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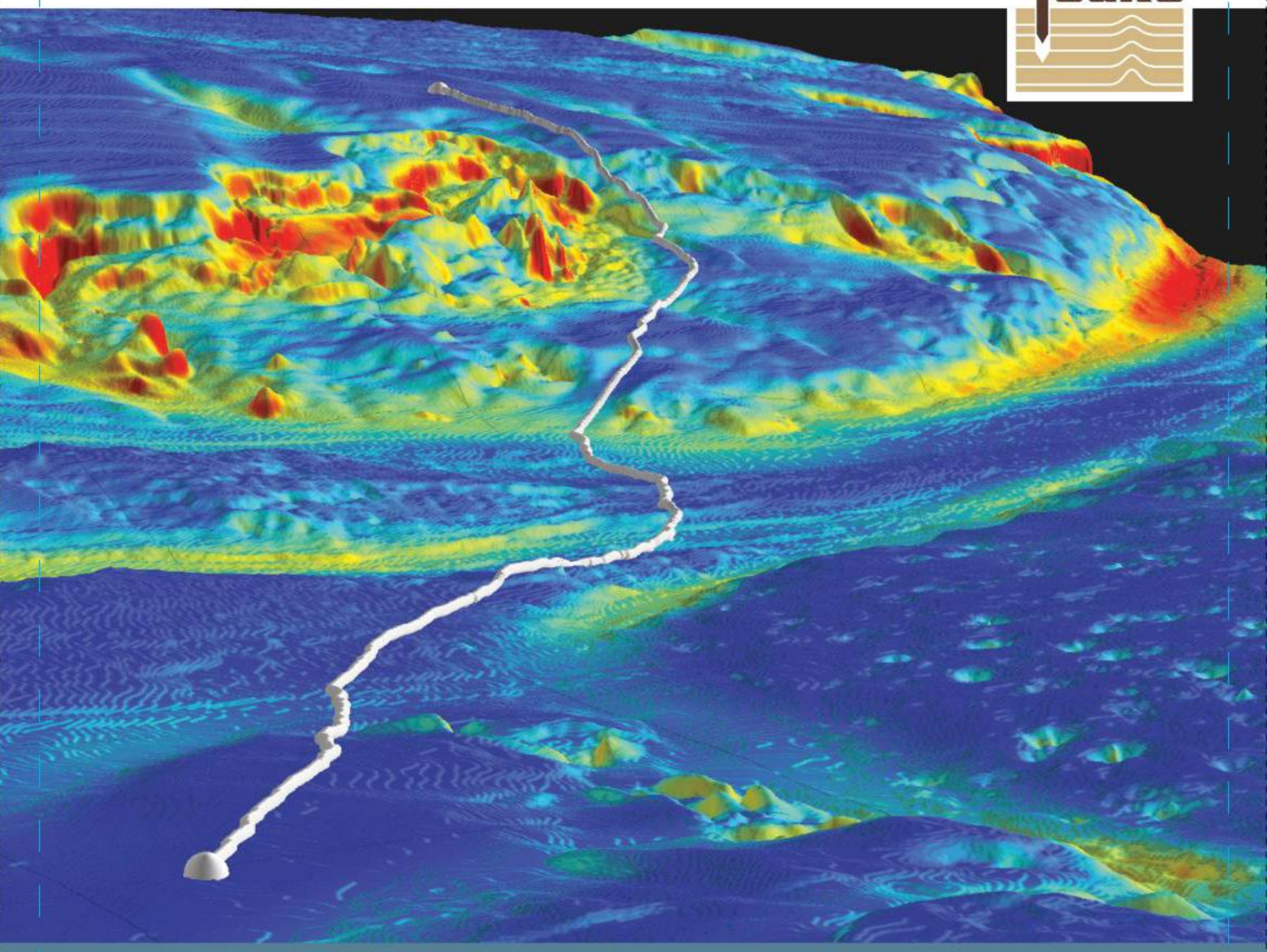

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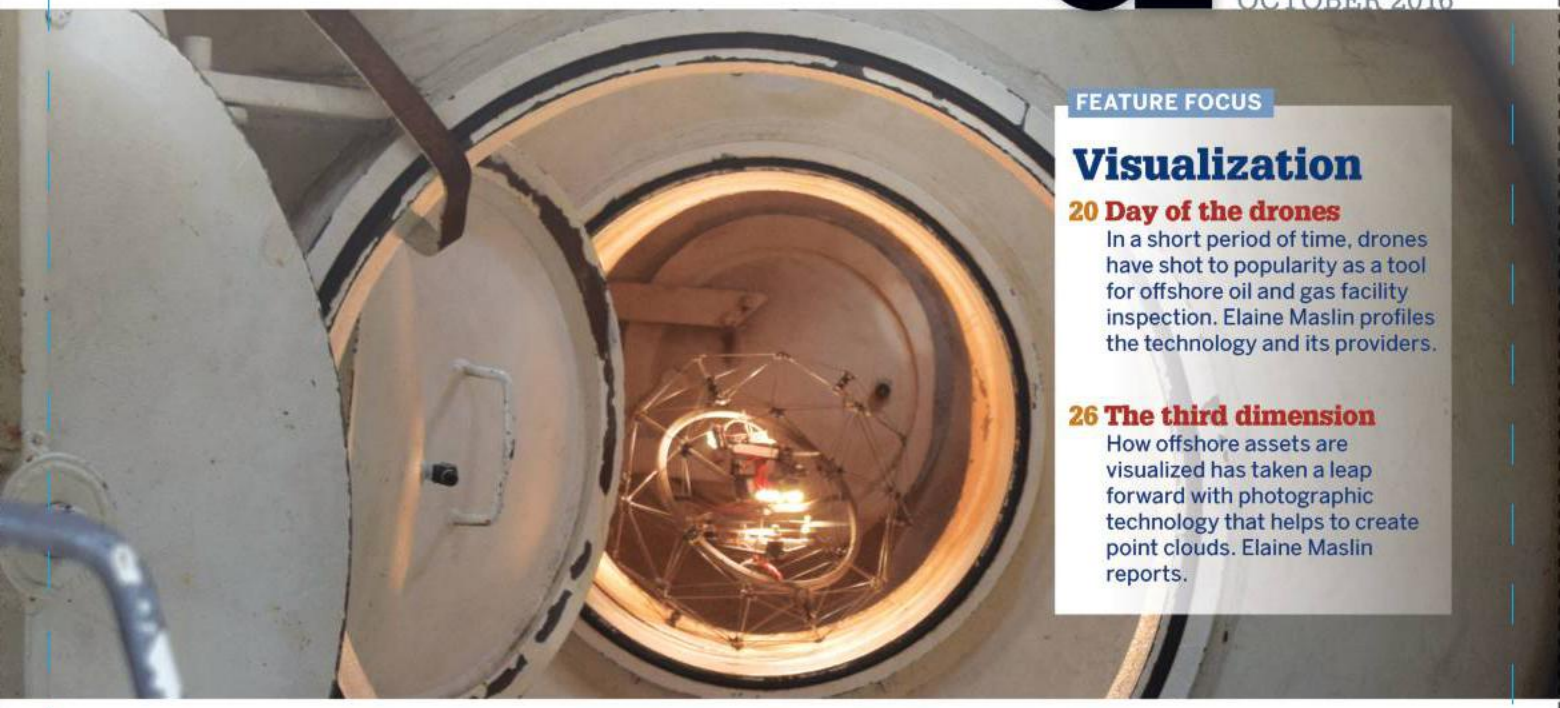

FEATURE FOCUS

## Visualization



# Features




ON THE COVER

**Eye in the sky.** Drones are gaining ground as an alternative method for offshore facility inspection and visualization needs. Elaine Maslin profiles companies making headway in this burgeoning new market on page 20. *Cover image is courtesy of Sky-Futures.*

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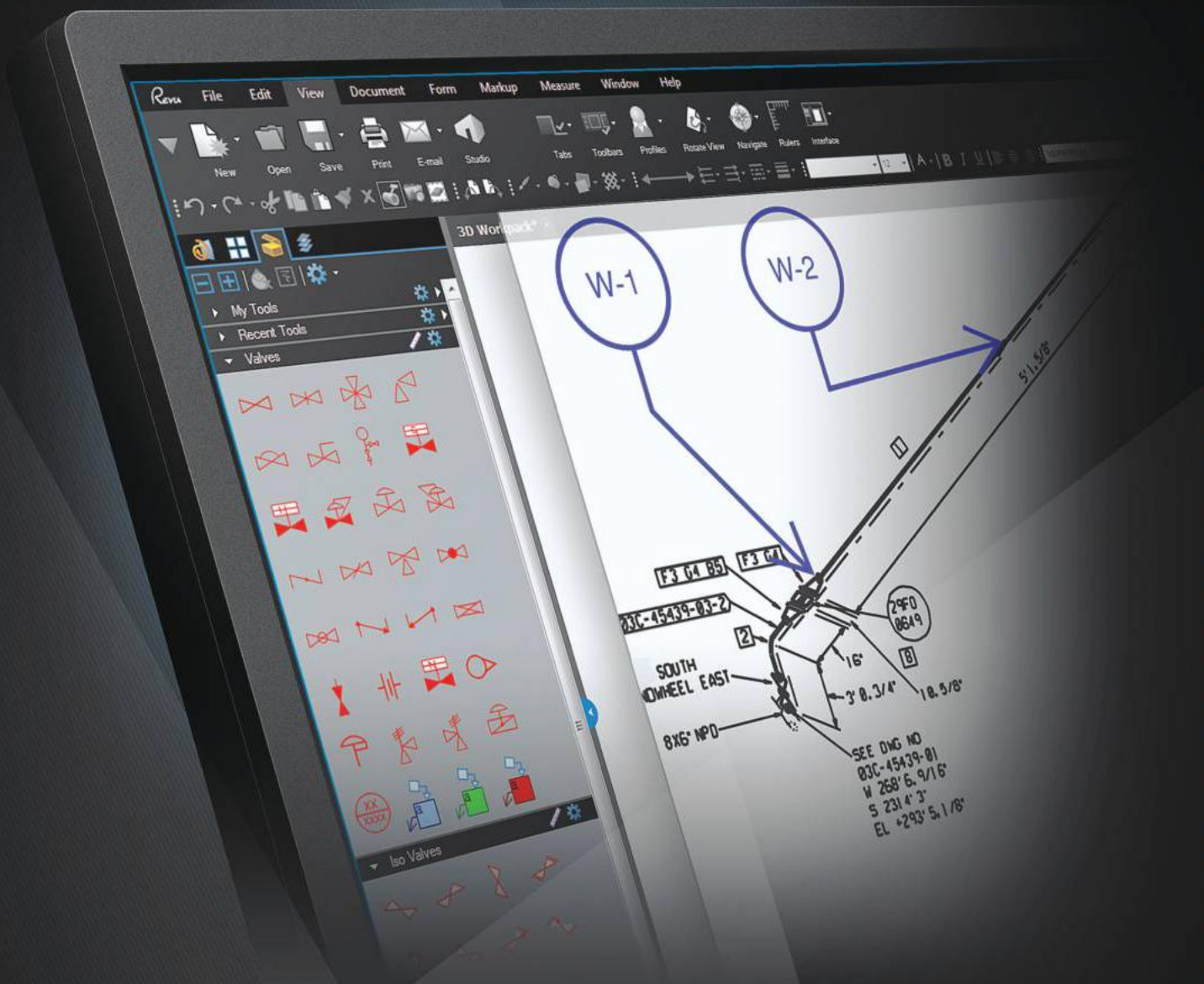


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Volume 41, Number 10 October 2016

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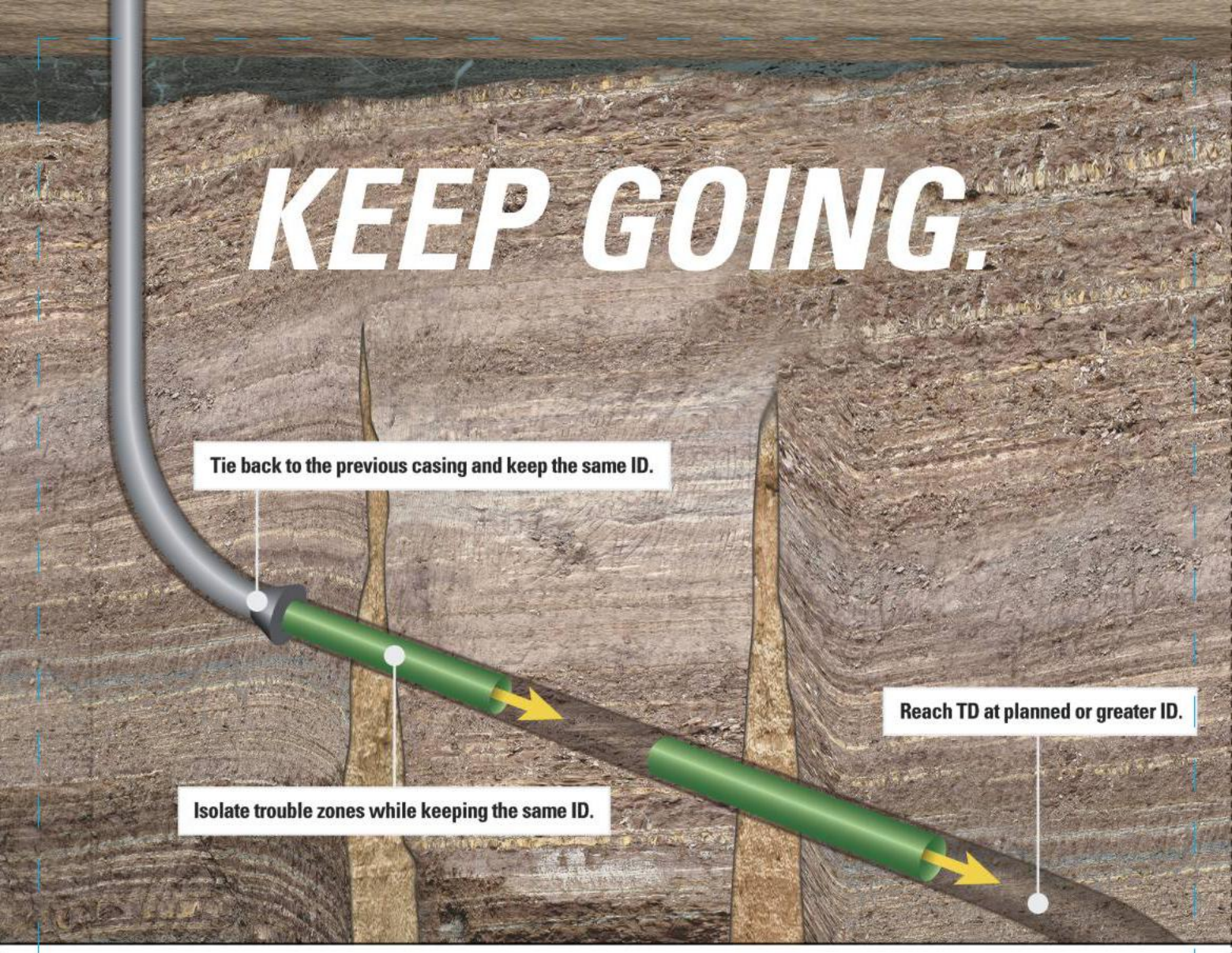
**OE (Offshore Engineer)** is published monthly by AtComedia LLC, a company wholly owned by IEI, Houston. AtComedia also publishes **Asian Oil & Gas**, the **Gulf Coast Oil Directory**, the **Houston/Texas Oil Directory** and the web-based industry sources **OilOnline.com** and **OEDigital.com.**

BPA WORLDWIDE BUSINESS

**US POSTAL INFORMATION**
Offshore Engineer (USPS 017-058) (ISSN 0305-876X) is published monthly by AtComedia LLC, 1635 W. Alabama, Houston, TX 77006-4196.
Periodicals postage paid at Houston, TX and additional offices.
Postmaster: send address changes to Offshore Engineer, AtComedia, PO Box 47162, Minneapolis, MN 55447-0162

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## Online Exclusive

### Looking toward the bright side

While the global deepwater drilling market is down, there are a few silver linings in certain key regions, according to data from Quest Offshore, a division of Wood Mackenzie. Melissa Sustaita sets out the detail.

## What's Trending

### Big moves

- Anadarko boosts GoM acreage in $2 billion deal
- Shell brings Stones online
- Petrobras cuts capex by 25%

## People

### Felin named Statoil UK MD

Hedda Felin was named the new managing director of Statoil Production UK. Based in Aberdeen, Felin is responsible for Statoil's upstream development and production activities in the UK and Ireland.

# Undercurrents

## All too human

While this year marked the 50th anniversary of the first exploration well on the Norwegian Continental Shelf, the biennial Offshore Northern Seas (ONS) show in Stavanger felt more sober than celebratory.

*OE* prides itself on highlighting technological feats created and deployed in the industry, especially in spite of the current price environment in which hundreds of thousands have lost their jobs. This industry is one that hinges on human endeavor – the work behind OneSubsea's subsea wet gas compressor is just one example (See page 16).

But, new redundancy rounds are still ongoing. There are operators putting immense pressure on contractors to reduce costs, or just not spending at all, leading to the risk that the companies they will one day want to use will no longer be there. Bright engineers are leaving the industry, looking for a more sustainable reward elsewhere. And, yet again, we'll be facing another skills shortage.

The positives are that we could be heading towards a stronger, leaner industry. There has been a 30-40% reduction in investment cost in Norway since 2014, according to the Norwegian Petroleum Directorate (NPD), enabling projects like Statoil's Johan Castberg (See page 54).

"Companies are optimizing drainage strategies, well strategies, efficiency," says Ingrid Sølvberg, director for development and operations, NPD. Projects like the Snorre expansion have moved towards being a subsea development rather than a tension leg platform, Wood Mackenzie's Malcolm Dickson told ONS. He also points to the decision to use an unmanned platform for the Oseberg West Flank development.

Operators are also adopting smarter ways of working – although it is questionable why it is now an epiphany that tracking hired equipment and or monitoring the health of rotating equipment (compressor failures are the biggest cause of production down time in the North Sea) could help improve margins. Celebrating coming in at budget and meeting deadlines is a sign of how poor things had gotten within the industry.

Operators are discussing new business models, and allowing the supply chain do what it does best. *OE* will look at this more in the November issue.

The consensus appears to be that a *slow* recovery will start in 2017. A survey of oil execs by business advisory firm Deloitte found 59% of respondents thought a recovery had started or would start in 2017, but that, even with an uptick in the oil price, the industry would not recover fully until 2018 or beyond.

Timing will be of the essence, Dickson said at ONS, urging companies to reinvest in 2017, and take advantage of low costs before others do, and prices increase.

Recovery will also mean different things in different places. For the UK North Sea, while the industry is expected to have a future beyond 2050, there's unlikely to be a return to the high-oil price driven investment boom years of 2013-14, most acknowledge, even with work in the decommissioning sector starting to enter the market. While production has increased this year, bucking a long-term downward trend, the pipeline isn't being replenished. Only 14 exploration wells were drilled in 2014, before the oil price collapse, and just 13 in 2015. This compares to 75 in 1986, 74 in 1987 and 93 in 1988, in years following a price collapse, points out petroleum economist Professor Alex Kemp, University of Aberdeen. The highest number of wells drilled in a year was in 1990, at 157, driven by BP's work program promises relating to its Britoil takeover.

It is hoped that we've reached the bottom. According to HR and employment law firm Empire, the number of redundancy related calls it received fell 5% in 1H 2016. Calls regarding redundancy at the firm had increased from 9% in 2014 to 22% in Q1 2016.

Back in Norway, "The outlook depends on the oil price and companies' willingness to act, not on resources," Sølvberg says. "Risk averse decision making is growing, but it is important to maintain a long-term perspective," she told ONS. "There is a risk cost cutting may have a negative impact on total resources utilization," she warns. OE

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## Gulf of Mexico

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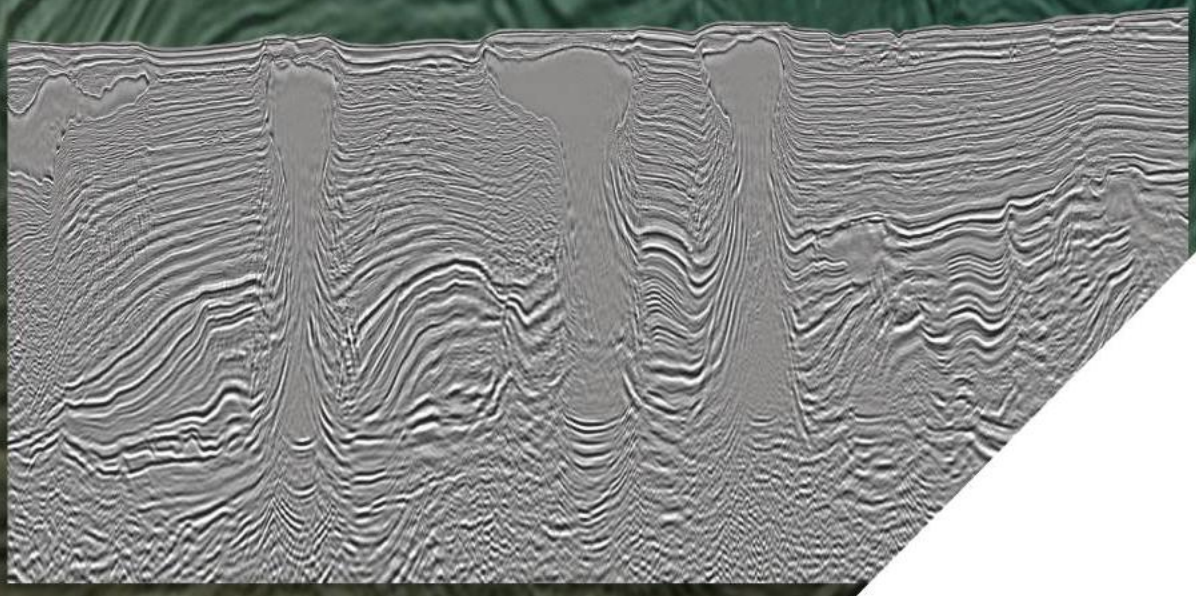

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# Global E&P Briefs

## A US lease sale attracts few bidders

Only three companies – ExxonMobil, BP, and BHP Billiton – participated in the US Bureau of Ocean Energy Management's (BOEM) Lease Sale 248 in late August – the first to be broadcast online. Out of the 4399 blocks offered, the sale only received bids for 24 of those blocks for a total of just over US$18 million.

ExxonMobil bid for and won two areas in East Breaks, Blocks 590 and 591, for a total of $1.75 million. BP bid for and won 10 blocks in the Garden Banks area for a total of $6.3 million. BHP Billiton bid for and won a total of 12 blocks, nine of which are in East Breaks and three of which are in Alaminos Canyon. BHP bid approximately $10 million.

"Though this sale reflects today's market conditions and industry's current development strategy, the bidding confirms that there is continued interest in the deepwater areas of the Gulf," said BOEM Director Abigail Ross.

## B Stones starts production

Shell started production from its Stones development in the deepwater Gulf of Mexico in early September. The field's FPSO (floating production, storage and offloading), *Turritella*, is the deepest floating production unit in the world, operating in 9500ft of water, and the Gulf of Mexico's second producing FPSO unit behind the *BW Pioneer*, which operates at Petrobras' Cascade/Chinhook development.

Shell says it expects production to ramp up to 50,000 boe/d by the end of 2017. The FPSO set sail from Singapore in November 2015, and arrived in the Gulf one month later. Stones is producing from two subsea production wells tied back to the *Turritella* FPSO. Shell expects to bring an additional six production wells online in a later phase.

## C Six offshore finds for Pemex

Mexico's national oil company Pemex has made six oil discoveries in the Gulf of Mexico, including two deepwater finds with super light crude deposits, and four shallow water light oil finds.

In deepwater, the biggest find called Nobilis-1 contains 40°+ API crude oil, with an estimated 15,000 b/d production capacity, and 3P reserves ranging 40-160 MMboe. Nobilis-1 is on the eastern flank of the Maximino field, in the Perdido Fold Belt, 220km off Tamaulipas at 3000m water depth.

In shallow water, the Teak-1 well encountered light crude and gas condensate estimated to contain 50-60 MMscf of 3P reserves. Pemex said that it expects the well could produce some 7000 b/d. The Teak-1 well is in 44m water depth, about 30km offshore, between the states of Veracruz and Tabasco.

Pemex says that it plans to continue offshore exploration next year, including 12 shallow water wells, and four deepwater wells in the Perdido Fold Belt.


## D Anadarko boosts GoM, Lucius interests

**Houston-based Anadarko Petroleum purchased the Gulf of Mexico assets of Phoenix, Arizona-based minerals company Freeport-McMoRan for US$2 billion cash consideration. While the sale adds approximately 80,000 boe/d net to Anadarko, a key piece of the deal finds the independent doubling its stake in the deepwater Lucius development, which started producing in January 2015. Previously, Anadarko held 23.8% interest and operatorship, now it holds 49%. Anadarko's partners in Lucius include US supermajor ExxonMobil (23.3%), Brazil's Petrobras (11.5%), Italy's Eni (8.5%), and Japan's Inpex (7.75%).**

**Anadarko also announced that Lucius continues to achieve strong reservoir performance and facility productivity. "As a result of this performance, the company is increasing the estimated ultimate recovery of the field to more than 400 MMboe from the previous 300+ MMboe," the firm said.**

## E Petrobras cuts capex

Petrobras announced further reductions in spending, opting to cut 25% of capex (or US$74 billion) from its previous business and management plan.

According to the new 2017-2021 business and management plan, Petrobras will allot $60.6 billion towards exploration and production, with 76% slotted for production development, and 11% going toward exploration. The remaining 13% will go toward operations support. By next year, Petrobras anticipates the startup of Tartaruga Verde, Mestica, Lula North and South, and Libra's extended well tests. In 2018, startups are expected from Berbigao, Lula Extreme South, and the Buzios 1, 2 and 3 fields. In 2019, Buzios 4 and Atapu 1 are expected to come online. In 2020, startup


production from the Sepia pilot, Buzios 5, Marlim revitalization project – module 1 – and commercial production from Libra is expected. In 2021, startup production is planned for Itapu, Libra 2, the integration of Parque das Baleais, and the Marlim revitalization project, module 2.

### F Interest falls in Norway round

As with the recent US licensing round, Norway's own Awards in Predefined Areas (APA) saw interest fall by about a quarter.

Some 33 companies have applied for licenses in Norway's 2016 APA licensing round, the Norwegian Petroleum Directorate (NPD) said in September.

Last year, 43 companies applied for licenses in the annual licensing round on the Norwegian Continental Shelf. The drop is despite there being more acreage on offer this year, at 139,942sq km, compared to 127,608sq km. Most of the interest is in the North Sea and the Norwegian Sea, the NPD says.

Despite the fall in interest, NPD exploration director Sissel Eriksen said it was positive so many companies were still interested. APA 2016 was announced on 17 March 2016. The awards are scheduled for early 2017.

### H ENGIE touts find near Gjøa

French operator ENGIE E&P made a 25-70 MMboe discovery at the Cara well in the Norwegian North Sea, 6km northeast of the ENGIE-operated Gjøa field.

The well, drilled using the *Transocean Arctic* semisubmersible, encountered a 51m gas column and a 60m oil column in the early Cretaceous Agat formation.

ENGIE is looking to tie the field back to the Gjøa facilities. ENGIE E&P Norge (30%) is operator with partners are Tullow Oil (20%), Idemitsu Petroleum (30%) and Wellesley Petroleum (20%).

### I Eni enters Montenegro

Italy's Eni won four offshore blocks in Montenegro's first international competitive bid round.

Eni will be operator with 50% stake in exploration licenses 4118-4, 4118-5, 4118-9 and 4118-10, which cover a total area of 1228sq km. Russia's OAO NOVATEK is a partner in the concession with the remaining 50% stake.

### J Russia halts Arctic licensing

Russian's government has temporarily banned new licenses for offshore field development on the Russian Arctic shelf.

The move appears to be aimed at focusing attention on current license obligations "and to better distribute their financial resources while

### G Hurricane hits Lancaster pay

**Hurricane Energy's pilot well on the basement reservoir Lancaster discovery West of Shetland has indicated resources "significantly greater" than the firm's 200 MMbbl base case.**

**Hurricane has completed testing and logging on the 205/21a-7 pilot well using the *Transocean Spitsbergen* semisubmersible drilling rig. The well flowed 38° API oil with no formation water at 6600 b/d on its own and then at 11,000 b/d with the use of an electrical submersible pump.**

**Hurricane will now plug the well before side-tracking the top hole to drill the 7Z horizontal sidetrack well.**

# Global E&P Briefs

carrying out geological exploration," according to a statement by Russia's Minister of Natural Resources and Environment.

State-owned firms Gazprom and Rosneft are the only companies that have been given access to Russia's Arctic Continental Shelf.

## K Gazprom makes Kirinsky discovery

**Russia's Gazprom has made a discovery on the Kirinsky block in the Sea of Okhotsk, a marginal sea of the western Pacific Ocean.**

**A substantial gas and condensate inflow was reported, signaling the discovery of a new field, while the firm was drilling an exploration and appraisal well on the Yuzhno-Lunskaya structure within the Sakhalin III project.**

**As soon as the well is tested and the geological information is analyzed, the reserves estimates for the new field will be submitted to the Federal Subsurface Use Agency.**

**Within the Kirinsky block, Gazprom also discovered the Yuzhno-Kirinskoye and Mynginskoye fields.**

## L Hyperdynamics eyes Guinea

Houston-based Hyperdynamics says that it will target Guinea's "vast and largely untested hydrocarbon potential" after having its production sharing contract (PSC) offshore Guinea extended. Through its wholly owned subsidiary, SCS, the PSC has been extended to 22 September 2017.

Hyperdynamics will retain an area equivalent to approximately 5000sq km in the Guinea offshore, and will drill one exploratory well with a projected commencement date of April 2017 with additional wells optional.

## M Zohr 5x tested

Eni has drilled and tested its fifth well on the Zohr field in the deepwater Shorouk block, offshore Egypt in the Mediterranean Sea.

The well, Zohr 5x, opened 90m of reservoir section to production, which produced more than 50 MMcf/d, limited only by the constraints of the drillship's production facilities. In full production, Eni is estimating that the well will deliver up to 250 MMcf/d.

Zohr 5x, 12km southwest of the Zohr 1x well in 1538m water depth, reached 4350m (14,271ft) and encountered about 180m (590ft) of continuous hydrocarbon column in the carbonate sequence with excellent reservoir characteristics. The results confirmed the potential of the Zohr field at 30 Tcf, Eni said.

Eni is planning to drill a sixth well this year, which is expected to accelerate a startup production rate of 1 Bcf/d, and to reach first gas by the end of 2017.

## N Tanzania drilling set

Shell is planning a US$20 million exploration drilling program offshore Tanzania for Q4 2016, according to partner Ophir Energy.

The program will comprise two wells on Blocks 1 and 4 and target >1 Tcf of gas, says Ophir.

The well on Block 1 will target Kitatange, with an estimated mean recoverable volume of 1.1 Tcf. The well on Block 4 will target Bunju with an estimated 1.4 Tcf. The wells, which have been given 40% chance of success, will fulfill outstanding exploration requirements on the licenses.

## O Spectrum to shoot off Mozambique

Spectrum will carry out a long-offset Broadband 2D multiclient seismic survey covering the southern Rovuma and northeastern Zambezi basins, offshore Mozambique.

The survey, totaling in excess of 16,000km, will image the subsurface potential in open areas of the southern Rovuma Basin and the western flanks of the Kerimbas Graben, west of the Davie Fracture Zone.

Potential targets along the Mozambique margin include Cretaceous and Tertiary turbidites and buried canyon plays. The survey will also aim to image the syn-rift structures and Late Cretaceous pro-delta stacked turbidite sequences in the northeast Zambezi Depression.

New 2D data will refine the understanding of what is believed to be an oil-dominated region offshore Mozambique.

## P ONGC starts Daman

ONGC started production from its first well C24-P4 No. 3, at the Daman development project offshore India in late August.

The well is producing sweet gas and condensate at a rate of 3.8 MMcf/d and 176 b/d, respectively. According to the Indian firm, three additional wells will be brought online very soon and add to production.

C24-P4 No. 3 is part of the first phase of the project, which comprises the installation of two wellhead platforms, C23-P3 and C24-P4, and one riser platform, C24-RP.

The Daman project aims to exploit the C-24 and B-12 marginal fields to produce over 953 Bcf gas and 31.5 MMbbl of condensate over the next 20 years. In all, the project will include seven wellhead platforms, a riser platform, 28 wells, and about 100km of subsea lines.

## Q Ophir restarts Bualuang

Ophir Energy restarted production at the Bualuang field in the Gulf of Thailand in early September after a 10-day shutdown, following the completion of the final tie-in work of a water debottlenecking project.

With drilling, workover and facility upgrades complete, the design capacity of the water handling and disposal system has increased from 50,000 b/d to 75,000 b/d. Production is now ramping up as the new system is brought onstream and tested, with mid-September production at an instantaneous rate of 9700 b/d at a water disposal rate of 64,000 b/d, an increase of 1400 b/d compared to production in late August.

## R CNOOC boosts production

China's CNOOC has started production from both the Enping 18-1 oilfield and Weizhou 6-9/6-10 comprehensive adjustment project in the South China Sea in September. The Enping 18-1 oilfield, in 90m water depth in the Pearl River Mouth Basin, will utilize the existing facilities of Enping 24-2 oilfield. There are currently three wells producing

approximately 2010 b/d, but is expected to reach its designed peak production of about 11,800 b/d within the year.

Weizhou 6-9/6-10 adjustment project, in the Beibu Gulf at about 35m water depth, has built an additional wellhead platform, and will utilizing the existing facilities. There is currently one producing well producing approximately 850 b/d. However, the adjustment project is expected to reach peak production of approximately 3800 b/d by 2018.

### Woodside, BHP in Scarborough deal

Australia's Woodside will acquire half of BHP Billiton's Scarborough gas assets in the Carnarvon Basin, offshore Western Australia for US$250 million on completion of the transaction and a contingent payment of $150 million upon a positive final investment decision.

The Scarborough area assets include the Scarborough, Thebe and Jupiter fields, which are estimated to contain gross 8.7 Tcf of gas resources. Woodside's net share of the resources is estimated to be 2.6 Tcf of gas.

The acquisition includes 25% interest in WA-1-R and 50% interest in WA-62-R, which together contain the Scarborough gas field. In addition, Woodside will acquire 50% interest and operate WA-61-R and WA-63-R which contain the Jupiter and Thebe gas fields.

### NZ starts Block Offer 2017

New Zealand has begun its Block Offer 2017, which will see consultation start on the awarding oil and gas exploration permits in the country – on- and offshore.

Consultation will take place on four proposed offshore areas, one proposed offshore/onshore area, and two proposed onshore areas, covering a total area of around 508,691sq km.

New Zealand adopted an annual Block Offer approach in 2012. The consultation period for Block Offer 2017 runs until November 2016. The final tender area will be announced in March next year.

# Contracts

### COSL inks Mexican rig deal

China Oilfield Services Ltd. (COSL) signed a rig and logistics integrated service contract with Mexico's Hokchi Energy. COSL's jackup drilling rig COSLHunter and marine support vessel *HYSY 614* will provide services for this contract. This marks the first foothold in Gulf of Mexico by COSL's marine support segment.

The contract is expected to begin in October, and marks the first oilfield service project available for tender by an oil company outside Mexico and it is the first public tender project by Mexico's energy ministry.

### Sulzer, FMC ink Shell Brazil subsea gig

Shell has awarded the duo of Sulzer and FMC Technologies a subsea multiphase boosting pump contract to upgrade one of the pumping modules at the Parque das Conchas deepwater oilfield offshore Brazil.

The pump modifications suit the specifics of the oilfield with a high shut-in pressure of 517 bar (7500 psi), and meet Shell's maintenance and service needs with high reliability and short turnaround intervention, Sulzer said.

Parque das Conchas, also known as the Shell BC-10 field, is approximately 120km (75mi) southeast of the Brazilian coastal city of Vitória. The BC-10 asset has water depths ranging from 1500-2000m.

The subsea pump will be manufactured from a global supply chain with a large amount of assembly and testing conducted at Sulzer's facilities in the UK. This first subsea pump for Shell from FMC Technologies and Sulzer will be launched in the field in 2017.

### Huisman scores multi-million contracts

Dutch lifting, drilling and subsea solutions company Huisman secured US$337.8 million (€300 million) in new crane contracts.

BigLift Shipping will receive two 900-tonne heavy lift mast cranes for Biglift's third Happy S-type vessel *Happy Sun*, which is expected to be delivered in Q1 2018.

Van Oord ordered a 1600-tonne leg encircling crane to replace an existing 900-tonne crane onboard the Aeolus jackup. The crane will be delivered and installed in Q1 2018.

Huisman will also deliver two 2200-tonne offshore mast cranes with deepwater auxiliary hoist system and two telescopic access bridges to OOS International for two newbuild semisubmersible accommodation crane vessels. Delivery is scheduled for 2019.

For Boskalis, Huisman will deliver a 3000-tonne offshore mast crane to be installed onboard an existing F-class heavy transport vessel. Delivery is expected by the end of 2017.

Allseas has also ordered a 5000-tonne tub mounted crane to be installed onboard the *Pioneering Spirit*. The crane design is based on the use of a 20m-diameter slew bearing and will be delivered in 2H 2018.

### Aker bags EPCIC work

Aker Solutions will provide engineering, procurement, construction, installation and commissioning (EPCIC) services to enable a tie-in of the Utgard gas and condensate field to Statoil's Sleipner installations in the North Sea.

The work, valued at about US$61.45 million (NOK 500 million), is for platform modifications at Sleipner T processing and $CO_2$ removal platform to tie-in the Utgard subsea field.

Aker Solution's work on the contract has started and will be completed in Q4 2019. The project will be managed and executed by Aker Solutions in Stavanger. Pre-fabrication will be executed at Aker Solutions' yard in Egersund.

### Topaz orders more vessels

Vard Holdings secured a contract worth about US$40 million for the design and construction of two additional module carrier vessels for Topaz Energy and Marine.

The vessels, of VARD 9 21 design and measuring 123m by 16.5m, are sister ships of a series of 15 identical module carrier vessels previously contracted by Topaz for delivery from Vard's shipyards in Tulcea and Braila in Romania, and Vung Tau in Vietnam.

They will be operated by Topaz through a consortium led by Blue Water Shipping.

One of the additional vessels will be built at Vard Braila and one at Vard Vung Tau.

Delivery of both vessels is scheduled in Q2 2018.

# Made in Malaysia

**Audrey Raj speaks to Shell and Technip about Malikai's TLP, a first-of-its-kind designed and built in Malaysia for the field offshore Sabah.**

This year, Shell and the Technip-Malaysia Marine and Heavy Engineering (MMHE) joint venture (TMJV) concluded the onshore fabrication and commissioning of the Malikai tension leg platform (TLP), destined to unlock substantial deepwater resources in the Malikai field 100km offshore Sabah, Malaysia.

The completion and sail away of Malaysia's first TLP is a major milestone for the country's oil and gas industry, given that the design, engineering, fabrication, and onshore commissioning were all done at Pasir Gudang in Johor, southern Malaysia.

Discovered in 2004, the Malikai field is Shell's second deepwater project in Malaysia, following the successful start-up of the Gumusut-Kakap field last year, from a deepwater semisubmersible, which now contributes up to 25% of Malaysia's oil output.

A joint venture between Shell (35%, operator), ConocoPhillips Sabah (35%), and Petronas Carigali (30%), Malikai is expected to come online early 2017 and have a peak production of 60,000 b/d. The field lies in about 500m water depth and comprises two main reservoirs, Kinarut and Kamunsu-2. It is part of the Block G production-sharing contract awarded by Petronas in 1995.

Wells for the Malikai development will be drilled from the 27,500-tonne TLP production facility, using a separate tender-assisted drilled unit. While the first stage of tophole drilling was completed in January 2015, the main drilling campaign will take place in 2016.

Through Malikai, Shell introduced a number of advanced deepwater technologies to unlock deepwater resources safely and efficiently, says Simon Ong, managing director, Shell Global Solutions Malaysia, Projects and Technology. "For example, it's the first TLP coupled with a tender assisted drilling rig, which allows cost saving, as opposed to using a permanent dedicated rig," he told *OE*.

## Malikai TLP, project team

While it is a deepwater project, Malikai will produce via the Kebabangan (KBB) shallow water platform, 50km away. The TLP is designed to partially process the gross production before evacuation to KBB, where it will be further processed before being sent onshore to the Sabah Oil & Gas Terminal for storage and offloading to tankers.

**Malikai TLP onboard Dockwise White Marlin HTV.** Photos from Shell.

In April 2016, the Malikai TLP loadout was safely completed on to the heavy transport vessel (HTV) *Dockwise White Marlin*. The platform was then brought to a near-shore location to allow the structure to float on its own.

Once the platform was floated-off of the vessel, further technical evaluations were conducted. The TLP was then towed back to the construction yard and berthed quayside at the fabrication yard for remaining construction and commissioning activities.

The 43-month construction of the Malikai TLP by TMJV, wasn't an easy one. Though, the team faced several, exceptional engineering and design challenges, that didn't stop TMJV from delivering the project safely with a high level of local content. "[The] Malikai TLP is the first [TLP] for Shell outside the Gulf of Mexico, and an overwhelming majority of the project team are Malaysians," Ong says. "The Malikai project brings capability development and contributes significant local content. The platform is designed in Malaysia; built in Malaysia; and will be operated by Malaysians. Collectively, the project has completed over 23 million man hours, including 10 million work hours without a loss time injury."

It's also a catalyst for MMHE, Ong says. Through the project, MMHE successfully achieved significant benchmarks in productivity, such as installing over 400 piping spool pieces and pulling more than 35km cables weekly, and fabricating 1000-tonne of steel structure a month.

## Technical challenges, technologies

The project offered unique technical challenges throughout engineering, procurement and construction, including during the design of the hull and tendons, the topsides mating super lift, loadout, and float-off phases.

There was also delays in delivery of some the equipment packages, says Patrick Hazlet, Malikai project director, Technip. "This resulted in changing the construction sequence, particularly for the topsides, to allow for equipment installation by skidding from the side or lifting through openings in the decks above," he says.

"The super lift operation to integrate the topsides with the hull was the world's first jacking and skidding operation ever conducted on this scale. The topside was constructed adjacent to the hull and when both were completed the topside was jacked up and skidded onto the hull.

"Extensive engineering to design the temporary works were required, together with detailed planning and subsequent execution of the operation, to successfully complete the super lift as planned," he adds.

Global heavy lift specialist ALE weighed and transported the four hull blocks, living quarters and mega beams for the super lift activities. This included skidding the topsides above ALE's Mega Jack System, jacking up the topsides using the Mega Jack System, skidding the topsides above the hull, and mating the topsides to the hull.

Following the super lift came the load out of the Malikai TLP onto the HTV. Hazlett said that too required careful design and operation of the hydraulic skidding arrangement and the ballasting system on the HTV. All so to ensure no overloading of the hull structure, particularly at the crossover stage when the load started to transfer from the quayside to the HTV.

During float-off of the TLP in deepwater offshore Desaru, the distribution of ballast in the hull was also critical, to give an even keel condition to ensure clearance of the HTV deck. Contracted by TMJV, InterMoor was responsible for the marine aspects of the float-off and tow of the Malikai TLP through the Johor Straits into the Singapore Straits.

The work scope included engineering analysis and procedures, project management for the nearshore operations, management of chartered vessels, provision of offshore personnel and various ancillary services. InterMoor also subcontracted UTEC Offshore Survey to provide survey and positioning for the TLP and marine spread.

The Malikai field will require about 17 wells drilled. During tophole drilling, Shell used IKM Group's mud circulation system technology, which prevents the discharge of drilling fluid, reducing environmental impact. Shell says the main drilling campaign will be conducted from aboard the platform using the tender assisted drilling unit, which helps to remove the need for a heavier platform rig and lowers costs.

Furthermore, the Malikai platform uses a special kind of pipe, or riser, for both drilling and production, each with a single lining. A system onboard holds the multi-use risers in place overhead. This innovative approach eliminates the cost of using two traditional sets of risers while cutting the number of steps needed to drill a well. **OE**

Malikai TLP.

# In-Depth

# Building the ultimate machine

**The Gullfaks subsea multiphase compression project made waves last year, becoming the first of its kind. In June, Bernt Helge Torkildsen was one of four people to be honored for their part in the project at this year's UTC. OE had an exclusive interview with him at the event.**


**Gullfaks wet gas compressor.** Photo by Harald Pettersen/Statoil.

For Bernt Helge Torkildsen, the UTF Subsea Award is recognition of nearly 30 years' work on an idea some thought would never work and, at times, only he was working on. Last year, the work culminated in the installation and startup of two OneSubsea subsea multiphase compressors at the Gullfaks field on the Norwegian Continental Shelf.

Torkildsen is proud, yet he's quick to praise and recognize others involved in this multi-decade-long journey. Without the foresight of Frank Mohn to set up a dedicated research company, Framo Engineering, without Mohn's successor Trond Mohn's ongoing support, and without support from Statoil and Schlumberger – which took a share in Framo before buying it outright, and then OneSubsea, Schlumberger's joint venture with Cameron, which it also now owns outright – plus the many staff and engineers involved, the technology might not have made it this far.

But, just as Torkildsen is quick to shrug off holding the fastest 3000m track record for 29 years, from 1978, his input, and thinking, based on an aeronautical background, shouldn't be underplayed.

It all started in 1983, with the formation of Framo Engineering. In an attempt to assess industry requirements, the team started reviewing North Sea infrastructure.

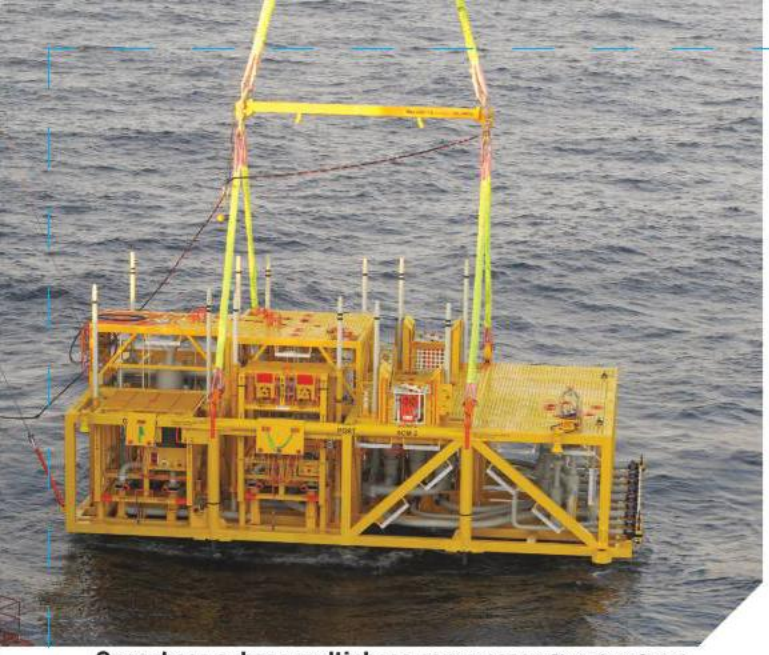
"On a map of the North Sea, circles of 50km around existing infrastructure were drawn. Although at that time, 80% of known reserves in the area were within these circles, new platforms had to be built for every new field. If the known reserves could be transported to the existing platforms, you could extract that 80% without building new platforms. One of the missing elements to do this was multiphase pumps," Torkildsen says.

Back then, pumping was Frank Mohn's "normal business," but mostly to ship cargo and for water lifting. The firm was starting to get into the offshore market and saw an opportunity to use its pumping know-how in that market.

Early on, Framo had had an agreement with Shell to develop a subsea booster station. At the time, Norwegian oil firm Statoil, French research center IFP, and oil firm Total were working on a hydraulic multiphase pump, under the Poseidon project, launched in 1984. Two licenses were issued to use the Poseidon technology, one to Framo Engineering and one to Swiss engineering firm Sulzer. But, Framo decided it wanted its own, and by leveraging technologies it already had, the contra-rotating concept (CR) and later wet gas compressor (WGC) concepts were developed. "The obvious benefit was that we didn't need the diffuser part [of a normal compressor] so you can have more impellers on the same shaft," Torkildsen says.

The concept proved to be particularly suitable and efficient for subsea wet gas compression. The first prototype was quite small, but performed well, and it was decided that a bigger unit should be built, and a new iteration was envisioned.

In 1990, a CR 400 (250Am3/h, 500kW) design was tested on the NAM-operated De Leer field, an onshore gas field in the Netherlands. Until then, all the development work related to the gas market was towards land-based applications. "This new design also performed well. But, it was still clear that the robustness of the design needed to be increased again to fulfill the desired requirement," Torkildsen says.



**Onesubsea subsea multiphase compressor.** Photo from Statoil.

The next iteration was the CRA compressor (1000Am3/h, 1000kW). "The size was starting to get more sensible and closer to what was needed for real application," Torkildsen says. "This unit was equipped with advanced instrumentation, including neutron back scatter technology, which was used in combination with radioactive tracers to show how gas and liquid were transported through the compressor internals." Previously, such information had not been readily available even in larger research organizations or in universities.

By 1995, despite the increase in knowledge, many in the market and within the engineering group remained skeptical that such a device could work. The need to deliver the multiphase compressor was also less urgent and so there was something of a fallow period.

"But, it was never shelved, and in 2000, with a drop in the oil price, we won some Demo 2000 funding, with support from the Norwegian Research Council and the Ormen Lange License," Torkildsen says. "At that time, it was for products to realize economics even for low oil prices. There was some reluctance, but we went ahead and developed a new WGC2000 and that was the first time we aimed it towards the subsea market. Before, we had aimed for topsides and the land market." Statoil was also now supporting the technology, alongside Shell and Norsk Hydro.

There were some who were predicting this would not work on real hydrocarbons and that its performance – the physics – could not be predicted. But, in 2002-2003, a WGC2000 machine was taken to Statoil's K-Lab for performance testing on real hydrocarbon wet gas. "It was a success," Torkildsen says, "but, again its capacity was too small for the likes of an Ormen Lange project." And again, the market fell a little quiet.

Torkildsen then brought his aeronautical engineering perspective into play. Torkildsen holds an MSc in aeronautical engineering and a pilots' license. He thought it would be possible to increase capacity at load from the 3.6MW, 1400 Am3/h WGC2000 unit to 5MW 6000 Am3/h. The Demo 2000 machine (WGC2000) was used, fitted and tested with new impellers and it worked with the target capacity being demonstrated.

"Traditionally, we were considered a pumping house," he says. "But I had a slightly different background and brought in some knowledge from other industries and looked at it a little differently from pumping," Torkildsen says.

# Quick stats

**OE**'s at-a-glance guide to offshore hydrocarbon reserves and key offshore infrastructure globally is updated monthly using data from leading energy analysts Infield Systems (www.infield.com).

## New discoveries announced

| Depth range | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|
| Shallow (<500m) | 76 | 74 | 57 | 16 |
| Deep (500-1500m) | 19 | 31 | 20 | 7 |
| Ultradeep (>1500m) | 34 | 13 | 13 | 6 |
| **Total** | **129** | **118** | **90** | **29** |
| Start of 2016 date comparison | 127 | 114 | 72 | - |
| | 2 | 4 | 18 | 29 |

*Note: Operators do not announce discovery dates at the time of discovery, so totals for previous years continue to change.*

## Reserves in the Golden Triangle

by water depth 2015-19

| Water depth | Field numbers | Liquid reserves (mmbbl) | Gas reserves (bcf) |
|---|---|---|---|
| **Brazil** | | | |
| Shallow | 9 | 34.50 | 333.28 |
| Deep | 11 | 941.00 | 1595.00 |
| Ultradeep | 39 | 11,090.50 | 12,273.00 |
| **United States** | | | |
| Shallow | 10 | 70.60 | 155.00 |
| Deep | 17 | 645.36 | 818.57 |
| Ultradeep | 20 | 2487.00 | 2518.00 |
| **West Africa** | | | |
| Shallow | 107 | 3,710.2 | 13,791.56 |
| Deep | 31 | 3392.50 | 5000.00 |
| Ultradeep | 10 | 1335.00 | 1000.00 |
| **Total** | **245** | **23,672.16** | **37,151.13** |
| (last month) | (246) | (23,687.16) | (37,451.13) |

## Greenfield reserves

2015-19

| Water depth | Field numbers | Liquid reserves (mmbbl) | Gas reserves (bcf) |
|---|---|---|---|
| Shallow | 864 | 32,780.73 | 405,753.29 |
| (last month) | (862) | 33,074.02) | (423.838.13) |
| Deep | 120 | 6600.52 | 68,856.21 |
| (last month) | (119) | (6600.52) | (68,856.21) |
| Ultradeep | 76 | 15,823.40 | 42,288.00 |
| (last month) | (76) | (15,823.40) | (42,288.00) |
| **Total** | **1060** | **55,204.65** | **516,897.50** |

## Pipelines

(operational and 2015 onwards)

| | (km) | (last month) |
|---|---|---|
| **<8in.** | | |
| Operational/ installed | 41,076 | (41,452) |
| Planned/ possible | 24,024 | (23,977) |
| | **65,100** | (65,429) |
| **8-16in.** | | |
| Operational/ installed | 81,443 | (82,864) |
| Planned/ possible | 49,499 | (49,316) |
| | **130,942** | (132,180) |
| **>16in.** | | |
| Operational/ installed | 94,052 | (94,116) |
| Planned/ possible | 42,994 | (42,918) |
| | **137,047** | (137,034) |

## Production systems worldwide

(operational and 2015 onwards)

| **Floaters** | | (last month) |
|---|---|---|
| Operational | 271 | (271) |
| Construction/ Conversion | 49 | (49) |
| Planned/possible | 301 | (299) |
| | **621** | (619) |
| **Fixed platforms** | | |
| Operational | 9145 | (9147) |
| Construction/ Conversion | 87 | (88) |
| Planned/possible | 1361 | (1361) |
| | **10,593** | (10,596) |
| **Subsea wells** | | |
| Operational | 4859 | (4858) |
| Develop | 393 | (397) |
| Planned/possible | 6423 | (6411) |
| | **11,675** | (11,666) |

## Global offshore reserves (mmboe) onstream by water depth

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|
| Shallow | 14,540.52 | 21,144.93 | 30,213.12 | 23,864.57 | 11,071.13 | 21,376.71 | 17,771.98 |
| (last month) | (14,537.52) | (20,490.00) | (30,551.10) | (23,906.22) | (14,283.72) | (21,491.21) | (17,655.35) |
| Deep | 4,477.34 | 976.73 | 4,847.45 | 2,833.28 | 2,585.84 | 4,317.83 | 4,155.73 |
| (last month) | (4477.34) | (976.73) | (4847.45) | (2833.28) | (2585.84) | (4317.83) | (4155.73) |
| Ultradeep | 2,342.81 | 1,922.92 | 3,145.58 | 2,481.25 | 3,457.52 | 4,144.56 | 10,050.25 |
| (last month) | (2342.81) | (1922.92) | (3145.58) | (2481.25) | (3457.52) | (4144.56) | (10,050.25) |
| **Total** | **21,360.67** | **24,044.57** | **38,206.16** | **29,179.10** | **17,114.49** | **29,839.09** | **31,977.97** |

6 Sep 2016

# Rig stats

## Worldwide

| Rig Type | Total Rigs | Contracted | Available | Utilization |
|---|---|---|---|---|
| Drillship | 100 | 68 | 32 | 68% |
| Jackup | 399 | 234 | 165 | 58% |
| Semisub | 122 | 76 | 46 | 62% |
| Tenders | 31 | 20 | 11 | 64% |
| Total | 652 | 398 | 254 | 61% |

## North America

| Rig Type | Total Rigs | Contracted | Available | Utilization |
|---|---|---|---|---|
| Drillship | 31 | 27 | 4 | 87% |
| Jackup | 25 | 3 | 22 | 12% |
| Semisub | 13 | 7 | 6 | 53% |
| Tenders | N/A | N/A | N/A | N/A |
| Total | 69 | 37 | 32 | 53% |

## Asia Pacific

| Rig Type | Total Rigs | Contracted | Available | Utilization |
|---|---|---|---|---|
| Drillship | 10 | 4 | 6 | 40% |
| Jackup | 120 | 65 | 55 | 54% |
| Semisub | 31 | 15 | 16 | 48% |
| Tenders | 22 | 13 | 9 | 59% |
| Total | 183 | 97 | 86 | 53% |

## Latin America

| Rig Type | Total Rigs | Contracted | Available | Utilization |
|---|---|---|---|---|
| Drillship | 27 | 18 | 9 | 66% |
| Jackup | 49 | 30 | 19 | 61% |
| Semisub | 23 | 17 | 6 | 73% |
| Tenders | 2 | 2 | 0 | 100% |
| Total | 101 | 67 | 34 | 66% |

## Northwest European Continental Shelf

| Rig Type | Total Rigs | Contracted | Available | Utilization |
|---|---|---|---|---|
| Drillship | 1 | 0 | 1 | 0% |
| Jackup | 49 | 36 | 13 | 73% |
| Semisub | 38 | 28 | 10 | 73% |
| Tenders | N/A | N/A | N/A | N/A |
| Total | 88 | 64 | 24 | 72% |

## Middle East & Caspian Sea

| Rig Type | Total Rigs | Contracted | Available | Utilization |
|---|---|---|---|---|
| Drillship | 1 | 0 | 1 | 0% |
| Jackup | 114 | 83 | 31 | 72% |
| Semisub | 4 | 3 | 1 | 75% |
| Tenders | N/A | N/A | N/A | N/A |
| Total | 119 | 86 | 33 | 72% |

## Sub-Saharan Africa

| Rig Type | Total Rigs | Contracted | Available | Utilization |
|---|---|---|---|---|
| Drillship | 18 | 14 | 4 | 77% |
| Jackup | 20 | 9 | 11 | 45% |
| Semisub | 5 | 3 | 2 | 60% |
| Tenders | 7 | 5 | 2 | 71% |
| Total | 50 | 31 | 19 | 62% |

## Eastern Europe

| Rig Type | Total Rigs | Contracted | Available | Utilization |
|---|---|---|---|---|
| Drillship | 1 | 1 | 0 | 100% |
| Jackup | 2 | 1 | 1 | 50% |
| Semisub | 1 | 1 | 0 | 100% |
| Tenders | N/A | N/A | N/A | N/A |
| Total | 4 | 3 | 1 | 75% |

Source: InfieldRigs 11 Sep 2016

This data focuses on the marketed rig fleet and excludes assets that are under construction, retired, destroyed, deemed non-competitive or cold stacked.

Torkildsen had spent some time in the European Space Research and Technology Centre (ESTEC) in the Netherlands and had always retained a high interest in aeronautics. As a result, he looked at the impellers as a series of airfoils, which needed to be improved in a way that hadn't been considered before. "It was a quite simple thing, but meant being able to increase capacity and efficiency," he says. "Standard compressors are not designed for wet gas or gas and liquids. They are designed and optimized for dry gas duty only. This thinking – how to be robust in handling both gas and liquid – had already been applied to multiphase pumps and could also be applied to the multiphase compressor," Torkildsen says.

During the whole WGC2000 development period, Framo was also developing multiphase pumps and working on increasing performance, making sure liquid mixes well with the gas through the pump. Controlling this process, stopping the liquid or gas separating out, is key.

"The contra-rotating concept has a good feature in that respect. It contradicts the separation effect," Torkildsen says. "Also, the inlet arrangement has a built in flow mixer to help condition the unprocessed well stream and any flow regime entering the compressor. If a normal compressor had this duty, the different impeller stages or impeller parts might experience very different loads resulting from gas and liquid separation compromising both performance and mechanical integrity. We make a 21-stage impeller, which means each is very lightly loaded, and because it is contra-rotating, each impeller provides twice the head of a conventional single rotating impeller. Specific loading is very low and hence the multiphase fluid is treated very gently as it moves through the compressor."

The step up in capacity came just before Norsk Hydro and Statoil merged. The team had already approached Norsk Hydro and were working on a topside, 3000Am3/h concept for the Tune field. However, in early 2007, following the merger, Statoil came up with the Gullfaks project.

This put Tune on the back burner, but created the opportunity to develop a unit for subsea use, at a time when it would have to compete with topsides alternatives. A technology qualification program was launched, this time with Framo Engineering in close cooperation with Statoil.

**Statoil's Gullfaks' B platform.** Photo from Statoil.

"The important thing was that we had made this increased capacity machine and tested it. Then we took the figures to Statoil," Torkildsen says. That is what got the Gullfaks process started, he says.

The next step was qualification of the whole Gullfaks compression system. This time Framo, now part-owned by Schlumberger, invested in its own test rig with 100-bar live hydrocarbon wet gas capability.

Framo Engineering also had to step up as a company, moving into full systems engineering. A cooling system would also be needed and the compressor, cooler, monitoring systems, etc., all qualified. The team working on the wet gas compressor suddenly grew. In 2011, Schlumberger bought out the remaining shares in Framo that it didn't own, before rolling the company into its OneSubsea business.

In 2015, two OneSubsea multiphase compressors were put onstream and became the first multiphase compressors with no requirements for an upstream separation facility or an anti-surge system, helping to simplify the subsea system requirements.

They are targeting an increase in recovery rate from 62% to 74% for the Gullfaks field. This will see some 22 MMboe increase in recovery from the Gullfaks South Brent reservoir.

Statoil has been keen to implement subsea compression, due to it having a bigger impact on recovery rates than conventional platform-based compression. It is also seen as an advantage that is does not take up space on platforms, as well as being a step towards Statoil's goal for the subsea factory.

In making their award, the UTF jury recognized the removal of the need for upstream separation facilities and the ability for light vessel intervention as being among innovative steps contributing towards cost reduction in subsea technology.

While the compressors have since been temporarily removed, due to a leak in a utility cable not related to the compressor stations, Statoil has confirmed that the units had been operating to its satisfaction.

Fast forward to today and the focus once more is increasing performance and capacity. "Internal work could yield yet another giant step in capacity," says Torkildsen, and there's no reason to disbelieve him.

The key with the Gullfaks compressor is that it is very compact, light, small and simple. It can be installed using small vessels and that was very important for the customer. These OneSubsea multiphase compressors, should never be too heavy as there is a sensible limit— in the 100-150-tonne range. If it is more than that, it may become too big and heavy for easy and efficient intervention."

Interestingly, the system could go full circle and be used onshore, Torkildsen says. "We are seeing what I think is the ultimate machine, taking into account all the constraints we need to consider. In the early days we focused on land; subsea compression was never mentioned."

It's been a long road. Torkildsen is keen to credit the foresight of all those involved through the years. For OneSubsea, the multiphase subsea compressor is a huge achievement. **OE**

# Day of

**In a short period of time, drones have shot to popularity as a tool for offshore oil and gas facility inspection. Elaine Maslin profiles the technology and its providers.**

They come in various guises and have been given numerous names - unmanned aerial vehicles, unmanned aerial systems, remote operated aerial vehicles, multipurpose inspection octocopters and even flying laptops.

Whatever you call them, so-called drone technology is proliferating. The worldwide market for drones was US$3.4 billion in 2014 and is anticipated to reach $36.9 billion by 2022, according to WinterGreen Research. Drone use is not just by the military, as a hobby, or a tool for photographers, it is also becoming a serious tool for industrial inspection.

Having entered the offshore oil and gas industry in the early 2010s (after being used onshore refineries), they're now increasingly used as part of routine work to inspect hard to reach areas, including under decks and inside tanks.

Combined with increasingly powerful computing software, such as automatic image recognition and search functions, they're making serious in-roads into asset integrity management. Automated flight may also be on its way, along with a world where structures are designed so that drones can communicate with them as they're being inspected.

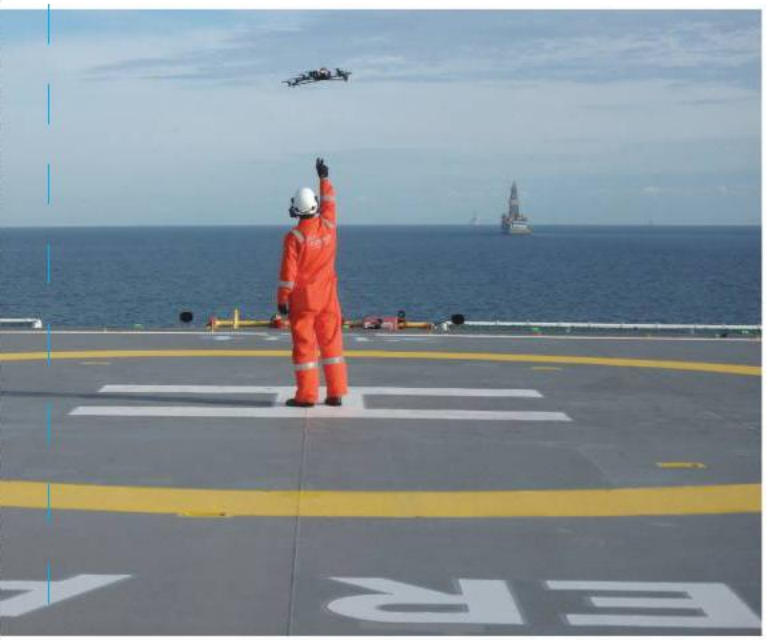
## Early days

For the oil and gas industry, this has been a relatively fast adoption of a new technology. The benefits early on were seen as being able to access hard to reach areas for inspection, such as flare stacks or wind turbine blades, without putting a person up a flare boom or on the end of a rope – and without having to shut in production.

Whereas in the military, the kit is bought and deployed, in oil and gas, it's being provided by contractors who have the staff to fly it. Two firms have led the field in the UK sector, Sky-Futures, set up by two ex-military personnel, who had used drones in Iraq and Afghanistan for data gathering, and Scotland-based Cyberhawk, set up by one of the very people who had the joy of working at height at the end of a rope, and saw a better way of doing such work.

The launch of this technology in the UK sector was helped by the fact that the Civil Aviation Authority stepped in early to set out regulations, including what commercial drones could and couldn't do, what requirements (insurance, operations manuals, etc.) were needed and a licensing regime. This meant there was a ready framework for the

# the drones



**Flying high.** Image from Sky-Futures.

likes of likes of Sky-Futures and Cyberhawk to start out.

Adoption in the Gulf of Mexico came later because it took the Federal Aviation Administration (FAA) longer to set out rules for flying drones. Initially, only research flights were allowed – something that BP conducted, onshore, in 2011. But it wasn't until 2014 that permissions were issued, via a Certificate of Waiver and Authorizations, allowing non-military unmanned aircraft systems (UAS) flights, over land, and then 2015 for the same over water.

This meant that it wasn't until January 2016 that the first unmanned aerial vehicle/drone inspection was carried out in the Gulf of Mexico for oil and gas industry, by Sky-Futures.

As in the US, work started onshore in the UK. The first commercial use in the oil and gas industry was a refinery inspection, by Cyberhawk in 2010. This was followed by the first offshore facility inspection in the North Sea in 2011. Sky-Futures' first job was a flare stack inspection with what was then Talisman, now Repsol, in the UK North Sea.

## Mini airlines

While flying these things might seem easy, it's not and it also comes with a lot of logistics, training and admin. "We are basically running mini airlines," says Phil Buchan, commercial director, at Cyberhawk. Each pilot has a log book to complete for every flight, every machine has its own log book and regular service and maintenance intervals. To get to work offshore, they've generally had to have about 18 months training and experience, he says.

Also, not any old drones are used offshore. While the likes of China's DG1 has been predicted to have a $10 billion market, costing $2000-9000 apiece, higher spec models are used for industrial inspection.

Cyberhawk uses different vehicles depending on the job, including an eight rotor Octocopter. At 1m across and weighing 2kg, the firm has done 13,000 flights using this model. It also has a smaller model, with four rotors, within a type of protective ball, for internal inspection.

Sky-Futures uses a Falcon 8 drone produced by Germany's Ascending Technologies, which was recently acquired by US supergiant semi-conductor chip maker Intel. It can fly at 29 knots (55-56km/hr) and only weighs about 2kg, says Chris Blackford, Sky-Futures' co-founder and COO. It has three autopilots, triple GPS systems, for redundancy, and can still fly on just six of its eight rotors, if rotor motors fail. Its lithium polymer batteries can support up to about 21 minutes' deployment, depending on wind strength, etc., he says. Standard payloads for these units includes an HD video camera and thermal camera or stills camera.

While 21 minutes might not seem long, "We can do a huge amount in that time," Blackford says. As an example, a flare tip and boom would take about half a day based on 4-6 flights using video and cameras. On a recent project for a North Sea client, 14 scopes of work were performed over 14 days that the client estimated would have taken 700 days using rope access. "From that job we probably took home about 40 GB of data," Blackford says.

**Chris Blackford, Sky-Futures**

What's more, "The use of drones is constantly getting more and more adapted by different customers," Buchan says. "Some customers are changing their inspection philosophy to inspect everything by drone and only send a man in if they think there is an issue. Over the next few years, we think we will see that become more day to day."

Significantly, as the technology has begun to be understood, the data collected and how it's used is also getting more sophisticated. But more on that later.

## Inner space

"One of the biggest milestones in recent years is the ability to conduct internal tank inspections," Buchan says. "Last year we carried out the very first inspection of an internal storage tank on board a Maersk Oil floating production vessel (FPSO), which was a major leap forward for the offshore industry." This was the *Gryphon* FPSO, stationed in the UK North Sea. More work is being done on procedures in this type of work

**An internal inspection using a Flyability drone.** Image from Sky-Futures.

to make it more effective, Buchan says.

In May this year, Sky-Futures said it conducted the first FPSO tank inspection, without personnel entry, working on BW Offshore's *Athena* FPSO and using a drone made by Swiss firm Flyability specifically for accessing inaccessible places.

Blue Bear, a UK-based developer of unmanned systems, which has been running for about 16 years – mostly in the military sector, but also in nuclear– has taken this concept a step further, towards automation. It recently flew an automated flight inside *HMS Illustrious*, an aircraft carrier that is being decommissioned. Without being piloted, the vehicle – called Riser – flew around, mapping the space and taking images as it went, without having had prior knowledge of the space in which it was flying around, says Ian Cowling, Blue Bear's technical director. Riser was developed for the nuclear industry, in order to go into spaces humans cannot go. "It can fly in an automated way in an unknown environment without risk of collision and without operator input," Cowling says. "The operator [sets] the flight pattern they want and it goes off and flies it." It then produces a 3D map of the space. Repeated surveys over time can they provide 4D data of internal spaces.

**Image created from the internal inspection on *HMS Illustrious* by Blue Bear.** Image from Blue Bear.

**Cyberhawk staff set off a drone offshore.** Image from Cyberhawk.

Riser is a four-rotor vehicle, with protected propellers, weighing 4.5kg with multiple sensors, including lidar and cameras, so it doesn't need to rely on GPS to fly and navigate. As long as it can be put into a space, it can fly around it and map it on its own, Cowling says. Blue Bear is working with classification society Lloyd's Register (LR), UK-based computing and electronics engineering firm Createc, and operator BP on tank inspection potential using the system.

## Big Data

How the imagery, or data, collected is now used is also getting much more sophisticated and the data more accurate. "There has been a massive shift in understanding this technology in the last 12-16 months," Blackford says. "In the early days it was very much put the drone up and take images." Now firms are getting more and more sophisticated about what they do with this data, which is usually processed and held on a secure cloud server for the client.

From the imagery collected, a lot of information can be extracted, including taking measurements.

For Cyberhawk, this has been important to achieve in offshore wind, where accurate measurement is needed to pinpoint an issue in a particular place on a blade. Renewables have been a growing market for Cyberhawk, with 450 blades inspected last year and rising to 1000 this year.

"Over the last couple of years, we have developed how to size and measure defects and locate them, say 40m from the tip and 1m in from the leading edge," Buchan says.

Cyberhawk also launched iHawk, a cloud-based visual asset management software platform, which converts the drone captured imagery into information that can then be used – defects categorized, for example – to make quick and effective management decisions, on a single dashboard, from which they can also access the high-resolution images, Buchan says. This helps to handle, in a condensed way, what is otherwise terabytes worth of data for just 10-20 turbines. Over time, it will also enable predictive maintenance. Up until now, this kind of support for clients to help them analyze and use the information captured has been lacking, he says.

Sky-Futures, meanwhile, has developed a technique it calls "finger printing." By using image recognition software, developed in-house, an anomaly spotted in video of a flare stack can be "finger printed," and then future videos of the anomaly can be searched automatically – instead of the hours it might take to have a human visually search the footage.

Sky-Futures has secured $11 million funding, from venture capital and helicopter operator Bristow Group, to build out a technology road map that is built around an inspection portal, which hosts all data collected. Platforms can be viewed in 3D for trend analysis. This could be looking at a flare tip over multiple years, using algorithms to predict what a crack or corrosion will look like in three months.

Shell – which set out its use of drones onshore Nigeria in 2011 at the SPE Nigeria Annual International Conference in August last year – says that with advances in machine vision technology, this could be done automatically, creating data on which to base predictive maintenance programs. In addition

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to that, the data could then be used to make assessments against other assets with similar structures or equipment, to help understand wider asset integrity trends, Blackford says.

Shell also says that there's the potential for the data captured to be used to create metrologically accurate 3D models of structures using photogrammetry or laser scanning. This would help quantify the extent of defects, i.e. the size of cracks. Sensors could also be added to perform gas sniffing and other types of sensors are being developed.

**Flare stack inspection.** Image from Cyberhawk.

**Image taken underdeck, offshore.** Image from Cyberhawk

## Setting standards

LR has seen the potential for UAS use, for asset inspections, including over time, predictive maintenance, and platform imaging for brownfield engineering and decommissioning work scopes – provided the 3D models created from data collected is based on accurate information. Earlier this year, LR launched some initial standards for use of drones, but it says these will develop further over time.

"LR is trying to establish some standards," says Chris Wilber, director, Pipeline Services, SGC Engineering, a member of the Lloyd's Register Group. "This is an object in the air. There are safety issues around that, [such as] if there is a malfunction of the UAS and it falls on someone or something." It's also about where UAS can fly and in what areas flying one could create a hazard. Also under consideration is how accurately an operator can fly an UAS by hand, in different conditions, which is one reason why there's a move towards automated flight, he says.

In an ongoing joint industry project, from its bases in Singapore and Southampton, LR is looking at how standards in this area can be improved.

"There are varying levels of uses, currently, and also the applications are very different," says Jason Knights, LR's global communications manager, i.e. flying in a ballast tank is different to flying around a flare, and to flying around an onshore site. How data collected can be verified is also being looked at, so that it can be used for verification purposes.

Indeed, insurers will also be interested in this technology, including best practice, Wilber says. While individual companies will have their set procedures, by having broader guidelines, more industry-wide guidelines and standards could be set, Wilber says.

"Does a company's plan include inspection of the UAS to make sure it is airworthy? Do they look at the weather conditions or the condition of the operator? Can they see the vehicle at all times or is it reliant on lidar positioning? Will the condition of the facility or vessel it is inspecting matter," he asks. "There may be gases you don't want to fly a drone into."

Setting out standards in these areas could give those operators who haven't tried this technology more confidence to try it, Cowling suggests. It could also be of great interest to the likes of the UK Health & Safety Executive, which could find access to detailed imagery and data around asset integrity of great interest and use.

## Automated flight

Automated flight also appears attractive. Cowling thinks this is something of interest to operators, as it would enable them to do more themselves. Shell has pointed to such a future.

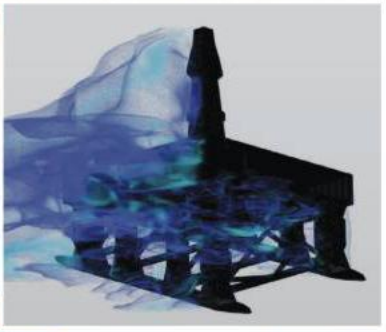
Thailand's PTTEP is also going down this path. Its engineers outlined a multipurpose unmanned aerial vehicle (the multipurpose inspection octocopter, or MPIO) they had developed for a range of monitoring and inspection tasks at OTC Houston in May this year. PTTEP has performed an onshore flare stack inspection, but says the next step is a fully automated MPIO, which will include auto take-off, auto flight control and auto-landing, the firm says.

Automation plays a big role for the future. There could be a drone on every platform that flies itself everyday, collects data, which is then processed and sent to those who need to see it automatically, Blackford suggests. "They are a flying laptop, essentially, and like cars they will eventually be driverless," Blackford says. "They will truly be unmanned, flying themselves."

Perhaps it's with this future in mind that the third-party operators are focused on the value they can add to the data they collect, so they remain of use as a contractor.

Looking further into the future, platform design could even be influenced by drone technology, LR's Knights says. "The way UAS is being developed across the world lends itself to how equipment and infrastructure could be designed," he says. For example, drones could speak with the infrastructure and vice versa (the Internet of Things). "This new technology will be intrinsic to the way the industry is shaped in the future." **OE**

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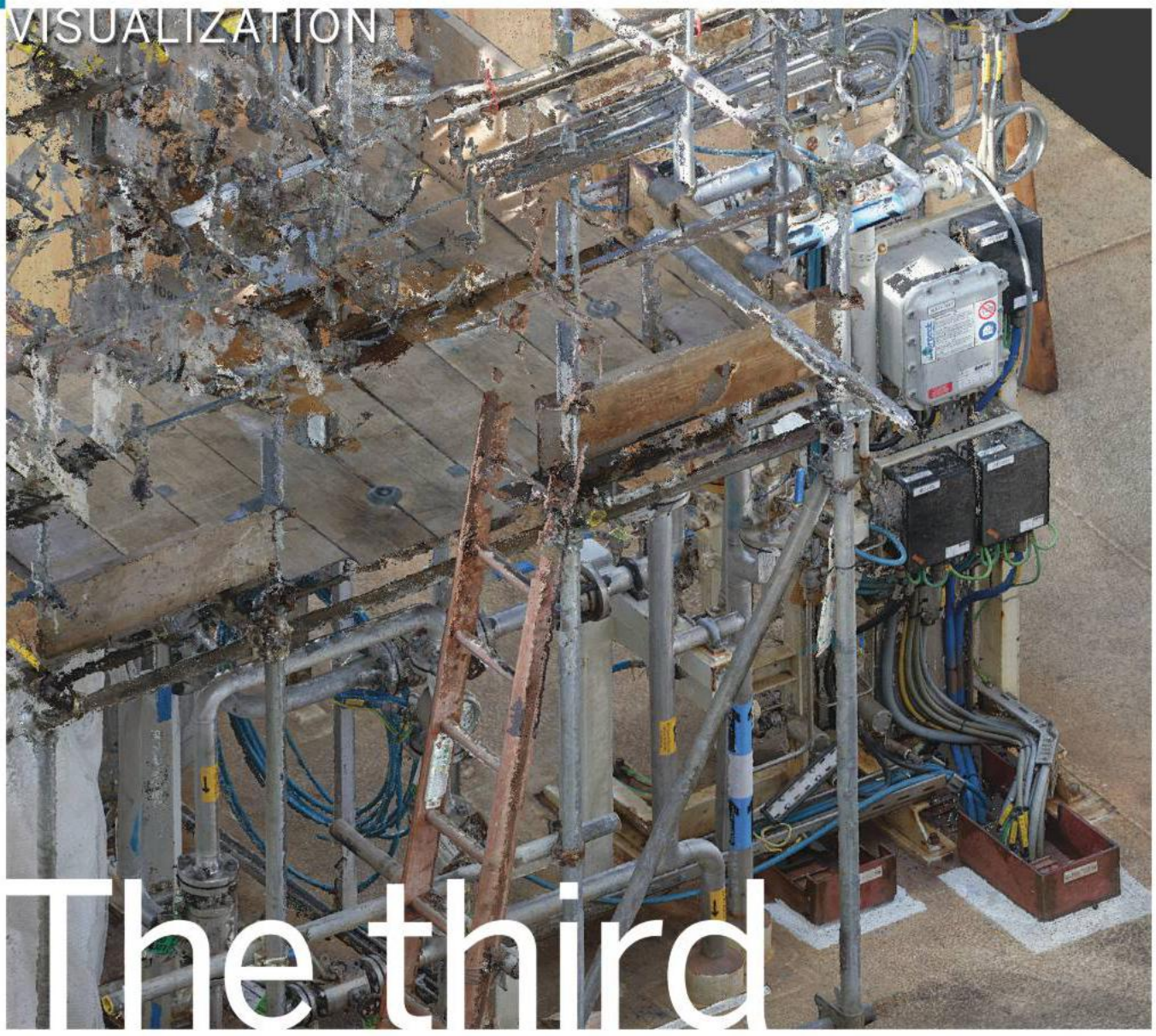


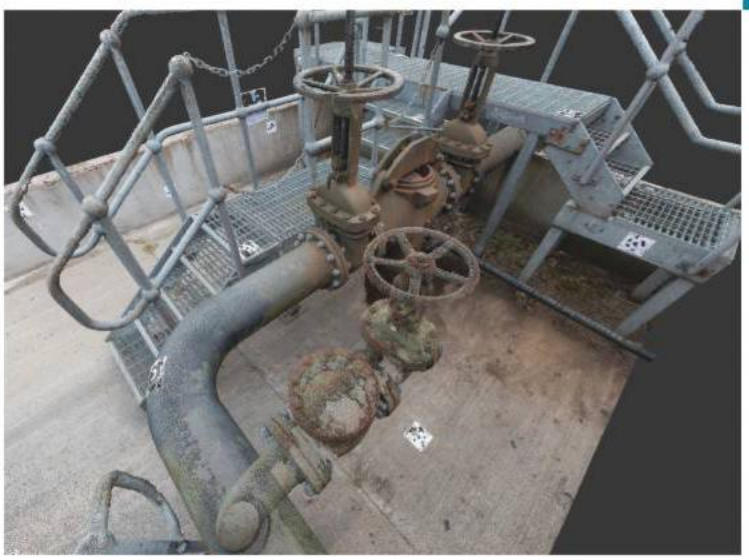
# The third dimension

**How offshore assets are visualized has taken a leap forward with photographic technology that helps to create point clouds. Elaine Maslin reports.**

How offshore assets are visualized and what can be done with those visuals has been evolving, fast.

When Return To Scene started offering its services to the offshore industry, its tool R2S was based on forensic technology with which investigators could create walk-through, 360° 2D images of crime scenes, or offshore platforms, warts and all, using spherical photography.

Now, as well as being able to virtually "walk-through" facilities, the firm has added a third dimension to its latest offering, called R2S Mosaic, by using trigonometry-based software. Because each pixel now has a coordinate, a 3D point cloud can be created – like a laser scan but without the need for a laser scanner.



**Turning photos into point clouds.** Images from Return to Scene.

This enables users to calculate depth more easily and accurately, automatically tag equipment, where there are engineering or CAD drawings available with location data, and merge with plant design and management systems (PDMS) and piping and instrumentation drawings (P&IDs), etc., aligning photographic point cloud images with engineering and process information, with the user able to navigate between the two systems.

"We have added depth so that every pixel knows how far it was from the camera," says Martin MacRae, head of product development and support services, Return to Scene. "You can automatically tag things in space if you have the coordinates. Taking measurements becomes easier. Every pixel has a depth, so a lot of user error is avoided and we are challenging lasers."

While measurements could be taken in R2S, points had to be selected twice, on the two sets of spherical images which are taken to create the walk-through images. With only one click now required on a point that knows its position relative in space, accuracy is increased and potential for user error reduced. Also, when something is tagged in one image, it is automatically now tagged at that coordinate in every image.

While a certain amount of "washing" might be needed to make sure the design data and what is captured photographically (i.e. what was actually constructed) aligns, this is an opportunity, MacRae says. This is not just for verifying what has been built, but could be useful for modifications or even decommissioning work, and just to help users more easily navigate engineering drawings, by being able to see their as built context.

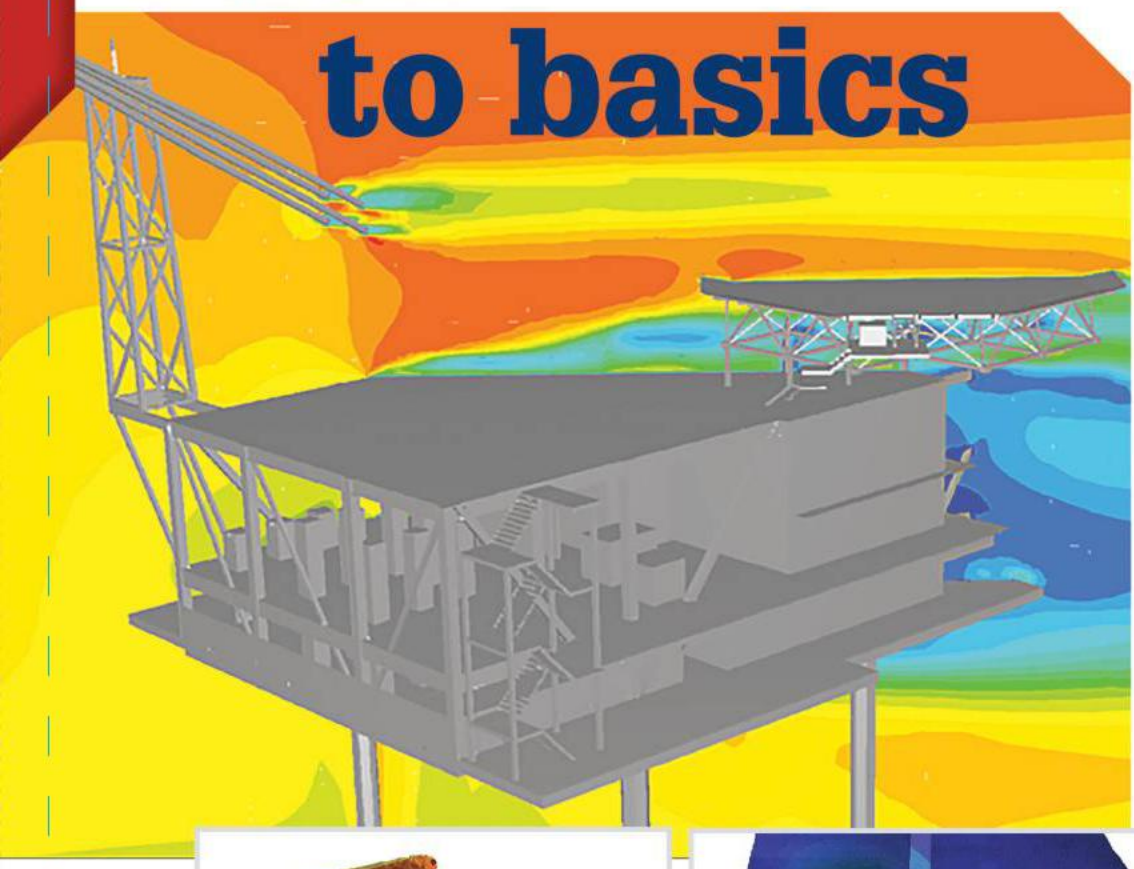
R2S Mosaic launched at SPE Intelligent Energy, in Aberdeen, last month (September). But, Return to Scene has conducted system trials with clients, including BP. The UK-based oil major will be piloting Mosaic on its Clair Ridge and Thunder Horse assets, in the UK North Sea and Gulf of Mexico, respectively, according to a presentation at SPE Intelligent Energy.

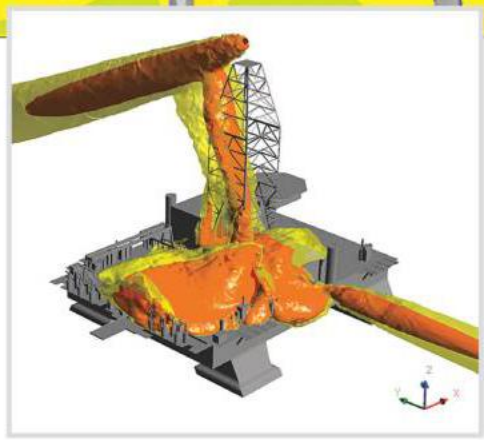
The author says that using the photographic point cloud effectively negates the necessity for laser scanning technology, traditionally required for the generation of point clouds. Searching the images will also be easier now, he adds. Because the images, stored on a secured cloud server, can be merged with PDMS models, searching a piece of equipment will also find the data relevant to it.

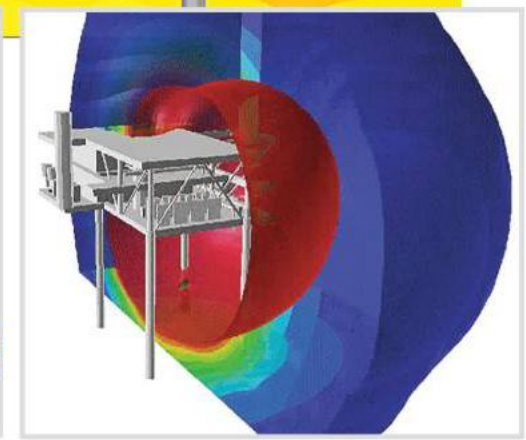
In Mosaic, live data – pressures, temperatures, fuel gauge levels, etc. – can be brought into the system, all viewed from the context of the visual images, with CCTV feeds, for remote facilities, also possible.

Together with an architecture open to third-party plugins, the system could open up the Internet of Things for the offshore space, with a platform in which data, monitoring and visuals are in the same place. **OE**

# Back to basics







**FEA and CFD in action.** Images from Abercus.

**FEA and CFD don't have to break the bank, especially with open source tools now entering the market. Abercus' Steve Howell explains.**

It is increasingly necessary for companies to collaborate and innovate to reduce capital and operating expenditures, especially in this current lower oil price environment. Now is the time to invest in research and development to deliver improved performance and reduced costs. As part of this drive, advanced engineering simulation approaches including computational fluid dynamics (CFD) and finite element analysis (FEA) are being used increasingly within our industry.

By using first principles approaches, they can provide valuable insight at the design stage, improve safety, enhance understanding of installation and operational issues, and demonstrate technology readiness for novel products and approaches.

There are several commercially available general purpose CFD and FEA codes, developed over the decades, which have evolved into extremely impressive software tools. They are capable of simulating a wide range of complex physics and can be applied across many different industries, including the nuclear energy, aerospace, automotive, elite sports, built environment and offshore sectors.

These codes continue to be improved, requiring significant investment, ultimately funded by users through licenses. For some, however, these fees, and the associated investment required for the training of the engineers who use the simulation codes, might be a potential barrier to the adoption of simulation technology within their business.

## Open source

One trend that may assist with the wider adoption of engineering simulation is the emergence of lower cost and open source simulation tools. These tools are freely accessible to everyone and for many applications within our industry they offer a fit-for-purpose solution.

While the commercial general purpose codes are undoubtedly powerful simulation solutions, they may be unnecessarily gold-plated for many applications within our industry. If a company operates within the subsea sector, for example, and is interested in, say, wave loading on a subsea structure,

then clearly it doesn't necessarily need a CFD code that can simulate combustion and radiation, too.

Similarly, if a company is primarily interested in topsides technical safety applications, such as atmospheric exhaust dispersion or simulating fires and explosions, it may not need a CFD code that can also simulate the sloshing dynamics of a free surface within a separator, or the impact of a sand particle on a pipe wall and the associated rate of material erosion due to the impact.

For some companies, the use of open source software may provide a fit-for-purpose solution, but without the associated overhead of any software license fees. It is Abercus' expectation that open source simulation tools will become increasingly used in the future, and that this will accelerate the democratization of advanced engineering simulation methods and their use in the offshore sector.

## Gaining confidence

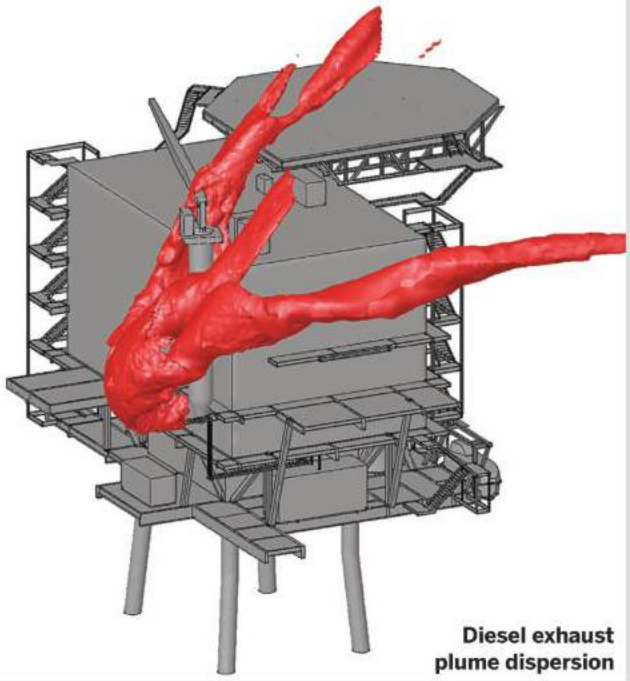
Verification and validation are the processes we must employ to gain confidence in our simulation models, to ensure that they are useful and fit-for-purpose. Verification is the process of determining that a computational model accurately represents the underlying mathematical model and its solution, whereas validation is the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model.

Verification is the domain of mathematics, demonstrating that the equations are solved correctly, whereas validation is the domain of physics, concerned with ensuring that the correct equations are solved for the application of interest.

By using a commercial simulation code, the code verification should already have been addressed because the software vendor should have delivered a code that correctly solves some set of documented equations. However, it remains the responsibility of the user to verify the calculation, for example, by demonstrating that the spatial and temporal discretization underlying the simulation is sufficiently resolved. When using an open source code, the user is responsible for verifying both the code and the calculation.

Regardless of whether the simulation tool is commercial or open source, it remains for the user to undertake validation activities to demonstrate that the equations being solved by the simulation code are actually the correct equations for the application of interest.

Ultimately, this requires a predictive capability assessment, which compares simulation predictions against some benchmark data from an experiment or some other engineering approach. Only if there is good agreement can there be confidence in the simulation approach for that particular application.



Diesel exhaust plume dispersion

## NAFEMS and ERCOFTAC

Anyone practicing in the field of engineering simulation should be aware of NAFEMS and ERCOFTAC. NAFEMS is the international association for the engineering modeling, analysis and simulation community, which covers the application of both CFD and FEA, and ERCOFTAC is a global association of research, education and industry groups focusing on the technology of flow, turbulence and combustion.

Both promote simulation best practice through the delivery of teaching courses and the organization of national/international conferences to promote the exchange of ideas and disseminate information. In recent years, NAFEMS launched its professional simulation engineer scheme, which is designed to provide a consistent framework to demonstrate the competence of simulation users.

Both organizations provide repositories of benchmark data for the purpose of validation. Benchmark data is incredibly important for the purpose of validation activities and there is always a need for more reliable benchmark data.

While there is often experimental testing undertaken during the course of projects, this tends to remain within the project. From the point of view of validation and general confidence in simulation this is unfortunate. Of course, for some applications it is necessary to keep experimental data guarded in order to protect the technology of interest, but, where credible experimental data is generic in nature, it could be shared with the simulation community, perhaps through organizations like NAFEMS and ERCOFTAC. This could help to significantly advance confidence in CFD and FEA across our industry.

## Conclusion

CFD and FEA are first principles, advanced engineering simulation approaches that have much to offer the offshore sector. Traditionally they have, perhaps, been regarded as high cost niche simulation tools. But, it is expected that the emerging open source tools will help to accelerate the democratization of these methods so that they become more mainstream within our industry. With the increasing use of engineering simulation, it is crucial that as an industry we are rigorous with respect to verification and validation in order to maintain confidence in the simulation approaches and tools that we use, and in the predictions they yield. **OE**

***Steve Howell*** *is technical director at Abercus, based in Aberdeen. He has held senior roles at Prospect Flow Solutions, Cundall, Mott MacDonald and Mobius Dynamics. He has a PhD in computational fluid dynamics from the University of Newcastle-upon-Tyne.*

# A rising spar

**Aasta Hansteen topside under construction at HHI. Living quarters in place.** Images from Statoil.

**Elaine Maslin reports on the progress of Aasta Hansteen, Norway's first spar development.**

Statoil's Aasta Hansteen spar development will move Norwegian operations into a new deepwater environment. The spar will be moored in 1300m water depth in the Norwegian Sea – the deepest previous project is Shell's Ormen Lange, at 900m. It will produce from the Luva, Snefrid and Haklang gas and condensate reservoirs, jointly known as Aasta Hansteen.

While the topsides are conventional, this will be Norway's first spar project – also the world's largest spar – and the first use of steel catenary risers (SCR) in the country. Three SCRs will connect three subsea templates to the spar, with another SCR to be used for export to the export pipeline system.

In another first for Norway, the spar's 17 mooring lines, spread into two clusters of six and one of five, are made from Gama 98 polyester, by Lankhorst Ropes, and are some 2.5km-long, each. When awarded the contract, Lankhorst said that it was the largest deepwater mooring rope contract.

The spar hull is also unique. Unlike others, it is fitted with storage space for condensate from the Aasta Hansteen fields, which will be exported by shuttle tanker. Gas will be piped through the Polarled pipeline to the Shell-operated Nyhamna gas plant. Statoil is also using mechanically lined pipe, another first for the North Sea (*Reel lay gets real attention, OE*: January 2015). Some 19km of 12in BuBi-Pipe has already been installed, using reel-lay.

Construction of the spar is nearing completion at Hyundai Heavy Industries (HHI) in Ulsan, Korea, under a consortium deal with Technip. The topsides are also under construction at HHI. Transport from Korea, and mating of the topsides and spar will take place during 2017. Meanwhile, subsea construction is complete, with just platform tow-out and hook up on the field remaining in 2018.

Torolf Christensen, project director, Aasta Hansteen, Statoil, says that for this project, new technology solutions were required on the Norwegian Continental Shelf (NCS).

Initially, a number of options were assessed, including ship-shaped and circular FPSOs. But, a moored spar with SCRs came out as the best solution. "This is a different development solution from what had been used before," Christensen says. "On the NCS, flexible risers are usually used. [In the North Sea] a spar in combination with SCR and this mooring system gave the best solution, for the forces that will be put on the risers. The wave and current pattern in the [Aasta Hansteen] area exceed what we have been exposed to before on the NCS. We have experience from high waves and high currents, but the combination of the two and the deepwater is unique on Aasta Hansteen.

"The fact that we are now also in 1300m depth means the normal size flexible risers normally used on the NCS would be far too heavy and wouldn't stand the forces and movements. We would have to have a small size flexible, which would increase the number of flexibles needed to something not very smart. Using SCRs was an elegant solution."

The SCRs and flowlines were fabricated at Subsea 7's spoolbase in Vigra, Norway. Marine operations to install the subsea infrastructure ran through 2015 and this summer. Christensen says that the marine operations were taken to the next level. "We have been through two seasons of marine operations with really good success," he says. "Subsea 7, the primary contractor, delivered excellent results."

Instead of guidewires to place equipment on to the templates in the fields, so-called toast rack guides are an integrated part of the template structures.

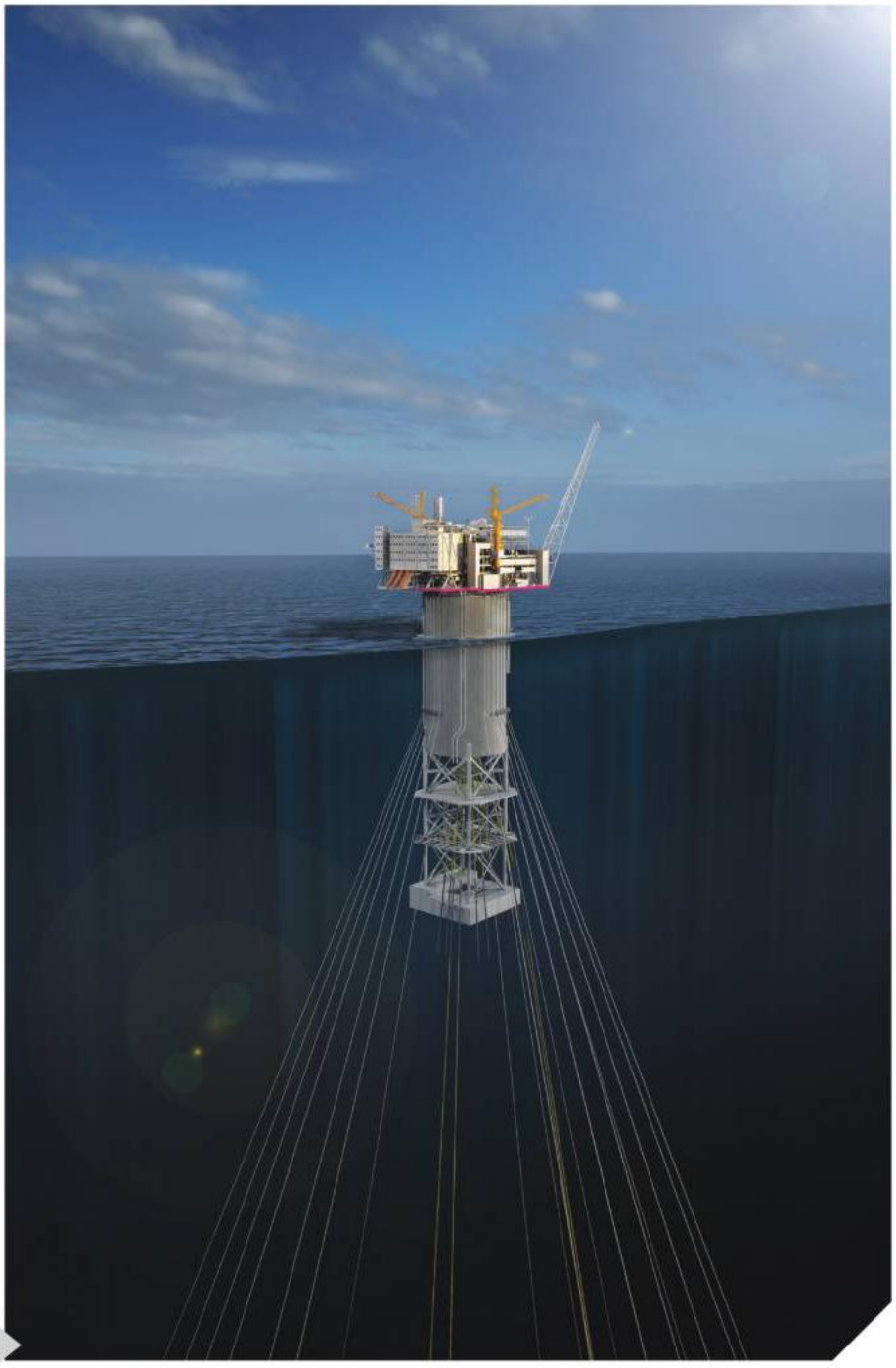
Christensen has been most impressed by the 45,000-tonne, 200m-long, 50m-diameter spar substructure construction. It is being constructed laying on its side on the ground, with sections weighing 2.5-6000-tonne then lifted in. Some five mega-lifts were required to complete the construction, all with the hull laid on its side. The final block installed was the top deck weighing 4500-tonne using a 10,000-tonne barge crane. It has been like a massive puzzle, Christensen says.

"There has been some fantastic precision work on the structure," he says. It contains 52 different compartments, all needing welding, painting, etc. "The steel tolerance is 4-5mm in 3D, but everything fit every time it was lifted [into place]." The tolerances were so tight that one mega-lift was done in the morning, before the steel could get warm and potentially expand.

The hull substructure will be floated and then transported to Norway on the *Dockwise Vanguard* horizontally. In Norway, it will be floated off in the Stord area west coast of Norway and upended. There, the topsides – weighing 25,000-tonne, offering accommodation for 108 people – will be mated with the hull in Digernessundet, Norway, at Stord before being towed out to the field. The living quarters were fabricated in the Netherlands. OE

## FURTHER **VIEWING**

**Building blocks.** Statoil shows how the final mega block, weighing 4500-tonne, was installed on the Aasta Hansteen substructure, in the summer of 2016. www.oedigital.com/component/k2/item/13532-video-aasta-hansteen-spar-construction



**Aasta Hansteen, as it will look. Artists' impression.**

**BG Group's FlatFish is one of a number of resident AUV concepts being developed.** Image from BG Group (now part of Shell).

# Underwater autonomy

**There's potential for growth in the AUV market. However, operators and manufacturers will need to clearly demonstrate the benefits of the technology if they're to move beyond being a niche solution. Douglas-Westwood's Ben Wilby explains.**

The autonomous underwater vehicle (AUV) sector has evolved from an emerging technology with niche uses, to a viable solution and an established part of operations in various marine sectors. A number of companies within the AUV sector have developed strong reputations as reliable providers of AUVs, but there is potential for further growth.

Douglas-Westwood's (DW) new AUV Market Forecast 2016-2020 considers the prospective demand for AUVs in the commercial, military and research sectors over the next five years. DW sees demand for units continuing to grow over the forecast period, with demand in 2020 expected to be 49% higher than in 2016.

This will be driven by continued high levels of military and research activity as well as consistent growth from the commercial sector. The prospects for growth in the use of AUV technology in the commercial sector are good – as a comparatively underutilized and developing technology, it will likely take time for the sector to fully mature. Yet, with growing acceptance from operators and a strong focus on research and development, demand for AUVs is forecast to increase for the foreseeable future.

## Emerging technologies

In the commercial sector, the future of AUVs is intrinsically linked with further technological advancements – the technology has yet to reach a level where oil and gas operators consider AUVs a vital aspect of operations.

AUVs have a number of limitations that are hindering uptake in the commercial sector, these include: battery life, autonomy and manipulation ability. Currently, AUVs average under 24 hours' battery life and this is significantly reduced if the unit is required to work in deepwater – thrusters are one of the largest drains on power. Consequently, current research is focused on improving battery life, either through improvements to existing technology or the introduction of new battery types. Many of these battery types are still conceptual and are likely to be a number of years from commercial availability.

Full autonomy is also an important target, many in the industry have told us that units are, "not as autonomous as we perceive them to be." Much of this is linked to battery life – with units requiring regular intervention for power purposes – however, it also relates to the current limits of programming and artificial intelligence.

At a commercial level, improved manipulation ability will arguably be the most important factor for increased uptake of AUVs. Units currently have limited ability to manipulate equipment once they are underwater, limiting their use to inspections and surveys.

This is a major difference between AUVs and remotely operated vehicles (ROVs) – the latter can be fitted with arms that can be controlled manually. There are a number of projects focused on improving manipulation ability, including Eelume, a Norwegian university spin-out that has developed a swimming robot concept. This AUV utilizes a snake-like design to allow for better maneuverability and will be capable of adjusting the valves and chokes on subsea trees. A collaboration agreement with Statoil and Kongsberg to further develop the concept was signed in April 2016.

Eelume's AUV design does not require the unit to resurface in order to be charged. This can take place on the seabed with the unit sending data up to the surface while charging. This solution improves a number of issues – increasing autonomy and removing many of the concerns over battery life. The development of "resident" AUV installations will be integral to growth of the technology for oil and gas operations.

Future developments could see subsea bases for AUVs that are based around a series of marginal fields – dramatically increasing the value proposition. Subsea 7 is one of a number of companies that already have "subsea resident" AUVs in development.

## Market forecast

The market demand for AUVs is expected to increase over the forecast at CAGR 10%, with every sector seeing positive growth due to increased utilization of the technology. The military is expected to remain the greatest user of AUVs with demand in 2020 for over 700 units – 73% of total demand. AUVs have a range of uses in the military including: anti-submarine warfare, mine countermeasures, oceanography, search and rescue as well as special operations.

Using AUVs for these tasks reduces costs and limits risk to military personnel. In recent years, military investment in research and development has been reduced, with only specialized projects receiving funding. This is primarily due to the widespread availability of commercial off the shelf (COTS) AUVs from a range of different companies – this was not the case 10 years ago. Specialized projects and unique AUVs are still being sanctioned and built. A key example is Boeing's new Echo Voyager, a 51ft AUV capable of staying underwater for over three months at a time.

The greatest growth in AUV usage is expected in the commercial sector – predominately from oil and gas operators. This will be a key market for the technology – despite the volatility of oil prices – as operators begin to understand the cost saving potential of AUVs. Consequently, the next few years are expected to be vitally important for AUV manufacturers and operators – both need to capitalize on increased interest before higher prices potentially lead to a return to the norm. However, low oil prices have reduced budgets and stymied investment in new technology, presenting a barrier to growth. Therefore, the onus will be on AUV manufacturers and operators to highlight the benefits of the technology.

DW expects demand for AUVs from the commercial sector to grow at a CAGR of 20%, with demand in 2020 105% higher than 2016. Over the forecast, commercial demand will represent only 4% of the total, highlighting that the technology remains a niche solution within the industry.

Despite accounting for the second largest portion of demand, the research sector will grow at a slower rate than the other two sectors. Research institutions typically utilize AUVs for a range of applications and have built units as research/engineering projects in their own right, or as a development test bed for new sensors, as well as to gather field data to support research efforts. Many institutions now purchase COTS AUVs rather than build them, however, there is often a great deal of integration work required in order for the AUV to meet project requirements. With the rise of modular, easy to change and open source platforms, this is likely to become less of an issue within the sector.


**Subsea 7's AIV concept.**
Image from Subsea 7.

DW expects demand in 2020 to be 14% higher than in 2016, rising at CAGR 3%. Research institutions typically do not require high numbers of AUVs and usually prefer to modify existing units where possible.

AUV technology was first developed in robotics departments within US universities – often in collaboration with the US military. Consequently, North America remains the largest market for AUV demand, accounting for 61% of total demand over the forecast. The uptake rate in other regions has been slower. However, we expect to see some demand in every region. Western Europe is the second largest market, accounting for 19% of total demand – largely originating from the military sector.

Gliders are an extremely well established aspect of the market and are typically used for oceanographic sensing and supporting military and scientific research. We forecast gliders based on additional yearly supply and expect consistent growth to 2020. In 2016 we expect to see 168 additional units utilized, growing to 326 units by 2020. The vast majority of these units will be based in North America – representing 70% of total supply over the forecast.

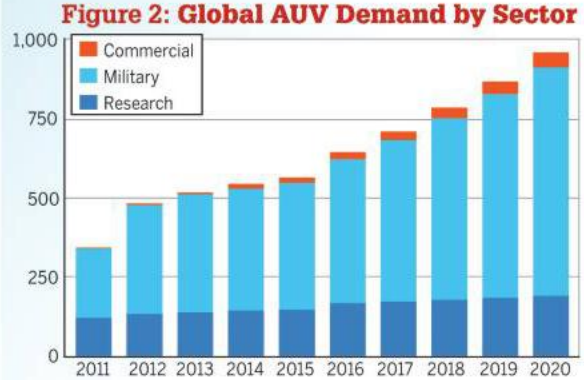
## Conclusion

AUV technology is still maturing and research and development spend remains high in universities, research institutions and from commercial operators. AUV demand is expected to increase substantially over the forecast, with demand in 2020 expected to be 49% higher than in 2016 – growing at CAGR 10%. The AUV sector is one of great promise, the technology has been widely accepted by the military and is seen as a vital tool in a number of research areas, yet uptake in the commercial sector remains limited.

With technological improvements and new designs regularly coming to market, strong growth in the sector is expected. However, operators and manufacturers will need to clearly demonstrate the benefits of the technology if AUVs are to move beyond a niche solution in commercial environments. **OE**

**Figure 1: Global AUV Demand by Region**


**Figure 2: Global AUV Demand by Sector**




Source: Douglas-Westwood, World AUV Market Forecast 2016-2020

***Ben Wilby** is an analyst at Douglas-Westwood and the author of the North Sea Decommissioning Market Forecast. In addition, he has authored Douglas-Westwood's' Subsea Hardware, FLNG and FPS reports. He holds a BA in history from the University of Chichester.*


# ROV in residence

**The Merlin UCV.** Photo from IKM Subsea.

**Elaine Maslin details Statoil's journey towards the resident ROV – using an existing ROV design.**

The concept of the subsea resident remotely operated vehicle (ROV) has been around for some time, mostly modeled on new types of vehicles.

A new project in Norway looks to take a different approach, which could see an ROV parked subsea permanently – or at least for periods of time, which will be extended – as early as Spring next year.

The project is being run by IKM Subsea under contract to Statoil and will see a resident ROV, or RROVs stationed underwater at the Snorre B platform offshore Norway, plus a more traditionally deployed ROV at the Visund facility.

By "parking" ROVs subsea, for drilling-related work, operational time could be increased, as deployment wouldn't be weather dependent. Furthermore, offshore staffing could be reduced – the vehicle could be piloted from shore. For other subsea work, the need for support vessels could also be reduced.

"The idea is it would always be available for operations because you're not dependent on weather anymore because it is constantly submerged – there is no splash zone," says Jan Vegard Hestnes, operations director, IKM Subsea, based south of Stavanger. "It just goes back to its station. You will only bring it to surface for planned maintenance."

The approach being taken by IKM and Statoil will build on a trend towards the electrification of ROVs, a move which helps increase energy efficiency, reduces hydraulic support functions and fluid use, and helps to reduce the size of umbilicals. It also creates the opportunity to use the ROV as an extension cord for other subsea electric power requirements, i.e. when you're not flying, you can divert power to subsea pumps or dredgers, etc.

While electric ROVs are in use, the resident ROV is still a goal – but perhaps not for much longer. Under a 10-year contract with Statoil, with a 15-year extension option, IKM will provide ROV and subsea services for the Visund and Snorre B facilities, including introducing the RROV (residential ROV) based on IKM's Merlin ultra-compact vehicle (UCV). The contract also covers ongoing RROV technology development. The vehicle will be parked close to its respective platform and in such a way that it could be brought up to the platform for any maintenance needs.

Hestnes says that docking will not be an issue. "For subsea docking, to have it down there, we don't need to actually

**Snorre B is a semisubmersible integrated drilling, process and accommodation facility, which came onstream in 2001, in the Norwegian North Sea. It produces, then pipes oil 45km to the facility Statfjord B for storage and export.**

**Statoil and its partners on Snorre, which also comprises the Snorre A facility, are evaluating redevelopment concepts for the field (the Snorre 2040 project – initially comprising a new platform, but revised to a subsea development early 2016). A plan for development and operation is expected to be submitted to the authorities at the end of 2017, according to the Norwegian Petroleum Directorate.**

**The Visund A facility is also a floating production, drilling and accommodation unit. It came on stream in 1999, in the Norwegian North Sea. Oil is piped to Gullfaks for storage and export. Visund began producing gas in 2005. ▪**

Photo by Harald Pettersen/Statoil.

develop any new technology, it is more using existing technology in a new way." More details are not yet available, however.

IKM's Merlin UCV, measuring 2.5m-long by 1.5m-wide and high. It's a 2750kg, 200HP, 3000m water depth rated vehicle with seven electrical thrusters with Schilling manipulators. Its pulling force is 8kN, forward, aft, vertical and lateral. It's an electrically powered vehicle, with interfacing for electric and hydraulic tooling, and auto heading, depth, altitude functions with dynamic positioning system.

All the thrusters are independently powered, so if one fails, the rest will continue to work and allow the vehicle to continue operating.

IKM designed the vehicle to be smaller but with the same capabilities as a larger work class type ROV, building on its Merlin WR200, which also has all electric propulsion. In comparison, the WR200 is 2.8m-long, 1.8m-wide and 1.7m-high and weighs 2800kg. The first Merlin UCV was contracted to Shell to work on the Draugen field offshore Norway last year, off a support vessel.

Because it is electric there are fewer components subsea, less hydraulic oil, and fewer fittings and connections, Hestnes says. "We think the future is in electric and we saw demand in the market for a smaller ROV, which still needs to have the same capability as a large ROV," he says. "Operators are working on subsea structures, which are narrow and difficult to access, so they need smaller vehicles. So, we looked at the WR200 and used the same technology but shrank everything. It's smaller, but has the same capability."

When deployed Snorre B, the Merlin UCV could be operated either from the platform on from an onshore operations center, Hestnes says.

While the vehicle will initially be tethered, and joined by a standard work class ROV and a standard UCV, and able to work out to an 800m radius, the idea is it will eventually drop its tether. "In the future we hope and foresee a RROV that is tetherless," Hestnes says. "More and more rigs will have this. It will help reduce persons onboard and make operations more cost effective. But it is important to do this step by step. First, we will have a submerged ROV, over long periods of time, and then move over to tetherless."

To achieve a full, tetherless work class ROV would also need to see battery technology developed, as today's batteries would be too big and make the RROV too big. "You can't take a Tesla battery and put it in an ROV," Hestnes says.

Another piece of this is the development in machine vision and machine learning technology, where the ROV will have situational awareness and the operator will be able to give it a command, instead of the complex, difficult manual positioning the industry has had. It's not yet capability the Merlin UCV has, but it's something IKM is looking at closely, Hestnes says.

A number of operators already have their own projects, most starting from a less capable machine, like an autonomous underwater vehicle (AUV) with the aim of increasing functionality as the design matures. Eni, for example, has been working on its AUV technology, Clean Sea, which the firm says is conceptually similar to a drone, but in the marine environment. *OE* has also covered Subsea 7's autonomous inspection vehicle (AIV) development, Total's inspection AUV concept (*OE*: October 2014) and Statoil's work with Oceaneering using the eNovus. **OE**

## Tether life

**ROV tether cables have a hard life. The tether, the physical connection between the ROV and its tether management system (TMS), supplies power and communications to the ROV.**

**The cable is installed onto a relatively small drum on the TMS, and spooled in an out, subject to strain, sharp movements, axial loading, hydrostatic pressure, not to mention repetitive bending across multiple planes.**

**With operations moving into 4000m water depth and beyond and excursion length reaching 1500m, the wear and tear of tether cables is continuously increasing.**

**The strength member in tether cables are typically fiber yarns, typically aramid, such as Kevlar, with the fibers used in contra-helically stranded layers around an electro-optical core. The core and the fiber yarns are coated with an outer sheath made of thermoplastic elastomer.**

**Now, the Norwegian ROV cable manufacturing business of France's Nexans is moving away from traditional fiber yarns. Nexans and Dutch firm DSM Dyneema worked together to create a new higher strength, fatigue resistant ROV tether, called ENABLE, using bending optimized Dyneema, called XBO Technology, made with ultra-high molecular weight polyethylene (UHMWPE) fiber, also known as high modulus polyethylene (HMPE).**

**"We are constantly trying to improve our designs," says Karin Vaslestad, sales and marketing manager, Nexans. While the market is tough, introducing improved products with longer service life should be a focus for the industry, she says. "It is something we have wanted to do for years but we have not found fibers with the unique and improved characteristics as the new XBO Technology fibers."**

**Comparative bend cycle testing between tethers with Dyneema (SK78 XBO) and aramid, showed that Dyneema outperformed aramid with regards to fatigue, and retained constant physical characteristics over time, while aramid shows a significant loss of strength due to friction abrasion.**

**To extend service life, conventional tethers require multiple re-terminations during their service life. The cable sees a lot of load and compression forces leading to internal friction and wear, resulting in loss of strength.**

**The number of re-terminations needed for conventional tethers is dependent on the application, however, a rough estimate would be 5-10 re-terminations per 1800 hours, according to Nexans and DSM. For the ENABLE trial cable (operated by Fugro Subsea Services), no re-termination was needed up to 1100 hours. ▪**

**Carbon fiber, from bobbin to umbilical.** Photos from Nexans.

# Rethinking subsea pumping

**GE Oil & Gas is set to offer a new, compact take on multiphase subsea boosting. Elaine Maslin reports.**

By the end of this year, GE Oil & Gas hopes to make great strides towards having a new weapon in its armory. The firm is developing a multiphase, modular contra-rotating pump (MCP) under a joint industry project (JIP) that includes majors Total, Shell, Chevron and Statoil.

The concept draws on expertise from across GE's turbomachinery and aviation businesses, as well as making use of the GE Store concept, which leverages the firm's global research teams' combined knowledge. The MCP concept is also being pursued through GE's FastWorks approach – a fail-fast mentality of technology development, designed to help accelerate innovation.

The MCP, as the name suggests, comprises of contra-rotating impellers, which are spun around a shaft on process lubricated bearings, with each impeller, or stage, driven independently by a shroud of permanent magnet motors.

One of the main benefits of the design is that it doesn't need barrier fluid and is all-electric, which means it can be compact and doesn't need hydraulic lines, so umbilicals can be simplified for power and communications, says Alisdair McDonald, business leader, Subsea Power & Processing, GE Oil & Gas. It also doesn't need topside hydraulic power units or variable speed drives, etc. Rotor dynamic issues are avoided as a result of the static shaft and, because the impellers are contra-rotating, they're more efficient than conventional systems that use diffusers. The set-up takes up less space, too.

Each stage is powered independently, which means there's no limitation to the number of stages that can be added, although of course there would be a practical limit, McDonald says.

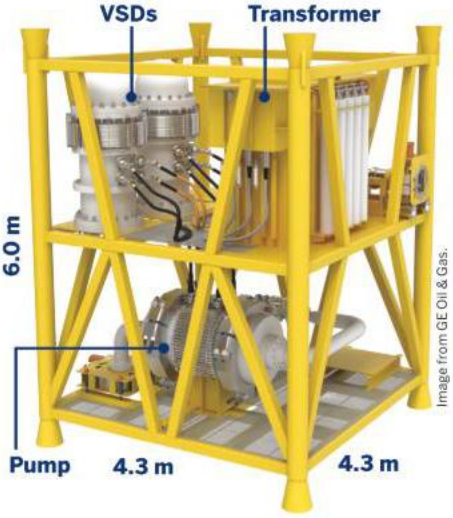



Image from GE Oil & Gas.

"For brownfields, where you want to pump late in life and don't have topside space for variable speed drives, hydraulic power units, etc., the MCP is an enabler," McDonald says. "Because of its compactness, its weight is much lower. We compared a conventional 15,000 psi multiphase pump with the MCP and it was 50% lighter, with the potential for up to a 50% reduction in topside footprint. We think it could be 20-30% cheaper than a conventional multiphase pump over life-of-field."

Because of its modularity, the MCP could be used in different ways, McDonald says, either by having a number of units, each with its own variable speed drive, tied into a hub, as a distributed system, with one power and communications umbilical, or dedicated boosting systems on shore tied back to individual wells.

"I can imagine a 1.5MW MCP on an individual well," he says, comparing the system to an electrical submersible pump (ESP). "Reliability is going to be much higher [than an ESP]. But, the system is really competing against conventional mudline multiphase pumps."

The concept for the pump was first unveiled in February this year, at GE's annual meeting in Florence, at which point Statoil and Total joined as initial phase partners. Since then, Chevron and Shell have also joined and an initial three phase demonstrator is being assembled at GE's facility in Bari, Italy. It is due to be validated through a series of tests by the end of this year.

"It's exciting because when we complete this project, the final product might not look exactly the same as it does now. Any learnings can be applied to the turbomachinery business, etc., and across other product companies within the GE portfolio," says McDonald.

The idea was developed after discussion between engineers based at GE's turbomachinery business, where work was underway on a conventional pump, and the aviation business. Inter-business unit collaboration is encouraged through the company's GE Store concept, which seeks out cross-pollination to drive technology breakthroughs, supported by scientists, engineers and researchers from across eight GE Global Research Centers.

"It's either a technology push or application pull that brings our teams together," McDonald says, "leading to a scenario whereby ideas and innovation can be shared and capitalized on across GE's different businesses."

The FastWorks methodology should also help rapid prototyping. "The FastWorks methodology is fail-fast, spend the minimum amount of money to develop a minimum viable product and test leap of faith assumptions," McDonald says. "If those assumptions are validated you go to the next stage. If it is not successful, you pivot and take a different approach or persevere. You're running it like a small startup business. But, one of the key things is that the customer is involved in the development process. They (Total, Chevron, Statoil and Shell) have a lot of operational expertise and, as part of the JIP, are integral to the decision-making process. We're not creating something in a vacuum, we're creating something essentially approved by the operator." OE

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# Brittle issues

**Balancing cost reduction with correct materials selection is key when it comes to problems such as hydrogen embrittlement, says William Hackett's Tim Burgess.**

Operators need to ensure that despite commercial pressures, the products used in the offshore environment are fully appropriate for their intended use.

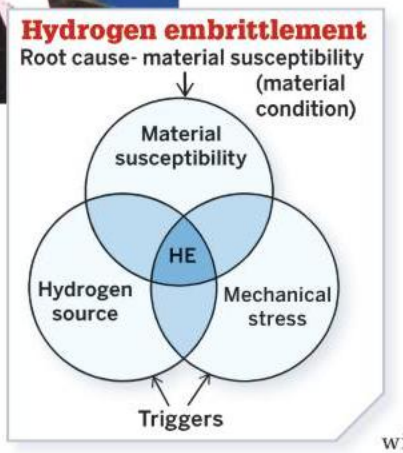
Standards and guidelines for the sector have continued to advance, based on accumulated knowledge, resulting in best practices being updated and then the standards that are applied to our sector converging and becoming harmonized. The application of these industry standards and guidelines is focused on how the product is intended to be used. But, having a detailed understanding of the properties of chain and links is equally relevant within the lifting offshore environment. Without the proper understanding, the end result is increased risk to operations.

Indeed, over the past two years, there has been a worrying increase in cases of hydrogen embrittlement impacting both chain and links, which are being used in lifting within the offshore environment. This has been the result of inappropriate product being used offshore, which may have been driven by cost cuts. This presents a huge safety implication, which could result in a catastrophic failure. The Hydrogen Embrittlement chart illustrates the implication of a failure, which also further highlights the need to fully understand the integrity of the product and also the traceability of the grade of steel used in production.

Hydrogen embrittlement is the process by which metals such as steel become brittle and fracture due to the introduction and subsequent diffusion of hydrogen into the metal and can also be described as stress corrosion cracking. For hydrogen embrittlement to take place, three elements are required.

Hydrogen can enter steel through the manufacturing process: steel making, heat treatment and finishing processes; and through the evironment: corrosion in water, cathodic processes linked to the pH content of moisture in the air.

The susceptibility of steel to hydrogen embrittlement is related to its composition, microstructure, strength and hardness, otherwise known as the material condition. It is important to note that the material condition is always the root cause of hydrogen embrittlement while the hydrogen source and the mechanical stress are triggers in the process.




As the hardness of a steel increases there is an increased risk of hydrogen embrittlement.

When high-strength steels are subjected to sustained tensile loads under normal ambient temperatures, dissolved hydrogen is attracted to the regions of high tensile stress.

As it diffuses to high stress regions, it is absorbed on planes of weaknesses, such as grain boundaries, where it reduces the attractive forces between the iron atoms. When the force required for de-cohesion of these plane is reduced to less than that required to cause plastic flow, slow cracking occurs. This is called stress corrosion cracking and is normally a result of hydrogen embrittlement.

## Mitigating the risk

While magnetic particle inspection can help to assess and in essence mitigate the risk of an incident occurring through hydrogen embrittlement, the risk is not eliminated and there is a cost attached to increased inspection schedules, which while safety is a critical concern, operators may not wish to bear.

The fundamental way to mitigate risk is to ensure that the product used offshore is suitable for that environment. This may appear an obvious statement to make, but it is critical to ensure that there is a clear understanding of how a product is going to be used and applied before it is exposed offshore.

For example, Grade 10, 12 or even higher master links are now being produced and all have a higher tensile strength and correlating hardness compared to lower grades. Using a higher grade product could reduce costs, if it were to replace a larger diameter product of a lower grade. The use of these products is totally appropriate for use in controlled industrial or construction environments, but not for the extreme conditions which steel is exposed to in the offshore environment, where they would face an increased susceptibility to stress corrosion attack.

To put this into context, a Grade 8 master link, when correctly heat treated, will provide toughness, tensile strength and resistance to shock absorption, at hardness levels that enable the steel within the product to withstand the extreme conditions of the offshore environment.

While the industry continues to face challenges of cost and operating in difficult environments, it is critical that there is a clear understanding on how products are being used to ensure that we all maintain the safety and performance within the sector. OE

***Tim Burgess** is managing director of William Hackett. He has run the lifting business since 1989 and then acquired the group business in 2008. Tim also sits on the Board of LEEA – the Lifting Equipment Engineers Association, which is the leading representative body for all those involved in the lifting industry worldwide.*

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# Reactivating valuable assets

**With the downturn taking many drillships off the market, ABS' Dave Forsyth and Landon Fields discuss how to bring those ships back up to speed when the market recovers.**

Sustained low oil prices have forced drilling contractors to lay-up assets, including deepwater drillships. According to *Rigzone*, 44 drillships have been stacked since the inception of the current downturn. These are sobering numbers, but the fact is that oil and gas is a cyclical industry, and a downturn inevitably is followed by an upswing in prices that will lead in time to demand for out-of-service assets. In anticipation of a market rebound, asset owners want to be prepared to reactivate units as rapidly as possible when they are needed.

The process of reactivating an asset is equally critical to the process of laying it up. After sitting idle, rigs need to be inspected to make sure they are fit for service before they can be reactivated, which poses a particular challenge for owners of high-specification drillships. Most of these complex assets are operated by programmable logic controllers with sophisticated onboard computer systems and advanced dynamic positioning systems. Owners want reactivation plans that are specially designed for each drillship so they can be sure the unit can be brought back into service as quickly and safely as possible.

## Plan in place

Part of a responsible plan for laying up a drillship is identifying the strategic steps required to bring the asset back into service. To help asset owners develop those plans, ABS has developed the *Guide for Lay-Up and Reactivation of Mobile Offshore Drilling Units*, which outlines how a survey would take place when the time comes to reactivate an idle asset. The basis of the plan factors in the amount of time the drillship has been in lay-up, major weather events such as severe storms, hurricanes or typhoons, corrosion that has occurred and any equipment that is found to be inoperable at the time of re-commissioning.

## Machinery and equipment

The inspection that precedes reactivation includes an extensive review of machinery and equipment. Drilling systems including the blowout preventer stack control system, derrick skidding system, braking system, heave compensation and riser tensioning hydraulic systems are checked for contamination or chemical degradation. Any system that is unserviceable is drained and sterilized if bacterial deterioration is present before being refilled with new oil or fluid. Prior to reinstallation, the drilling and well control equipment are thoroughly examined to verify that all equipment is in proper working condition.

Within the scope of machinery, the ballast system and bilge pumping arrangements are tested along with all watertight and weathertight doors, fire dampers, ventilators, hatches and closing devices. The survey inspection also involves cleaning and flushing potable water tanks. Diesel engines and

**Safe and rapid reactivation following lay-up is a top priority for owners of high specification drillships.** © am70/Shutterstock.com

accessory gears are selectively opened and examined for corrosion, excess wear, damage, proper tensioning and torque. The drillship's low-speed engine crankshaft deflections are recorded, and protective trips and alarms are verified. As with the drilling equipment fluids, engine lubricating oil, stern bearing and steering system hydraulic fluids are analyzed for contamination.

**An extensive review of machinery and equipment is critical before a drillship is redeployed.** © am70/Shutterstock.com

Drillships that have experienced extreme events while laid up require a nondestructive trial of the underwater connections and an underwater examination of the hull and thruster system to determine if it is necessary to remove any marine growth. On the surface, cleaning underneath the drillship might appear to be an insignificant step in the reactivation process, but it is critical that no foreign objects compromise operations. A mooring system that is blocked or clogged will not function properly.

When a drillship that has a mooring system is being reactivated, it is critical to test the system to determine its ability to hold the drillship in place in real operating conditions; so evaluations of holding capacity have to be carried out using relevant wind, waves and current data. The dynamic positioning system also undergoes a full failure mode effects analysis (FMEA) trial to confirm that all of the systems are fully operational. If there have been any changes in the software that enables communication between systems, the FMEA trial will bring it to light, and any failures will be corrected prior to drilling. Testing provides a complete performance evaluation of the dynamic positioning system that includes all operation modes with simulations of different failure conditions.

Mooring chains, fairleads and anchors also are operationally tested before the vessel is reactivated. For a drillship that has spent more than five years in lay-up, it is prudent to check any mooring chains that are used for permanent mooring and to test fairleads using nondestructive examination.

## Hardware and electrical systems

Today's drillships are equipped with the latest and most advanced computers, which means a pre-activation survey has to make sure the onboard computer system hardware is functioning properly.

During the time the drillship has been in lay-up, computer systems may have been subjected to software updates that haven't been tested to determine if the changes to the software will have an unexpected impact on operations.

A computer is responsible for activating thrusters in the dynamic positioning system to keep the drillship in place and to monitor winds and waves to adjust the thrusters accordingly. Hardware has to be tested for compatibility with the software to confirm all of the functions are operating correctly. It is critical to ensure there are no computer glitches before a drillship is redeployed. Because equipment that has not been in operation for a period of time can be affected by moisture and corrosion, it is important to evaluate functionality. For onboard electrical systems, this means inspection should be carried out on insulation resistance for all power and lighting circuits as well as generators, motors and switchgears to isolate deficiencies. Testing includes lighting, fixtures and instrumentation in hazardous areas and all fire and gas detection systems to confirm that everything is in working order.

## The value of a plan

Depending on its status and condition, a drillship can take one to two months to reactivate safely. Having a systematic plan in place expedites the process and allows owners to get these valuable assets back into service safely.

For drillships with an average cost of US$600 million, getting them back on contract in good working condition is a top priority for owners. **OE**

***Dave Forsyth** is chief surveyor/offshore for ABS in the Corporate Classification department. He has been with ABS for more than 36 years. During his career, Forsyth has held the positions of surveyor, senior surveyor, principal surveyor, and assistant chief surveyor/offshore. He holds a BS in marine engineering technology from Mississippi State University.*

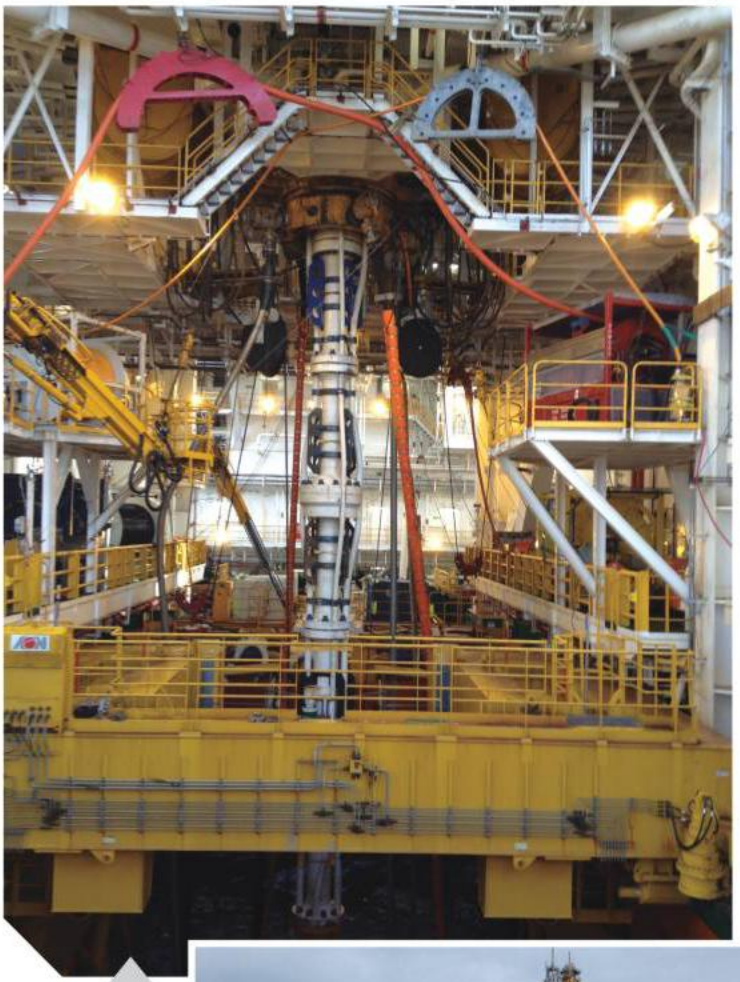
***Landon Fields** is divisional lead surveyor offshore of North America for ABS. In his current role, Fields provides guidance and oversees classification and statutory survey work. He verifies that surveys are in compliance with ABS rules, guidelines and statutory requirements. Fields has more than 20 years of experience in the offshore industry.*

# Preparing for pre-salt

**Jerry Lee speaks with Seadrill to discover how the firm prepared for drilling operations on the giant Libra field offshore Brazil.**

Drilling in pre-salt geology presents challenges on which Brazilian operator Petrobras has spent years working. When selecting the approach to the giant Libra field, offshore Brazil, the operator chose sister drillships from Seadrill, to assist in unlocking the field's potential.

The Libra field, 183km south of Rio de Janeiro, covers 1547sq km in the ultra-deep waters of the Santos Basin pre-salt. Discovered in May 2010, in about 2000m water depth, the field contains an estimated 8-12 billion boe of reserves in pre-salt limestone coquina reservoirs. Though the prize is large, getting to it is a challenge.



**RGH (riser gas handling system) riser joint in the moonpool during running.**
Photos from Seadrill.

Before the salt layer, the drilling challenges are the very narrow drilling margins resulting from the difference in the fracture- and pore-pressure, says Jay Lancaster, managed pressure drilling (MPD) and well control technical superintendent, Seadrill. Due to this narrow window, applying too much bottomhole pressure (BHP) can cause fractures and losses of expensive drilling fluid; applying too little BHP can cause influx or even kicks, which may lead to blowouts.

Following the post-salt section, the well will have to pass through a thick salt layer, which can be a problem because it creeps, so drilling and casing must be done quickly. After the salt layer, the challenges of drilling in the pre-salt section become two-fold: large vugular carbonate sections, which are known to be loss zones, and greater pressure uncertainties.


**Seadrill's *West Tellus* drillship, which was built by Samsung Heavy Industries in 2013.**

With these challenges in mind, the Libra consortium – Petrobras (40% interest, operator), Shell (20%), Total (20%), CNPC (10%) and CNOOC (10%) – offered drillship tenders in 2014 and awarded two, two-year contracts, with the option for two-year extensions, to Seadrill's *West Tellus* and *West Carina* ultra-deepwater drillships.

The *West Tellus* and *West Carina* are sixth generation DP3 drillships built by Samsung Heavy Industries in 2013 and 2014, respectively. Both are capable of operating in 12,000ft water depth. But, what sets these vessels apart are that the MPD systems are fully integrated as part of the vessels' drilling systems. The equipment offers greater efficiencies, technically and financially, than temporary MPD kits, and was the main driver behind Petrobras awarding the contracts, says David Gouldin, drilling and well control manager, Seadrill. With their integrated MPD systems, the *West Tellus* and *West Carina*, will be able to convert between the two MPD variations essential to drilling the field: constant bottomhole pressure (CBHP) and pressurized mudcap drilling (PMCD).

MPD can help address both the post-salt and pre-salt challenges that Libra faces. In the post-salt section, CBHP can prevent influxes and losses while navigating through the narrow drilling windows. The MPD system compensates for the loss of frictional pressure when pumps are turned off while drillpipe connections are being made. The MPD choke can be adjusted to decrease or increase BHP, to stay within the drilling window. In the pre-salt section, the vessels can switch to PMCD to address loss zones. With PMCD, sacrificial fluid (e.g. sea water) is pumped down the

drillpipe to fill the pores of the loss zone, while mud is simultaneously pumped into the annulus to keep it full – to maintain communication with the bottom of the well and the necessary hydrostatic pressure – allowing drilling operations to continue.

To enable these capabilities on the *West Tellus* and *West Carina*, Seadrill contracted Weatherford to supply the equipment needed for the MPD systems, particularly an MPD riser joint, which is comprised of a rotating control device, an annular isolation device and a MPD flow spool, as well as the associated MPD ancillary equipment and piping needed to be able to perform MPD operations. Seadrill also invested more than 5000 man-hours into training the crew.

"Everyone had some form of training on the rig so there was full understanding of what we were doing," Gouldin says. "At the time, it seemed a bit over the top, but understanding the campaign we were going to start gave a lot of confidence to the crews."

With the MPD equipment fully integrated in Q2/Q3 2015, the *West Carina* began drilling its first well in August 2015, Lancaster says. The well, 3-RJS-739A, is south of the Libra discovery well, 2-ANP-2A-RJS, in the northwest area of the Libra block. While the newbuild had only recently had the equipment integrated into its system, it was immediately put to use due to the narrow drilling margins at that well. Pre-drill estimates put the pore pressure at about 10ppg, however, when the mud weight was increased to an equivalent circulating density of 10.2ppg, losses were seen, so the crew knew they were dealing with about a 0.2ppg window. As a result, the equivalent mud weight was reduced to 10.16ppg which reduced losses and allowed drilling to continue, Lancaster says.

Petrobras announced in a February 2016 that the well intersected ca. 270m column of 28° API oil. The reservoir had excellent productivity and was in communication with other wells in the area.

The *West Tellus* began drilling its first MPD well in September 2015, Lancaster says. Also located in the northwest area of the Libra block, the well, 3-RJS-741, is 8km northeast of the discovery well. While drilling the well, high loss conditions came on unexpectedly, and light annular mud was not available on the field. With the high losses, the well would have been a prime candidate for PMCD, Lancaster says.

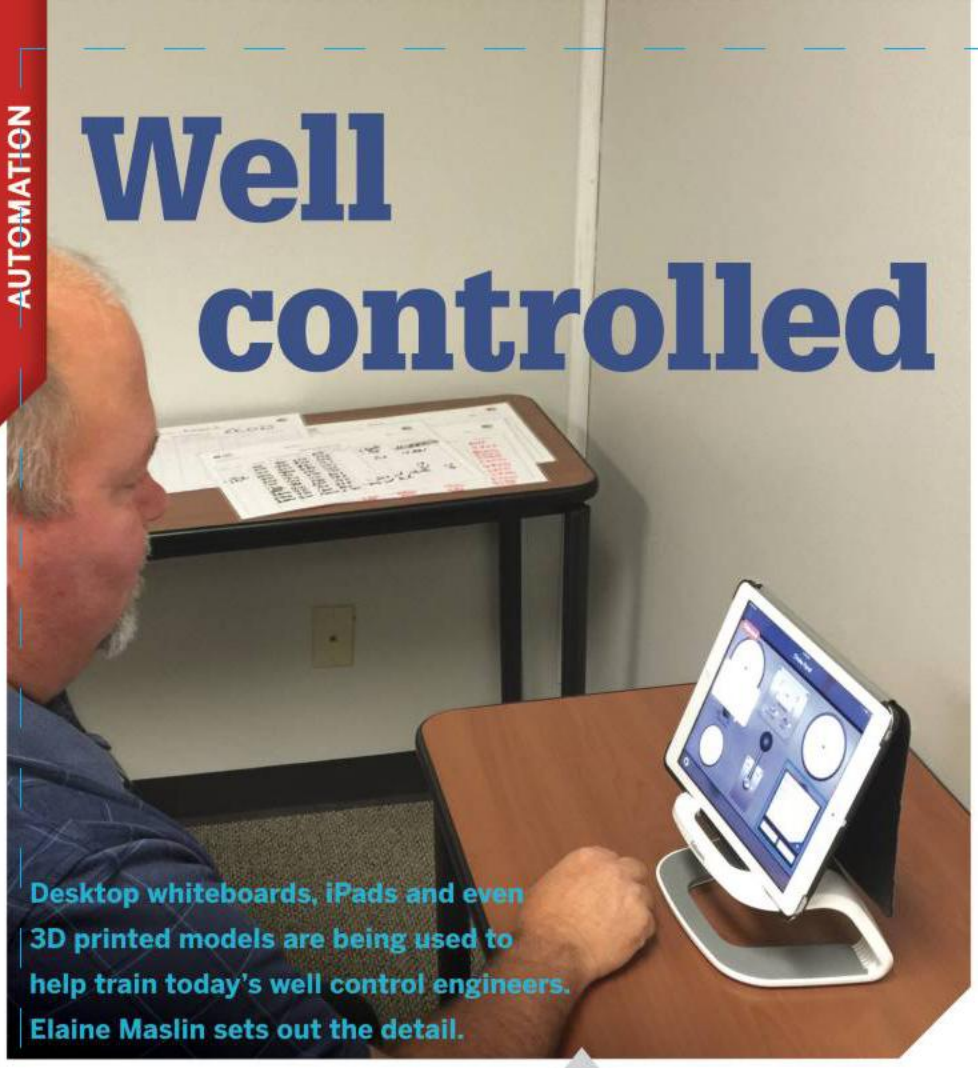
"Though 30,000bbl of mud were lost, the well had good show and is expected to be put online," Lancaster says. "Without the MPD system that well would not have been drillable."

In March 2016, Petrobras announced that the well encountered a 301m column, the biggest discovered on the field at that time, of 28° API oil and excellent productivity.

Together, the vessels have completed operations on four wells on the field, with and without MPD.

Since the Libra field was discovered in 2010, seven wells have been drilled with the seventh well, appraisal well 3-RJS-742A (NW2), completed in June 2016, Petrobras announced that same month. NW2 is currently the largest discovery on the field to date, with 410m of net pay, showing 27° API oil. Petrobras also announced in June that the eighth appraisal well, 3-RJS-743A, is being drilled in the northwest region of the block. **OE**

# Well controlled



**Desktop whiteboards, iPads and even 3D printed models are being used to help train today's well control engineers. Elaine Maslin sets out the detail.**

**From the comfort of your iPad.** Photo from Learn to Drill.

Well control training has come a long way in the past five years since the 2010 Macondo disaster. In the years since, the International Association of Oil & Gas Producers' (IOGP) Report 476 of 2012 called for enhanced well control training, and the International Well Control Forum (IWCF) has provided new training guidance. Training is taking on a plethora of new forms and now includes human factors and team-based scenarios.

Full scale simulators are being used, as well as a string of other new systems. But, simulation-based training also comes in the form of iPads/tablets, desktop white boards, 3D printed models, and on standard PCs. A few of these were on show at the IWCF's Well Control Workshop, as part of the Offshore Well Intervention Europe conference in Aberdeen earlier this year.

David Conroy, chief technical officer, at the IWCF, says that while well control events during drilling, such as kicks, have been reduced thanks to improved training, focus has shifted to activities during operations other than drilling, such as casing running, preparing the well for completion or pulling out of hole with a perforation string, during which about one-third of all kicks occur.

"It is much more difficult to detect an influx during these types of events as the drill crew are not the only people operating on the well. Regular training can't prepare the drill crews for these 'abnormal' situations," he says. "Most often the well operations being performed will have an impact on the fluid volume of the well, meaning careful and accurate monitoring of well fluid volumes during these critical operations is essential for early influx detection."

In 2015, IWCF provided the industry with guidance on enhanced well control training aimed at providing a curriculum more suited to these kinds of well control issues. It has been working with a number of firms to implement this enhanced training, during which classroom learning is reinforced with practical, simulator-based training, using data from real-life 'abnormal' well control events that have either occurred or could have escalated into a more serious event.

"Developments in simulator technology have changed how training can be delivered, even in the last few years," Conroy says. "Simulator training also offers greater flexibility than other teaching methods and there is the capability to simulate the equipment the crew will be using, allowing them to practice exactly how they would respond in a real-life situation."

But, Conroy also thinks simulator training will be enhanced even further in future, exploiting modern technology to make scenarios more realistic and to further incorporate the team environment, recognizing the fact that well control events involve a large team of rig site- and office-based staff.

## Learn to Drill

US-based Learn to Drill has developed an iPad-based workover- and well intervention-focused well control simulator, with the goal of helping to increase simulation access time.

Accessible from the iTunes App Store, the simulator can be downloaded by anyone onto their own tablet or (soon-to-be) smartphone device. It can be accessed for unlimited review and refresher before, during, and after a well control class, allowing students to practice challenging and complex well control scenarios.

The simulator includes a series of simulations, ranging from manifold line-up to kick detection and driller's method, all designed to match the IOGP standard of all well control simulations required for effective training.

It was developed by the company's founder, young entrepreneur Ruchir Shah. In 2011, while studying at Rice University in Houston, Shah was doing research on the BP Macondo blowout. "Through my research, I realized one of the biggest causes of the incident was ineffective training in well control," he says. "In college, I had a lot of background with education and technology as founder of EZ Comics, [a non-profit app] that made history interesting for kids [The work led him to speak about 'ideas worth sharing' platform TEDx]. I wanted to see if there were any ways that software and technology could improve oil field training."

He attended a classroom-based well control class, "and hated it," he says. "It was extremely boring and I didn't learn anything and was left with so many questions," he added. After graduation, he took

a job as a trading analyst, and worked part-time on his training app idea, working with the International Association of Drilling Contractors (IADC), the IWCF and the accredited syllabus.

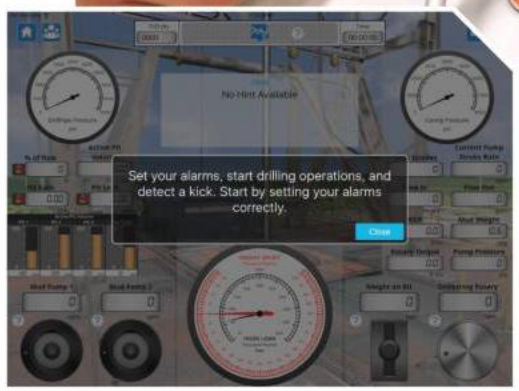
Shah hired animators and drew on a network of consultants to help with technical issues and, in Fall 2013, started working full-time on the project. He's since been making sales, including to Noble Drilling, Halliburton and Schlumberger, developed 15+ accredited courses, a series of refresh course apps, opened an office in Mumbai, India, and has a global partner, Falck Safety Services.

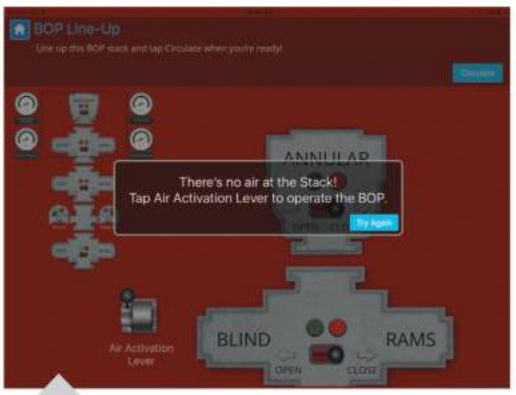
Every simulation exercise on the app comes in three modes, Learn Mode, which has animated e-learning content and theory, Practice Mode, which guides students through the simulation with a virtual instructor, and Test Mode, which runs through the exercise with all hints and help removed. In Test Mode, scoring is given according to IADC grading guidelines.

"So far, the simulation exercises have been used by several hundred students in Learn to Drill's online IADC Accredited Workover and Well Servicing well control courses," Shah says. "In addition, many operators have expressed a desire to use the simulations as a competency tools: pushing students' simulation exercises to review and refresh procedures offline, at the rig site offshore.

"Initial results have been a huge success – students love the layout of a tablet- an interface they already understand – and they love being able to simulate for an unlimited amount of time. Instructors love the knowledge students gain from practicing in an interactive way. And companies love that they can track student competency in the field, in between the two-year well control training cycle."

Future plans include a much more extensive simulation suite with an added focus on coiled tubing, wireline, and snubbing as well as full multiplayer capabilities and accessibility on Android.



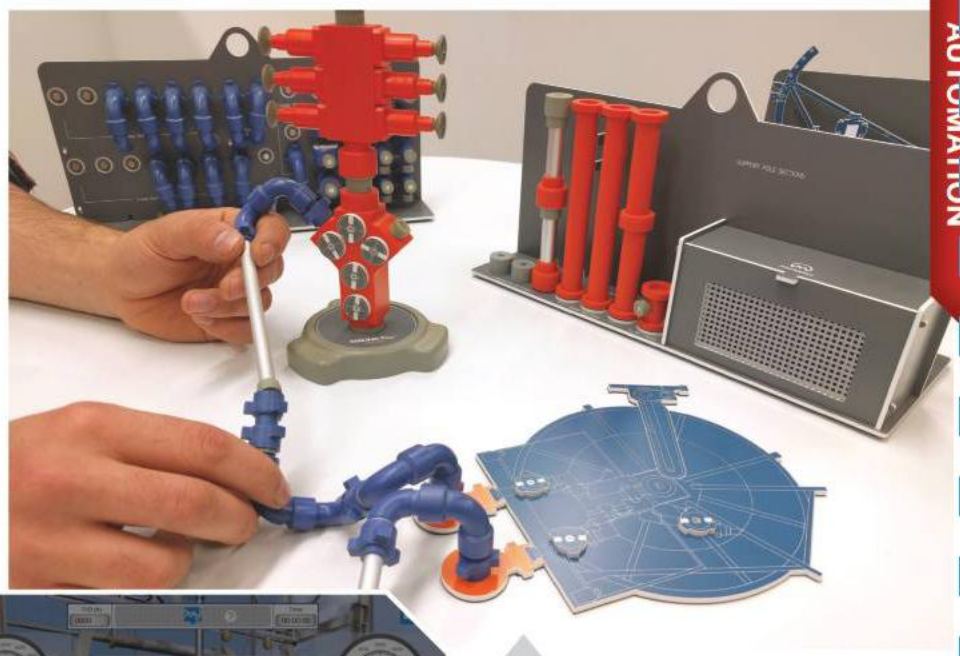

**Online learning.** Photo from Learn to Drill.

## Desktop learning

Aberdeen-based Marketec has something more hands on. The firm's Scenario Learning System (SLS) uses a dry-wipe surface with system models, which are used with exercise scripts for simulation exercises – together called tabletop simulation exercises.

Bruce Adam, Marketec's operations director, says that role-based scenario training and tabletop simulation are versatile and flexible methods of training and assessment used widely in other industries, such as medical/healthcare, military, emergency services, etc.

"Perhaps the closest example is the military sand box, used for both training and planning, i.e., it's not just a training tool; it is a method of preparing for a mission/deployment," Adam says. "In this application they shape and profile the sand to create a representation



**Marketec's desktop models.** Photo from Marketec.

of the terrain. A good understanding of terrain is crucial for planning offensive/defensive tactics.

"The SLS table and components are designed to provide similar features/benefits, but using a magnetic dry-erase surface, we can build up the 'terrain' (i.e., equipment and systems) applicable to engineers and drillers using models and props. In team or work group training, this enables everyone to see/share the same mental model, eliminating confusion and ensuring focus is maintained on the relevant area."

Furthermore, the tool helps improve team performance, he says, a key area for improvement in the industry, alongside communication, leadership and situational awareness. "I think we need to shift our perspective of training from 'what people should know' to 'how can we help people contribute to the performance of their team/crew/work group.' Sure, they must know stuff, but we should focus more on doing and practicing."

So far, Marketec has done pilot tests and demonstrations and there's good interest, but it's a difficult environment to sell into right now, Adam says, with little being spent on training and recruitment. The firm launched the SLS Table and Tabletop Simulation concept in late 2014, "just at the point when the industry perspective on recruitment, training and skills development flipped from 'need all the help we can get' to 'don't need anything/can't spend any money,'" Adam says. **OE**

# Arctic

# Cold comfort

**While it seems most Arctic exploration activity has slowed, it really depends on where you look. Bruce McMichael reports.**

**Gazprom Neft's Prirazlomnoye facility, in the Russian Arctic.**
Photos from Gazprom Neft.

About 22% of the world's undiscovered oil and natural gas reserves are believed to lie within the Arctic Circle. Huge technical, environmental, and legal challenges suggest that this figure is unlikely to change in the short- to medium-term, while a rolling series of good news, bad news stories has created a "will they, won't they" atmosphere of development.

With the ongoing impact of US-produced shale gas and oil, volatile global prices and the legislative fallout of environmental disasters such as the *Deepwater Horizon* disaster of April 2010 in the Gulf of Mexico, exploration sputters across the Arctic.

Opening up remote, challenging frontier areas such as the Arctic brings significant logistical challenges ranging from using nuclear-powered icebreakers to cut through meters of pack ice sheets to delivering equipment from drilling rigs to pipes, chemicals and people. Communications are complicated and expensive, generally requiring satellite connections, and remote medical services are likewise expensive and complex to arrange. Wherever you are in the Arctic, it's a frontier play without infrastructure.

## Discovery to production

On average, fields in the Arctic region have taken 13 years from discovery to production, one of the longest industry lead-times. To date, close to 40 fields have been developed from an estimated 180 discovered fields, onshore and offshore.

This estimate, by the US Energy Information Administration, puts potential assets in territory claimed by littoral states and a couple of extras: Russia, the US, Norway, Canada, Denmark (Greenland), Finland, Iceland and Sweden. Finland and Sweden do not border the Arctic Ocean and are the only Arctic countries without jurisdictional claims in the Arctic Ocean and adjacent seas.

To date, most exploration and development has been in frontier areas close to existing infrastructure or offshore, including the Russian and Norwegian sectors of the Barents Sea, Sakhalin Island in Russia's far east, and Alaska's Beaufort and Chukchi Seas.

The high profile exit of Shell from its Alaskan exploration program in the Chukchi Sea earlier this year and French oil major Total's decision to relinquish its 25% stake in the Shtokman Phase 1 field development in the Russian sector last year created the impression that big oil was backing away from Arctic development.

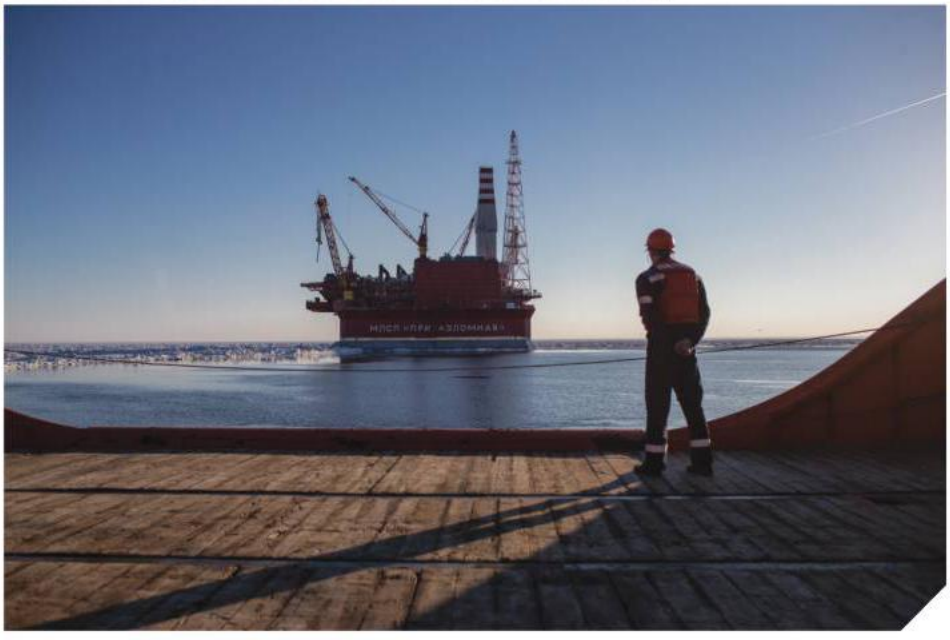
However, activity in the Russian sector of the Arctic has continued. Norway is also an aggressive investor, with around one-third of offshore spend in the Arctic expected to originate from Oslo and Stavanger, according to a 2012 report by Infield. It said, in the latter part of a 2012-2018 forecast period, most of the projected spending would be on the back of the Eni-operated Goliat project as well as the development of Statoil's Johan Castberg development, (*See an update on Johan Castberg on page 56 of this issue*).

## Russian expansion

Much of Russia's investment has been in the sub-Arctic region, in fields surrounding Sakhalin Island. This area was expected to draw around 20% of Arctic area spending capex in 2012-2018, according an Infield report.

Russian focus has also been on the Russian Arctic continental shelf. In 2013, the Prirazlomnoye facility came onstream. It is expected to yield 5 million-ton of Arco (Arctic Oil), a high density, high sulphur oil, between 2016-2017.

"The Prirazlomnoye project has yet to reach its design capacity. There are plans to drill and launch nine extraction

wells in 2016-2017, which would produce more than 5 million-ton of oil," said Minister of Natural Resources and Environment Sergei Donskoi, in June 2016.

This summer, Gazprom Neft said two further production wells (its third and fourth) had come online at Prirazlomnoye, plus the second and third injection wells. As a result, production had breached 6000-tonne/d. In total, some 32 wells are expected in the field.

In 2014, Rosneft also made the Universitetskaya-1 (Victory) discovery in the Kara Sea, with partner ExxonMobil, despite EU and US sanctions.

However, progress in the Russian Arctic could be slowed by a recent government decision to ban new licenses for offshore field development on the continental shelf. The decision appeared to be aimed at focusing the country's efforts on gas production from existing developments, such as those in the Yamal Peninsula area, focused on LNG development, given global trends towards resource use and amid "the macroeconomic instability we face right now," Donskoi told a mid-September meeting with Russian President Vladimir Putin. Gazprom and Rosneft are currently the only firms allowed to hold offshore exploration and production licenses.

## Alaska start and stop

Supermajor Shell drilled its Burger J exploration well in the Chukchi Sea, offshore Alaska, in July 2015, and while shows of oil and gas were reported, they were not found in sufficient quantities to justify spending more on top of the US$7 billion already invested over two drilling campaigns. Operations were abandoned within a year.

At the end of 2015, the US government "froze," at least until the end of 2016, exploration drilling off the coast of Alaska, while revoking existing permits (Shell until 2020 in the Chukchi Sea and Norway's Statoil until 2017) in the Beaufort Sea.

Then, just before May 2016, Shell and ConocoPhillips officially pulled out of Arctic exploration, and the acreage was returned to the US government shortly ahead of a 1 May due date to pay rent to keep holdings that lie in the Chukchi Sea north of Alaska. However, Shell held onto the lease containing the Burger J find, at a potential cost of $132,456 over the next four years, according to Curtis Smith, a company spokesman, because there is "value in the data the company gathered during its 2015 exploratory drilling."

Companies generally have to give the US government the geological information they glean from oil and gas development in federal waters, but they can get an extra 2-10 years to turn over that data as long as they still hold the territory.

Other companies that relinquished rights include Statoil, which had a sizeable chunk of 16 leases, Italy's Eni (four leases, Chukchi Sea) and Canada's Iona Energy (one, Chukchi Sea).

Shell said it had indefinitely halted oil exploration in the US Arctic, although it is hoping to get a lease extension from 2017.

In the 2017-2022 US offshore leasing program, there are leases available in the Beaufort Sea scheduled for 2020, and Chukchi in 2022, however it remains to be seen if the sales will continue. Industry associations have called for the US

# Arctic

**The *Noble Discoverer*, used by Shell in its last Alaska drilling campaign.** Photo from Shell/Flickr.

government to have the leases remain in the program.

## Canada

In 1996, offshore the eastern coast of Canada, the ExxonMobil-operated Hibernia platform was installed on the seabed, 315km southeast of St. John's, with an expected lifespan of 20 years. However, ongoing development of satellite fields, including the Hibernia South Extension, have significantly increased oil reserves, and production is now expected to continue for a further two decades years. The ongoing success of Hibernia is expected to encourage further exploration drilling and the company now has successfully bid for more than 1.5 million hectares of offshore licenses.

First oil production at Exxon's Sable Offshore Energy Project (SOEP) started in 1999, the development of five natural gas fields near Sable Island, 225km off the east coast of Nova Scotia. Field decommissioning is expected to start in 2017.

## Barents Sea

The Norwegian Petroleum Directorate estimates that the Barents Sea holds almost half of Norway's undiscovered 18 billion bbl of hydrocarbons. While less hostile than other parts of the Arctic, due to the regional effect of the Gulf Stream weather system, the Barents Sea remains a remote area with minimal infrastructure and only two fields in production to date: Statoil's Snøhvit subsea gas field and Eni's Goliat floating oil project.

Norway is getting closer to the development of other regional fields, among them Lundin Petroleum's Gotha, with an expected 100 MMboe in reserves, and Johan Castberg, which is believed to hold 550 MMbbl, with a green-light production cost of above $45/bbl (*OE*: August 2016).

A third discovery in the Barents Sea is Wisting. In May, Austria's OMV announced it had successfully completed drilling and testing of its Central II appraisal well on Wisting. The horizontal well was drilled about 310km north of Hammerfest and is the northernmost oil discovery in Norway. Wisting Central II is the fifth well in the production license (PL) 537, which was awarded in the 20th licensing round in 2009.

More exploration could follow, thanks to the 23rd licensing round, which saw three new license areas issued in the Barents Sea, acreage previous out of bounds to the industry, alongside seven other licenses. Statoil won four operated licenses, Lundin picked up three operated licenses, and Det Norske, Centrica and Cairn Energy, were each awarded one operated license.

In August, Statoil announced it will conduct a major exploration campaign in several parts of the Barents Sea in 2017.

"For 2017, we see promising prospects in different parts of the Barents Sea. For example, we want to explore the Blåmann prospect in the Goliat area, Koigen Central in PL718 on Stappen High and the Korpfjell prospect in PL859 that was awarded in the 23rd licensing round," said Jez Averty, Statoil's head of exploration on the Norwegian continental shelf, at the time.

## Shallow waters

Engineers have built gravel islands from which oil is produced in shallow waters offshore Alaska – including Texas-based Hilcorp's Northstar Island and Eni's Spy Island.

Hilcorp is also planning the Liberty project, approximately 5.5 mi (8.6km) offshore in the Beaufort Sea's barrier islands in 6m of water. If developed, Liberty would be the first producing oil-field entirely in the federal outer continental shelf off Alaska. According to US Bureau of Ocean Energy Management (BOEM), Hilcorp estimates that the Liberty contains approximately 150 MMbbl of recoverable crude oil.

BOEM is conducting an environmental review of the project and expects to release a draft Environmental Impact Statement next summer, said John Callahan, a spokesman for the agency. **OE**

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# Arctic

# Being **responsive**

**Joe Mullin gives an update on the Arctic Response Technology joint industry project.**

**Workers conduct field trials of the first-of-its-kind aerial oil spill response system near Fairbanks, Alaska.**
Photos from Arctic Response Technology.

The oil and gas industry has a wide range of viable technologies, beyond mechanical recovery, for oil spill response in the presence of ice in open water.

The key characteristic that distinguishes the Arctic from other oil and gas production areas in which industry has operated is the presence of ice.

Ice conditions can vary substantially throughout the Arctic, depending on the season and location. The need to adapt to these conditions in turn drives selection of options for effective response. Operational challenges for Arctic oil spill response include: remoteness, low temperatures, seasonal darkness, and the presence of seasonal sea ice. While the industry remains focused first and foremost on preventing any oil spill in the Arctic, it is also committed to be prepared for a spill, however unlikely.

To build on the existing research and continue improving the technologies and methodologies for Arctic oil spill response, a joint industry program (JIP) was established in 2012, sponsored by nine international oil and gas companies (BP, Chevron, ConocoPhillips, Eni, ExxonMobil, North Caspian Operating Co. (NCOC), Shell, Statoil and Total).

Its members work collaboratively to create international research programs to further enhance industry knowledge and capabilities in the area of Arctic oil spill response, advance Arctic oil spill response strategies and equipment, and increase understanding of the potential impacts of oil and oil spill response methods on the marine environment.

As the largest program dedicated to this area of research, the JIP has engaged the world's foremost experts on oil spill response, development, and operations from across industry, academia, and independent scientific institutions to perform scientific research to address the differing aspects involved in oil spill response. This includes the methods used, and their applicability to the Arctic's unique conditions. The core

research themes cover dispersants, environmental effects, trajectory modeling, remote sensing, mechanical recovery, and in-situ burning (ISB).

## Technological advances

The JIP has so far delivered improvements in remote sensing, oil slick ignition and trajectory modeling. A significant achievement has also been in the area of herding agents (herders).

Herders work by rapidly spreading across a water surface to create a surfactant monolayer that reduces the water surface tension. When the surfactants reach the boundary of a thin oil slick, they affect the balance of surface forces acting at the edge of the slick and cause the oil to contract to a new, thicker equilibrium state. The slick thickness produced by herders, at 3-5mm, provides favorable conditions for effective ignition and ISB without the need for containment booms.

**Ignition of herder oil slick with the Helitorch.**

There have been decades of studies, extensive laboratory and field research on the use of herding agents, which has proved they can provide an additional tool to support the use of ISB as an effective response strategy in ice-covered and open waters. Herder research has continued under the auspices of the JIP with the development of an integrated herder delivery and aerial ignition system, with field research experiments conducted in Alaska and offshore Norway.

ISB has been considered a primary spill counter-measure for oil spills in ice-affected waters for over 40 years, from the start of offshore exploration and production in the Beaufort Sea in the 1970s.

## Field research

In April 2015, the JIP conducted a series of first-of-their-kind tests of an aerial oil spill response system for the Arctic offshore in a purpose-built test basin at the Poker Flat Research Range outside Fairbanks, Alaska.

With the purpose to validate the use of herders in combination with ISB when both are applied by helicopter, five releases of Alaska North Slope (ANS) crude oil, were conducted using a variety of delivery platforms to spray herders and then ignite the herded slick. The aim was to develop a rapid response aerial system that enhances responders' ability to use offshore ISB in drift ice conditions.

The tests successfully demonstrated that applying herding agents and subsequently igniting a free-floating oil slick using equipment mounted on a helicopter is feasible. The JIP used the results from the Alaska test program to initiate a new project to develop and test an integrated herder delivery and ignition system, which will allow both functions to be employed in one flight without landing or hovering to pick up another load. The system will be flight tested and then approval sought from the Federal Aviation Administration and the European Aviation Safety Agency.

## Step change in response

Aerial application of herders to enable ISB without booms is potentially a significant advance for offshore oil spill response in both open water and ice. This technology will have the ability for aerial application of both the herding agent and ignition source (igniter) and as such, becomes an extremely rapid and effective new response tool, which can potentially achieve high removal efficiencies in remote areas with faster response times.

## Transfer of technology

Realizing an opportunity to transfer herder and ISB technology, the JIP recently participated in the 2016 Norwegian Clean Seas Association for Operating Companies (NOFO) oil on water exercise conducted offshore Norway. These field trials were conducted to validate the use of herders in open water conditions and to examine the ability of herders to dampen breaking waves to determine if herders can increase the window-of-opportunity for ISB.

## Conclusions

Results from the JIP have highlighted the large body of existing knowledge supporting industry Arctic oil spill preparedness with a wide range of viable oil spill response technologies in the presence of ice in open water beyond mechanical recovery.

Research underway is advancing dispersant effectiveness; improving capability for modeling the fate of dispersed oil in ice; extending understanding of the environmental effects of an Arctic oil spill; advancing oil spill modeling trajectory capabilities in ice; extending the capability to detect and map oil in darkness, low visibility, in and under ice; aerial ignition of oil spills; and developing new capability to use herders to expand the "window of opportunity" for ISB response operations.

Sixteen research reports are available on the JIP website (arcticresponsetechnology.org) with fifteen additional reports expected in the near future. The JIP will complete all research projects on or before 31 December 2016 with reporting and manuscript submission to peer reviewed journals continuing through Q2 2017. **OE**

***Joe Mullin** has more than 40 years of scientific research and program management experience in the areas of marine science, oceanography, and oil spill response. Following his retirement from the US government, he was hired as the program manager for the Arctic JIP.*

Arctic

# Keeping up with Arctic regulations

**Jerry Lee looks into Arctic-rated safety equipment that seeks to make it easier to comply with regulations around the globe.**

Operating in the Arctic can be tough. There are extreme weather conditions and short operating windows in remote locations, but also stringent rules and regulations. Not much can be done about the first two, but companies are aiming to help operators with the last and one firm, at least, has successfully done so in the Russian and US Arctic.

In July this year, the US Bureau of Safety and Environmental Enforcement's (BSEE) new well control rule went into effect, requiring several changes to increase safety and ensure reliability of well control-related equipment. The rule called for expanded accumulator capacity and operational capabilities for increased functionality: 30 CFR Part 250 § 250.734(a)(b). Trendsetter Engineering is looking to address these changes with its subsea accumulator module (SAM), which can augment existing hydraulic capacities for subsea equipment.

"A SAM is basically a store of subsea hydraulic power for the purpose of providing pressurized hydraulic fluid to the desired operation through flexible hoses or flying leads, which are installed by a remotely operated vehicle (ROV)," says Brett Morry, global technical manager, Trendsetter Engineering.

Hydraulic fluid is stored and pressurized in accumulator bottles – piston or bladder type – which have been pre-charged with nitrogen gas. When opened, the nitrogen causes the hydraulic fluid to be pushed out at the desired pressure and rate; to compensate for greater water depth, the accumulators can be pre-charged with more nitrogen.

Trendsetter's SAM is designed with 40 accumulator bottles, pressure regulators (as necessary), hotstab flying leads, a structural frame with the capacity to carry tubing, and a mudmat foundation consisting of a skirt

**Arctic capping stack with remote BOP control and intervention subsea accumulator module.** Photos from Trendsetter Engineering.

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# Arctic

and hydraulically-operated mud wings for soft soil conditions. The SAM can be installed on the seafloor, typically within 250ft of the subsea equipment it will augment. It can be operated by a single ROV, or using hydraulic or acoustic controls.

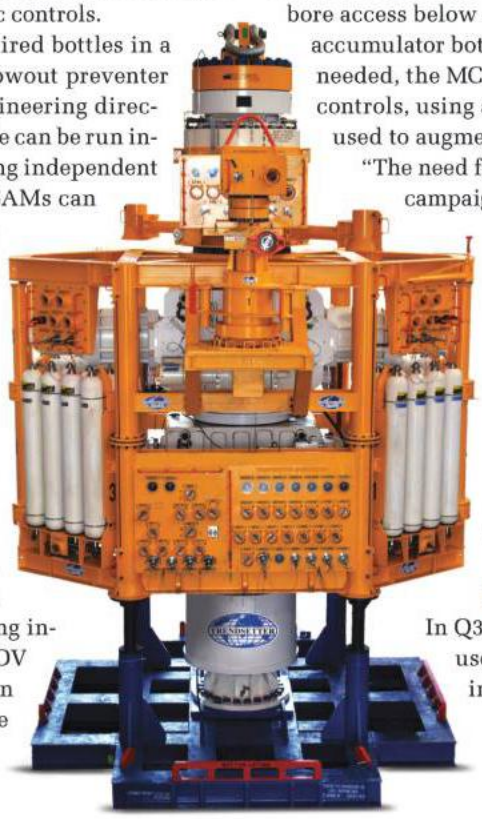
"Trendsetter's SAM provides the required bottles in a separate module so as not to impact blowout preventer (BOP) design," says Antony Matson, engineering director, Trendsetter Engineering. "The module can be run independently from the BOP stack, allowing independent servicing and scalability as additional SAMs can be added to the system to provide greater quantities of accumulated supply depending on the operational criteria of each drilling location."

## Alaska

Trendsetter's SAMs were used to augment the BOP system at an exploratory well during an Arctic campaign in the Chukchi Sea, offshore Alaska, in Q3 2015.

In the US Arctic, BSEE requires subsea wellheads to be set within a mudline cellar. This results in the BOP stack being installed in the cellar, offering limited ROV access to the BOP panel, which creates an issue due to a separate rule requiring the BOP panel to be accessible by ROV.

"Trendsetter resolved this by placing a duplicate panel on a seabed deployed SAM, with the unit connected to the BOP via a multi-line hydraulic flying lead," Morry says. "In the event remote BOP intervention was required, the ROV could access all the required BOP functions from the SAM instead of the BOP."



**Trendsetter Engineering's 18.75in 15M Drill Through Mudline Closure Device.**

Using this system allowed the operator local direct hydraulic control of the drilling BOP, Matson says, and provided additional hydraulic supply, enabling compliance with BSEE's regulations. The SAMs, charged to 5500psi, and located within 150ft of the drill site, were deployed for the entire drilling campaign for over 50-60 days. Though the units were not used to actuate any function, they were fully charged, connected to the BOP system and full function tested subsea. Backup SAMs were set on the back deck of the ice breaker *MSV Fennica*, as emergency response equipment for the campaign.

## Mudline closure device

In the event of an Arctic well control event, although capping stacks are on standby, they may not be the most appropriate equipment for every drilling campaign – due to time or location, Matson says. As an alternative, operators can deploy a mudline closure device (MCD).

"A MCD is a pre-installed well control device used to shear, seal, and isolate a well if the rig BOP drilling system suffers a loss of well control," Matson says. "The MCD is installed directly on the subsea wellhead with the subsea BOP landed on the MCD mandrel or connected to a surface BOP by way of a high pressure drilling riser."

Trendsetter's MCD is equipped with acoustic/electro-hydraulic controls, independent of the rig's BOP controls, two blind shear ram BOPs – with ram position indicators and bore access below – local ROV overrides, and 32 onboard accumulator bottles to operate all onboard functions. If needed, the MCD can be configured to accept umbilical controls, using acoustics as backup, and SAMs can be used to augment hydraulic capacity.

"The need for an MCD is based entirely on the drilling campaign profile of specific wells or fields," Matson says. "The main drivers are going to be remote location, environmentally sensitive areas, shallow water, and/or high discharge wells. All four drivers lend themselves to a proactive well containment approach through use of the pre-installed MCD as reactive capping stack mobilization may not be feasible (remote location, environmentally sensitive like the Arctic) and installation may not even be possible (shallow water, high discharge rates)."

## Russia

In Q3 2014, Trendsetter's SAM and MCD were used on an exploratory well, in the Kara Sea, in the Russian Arctic.

There were several challenges associated with the well: drilling in an environmentally sensitive region, short drilling season, remote location, and shallow water depth. Should there be a loss of well control, a capping stack may not be able to be deployed quickly enough, especially at the end of the drilling season. Additionally, accommodating all the necessary drilling equipment, rig and capping stack could be an issue in the shallow waters due to the limited space between the wellhead and rig, Morry says.

Using a MCD became an operational requirement, Matson says, due to the aforementioned challenges, governmental and environmental concerns, and operational prudence. A MCD package was pre-installed at the well, augmented by two SAMs charged to 5500psi, which gave the operator control over isolating the well. The package was deployed for 60 days and performed as expected with no loss of controls, hydraulic pressure, or acoustic communications during the duration of the campaign, Matson says. Following completion of the campaign, Trendsetter's equipment was demobilized and sent back to Houston.

In September 2014 Rosneft announced the discovery of a new Arctic field, Pobeda (or Victory), in the East-Prinovozemelskiy-1 area, licensed by Rosneft. In this same announcement Rosneft's President, Igor Sechin, thanked the companies involved, which included Trendsetter Engineering. According to Rosneft's announcement, the discovery well, Universitetskaya-1 (also known as University-1), took 1.5 months to drill. According to Rosneft's August 2014 press release, the well was operated by Karmorneftegaz SARL, a Rosneft (66.67%) and ExxonMobil (33.33%) joint venture. **OE**

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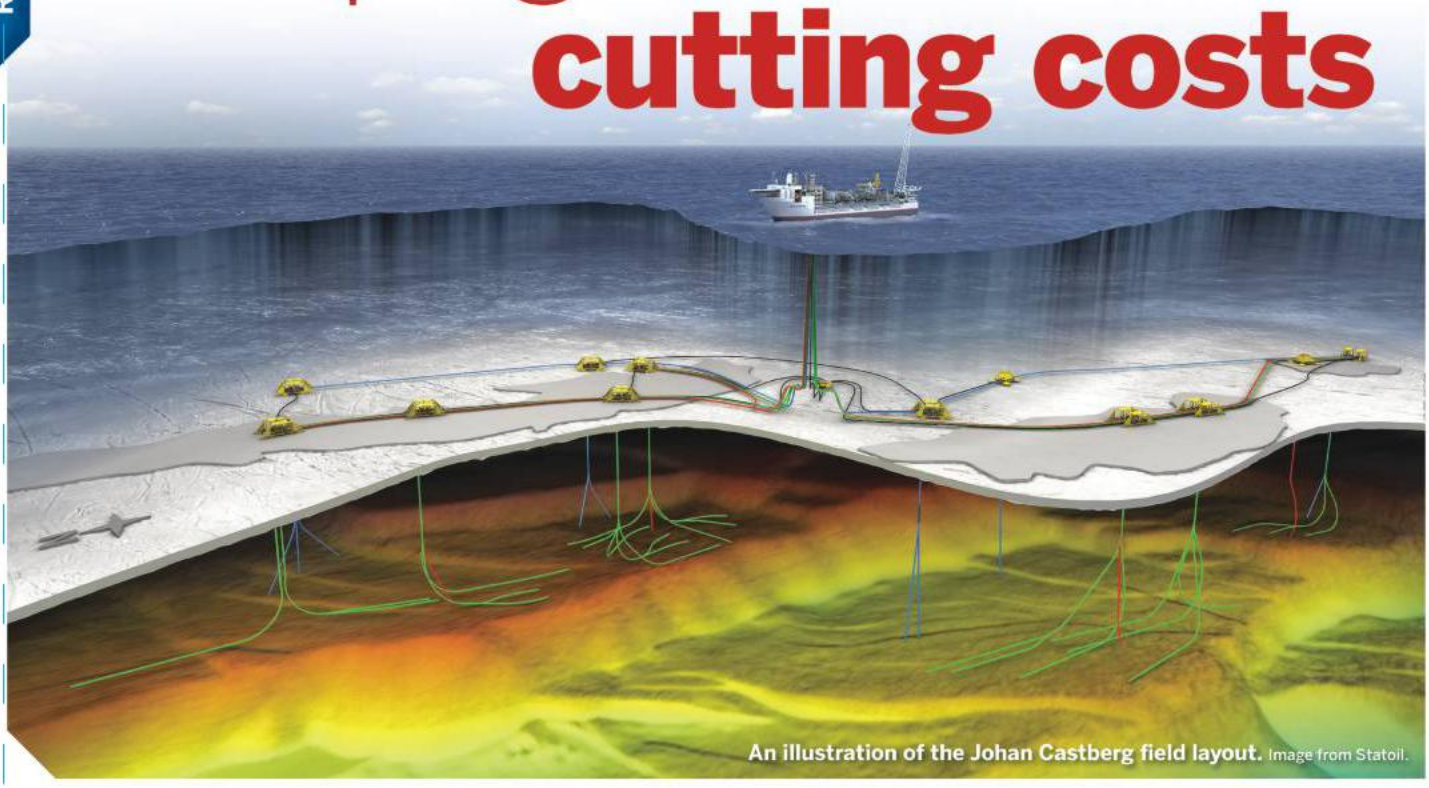
# Arctic

# Keeping cool, cutting costs



An illustration of the Johan Castberg field layout. Image from Statoil.

**Scope reduction has been the key focus on Statoil's Johan Castberg floating production project. Elaine Maslin reports.**

Statoil's Johan Castberg development is set to become one of Norway's northern-most oilfields, sitting in the Barents Sea some 240km northwest of Hammerfest.

It's at a latitude north of Alaska, far from existing infrastructure in 370m water depth. The Johan Castberg development comprises three oil fields, Skrugard, Havis and Drivis, discovered in 2011, 2012 and 2014, respectively, in 380-400m water depth in PL532.

To help make this 460-650 MMboe project economically viable, operator Statoil has selected a floating production development with a simplified subsea infrastructure for the field, as set out in our August issue (*De-engineering, OE*: August 2016). This, together with reducing the number of wells on the field from 40 to 31 and the number of templates from 15 to 10, plus two satellites, has helped slash about 50% off the cost of the development, from US$11.3 billion to about $6 billion.

Aker Solutions has been charged with coming up with a lean concept for the floating production, storage and offloading (FPSO) facility for the project. Aker Solutions' project director Nils Olav Solheim gave an update on progress on the concept at ONS in Stavanger, Norway, in late August.

He said that Aker Solutions' study has gone through every function on the FPSO, looking for simplification and taking off equipment not needed to slim down the cost of the unit.

The unit is currently 295m-long and 54m-wide. It will have 1.1 MMbbl storage capacity and 30,000 cm/d oil processing capacity and 8.3 MMcm/d gas capacity. The turret, positioned forward of the center of the vessel, for weathervaning, will weigh 7000-tonne, and the topsides will weigh 18,000-tonne.

The original storage capacity was 1.3 MMbbl, on a 320m-long vessel, but it was reduced 1 MMbbl as the vessel was slimmed down, then increased slightly without increasing size of boat due to a better solution of oil export pumps, Solheim says. The living quarters has been slimmed down from 140 to 120 cabins, with 20 of those having turnable beds to accommodate short-term increased capacity for maintenance.

One of the key considerations for the vessel has been around being able to operate in the harsh Arctic weather conditions. A laydown area has been set out from where equipment can be moved to a heated area. Life boats are protected, covered on all sides, and could be heated with an infrared heating system to ensure release mechanisms will work. Process heat will be used to heat water to clear the helideck and there will also be covered walkways, to protect staff. Ice and snow could also impact production. If there is a lot of snow fall and ice, production may have to stop, so that the unit doesn't become too heavy with produced oil, as well as the ice and snow. However, Solheim doesn't see this happening more than once in 10 years.

A more likely issue is not being able to export due to bad weather. But still, this is no more of an issue than elsewhere on the Norwegian Continental Shelf, he says. The design temperature here is five degrees lower than on the Haltenbanken, but, the weather conditions are in fact worse on the Haltenbanken.

Thanks to the reduced wells scope, meaning fewer templates and so risers, the turret was able to be slimmed down, from the original 11,000-tonne to a far leaner 7000-tonne.

On the process side, initially the design included three separation stages. One, the second stage separator has been removed – "we don't get more oil with all three," Solheim says. By taking away the unnecessary separator, piping and controls are also reduced, he adds.

The FPSO will have a chemical injection plant, including triethylene glycol, or TEG, to prevent hydrates. Gas injection, using a gas compressor, and water injection pumps, both up to 200 bar, are also included in the project for pressure support and for improved lift. Produced water, plus treated seawater, will also be reinjected, post-treatment in a sulphur removal module.

The vessel also has a fiscal metering package. Offloading will be with a shuttle tanker every 4-5 days at the start and for some period thereafter. Extra deck space has been created for future tie-ins and there are also spare riser slots.

How the field will be powered has yet to be decided. Solheim says there are several studies, but it will be up to Statoil. Power from shore has been a hot topic in Norway, with a number of projects already using renewable power from the mainland to power process facilities, including Valhall, Gjøa and Goliat, which is the only producing oilfield in the Barents, and which had a recent power outage issue. The longest power from shore cable to date is to Goliat, at just over 100km. A longer cable is planned for the Martin Linge field, at 163m-long, but this is some way short of the 240km for Johan Castberg, which could require new cable technology.

The next milestone for Johan Castberg will be a decision to go into front-end engineering in design later this year. Then, next Autumn, an investment decision is due to be made. Detailed design would then likely be over 1.5 years, with first production potentially around 2022. **OE**

## FURTHER **READING**

**Read more:** www.oedigital.com/component/k2/item/13130-de-engineering

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**1. Publication title:** OE (Offshore Engineer)
**2. Publication number:** 1705-8
**3. Filing date:** September 22, 2016
**4. Issue frequency:** Monthly
**5. Number of issues published annually:** 12
**6. Annual subscription price:** $99.00
**7a. Complete mailing address of known office of publication:** AtComedia, 1635 W Alabama St., Harris County, Houston, TX 77006
**7b. Contact person:** Audrey Miller/Byron Pettit
**7c. Contact telephone:** 281.995.1290/713.874.2211
**8. Complete mailing address of known office of publisher:** AtComedia, 1635 W Alabama, Houston, TX 77006
**9a. Full name and complete mailing address of publisher:** Shaun Wymes, 1635 W Alabama, Houston, TX 77006
**9b. Full name and complete mailing address of editor:** Audrey Leon, 1635 W Alabama, Houston, TX 77006
**9c. Full name and complete mailing address of managing editor:** n/a
**10. Owners:** International Exhibitions Inc. (50%), 1635 W Alabama, Houston, TX 77006; PL Investments LLC (50%), 1635 W Alabama, Houston, TX 77006
**11. Known bondholders, mortgagees, and other security holders owning or holding 1% or more of total amount of bonds, mortgages or other securities:** None
**12. Tax status:** Has not changed during preceding 12 months
**13. Publication title:** OE (Offshore Engineer)
**14. Issue date for circulation data below:** September 2016
**15. Extent and nature of circulation:**

| | Average no. copies each issue during preceding 12 months | No. copies of single issue published nearest to filing date |
|---|---|---|
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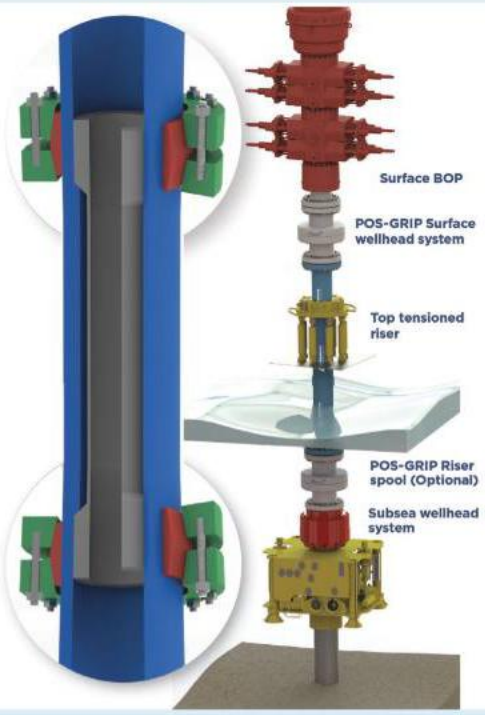
# Solutions




## HPHT riser system for jackup alternative

**Aquaterra Energy and Plexus Holdings have developed a lightweight dual barrier high-pressure, high-temperature (HPHT) riser system, which can be deployed by a jackup as an alternative to semisubmersible installation for HPHT well operations.**

**By uniting Aquaterra Energy's HPHT riser system and Plexus' POS-GRIP wellhead engineering technology, an inner riser string is installed inside a conventional high pressure riser to span the gap between a dry surface blowout preventer and a wet subsea tree. Suitable for shallow water depths up to 150m, the system provides full 20,000 psi capability and utilizes all metal-to-metal gas tight seals on both the external and internal riser string. The system also aims to eliminate the issues associated with surface wellhead developments that contain elastomeric seals, particularly those located between the mudline and surface.**

**In comparison to semisubmersible mobile units, new generation heavy duty jackup drilling units can now undertake drilling, completion, intervention and abandonment activities at lower day rates. Moreover, they can potentially mitigate the heavy loading implications and weather constraints often associated with semisubmersibles and extend the operating envelope. www.aquaterraenergy.com**

## GustoMSC launches new rig design

Dutch outfit GustoMSC unveiled a new harsh environment drilling semisubmersible series, OCEAN-HE.

The OCEAN850-HE and OCEAN1600-HE have been designed for midwater and deepwater harsh environment regions. The series' semisubmersible hull shape has been designed for low motion characteristics and optimum station-keeping capabilities.

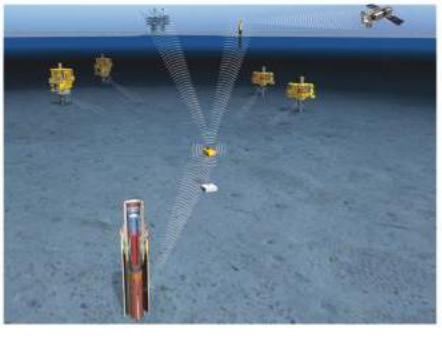
The OCEAN1600-HE will have maximum displacement of about 70,000-ton, a large derrick, DP3 and a 16-point mooring system for station-keeping, combined with a large deck area and large variable deck load. It is designed to cope with the North Atlantic environmental conditions, says GustoMSC.

The OCEAN850-HE is a cost efficient midwater harsh environment design, says the firm. It is a moored-only, harsh environment semisubmersible, with about 50,000-ton displacement, 1000m water depth rating and a 6th generation single derrick combined with horizontal riser storage. **www.gustomsc.com**

## FMC installs annulus monitoring system in Petronas well

FMC Technologies has installed and tested its annulus monitoring system (AMS) in an offshore well in Malaysia owned by Petronas.

A winner of the 2015 Offshore Technology Conference Spotlight on New Technology award, FMC Technologies' AMS is a wireless communication system that provides crucial, independent condition-monitoring within a subsea wellhead to operators from the onset of drilling and throughout the life of the well. The AMS delivers actionable information to the operator about annular fluid and components during critical phases of well installation and startup, when well conditions are most unpredictable.



The system provides real-time data collection and feedback, which would allow operators to complete their drilling and abandonment operations ahead of schedule. **www.fmctechnologies.com**


## Teledyne upgrades HD cameras

Teledyne Bowtech has updated their L3C-HD and L3C-HDX underwater cameras.

The updated L3C-HD camera now features full HD 1080p up to 60fps, simultaneous SD and HD-SDI output capability, and is fitted with a fixed focus wide angle lens that provides a 67° diagonal angle of view in water. The Titanium housing is depth rated for 1000m, 4000m or 6000m and

is capped by a scratch resistant and 99.8% optically pure Sapphire window. Additionally, the L3C-HD camera is approximately 40% smaller and lighter than its predecessor.

Built with the same Titanium housing and Sapphire window as the L3C-HD, the key feature of the L3C-HDX camera is that the digital signal from the cameras is a visually lossless compressed signal that will travel up to 250m on a Teledyne Bowtech coax.

Both the L3C-HD and the L3C-HDX cameras are suited to tooling, diving and ROV/AUV applications.

**www.teledynemarine.com**

## Cubility develops Cubelink


Cubility has launched CubeLink, a technology designed to safely transports drilling waste directly from shale shakers or MudCube to a storage unit or final processing unit on a drilling rig.

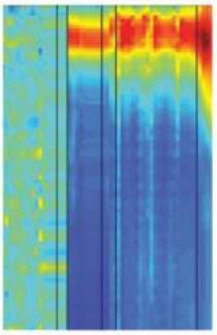
CubeLink consists of a recurring belt shaped in a drop-belt configuration. The system opens up in a U-shape in the feeding station to receive drilling waste that is fed by gravity from one or several shakers or MudCubes into the feeding station. The belt is then closed and routed to the destination. The belt opens up and returns flat over a turning roller where the drilling waste drops by gravity into a receptacle.

The technology is designed to handle dry and moist drilling waste horizontally and vertically, provide real-time information on the weight, volume and degree of moisture in the cuttings, extract mud from cuttings through an absorption feature, and provide HSE benefits through the drop-belt (pouch) configuration to avoid spillage of harmful waste and odor/gases.

**www.cubility.com**

## Halliburton adds ACX leak detection service

Halliburton introduced a new-generation acoustic analysis tool, called Acoustic Conformance Xaminer (ACX), which



uses hydrophone array technology to locate and describe communication paths and flow areas—vertically and radially in the wellbore area in real time.

The array triangulates on the sound/flow source in or around the wellbore. The array analysis helps eliminate false picks off of frequency and magnitude shows that have more to do with the well structure than the leak source. The radial locator has proven invaluable in some wells that have been logged by identifying which annulus or component of a completions system is leaking.

The ACX service also reduces time by providing a continuous mode to quickly identify areas of interest of possible leaks in the wellbore. In addition, it can accomplish stationary measurements to refine and reaffirm areas where leaks are identified by monitoring activity.

**www.halliburton.com**

# Activity

## DNO forms alliance with Aker, Subsea 7

Norwegian operator Det norske oljeselskap (DNO) has formed an alliance with Norway-headquartered Aker Solutions and UK-based Subsea 7 to come up with integrated solutions for DNO's subsea field portfolio.

The deal combines Aker Solutions' experience in front-end engineering, brownfield modifications and subsea systems and Subsea 7's capabilities in the engineering, procurement, installation and commissioning of subsea umbilicals, risers and flowlines.

Led by a manager from DNO, the companies will form an integrated project management team with experts from each. This will enable continuity from one field development to another and facilitate a reuse of solutions and technology that will lower costs, reduce development time and promote safe and more efficient work methods amid a focus on continuous improvement. Overall management of the alliance will be through a steering committee comprised of senior management from each company.

"This is collaboration through integration," said DNO CEO Karl Johnny Hersvik. "We don't want just an integrated team or a shadow organization, but one project management organization with the 'best' personnel from each company to extract the greatest synergies.

The alliance comes after DNO announced a four-year framework agreement in June with Aker Solutions to provide subsea production systems and services for the operator's oil and gas developments in Norway and with Subsea 7 for SURF services. ▪

### Statoil opens new command center

Statoil opened its new operations center for the UK Continental Shelf (UKCS) in Aberdeen, Scotland, where it plans to grow its workforce by 40 people.

"Starting with just a handful of employees in the spring of 2013, Statoil has grown its workforce in Aberdeen to around 140," said new managing director for Statoil Production UK, Hedda Felin. "This autumn we will initiate another significant recruitment process."

Statoil also unveiled plans to increase both exploration and operational activity in the UKCS, with three wells to be drilled in 2017, including one in the Mariner area and two wildcats elsewhere, Felin, said. Additionally, next month (November), Statoil will begin pre-drilling of production wells for the Mariner field, which calls for four to six wells to be ready before start-up on the field in 2018, Felin added.

### NKT acquires ABB business

Germany's NKT Cables is acquiring ABB's global high-voltage cable system business, part of ABB's Power Grids division.

ABB's cable system business offers turnkey solutions including design, engineering, supply, installation, commissioning and service, while NKT Cables designs, manufactures and supplies power cables for low-, medium- and high-voltage solutions mainly in the alternating current (AC) area.

"As part of the strategic partnership, ABB and NKT Cables will work together on future projects to access market opportunities in areas like subsea interconnections and direct current (DC) transmission links," said Claudio Facchin, president of ABB's Power Grids division. The transfer of assets also includes a new cable-laying vessel, currently under construction. The 140m-long DP3 vessel was ordered in 2015 and is being constructed at the Kleven yard in Norway with delivery expected in 2017.

The transaction is anticipated to close in Q1 2017, subject to regulatory clearances and conditions.

### Offshore trio offers integrated solution

Aqualis Offshore, Aptomar and Kolos Marine have entered into a cooperation that will provide oil companies and rig operators with an integrated offering of marine operations and field monitoring services on the Norwegian continental shelf.

Under the cooperation agreement, Aqualis will head up the three-party initiative and will be in charge of project management for marine operations and assist clients with all aspects of the marine scope.

Aptomar will provide integrated field monitoring services, including 24/7 monitoring of offshore traffic and safety zones, continuous monitoring and detection of unintended spills, and detection, counting and documentation of species of birds and mammals.

Kolos will monitor and follow up mobilizations and demobilizations, provide offshore attendance and equipment recommendations.

### IMES acquired by Seanamic

Seanamic Group has acquired the business and trading assets of IMES, an inspection and monitoring engineering solutions company headquartered in Aberdeen.

Seanamic, a provider of integrated surface to seabed systems, is comprised of Glasgow-based Caley Ocean Systems, a marine handling systems specialist, and Houston-based Umbilicals International (UI), an umbilicals and cable manufacturer.

IMES provides bespoke monitoring and load measurement systems, which enable companies to better manage the life cycle costs, performance and safety of their cranes, lifting equipment and load bearing structures. IMES also has a growing inspection product range which can diagnosis integrity issues including subsea electrical fault isolation, integrity

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- ❑ 32 Marine Support Services
- ❑ 33 Service, Supply, Equipment Manufacturing
- ❑ 34 Finance, Insurance
- ❑ 35 Government, Research, Education, Industry Association
- ❑ 99 Other *(please specify)* _____

**3. Do you recommend or approve the purchase of equipment or services?** *(check all that apply)*

- ❑ 700 Specify
- ❑ 701 Recommend
- ❑ 702 Approve
- ❑ 703 Purchase
- ❑ 704 N/A

**4. Which of the following best describes your personal area of activity?** *(check all that apply)*

- ❑ 101 Exploration Survey
- ❑ 102 Drilling
- ❑ 110 Production
- ❑ 103 Subsea production, construction (including pipelines)
- ❑ 104 Topsides, Jacket Design, Fabrication, Hook-Up & Commissioning
- ❑ 105 Inspection, Repair, Maintenance
- ❑ 106 Production, Process Control Instrumentation, Power Generation etc.
- ❑ 107 Support Services, Supply Boats, Transport, Support Ships etc.
- ❑ 108 Equipment Supply
- ❑ 109 Safety Prevention and Protection
- ❑ 111 Reservoir
- ❑ 99 Other *(please specify)* _____

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# Activity

## Maersk realigns


AP Møller - Mærsk, the parent company of Maersk Oil and Maersk Drilling, which also owns a transport and logistics business line, announced plans to reorganize the business.

The move will split the business into two independent divisions; an integrated transport and logistics division, and an energy division.

"This will ensure focus on driving synergies and developing new products and services in transport and logistics as well as focus on separately developing structured solutions for our oil and oil related businesses," the company said in late September.

The energy business will consist of Maersk Oil, Maersk Drilling, Maersk Supply Service and Maersk Tankers. The company says that Maersk Oil will adjust its current strategy to focus its portfolio in fewer geographies to gain scale in basins, particularly in the North Sea, where it can leverage its strong capabilities within subsurface modeling, well technology and efficient operations. Maersk Oil will aim to strengthen its portfolio through acquisitions or mergers, the press release said.

Further, Maersk Oil will mature existing key development projects, while keeping exploration activities and expenses at a low level. While the strategic focus will be reflected in a disciplined capital allocation, investments in strategic projects already sanctioned or under development will continue as planned.

Maersk Drilling, Maersk Supply Services, and Maersk Tankers will continue to optimize their market position and operation with the existing fleet and order book. Additional investments in the company's offshore service businesses and Maersk Tankers will be limited.

"Both Energy, and Transport and Logistics have strategies positioning them for growth and strategic agility," said Group CEO of AP Møller – Mærsk, Søren Skou. "Energy is well positioned to leverage Maersk Oil's expertise and gain scale in select geographies, particularly in the North Sea. Its structural agility will enable management to pursue new and different structural solutions and investment."▪

assurance of FPSO (floating production, storage and offloading) risers and marine vessel tailshaft integrity assurance.

"The high quality inspection services and monitoring products offered by IMES are an excellent fit with our existing systems focused businesses," said David Cooper, CEO, Seanamic Group. "As we operate in many of the same industry sectors, we see tremendous synergies with the range of IMES services and products. All aspects of the old IMES business have transferred to a new company, IMES International."

## EIC opens new Houston office

London-headquartered Energy Industries Council (EIC), a trade association for UK companies operating in the energy industry, opened its new Houston office in early September. The facility, in Houston's Energy Corridor on the west side of town, includes offices, a large conference room and hot-desks available for use by EIC member companies.

"Moving up one floor to our new office means we can offer [clients] better facilities than ever before to help them expand into the lucrative North and Central America region; Houston being the gateway to the Americas market," said Clarisse Rocha, EIC head of Americas.

EIC CEO Stuart Broadley presided over the opening ceremony. He was joined by Karen Bell, British Consul General in Houston; Mike Laster, Houston City Council member; and Betty Russo, part of the Governor of the State of Texas, Greg Abbott's Community Relations team.

## CGG forms Ghana JV

France's CGG and Ghana's GNPC Operating Services Co. (GOSCO) formed a joint venture (JV) for high-end 2D, 3D and 4D marine seismic acquisition and related services offshore Ghana.

Based in Accra, Ghana, the JV, to be known as GOSCO Geoscience Ltd. (GGSL), will provide seismic vessels and marine seismic acquisition technologies and services to companies operating in Ghana. The JV recognizes and supports the requirement for knowledge transfer and capacity-building in the Ghanaian E&P industry as well as the need for safe and efficient oil and gas operations.

"This move is another example of CGG's strategy to work in partnership with local oil and gas players to benefit from their experience of working in the country while bringing them the benefit of CGG's global expertise as a leading technology provider," said CGG's CEO Jean-Georges Malco.


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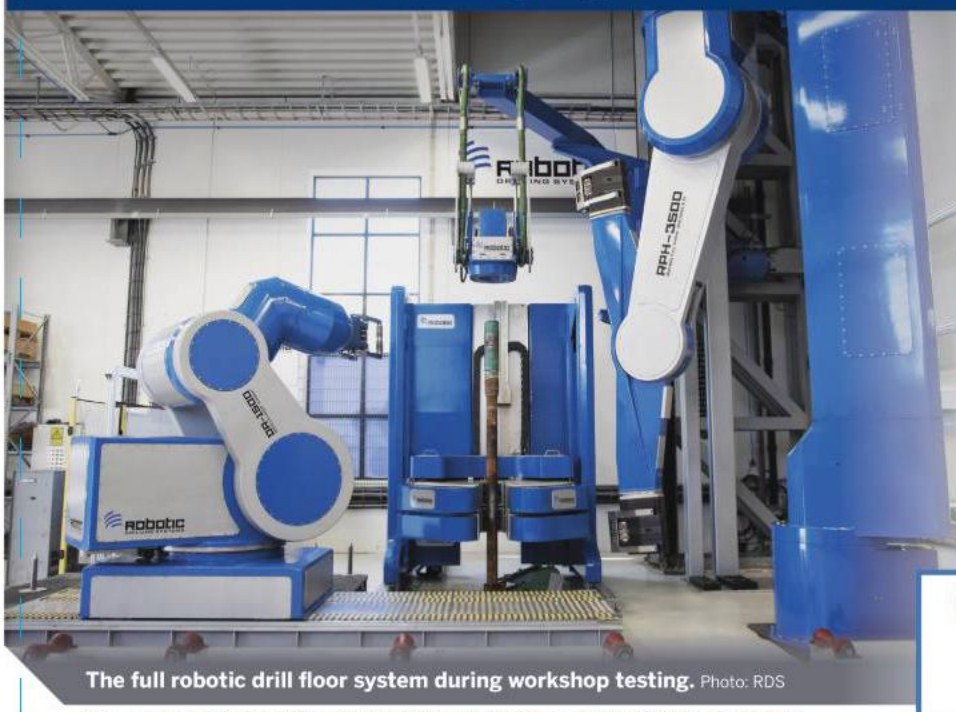


The full robotic drill floor system during workshop testing. Photo: RDS

### Feature – Intelligent Oilfield

Intelligent energy still means quite a lot of different things to different people, including the extent of its role in the oil and gas business. Elaine Maslin reports from SPE Intelligent Energy in Aberdeen on what the oil majors (BP, Shell, Chevron, and ConocoPhillips) are implementing.

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