsea structures.

A ‘relocalisation’ method was successfully developed to enable close subsea structure inspection with no risk of collision. This method builds on earlier research and, in real time, compares live sonar imagery in three dimensions with a world model on board the vehicle to determine its exact location and proximity to subsea infrastructure.

The method was developed through the Prototype Autonomous Inspection Vehicle (PAIV) programme before being deployed onto the AIV.

Our current AIV model has successfully completed four offshore demonstration trials, including one autonomous mission that completed 36 inspection tasks within a single 18-hour dive.

i-Tech 7 has now secured key technology elements which are critical to meeting industry demand for new and smarter ways of working. Working with customers, partners and the wider supply chain, every technological step we take is aligned with a strategic development roadmap to meet current and future market demands.

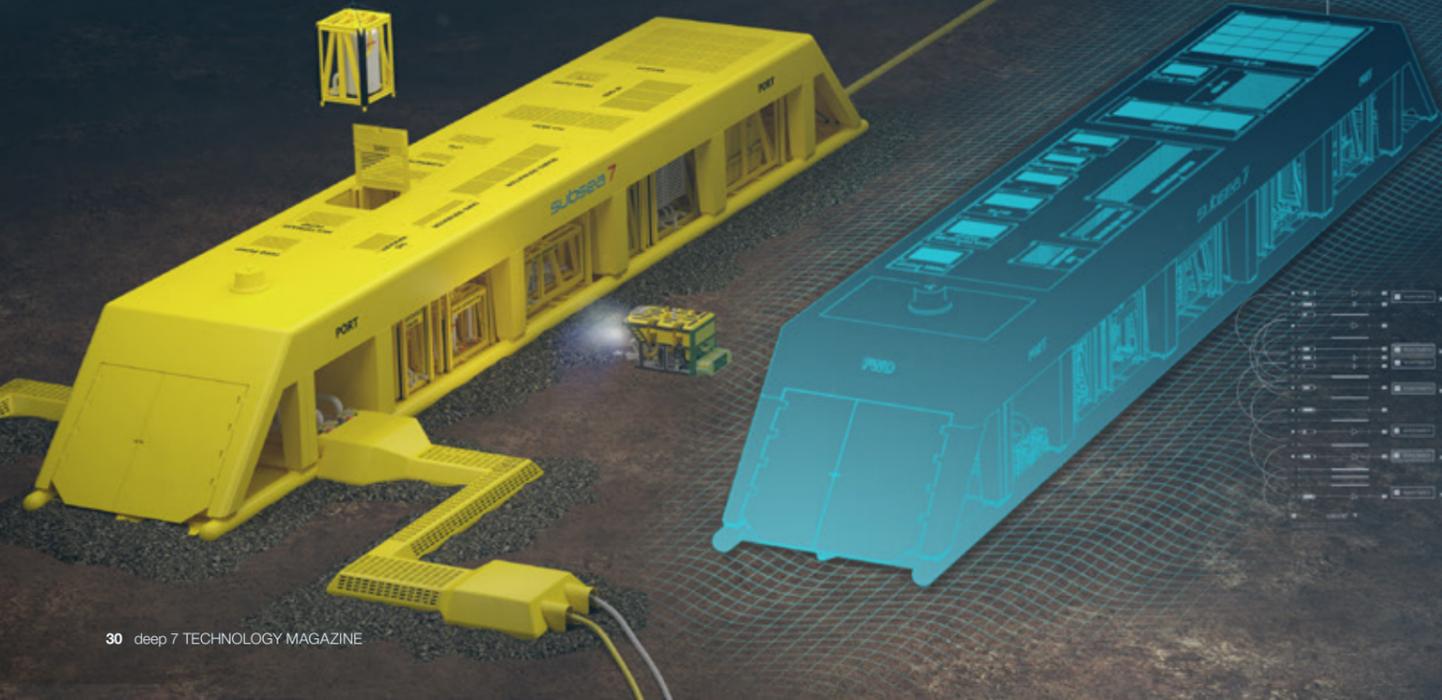
“Merging long-range vehicle navigation with close-up positioning around subsea structures.”



OUR TECHNOLOGY WORLD



OUR TECHNOLOGY WORLD





SEVEN VIKING HYBRIDISATION

In early 2019, *Seven Viking*, our advanced harsh-environment IRM and light construction vessel, became the first vessel in the Subsea 7 fleet to undergo conversion to hybrid electric/diesel power.

The pioneering conversion has resulted in significantly lower fuel consumption, reduced CO₂ and NO_x emissions and enhanced Dynamic Positioning (DP) capability. Hybridisation of DP vessels is a particularly attractive eco-efficient proposition because of the high engine load variations encountered during DP operations.

Built in 2013 to an innovative X-bow design, the hybrid vessel has started a long-term IRM contract for Equinor's 560 subsea wells on the Norwegian Continental Shelf, executing around 160 assorted work scopes in the first eight months of the contract.

At the heart of the conversion was

the installation of a new storage battery room beneath the helideck with a capacity of 1300kWh – the equivalent of 32 electric cars.

The battery system allows the vessel to optimise the operation of its diesel-fuelled electrical generators, making the power system more energy-efficient and environmentally friendly.

The fast power response from the hybrid energy system also makes the vessel more responsive, increasing dynamic performance in critical operations.

In particular, the battery system serves as a 'spinning reserve' that reduces the number of generators operating and delivers 'peak shaving' by buffering or balancing short-term engine load variations.

The first 12 months in operation show a reduction of 19% in fuel consumption, saving over 960 tonnes of diesel fuel and



STUART SMITH
Vice President Asset Development

reducing CO₂ emissions by 2,900 tonnes.

The battery system delivers further efficiencies with lower maintenance requirements and enables further energy-efficient activities, such as regenerating power from project equipment and the in-field charging of autonomous electrical ROVs.

Seven Viking is a good example of advanced electrical marine technology being applied both to reduce the carbon footprint of an asset and to enhance its operational capability.

“The fast power response from the hybrid energy system also makes the vessel more responsive.”



TECHNOLOGY DRIVE TOWARDS SUSTAINABILITY



DWAYNE HOPKINS
Technology Country Manager Canada

Subsea 7 is refocussing our technology development plans to ensure that the value proposition that we offer includes a sustainable approach based on a broader range of stakeholders, including the natural environment and society itself.

“Through active technology leadership, we have an opportunity to drive sustainability and uncover new value opportunities with benefits to people, the planet and our profits,” says Dwayne Hopkins, Technology Country Manager Canada.

“We are extending our vision for technology development so that we become a leading provider of environmentally sustainable subsea solutions and services.

“The value created through our new environmental initiatives will open up business opportunities in the future.”

One example of this is the pioneering work Subsea 7 is undertaking to adapt onshore pumped power storage technology for marine application, with a prototype towed power storage unit based on adapted Pipeline Bundle technology due for testing in the next twelve months.

The trend towards integrated power storage in renewable schemes will accelerate as the need to decommission

conventional power generation becomes more pressing.

This opens a new market with significant potential for integrated Subsea 7 and Seaway 7 capabilities, aligning our subsea expertise with a growing need in the offshore renewable energy market to store energy for periods of lower power generation.

Key areas of sustainability which have already been targeted for integration into our technology portfolio are ecological impact, operational eco-efficiency, energy efficiency and energy storage.

Subsea 7 is introducing ambitious metrics (KPIs) in these areas to measure performance, support ongoing investment in appropriate technologies and demonstrate industry leadership in the drive for greater sustainability.

To minimise ecological impact, we are concentrating on developing solutions which can be recycled, reused or repurposed so that nothing goes to landfill.

One major initiative consists of the refloating, reconfiguration and reuse of our prefabricated Pipeline Bundles. This high-performance concept reduces capital cost amortisations and makes a substantial contribution towards environmental sustainability.

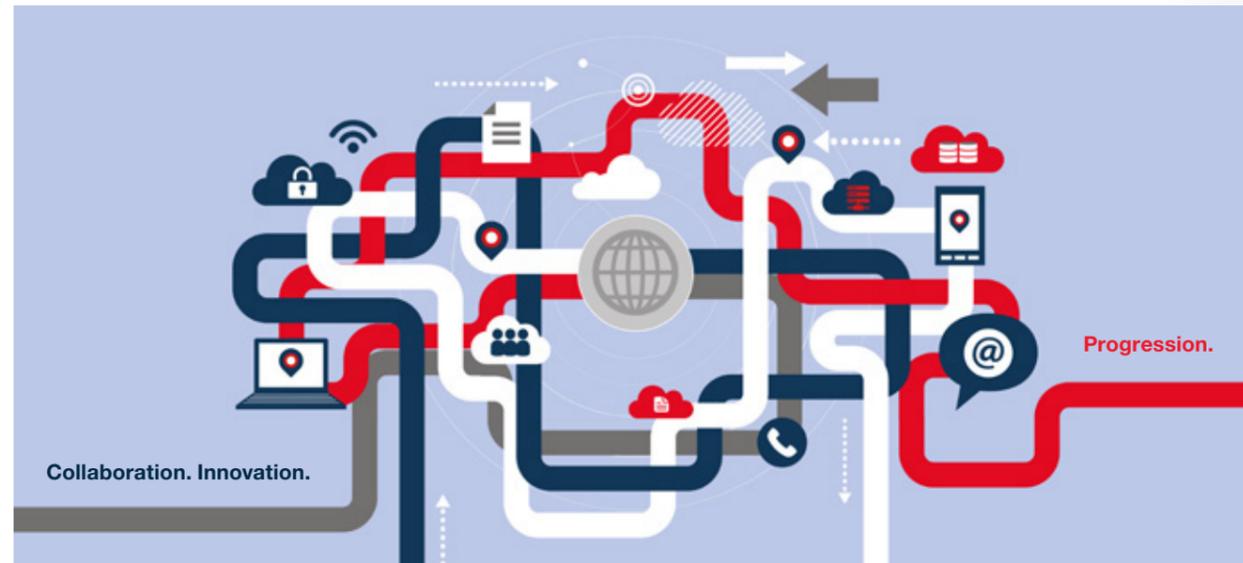
In operational eco-efficiency, we have

already started work on converting vessels in our fleet to hybrid electric/diesel power with the hybridisation of our advanced IRM vessel *Seven Viking* early in 2019.

Through our strategic investment in companies such as GEPS Techno (off-grid renewable energy) and our extensive experience in the installation of offshore renewable energy facilities, we are already a leading provider of low-carbon offshore energy solutions.

“We plan to expand our investment in technologies that support a new generation of energy and storage solutions,” says Dwayne. “The company is committed to achieving a quantifiable carbon footprint reduction for our clients and our own operations.”

“A sustainable approach based on a broader range of stakeholders.”



THE KEY TO RAPID TECHNOLOGY DEVELOPMENT

GAVIN MCCLAFFERTY
Open Innovation Lead

“The OI journey is about acquiring knowledge and pulling it back into our business.”

Subsea 7 has earned a reputation for developing innovative, practical technologies. We already have global teams of talented and determined problem-solvers tackling key technology challenges, but we are now looking towards new collaborations for faster, better results.

“We live in an era where the most rapid acceleration of technological innovation ever seen is transforming our lives,” says Gavin McClafferty, Subsea 7’s Open Innovation Lead. “Our most precious currency is time – not only how effectively we can meet the challenges but also how quickly we can create the capacity for technological disruption.”

Open Innovation (OI) is the key to building at speed on our extensive in-house expertise to develop the next generation of transformative technologies.

It has been estimated that around 80% of the world’s technology problems have already been solved – but the answer to any particular challenge may well be sitting in a place that we’re not aware of.

In 2015, Subsea 7 took its first steps towards Open Innovation technology collaboration with our 7INNOVATE programme and the results to date have been both surprising and highly impressive.

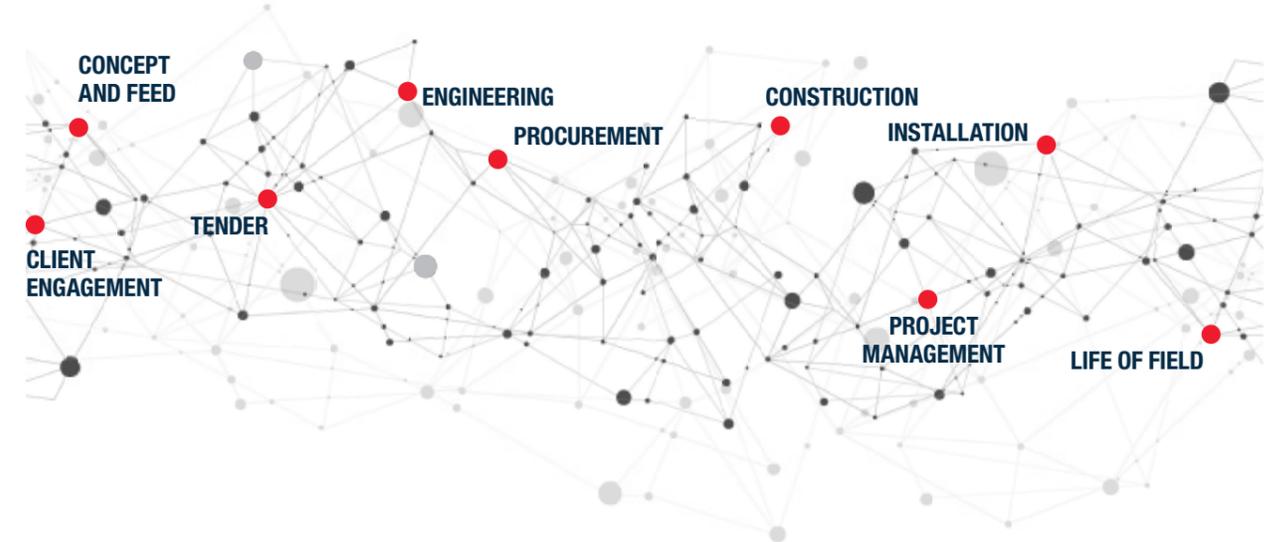
Our 7INNOVATE toolkit is based in a partner ecosystem which includes global OI organisations like NineSigma, together with leading academic and research institutions.

Our first nine external challenges were based on highly specific, real-life technological issues and yielded over 100 potential technical solutions from NineSigma’s 2.5 million members. A parallel confidential technology search led to a further 50 potential solutions, not only meeting the identified challenges but also generating resolutions to other issues which we weren’t expecting.

We also broadened the scope of our internal problem-solving capabilities with three highly successful Ideation campaigns, which yielded 128 ideas from every part of the Subsea 7 organisation.

“The Open Innovation journey for Subsea 7 is about acquiring knowledge and pulling it back into our business,” says Gavin. “The 7INNOVATE toolkit allows us to collaborate externally and advertise challenges either openly or anonymously.”

We then deploy Subsea 7’s differentiating capabilities in creativity, relationships and solutions to establish a framework that enables all parties to benefit from co-developing solutions for our clients.



DAVE WILLIAMS
Vice President Digitalisation

“We weave together all project lifecycle data and multiply its stand-alone value.”

INVESTING IN AN INVALUABLE ASSET

Subsea 7 is currently driving an advanced Digitalisation programme which will unlock our data and transform the way we work.

“One of the most valuable assets we possess is the data that we create every day in everything we do,” says Dave Williams, Subsea 7 VP Digitalisation.

“In building a state-of-the-art infrastructure of integrated digital technology, we will be able to weave together all our project lifecycle data in a way that multiplies its stand-alone value.”

This ‘digital thread’ will maximise opportunities to take informed actions based on insights provided by this connected data, and will become a comprehensive database of invaluable knowledge for Subsea 7 and our clients.

Subsea 7’s integrated digital technology is underpinned by a crucial Common Data Environment (CDE) which acts as a data exchange, management and visualisation platform. The CDE can cross-collaborate with clients’ and suppliers’ systems and data pools as well as our own and is already delivering value by integrating data to support our business.

“We want to enable clients to work seamlessly with us, and to have access to relevant data as the project progresses through the lifecycle,” says Dave Williams. “A key part of this strategy is the implementation of a Project Lifecycle

Management (PLM) platform.”

“To achieve this our system design works on the principles of a secure, flexible and platform-agnostic interface to maximise connectivity for clients and partners in combination with the key implementation of a project.

“The PLM will visualise data, documents and project progress in real time and enable effective collaboration on a common platform.”

To support the implementation of the PLM, Subsea 7 is modernising systems across its technology landscape to transform procurement, estimating, cost control and resource management systems.

The Digitalisation programme is investigating and piloting initiatives to help Subsea 7 and our clients to reduce their carbon footprint, mitigate HSE risks and optimise costs more effectively than is currently possible.

“The efficient use and reuse of good-quality data will enable us to reduce wasted time and effort, allowing us to execute more work with the same resource pool,” says Dave Williams.

“Everyone in Subsea 7 is playing their part to help structure and standardise our data to realise the benefits. Ultimately, this same data will then become the springboard for our Life of Field teams to leverage Subsea 7 whole-lifecycle capabilities as a unique digital service offering to our clients.”



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CRAIG BROWN
 Assistant Project Manager

LARGEST TOWHEAD EVER TRANSPORTED THROUGH WICK

Subsea 7's Pipeline Bundle towheads are unique structures which can incorporate valves, pipework, controls, monitoring, chemical injection and heating equipment as well as acting as a breakout for tying the Pipeline Bundle into subsea and platform infrastructure.

In March, we successfully transported our largest towhead to date from Wick harbour in the extreme North of Scotland to our nearby Pipeline Bundle fabrication site at Wester.

The Northern Terrace Manifold (NTM) Towhead for the North Sea CNOOC International-operated Buzzard Phase II (BPII) Project weighs 290 tonnes and at 37 metres in length was five metres longer than any previous towheads transported through the town.

Using a combination of Virtual Reality modelling developed by the specialist Subsea 7 Pipeline Bundle design team and high-performance abnormal load Self-Propelled Modular Transportation,

the massive structure was successfully manoeuvred through the narrow streets of the town in a record-breaking two hours.

"The BPII Pipeline Bundle incorporates our first 12-well slot multi-functional manifold system (eight production well connection slots and four water injection slots)," says Assistant Project Manager Craig Brown.

"This offers the flexibility for future expansion after the Pipeline Bundle is tied back to the existing Buzzard Complex."

The Pipeline Bundle is part of a substantial integrated development project being delivered by an Integrated Alliance of supply chain partners, including AGR Well Management, Baker Hughes, COSL Drilling, Worley and Subsea 7.

Under the contract, a new topsides module is also being installed by Seaway 7 to the existing production platform to house all processing pipework and packages to support the new development.

"The BPII NTM Towhead incorporates our first 12-well slot multi-functional manifold system."



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JEAN-LUC LONGEROCHE
 Chief Executive Officer, GEPS Techno

OFF-GRID RENEWABLE MARINE ENERGY

To accelerate our capability in renewable energy solutions for off-grid marine power applications, Subsea 7 acquired a shareholding during 2017 in GEPS Techno, a French wave energy developer which has achieved an important recent qualification milestone.

In June 2019, GEPS Techno successfully deployed a 150kW hybrid renewable energy pilot at sea on a test site off the French coast with the installation support of Seaway 7. The operation consisted of two separate elements – installation of the mooring and connection of the pilot to the mooring, both of which were executed in under 24 hours.

"The successful operations confirmed the simplicity of both the mooring and the pilot installation procedure," said GEPS Techno CEO Jean-Luc Longeroche. "Since the summer installation, the platform has demonstrated the ability of the pilot and its mooring to withstand

extreme weather conditions, including wave heights up to 12m.

"In recent months we have also introduced technical advances in our highly innovative electrical conversion chain to enhance the reliability of our power production.

"Working with Subsea 7 has helped to broaden business opportunities for us. Offshore renewable energy supply solutions for subsea installations are no longer a dream – we are already working towards on-site qualification processes to supply power to subsea trees, AUV docking stations and other remote applications".

"The successful operations confirmed the simplicity of both the mooring and the pilot installation procedure."

RENEWABLES AND HEAVY LIFTING

DP REDUCES MONOPILE INSTALLATION TIMES

Seaway 7, Subsea 7's Renewables and Heavy Lifting business, achieved a significant milestone in the installation of monopile offshore structures towards the end of 2019 offshore Rotterdam in the North Sea.

State-of-the-art crane vessel *Seaway Strashnov* demonstrated the feasibility of installing large monopiles using Dynamic Positioning (DP) when it successfully installed and removed a 6.5m diameter 600t monopile remaining within inclination tolerances using a motion-compensated gripper.

"This achievement confirms the potential of advanced DP to deliver considerable reductions in the installation time of such structures," says Richard den Hollander, Business Development Director Renewables at Seaway 7.

"One of our recent technology innovation programmes was designed specifically to investigate how we can eliminate the time-consuming anchoring process and enable the vessel to adjust its heading more responsively in changing offshore conditions for higher workability.

"We reached this milestone operation following an extensive research programme based on extensive data collection during numerous monopile installation campaigns with our floating crane vessels, the development and validation of a simulation model and the subsequent modification of the vessel software."

Seaway 7 started installing mono pile foundations in 2009 and is committed to ongoing vessel development programmes that deliver cost reductions and improved workability to avoid schedule risks.

Seaway Strashnov is an ultra-high-performance crane vessel which combines exceptional mono-hull working characteristics with a high transit speed of 14 knots.

The unique vessel spearheads Seaway 7's client offering in providing transportation and installation services for wind turbine foundations and substations and cable systems for the offshore wind farm sector.

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RICHARD DEN HOLLANDER
 Business Development
 Director Renewables



"Eliminates the time-consuming anchoring process and enables higher workability."

DEEPWATER RISERS



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MARTIN VAN ONNA
 Chief Commercial Officer
 Airborne Oil & Gas

TCP RISERS QUALIFICATION COLLABORATION

Subsea 7 and Airborne Oil & Gas are accelerating their collaborative development programme of a fully-bonded Thermoplastic Composite Pipe (TCP) in dynamic flexible risers for ultra-deepwater markets following a number of reported corrosion-induced failures offshore Brazil.

The next stage of product development is to secure a pilot project for delivery in 2022/23 to build on the multi-phase qualification programme which has been ongoing since Subsea 7 made its investment in Airborne in 2017.

"As the pioneering and leading manufacturer of TCP pipe for offshore oil and gas applications, we have successfully demonstrated its key qualities of weight reduction, high fatigue-resistance and installed cost advantages over conventional steel linepipe in static applications," says Martin van Onna, Chief Commercial Officer at Airborne Oil & Gas.

"However the recent experiences

in Brazil have attracted renewed industry interest in TCP's suitability for dynamic riser applications because of its extremely high corrosion-resistant properties.

"The fluid composition in many ultra-deepwater developments is extremely challenging, which is why we are accelerating this particular development programme with Subsea 7."

The Netherlands-based manufacturer welcomed the decision by Subsea 7 to formalise its interest in the product with investment in 2017.

"Together, we are a really good fit," says Martin van Onna. "Subsea 7 has global installation credibility and is capable of working with us on product qualification right through the entire life of field cycle.

"The industry is now looking for us to advance beyond product qualification and fast-track to a pilot project delivery stage, which we are well placed to deliver in partnership with Subsea 7."

"Suitable for challenging deepwater dynamic riser applications because of TCP's extremely high corrosion-resistant properties."



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