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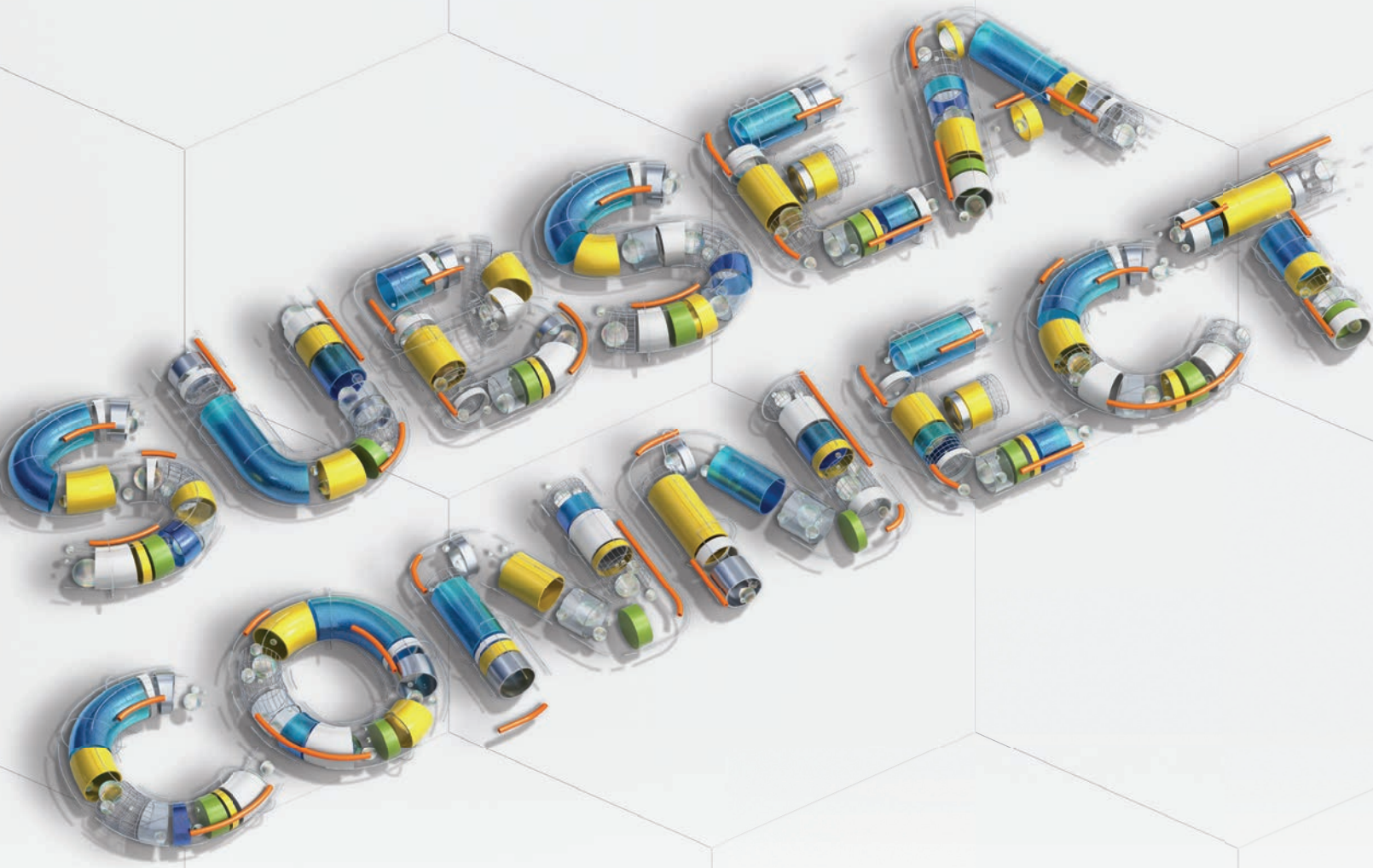
Underwater Vehicles
The rise of subsea residency

North America
The US outlook

VOL. 44 / NO. 2



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FEATURES

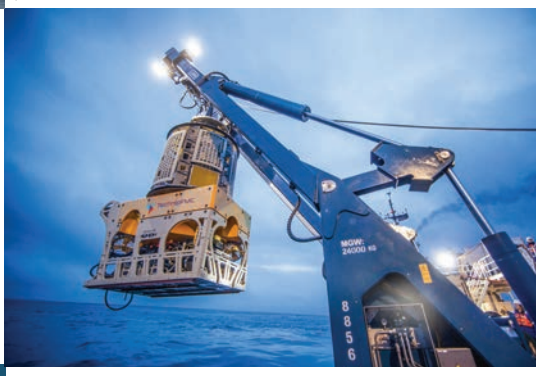
Source: Boskalis

ON THE COVER: Pioneering Spirit transported and installed the topsides for the Johan Sverdrup field. (Source: Equinor)

FEATURES

Source: BSEE

Source: Wintershall



Source: TechnipFMC

Source: Oceaneering

OE OFFSHORE ENGINEER
THE FUTURE OF OFFSHORE ENERGY & TECHNOLOGY.

www.OEDigital.com
Vol. 44 No. 2
ISSN 0305-876x
USPS# 017-058

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fax: (212) 254-6271

OFFSHORE ENGINEER (ISSN 0305-876X) is published bi-monthly (6 times per year) by AtComedia, Inc. 118 East 25th St., 2nd Floor, New York, NY 10010-1062. Periodicals postage paid at New York, NY and additional mailing offices.

POSTMASTER: Send All UAA to CFS. NON-POSTAL AND MILITARY FACILITIES send address corrections to Offshore Engineer 850 Montauk Hwy, #867 Bayport, NY 11705

SUBSCRIPTION INFORMATION

In U.S.:
One full year (6 issues) $60.00
Two years (12 issues) $110.00

Rest of the World:
One full year (6 issues) $129.00
Two years $199.00 (12 issues)
including postage and handling.

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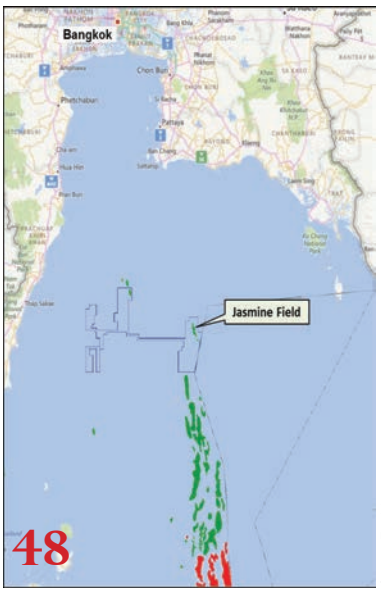
f: (212) 254-6271

DEPARTMENTS

Source: Weatherford

Source: Sonardyne



Source: Tendeka

Source: Yanmar

BY THE NUMBERS

RIGS

Worldwide

Rig Type	Available	Contracted	Total	Utilization
Drillship	28	62	90	69%
Jackup	149	296	445	67%
Semisub	41	60	101	58%

Africa

Rig Type	Available	Contracted	Total	Utilization
Drillship	1	15	16	94%
Jackup	9	24	33	73%
Semisub	1	4	5	80%

Asia

Rig Type	Available	Contracted	Total	Utilization
Drillship	5	9	14	64%
Jackup	52	90	142	59%
Semisub	12	16	28	57%

Europe

Rig Type	Available	Contracted	Total	Utilization
Drillship	16	2	18	11%
Jackup	14	36	50	72%
Semisub	13	20	33	61%

Latin America & the Caribbean

Rig Type	Available	Contracted	Total	Utilization
Drillship	3	16	19	84%
Jackup	4	5	9	56%
Semisub	7	6	13	46%

Middle East

Rig Type	Available	Contracted	Total	Utilization
Drillship	0	1	1	100%
Jackup	29	114	143	80%

North America

Rig Type	Available	Contracted	Total	Utilization
Drillship	3	19	22	86%
Jackup	30	25	55	45%
Semisub	3	8	11	73%

Oceania

Rig Type	Available	Contracted	Total	Utilization
Jackup	1	2	3	67%
Semisub	2	3	5	60%

Russia & Caspian

Rig Type	Available	Contracted	Total	Utilization
Jackup	4	6	10	60%
Semisub	3	3	6	50%

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

Data as of April 1, 2019.
Source: Wood Mackenzie Offshore Rig Tracker

DISCOVERIES & RESERVES

Offshore New Discoveries

Water Depth	2015	2016	2017	2018	2019
Deepwater	26	13	15	6	3
Shallow water	84	65	71	29	9
Ultra-deepwater	18	15	12	14	3

Shallow water (1-399m)
Deepwater (400-1,499m)
Ultra-deepwater (1,500m+)

Offshore Undeveloped Recoverable Reserves

Water Depth	Number of fields	Recoverable reserves liquids mbl	Recoverable reserves gas mboe
Deepwater	219	26030.40199	9143.815
Shallow water	1171	112562.6518	31296.2492
Ultra-deepwater	119	20116.87834	6428.5484

Contingent, good technical, probable development. The total proven and probably (2P) reserves which are deemed recoverable from the reservoir.

Woodmac Child Fields

Offshore Onstream & Under Development Remaining Reserves

Water Depth	Number of fields	Recoverable reserves liquids mbl	Recoverable reserves gas mboe
Africa	221	19688.2937	22343.11074
Asia	207	10678.8816	26390.12016
Europe	442	15341.5296	14794.0571
Latin America & the Caribbean	82	32480.8911	8002.832553
Middle East	84	124757.0778	107311.5209
North America	197	15566.0335	3248.143266
Oceania	55	1928.2245	16081.83812
Russia and the Caspian	35	20360.5898	17219.52135

Onstream and under development.
The portion of commercially recoverable 2P reserves yet to be recovered from the reservoir.

Woodmac Parent Fields

Source: Wood Mackenzie

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Oirere


Pallanich


Paschoa


Stoichevski

ENERGY INNOVATION

As this edition of *Offshore Engineer* was closing down and headed to the printer I was returning from Southampton, England, and Ocean Business 2019, an event I have attended with my *Marine Technology Reporter* hat on since it started in 2007. It is unquestionably the year's biggest, best and most influential meeting for subsea technology companies serving academia, defense and offshore energy.

While the event is a far cry from a true offshore energy show, a walk in and around the booths and on the docks at the National Oceanographic Center inside the Port of Southampton proved to deliver many familiar technologies and faces that serve the offshore energy business. To be frank, this group collectively and closely tracks its health with that of offshore energy. There are a handful of larger corporate entities dotting the exhibit floor ... Teledyne, Kongsberg and Forum, to name a few ... but by and large this is a group of medium to small companies, true innovators at devising the means to work efficiently in the world's most inhospitable subsea environments.

While this is hardly scientific proof, there was a palpable buzz at Ocean Business, as the majority of attendees and exhibitors interviewed by our staff indicated that business is slowly turning positive. While an uptick in business and revenue is always nice, in the bigger picture the subsea sector is genuinely excited in that it sees greenfield opportunities in the 'new norm' that is offshore energy, an industry which is on the prowl for innovative technologies and techniques that will deliver measurable efficiencies and cost-savings, helping to lower the cost of offshore energy discovery and recovery.

In this edition and every day on **OEDigital.com**, *Offshore Engineer's* editors and writers dispersed globally seek to deliver exclusive insight on the emerging technologies that are designed to deliver efficiency. If you turn the page you will see that we are starting fast with Elaine Maslin's *Google Translate for Oil Wells*, looking at Sensalytx, a startup that is harnessing artificial intelligence (AI) to allow oil companies to do more with the data (as well as the oil) they get from their wells. The discussion on data generally includes everything from quantity to integrity to security, but this discussion looks at what is – or in many cases what is not – done with the masses of information collected.

Another one of those technologies is covered in depth starting on page 32 in our feature entitled *A Sliding Scale of Residency*, which examines new means to keep unmanned underwater vehicles under the surface longer, for weeks, months and even years at time. This helps to dramatically reduce the number of human and support ship touches, and consequently, the cost.

While much of the discussion on the offshore recovery is anecdotal, our feature *Drilling Down Deep* starting on page 24 explores the impetus for renewed vigor in deepwater drilling and operations. According to Wood Mackenzie the cost of developing new deepwater barrels has fallen by more than 50% since 2013, as project downsizing, a focus on subsea tiebacks and more efficient project execution have all conspired to help cut costs. With that, deepwater is garnering attention and investment.

Offshore Engineer and **OE TV** will occupy booth number 6604 at this year's OTC in Houston. We welcome your visit, or the chance to set up a meeting or a video interview in advance to discuss insights on your business, the challenges you face and the opportunities you see.

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GOOGLE TRANSLATE FOR OIL WELLS

BY ELAINE MASLIN

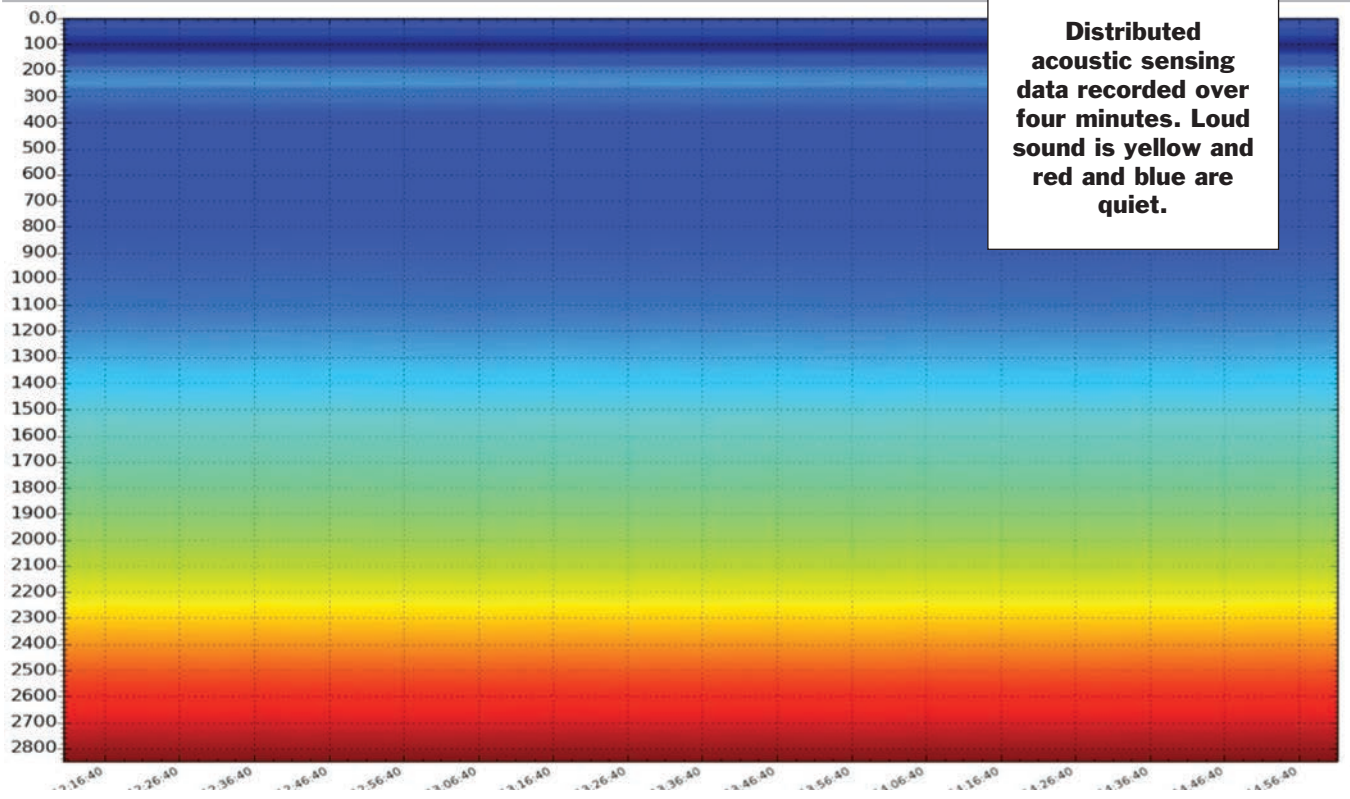
A startup is looking to harness the world of artificial intelligence to help oil companies do more with the data, as well as the oil, they get from their wells.

Big data is often billed as having the potential to offer the oil and gas industry huge benefits in improved efficiency and production, helping operators to understand more about their reservoirs, wells and process equipment.

But, a lot of the time the problem isn't access to data, it's what's done with it. All too often, large amounts of the data produced are simply not used. Fiber optic cables, for example, are now being used in the industry, including for distributed acoustic sensing (DAS) and distributed temperature sensing (DTS), inside and along well bores. They're capable of detecting vast amounts of temperature and sound data, from which a lot of information could be derived about the conditions in the well.

"They can hear everything, including fluid flow inside or outside the well bore, fluid flowing through the formation, for example," says Graham Gaston, CEO of Sensalytx, a start-up company creating tools for the industry to help them with fiber optic data interpretation. The sounds detected can show where water is coming into the well, so operators can shut off that zone, or where solids, such as sand, are blocking the path into the well. They can also be used to assess the condition of the well, so operators can optimize plugging and abandonment operations.

"The potential is huge. There's currently only 5,000 kilometers of fiber installed in the industry to date and it produces an estimated 1.2 petabytes of data a year," says Gaston, who recently completed the Aberdeen-based Oil & Gas Technology Center's TechX technology accelerator program. Many millions more kilometers of the cables could be installed glob-



Distributed acoustic sensing data recorded over four minutes. Loud sound is yellow and red and blue are quiet.

Source: Sensalytx

ally, producing vast amounts of data to be used for companies.

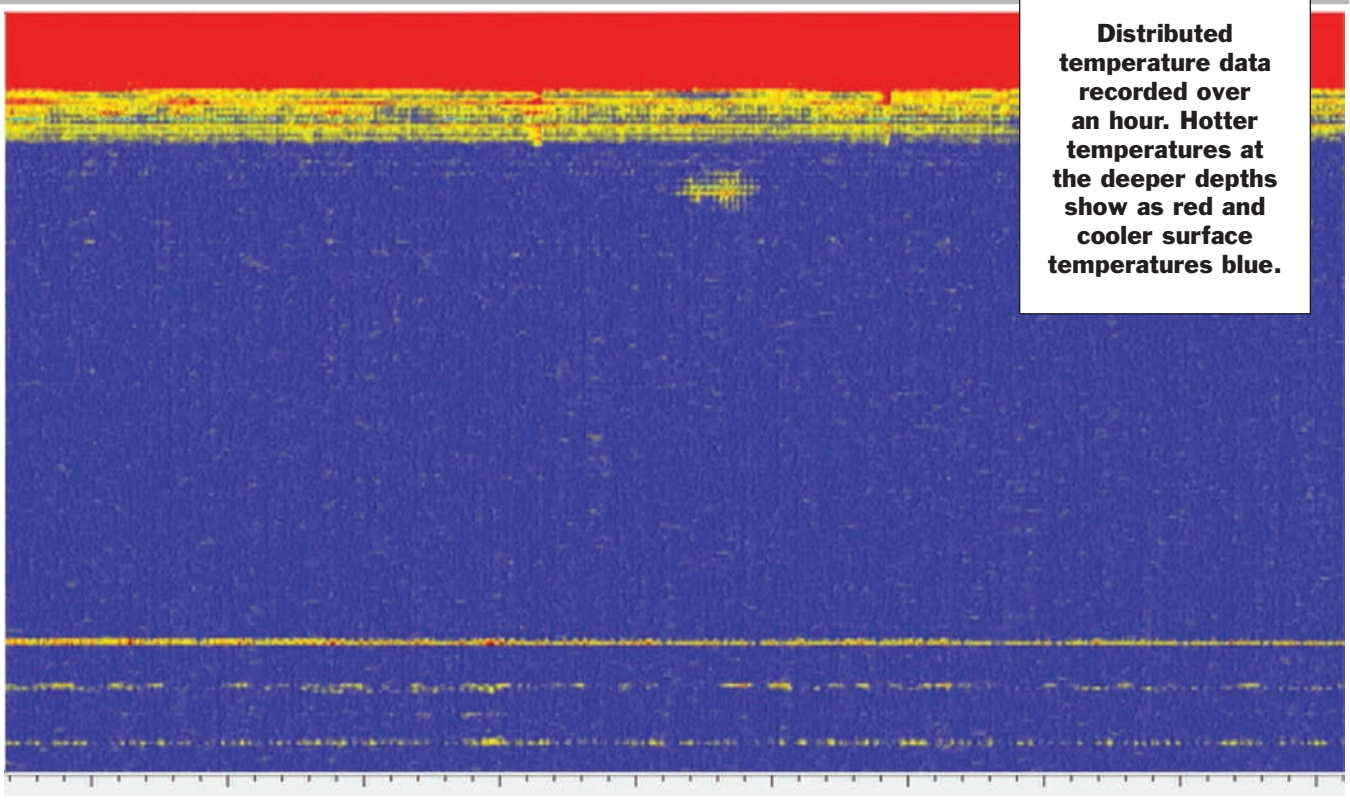
But there's a chicken and the egg problem, Gaston says. Only about 5-10% of the data harvested from the currently installed fiber optic sensing systems is actually being used to create value. This is partly because tools to evaluate this data are few and far between, so companies have yet to experience the full potential or see the benefits, which means they've not been fast to take up fiber optic installation. "While new generation interrogation boxes and second generation fibers are bringing them more accurate data, there's still a lack of progress in analysis," he says.

Gaston has been a consultant to the industry for many years and, before founding Sensalytx, he had found himself interpreting fiber optic data from wells on a field offshore Norway. It was a slow and painful process and he decided there had to be a better way to do it.

"A full interpretation took four to six weeks and it was a manual process in [Microsoft] Excel and PowerPoint," he says. "It was slow. It's drudgery going through terabytes of data. I thought that there must be better ways of doing this." Gaston has turned to data analytics, specifically, artificial neural networks (ANN), a form of information processing inspired by biological systems such as the brain. It involves a large number of highly interconnected processing elements that work in unison to solve specific problems. It learns by example and aids pattern recognition and data classification.

Sensalytx CEO Graham Gaston

"What AI does is allow the automation of the pattern recognition which is essential to the analysis. AI or ANN can recognize the patterns I was finding manually, but much faster, and would allow non-subject matter experts to play with the data and get value from it instead of it sitting with a very few specialists, which is why the (fiber) industry isn't growing," Gaston says. "We needed software to do this, but no one was



Distributed temperature data recorded over an hour. Hotter temperatures at the deeper depths show as red and cooler surface temperatures blue.

Source: Sensalytx

doing it." While there are companies offering the fiber optic acquisition equipment – cables and interrogators – they were not offering interpretation software.

It's a challenge Sensalytx is looking to solve – taking the interpretation time down from six weeks to six minutes. The company, which formed in July 2017, is working with developers and data scientists at Robert Gordon University in Aberdeen to develop advanced algorithms.

It's also bringing in techniques from other industries, for example gaming, which will help to visualize the data 4D and even 5D, using virtual reality so that people can literally go into the data, to see what is happening.

"We can use AI and then the visualization and virtual reality capabilities developed in the gaming industry to show the information in the third, fourth and fifth dimension," Gaston says. "With VR you can get close to the data."

Gaston admits that the processing will still need high-powered computers, but, he says the technology is coming. Computer processing units and graphics processing units are coming that could enable this analysis to be done on the equivalent to a laptop. "These are step changes that will enable the analysis to be done quickly on the desk, rather than by a massive computer," he says. "It's going to be simpler, cheaper and easier to deal with the volumes of data and visualize it.

"Ultimately, what we want to do is offer on-demand production optimization. We call it the equivalent of Google Translate for wells. If there is fiber is in the well, you will be able to tell where production fluid is coming from, whether it's optimized, how much water it contains, and you can use that to increase production efficiency and maximize recovery from the reservoir."

Sensalytx was developed out of the Grey Matters Program, which was set up to leverage the knowledge and experience of oil and gas industry professionals who were at risk of re-

Downhole fiber optic installation offshore.

Images: Weatherford

dundancy or made redundant during the downturn, with a view to forming new companies.

It was then given a major boost by being one of 10 companies involved in the TechX technology accelerator. The program has given the firm access to funding, but also mentors and operators. As a result, Sensalytx is now in talks with two operators with a view to accessing well data which can be used to start training the AI. The firm also has a letter of intent to support a global fiber optic hardware supplier, working in mining and other industrial processes, which is trying to enter the oil and gas industry. Gaston says well surveillance is also just the start for Sensalytx. While fiber is being used for about five applications at the moment, he's identified at least 300 more – just in oil and gas. The technology could also be used in other industries. Fiber is being installed in everything from pipelines to railways and into roads for autonomous cars.

THE U.S. OUTLOOK
Deepwater Producton Rising

BY JENNIFER PALLANICH

Currently one in every five barrels produced in the United States comes from the Gulf of Mexico (GoM), and 88% of that output flows from reservoirs in water depths greater than 500 feet.

In 2016 the GoM produced 575 million barrels of oil, and in 2017 621 million barrels. In 2018, it was almost 639 million barrels, according to Scott Angelle, director of Bureau of Safety and Environmental Enforcement (BSEE). In 2017, 11 GoM facilities produced 50% of all offshore oil, which was 1% of the 974 producing facilities. A decade ago, it took 37 facilities to produce 50% of the total GoM production. The 37 facilities still represented only 1% of the total facilities producing at that time, which was 2,118.

"The change is because oil exploration has moved to deepwater areas," Angelle says. "The Gulf is changing. There are fewer production facilities, and those facilities are larger, in deeper water and more technologically advanced."

Angelle notes oil production on the shelf, where production began 70 years ago, has declined 77% in the last 20 years, while deepwater oil output has risen by 198% in the same period. Gas production on the shelf is down 92% in the same two decades while deepwater gas production has remained flat. About 50,000 wells have been drilled on the shelf compared to about 5,000 wells in deepwater, where production began about 45 years ago.

Optimism in the GoM's resources is strong. Last year, Hess's Stampede and Chevron's Big Foot tension-leg platform developments went onstream. A host of pipeline and subsea tiebacks have begun producing or are slated to begin operation in 2019, and Shell's Appomattox semisubmersible is slated to go online later this year.

When Appomattox begins produc-

Source: BSEE

BSEE Houma district well operations inspection unit supervisor Josh Ladner (left) discusses the offshore inspection process with BSEE director Scott Angelle (center).

"I THINK THE WORD IS OUT. THE GULF OF MEXICO IS BACK, AND AMERICA IS INTERESTED IN SEEING INVESTMENT THERE."

SCOTT ANGELLE
DIRECTOR, BSEE

tion, "that's going to tell us a lot," William Turner, senior research analyst at Wood Mackenzie, says of the first Jurassic reservoir to begin production. "Everyone is going to be eager to learn more about that reservoir. It will tell about future development and investment in future Jurassic plays."

The Appomattox semi is a "monster" facility that has "taken almost an urban planning approach," Turner says, noting its potential as a game changer for future investment opportunities around Appomattox as a hub.

At the same time, Turner is keeping a watch out for final investment decision at Chevron's Anchor field, which would be a play-opener in the lower tertiary. Analysis has indicated play-openers tend to be some of the most "significant finds" in that play, he adds.

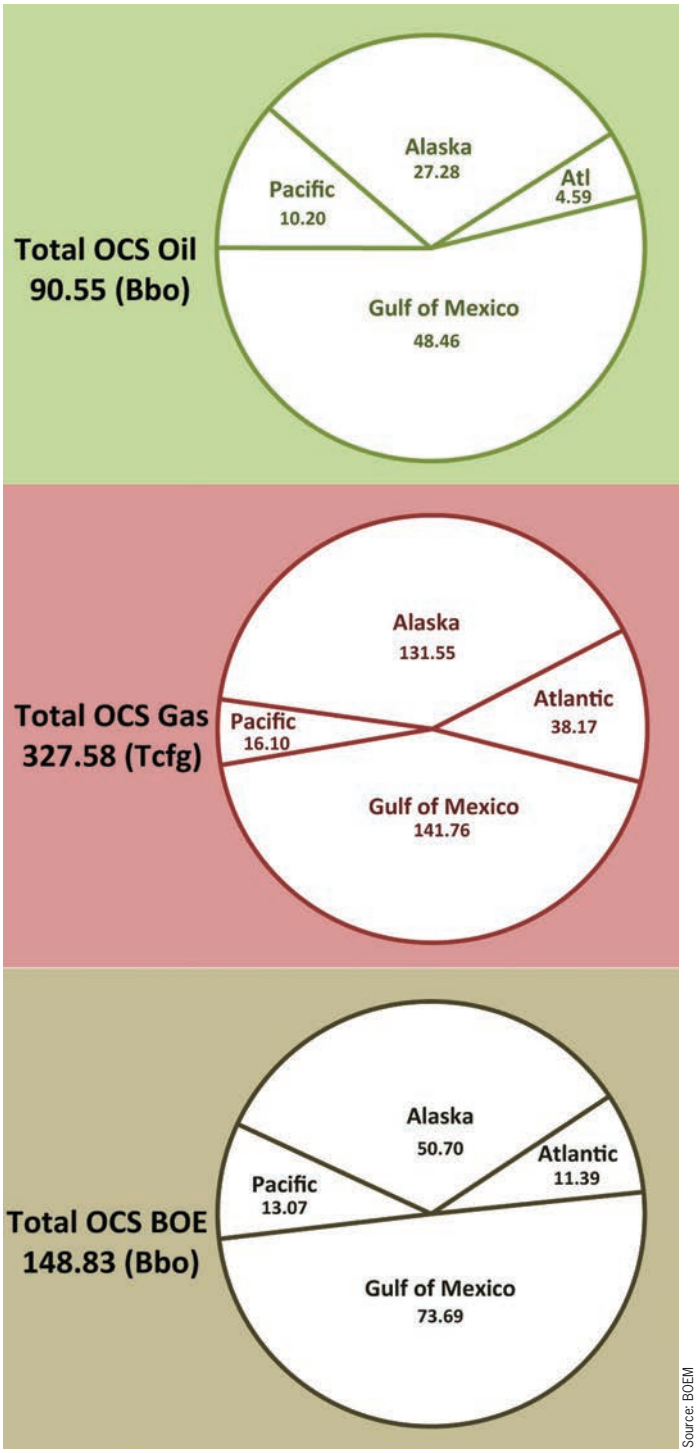
Angelle notes some significant recent discoveries in the deepwater GoM include Chevron's Ballymore find, Shell's Whale discovery, and LLOG's discovery on the Nearly Headless Nick prospect.

"There has been a recent upward trend in drilling permits approved in both shallow and deep water," Angelle says, noting a 44% increase in applications for permits to drill new wells, bypasses and sidetracks from 2016 to 2018. He says 141 permits to drill were issued in 2016 and 202 in 2018. There's been a 36% increase in wells spud on the outer continental shelf, with 139 in 2016 and 190 in 2018.

"Folks believe that the commodity prices are where they need to be on the crude oil side to spur investment," he says.

Angelle believes the country's predictable and reliable regulatory regime, coupled with a focus on safety, is attracting interest in developing the country's resources.

"I think the word is out," Angelle says. "The Gulf of Mexico is back, and America is interested in seeing investment there and is making it as competitive as possible."



Source: BOEM

Mean undiscovered technically recoverable resources by type and region from BOEM's 2016 assessment, which includes data and information available as of January 2014.

Source: BOEM

"WE BELIEVE THERE IS STILL A LOT OF POTENTIAL LEFT IN THE OCS."

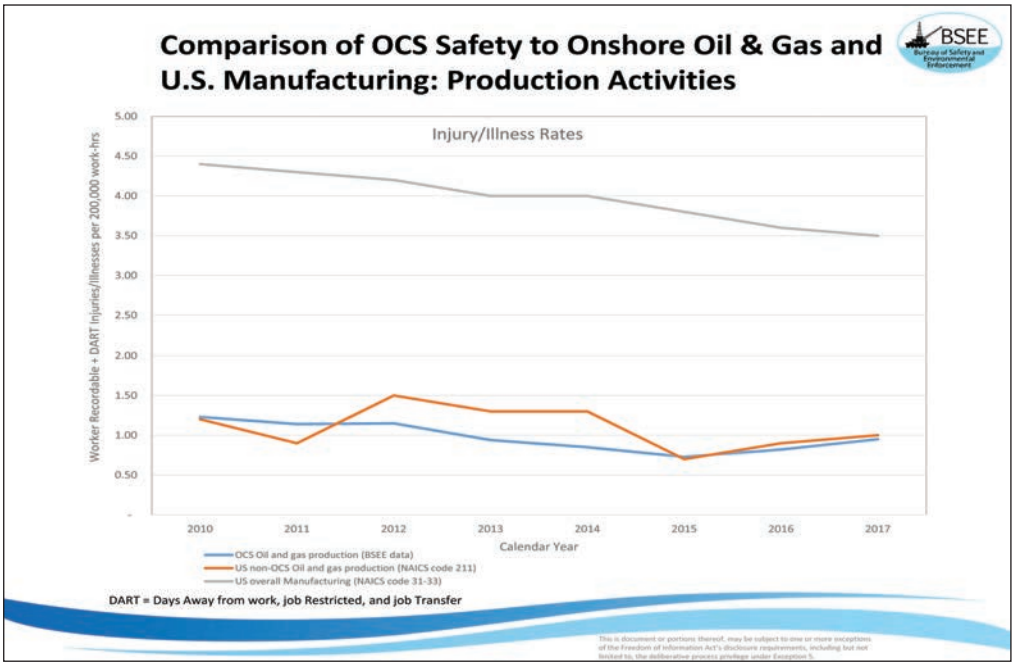
WALTER CRUICKSHANK
ACTING DIRECTOR, BOEM

Last year was one of the safest years the offshore industry has ever had, and was the highest producing, Angelle says.

When comparing industry-wide illness and injury data since 2010, the offshore industry has a better safety record than the onshore oil and gas, construction and mining industries, Angelle says.

From 2016 to 2018, BSEE has increased overall inspections by nearly 21%. At the same time, participation in the SafeOCS voluntary near-miss reporting program shot up by about 2,700% from operators representing 3% of US Outer Continental Shelf (OCS) production in 2016 to operators representing 85% of OCS production in 2018.

One of BSEE's recent safety initiatives, the Risk-Based Inspection Program, which was in pilot phase in 2017 and implemented in 2018, supplements BSEE's annual inspection program and focuses on higher risk facilities and operation.



Last year was one of the safest years ever for the offshore industry.

"It's not either/or. It's not safe operations and good environmental stewardship or robust production," Angelle says. "We aren't instituting an either/or but an and equation. We can have it all. We are proving to America that we can produce in a robust, safe and environmentally sustainable way."

While the GoM has been a powerhouse of production, and there is some production off the coasts of California and Alaska, the country is working to open up other offshore areas to production.

Walter Cruickshank, BOEM acting director, says the country's next five-year OCS leasing plan may open up more of the country's coastlines to exploration. For decades, lease sales have been in the Gulf of Mexico and offshore parts of Alaska. No leasing has occurred on the West Coast since 1984 and none in the Atlantic for about 35 years, he says.

Development of the new National OCS Leasing Program, under the America First Offshore Energy Strategy covered by executive order 13795, began in July 2017 with information gathering. The first draft, released in January 2018, received about 2 million comments, which "was a record for us," Cruickshank says. BOEM is conducting a detailed analysis of the proposed schedule of sales, and the second draft of the five-year plan was expected to be released this spring. The final draft of the plan could be approved around year's end.

"What we're seeing in this program, for the first time since the 1982-87 program was put together, is an analysis of the entire OCS," Cruickshank says. "We believe there is still a lot of potential left in the OCS."

There has been interest in seismic activity in the Atlantic, he says.

"There's a lot of reprocessing of what (seismic) exists, and analogs from West Africa to better understand the resources, but seismic has not been collected there in over three decades. The technology then just couldn't see as deeply under the seabed as current technology," Cruickshank says.

BOEM geologists are also bullish on the GoM. "It is the view of our geologists that half of the total endowment of oil and gas in the Gulf of Mexico is not yet discovered," Cruickshank says. "We think there is a lot left there to find."

Alaska is an area with "a lot of promise" and BOEM geologists believe it holds 27 billion barrels of oil and over 130 trillion cubic feet of natural gas to be discovered.

Source: BOEM

"IT'S PRETTY CLEAR THAT WIND ENERGY IS GOING TO HAPPEN, AND IT'S GOING TO HAPPEN IN A BIG WAY."

JIM BENNETT
CHIEF OF THE OFFICE OF RENEWABLE ENERGY PROGRAMS, BOEM

"The draft proposed program includes Alaska planning areas, which could put the Arctic back on the table for leasing," Cruickshank says. Currently, there's some production off the coast of Alaska, and BOEM has approved the development and production plan for Hilcorp's Liberty asset, which is entirely in federal waters.

There are still 34 producing leases offshore southern California, although a few decommissioning plans are expected there in the coming years, he says.

Renewables

While the only commercially operating wind farm offshore the US is off the country's tiniest state – Rhode Island – many of the larger and more populous states, particularly in the Northeast, are committed to power generated by offshore wind farms.

World-class winds, a shallow continental shelf and relatively high energy demand all combine to make the northeast coast a prime area for the country's first series of wind farms.

According to IHS Markit's Rafael McDonald, Director of North American Renewable Power, those states are seeking to add large amounts of offshore wind power.

"These numbers are getting bigger and bigger," he says.

Massachusetts has legislated 1.6 gigawatts (GW) of offshore wind, of which awards have gone out for 800 megawatts (MW). The state is also studying the benefits of adding another 1.6 GW of offshore wind off the state's coastline. New York legislated 2.4 GW of offshore wind power, then increased the target to 9 GW after New Jersey legislated 3.5 GW. Maryland is looking for several hundred MW while the governor of Virginia has recommended setting a goal for 2 GW. The state has approved a 12 MW project. Connecticut has committed to 300 MW, and Rhode Island wants to add 400 MW more to its existing 30 MW of offshore wind production.

"The pace is unheard of in North America before," McDonald says. "The states seem to be leapfrogging each other."

The states are even investing in port improvements to accommodate the added activity and attract projects and the associated economic benefit, McDonald says.

Wood Mackenzie Power & Renewables Analyst Anthony Logan called it a snowball effect. "As more states adopt policy mechanisms and offshore wind mandates, their neighbors, drawn by the prospects of attracting part of the sector's supply chain and logistics infrastructure, often follow suit, while states with existing policy mechanisms have been regularly increasing their appetite."

Jim Bennett, chief of the Office of Renewable Energy Programs for BOEM, is bullish on offshore wind energy.

"It's pretty clear that wind energy is going to happen, and it's going to happen in a big way," Bennett says.

That's because all the pieces – economics, technology and political will – have come together at the right time, he says.

BOEM's recent lease sales for wind have been "incredible," Bennett says. "These leases have been a long time coming." He anticipates "pretty substantial results" with the New York Bight lease sale set for early 2020. That could be followed up by lease sales off the coasts of the Carolinas and California.

The leases, he adds, are "morphing into actual steel in the

water." Bennett says new construction could begin as early as this year. He believes 10 to 12 projects will be executed over the next decade, possibly averaging a project every year through 2030.

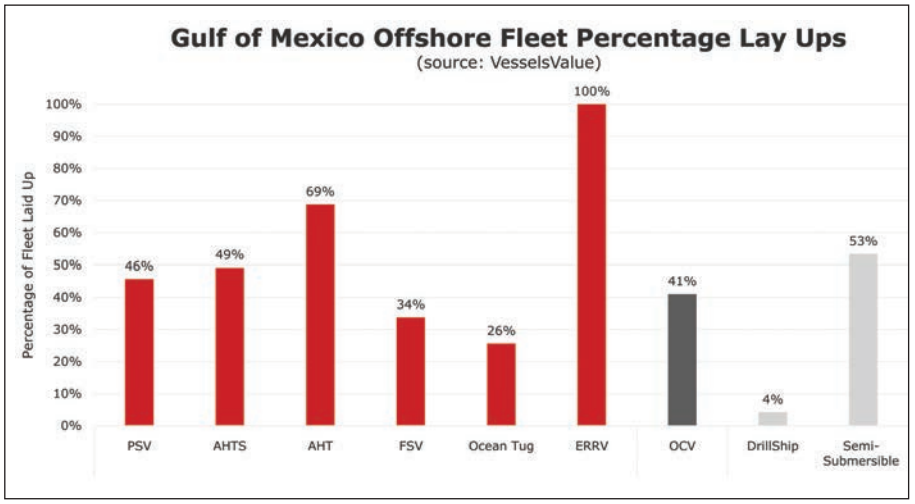
"That's the prognosis on the East Coast, just from the leases that have already been issued," Bennett notes.

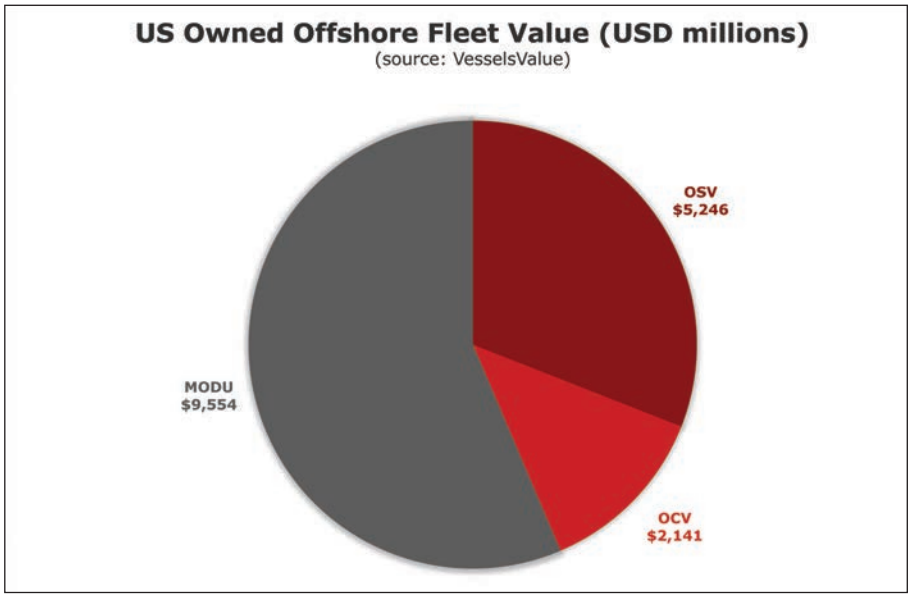
The story is fundamentally different on the West Coast, where water depths are deeper closer to shore, which means floating technology would be required for offshore wind farms, Bennett says. There are 14 nominations for lease areas off the West Coast, and he predicts California could have its first wind farm installation within the decade.

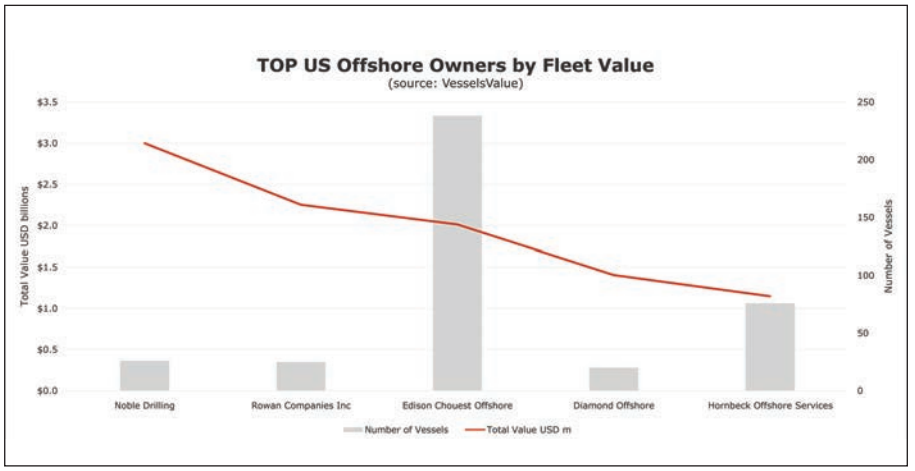
What makes for an interesting possibility, Bennett says, is island economies, like Hawaii. "For island economies, it's fair to say fossil fuel is very expensive, and wind energy offers a promising alternative."

While the pace of activity is accelerating quickly, the country still lags well behind Europe's offshore wind industry. McDonald suggests North America will benefit by not being a first adopter of the technology and by taking advantage of the lessons learned to date, primarily in cost and installation learnings. The majority of companies jumping into US offshore wind have experience developing offshore wind projects in Europe.

Powered by VesselsValue







M&A SCORECARD

As the offshore energy industry recovers, merger and acquisition (M&A) activity accelerates. Here's a look at the result of a few recent deals.

Soure: VesselsValue
($ in USD millions)

Merger: ENSCO and Rowan Companies

	Live	
	# Vessels	*Value $*
ENSCO	56	$4,296
Rowan	25	$2,251
Total	81	$6,547
	On Order	
	# Vessels	*Value $*
ENSCO	3	$831
Rowan	–	–
Total	3	$831
	Total	
	# Vessels	*Value $*
ENSCO	59	$5,127
Rowan	25	$2,251
TOTAL	**84**	**$7,378**

Tidewater Marines Acquisition of GulfMark Offshore

	Live	
	# Vessels	*Value $*
Tidewater	181	$837
Gulfmark	66	$300
Total	247	$1,137
	On Order	
	# Vessels	*Value $*
Tidewater	6	$74
Gulfmark	–	–
Total	6	$74
	Total	
	# Vessels	*Value $*
Tidewater	187	$911
Gulfmark	66	$300
TOTAL	**253**	**$1,211**

Transoceans Takeover of Ocean Rig

	Live	
	# Vessels	*Value $*
Transocean & Ocean Rig	52	$5,956
	On Order	
	# Vessels	*Value $*
Transocean & Ocean Rig	5	$1,522
	Total	
	# Vessels	*Value $*
Transocean & Ocean Rig	**57**	**$7,478**

Borr Drilling Takeover of Paragon Offshore

	Live	
	# Vessels	*Value $*
Borr & Paragon	26	$2,516
	On Order	
	# Vessels	*Value $*
Borr & Paragon	10	$1,599
	Total	
	# Vessels	*Value $*
Borr & Paragon	**36**	**$4,116**

size does matter

Allseas

2020: CAUTIOUS OPTIMISM FOR AN OFFSHORE RECOVERY

BY GREGORY BROWN, Associate Director - Offshore, Maritime Strategies International Ltd.

Much has been made of an expected recovery for offshore. We share that optimism. We think there will be around 20 final investment decisions (FID) for floating production, storage and offloading units (FPSO), nearly 60 subsea projects and a total of 330 trees going ahead this year. However, we are concerned that 2020 may not offer such a positive outlook for new development activity and that momentum could turn negative.

The weaker medium-term outlook reflects the impact of 2015-17 exploration and production (E&P) capex cuts and the cyclicality of the industry. Despite having a constructive view on offshore overall, we think it would be prudent to model cautious optimism for order intakes for 2020 and beyond.

From the 2016 trough, order intake has rebounded; for subsea trees, the market has grown fourfold. Just 78 trees were awarded at the bottom of the market. For 2019, we think that more than 330 will be ordered, but to expect another year of +/-30% growth in a cyclical market looks far too optimistic to us. While we believe that the supply chain would be able to handle such an increase without incurring material cost inflation, the projects pipeline looks insufficient at this stage to underpin another year of such solid growth.

As well as a lack of projects in the pipeline, recent oil price volatility has compounded the issue. Downward pressure has softened medium-term confidence. In some cases the uncertainty has caused development portfolios to be reassessed, with upstream companies unwilling to catch the falling knife and FID a project in the midst of an oil price slide. The subsequent delays in finalizing concept selections have seen several project timescales slip to the right, while procurement teams have hesitated to move projects through decision gates.

The impact of these delays is that subsea orders could cool in 2020, and that FPSO orders will likely remain broadly flat. We expect around 290 subsea trees to be awarded, alongside 19 FPSOs over the course of 2020. Although perhaps disappointing in terms of momentum, this forecast should be viewed in the context of how bleak the market was between 2015 and 2017, and in light of oil companies' newfound commitment to capital discipline and flat capital expenditure budgets. The market is still likely to offer far more opportunities than those that were presented during the downturn.

While we advise caution for the market overall, we are more optimistic on deepwater. In particular, we are confident that the Brazilian pre-salt market will drive growth for the industry. We expect well over 100 trees to be awarded over the next four years, along with 13 FPSOs. These will provide opportunities for the domestic and international supply chains, from engineers, through to rigs, pipe makers and offshore installation work. Among the FPSOs we expect to go ahead, we highlight the two replacement Marlim FPSOs and the second Mero vessel as strong candidates for award in 2019, along with Buzios 5. Moving into 2020, we expect the market to benefit from the opening up of pre-salt fields to international operators and investment. Equinor is likely to FID the Carcara vessel alongside the likes of Petrobras' Itapu and Parque das Baleias projects.

Beyond Brazil, we're encouraged by greenfield deepwater basins off Guyana and India which together are likely to offset the lack of progress off Mexico deepwater investment has been curtailed in the short-term by the decision to halt upcoming license rounds. The Angolan and Nigerian markets also offer opportunities for the supply chain, with Angola in particular offering a robust hopper of subsea tiebacks as Sonangol and its partners look to arrest a steep production decline. In Nigeria, we're hesitant to call a deepwater recovery on the back of continued delays at Bonga Southwest and Zabazaba but do note the likes of Owowo and Preowei tiebacks as projects gathering positive momentum.

Overall, we expect deepwater projects to account for around 55% of subsea FIDs in 2019 and close to 60% in 2020.

Beyond 2020 the lack of recent discoveries may weigh on the development hopper. While exploration and appraisal activity should be robust over the next 18 months, it will take time to filter through to project awards. The industry has made admirable progress in shortening lead-times but we do not think that they have shortened to such a point where larger

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projects can be discovered and developed en masse in less than three years which thus impacts our 2020/21 expectations materially.

The industry has made better progress on smaller tiebacks which offer faster paybacks. It is here we expect the bulk of investment in 2020, particularly for the subsea industry. The likes of Atlantic Phase 3 in the US Gulf of Mexico and Luno 2 are recent examples of incremental production being tied back into existing infrastructure and set a trend going forwards. We note that Lundin has a host of tieback candidates to the Edvard Grieg platform in the pipeline, while in the US, new seismic techniques adopted by the likes of BP have filled the pipeline.

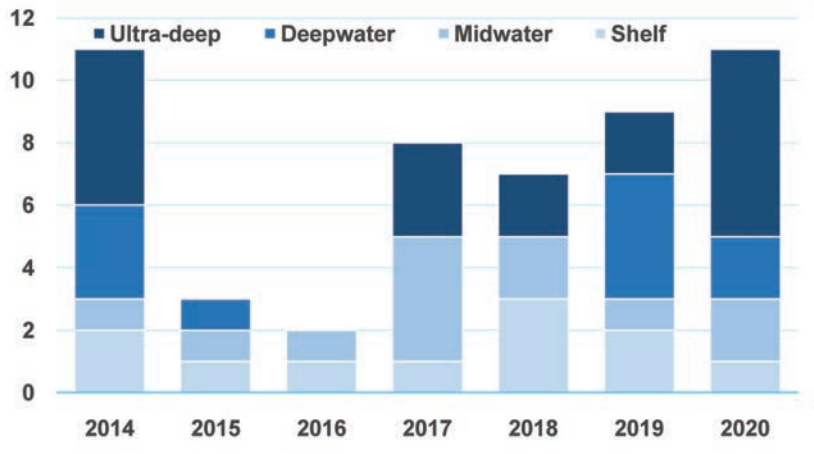
Elsewhere in the Gulf of Mexico, independent E&P operators which remained committed to offshore through the downturn, such as LLOG, should be able to take advantage of the low-cost environment and FID the likes of Kahleesi, Mormont, Red Zinger and Nearly Headless Nick, among others over the next 18 months.

Looking to the longer-term and post-2021, the industry should start to benefit from greater exploration activity. We're confident that FID activity should be robust with a host of opportunities across the North Sea, Gulf of Mexico, South America and elsewhere. Activity should be supported by heightened investment related to Asian projects, while Brazil is likely to be the single largest market.

For the near-term, the market may have recovered from the lows but we are far from the previous cycle's peak, with no obvious route back to the summit. To see a return to 2012-2014 type levels of activity, and therefore pricing, looks far too optimistic given the uncertain macro climate.

For the supply chain, in the absence of a volume-based recovery, and in light of a cautiously optimistic outlook, the offshore industry should look to differentiated offerings and enabling nascent technologies to thrive in the new normal. Technology such as SBM Offshore's Fast4Ward FPRO design that can accelerate time to first oil should help secure market share gains in a sector that looks to be structurally smaller than previous cycles.

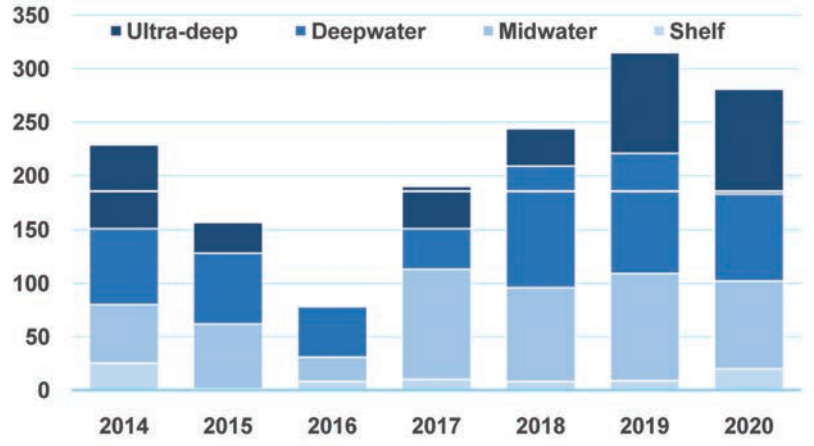
FPSO FIDs by Water Depth



Water Depth Group	2014	2015	2016	2017	2018	2019	2020
Shelf	2	1	1	1	3	2	1
Midwater	1	1	1	4	2	1	2
Deepwater	3	1	0	0	0	4	2
Ultra-deep	5	0	0	3	2	2	6
Grand Total	**11**	**3**	**2**	**8**	**7**	**9**	**19**

Source: Maritime Strategies International

Subsea FIDs by Water Depth



Water Depth Group	2014	2015	2016	2017	2018	2019	2020
Shelf	25	1	8	10	8	9	20
Midwater	55	61	23	103	88	100	82
Deepwater	71	66	47	38	113	112	81
Ultra-deep	78	29	0	39	35	94	98
Grand Total	**229**	**157**	**78**	**190**	**244**	**315**	**281**

Source: Maritime Strategies International

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Drilling Down

Pacific Drilling's Sharav drillship

Source: Chevron

Deepwater exploration is starting to get serious, again. If fact, French oil major Total is lined up to drill what will be a new deepwater drilling record later this year, offshore Angola. At about 3,600 meters water depth, it will break a previous record set by total at the Raya-1 well in Uruguay in 2016, at 3,400 meters.

The stakes are big but so are the prizes, and that's what's driving renewed interest. It's a turnaround compared with 2015, when analysts Wood Mackenzie said that, since late 2014, 68 major projects and 27 billion barrels of oil equivalent (BOE) of commercial reserves have been deferred, due to the oil price crash. In the last five months of 2015, deepwater projects had been hit hardest, accounting for over half of the total $380 billion of total project capital expenditure (capex) deferred (real terms), from the 68 projects.

Now, following a year of relatively steady oil prices in 2017, and strides made in project economics made since 2014, spending is once again expected to increase. In November, Wood Mackenzie said total annual deepwater capex is expected to rise from around $50 billion currently to nearly $60 billion by 2022, driven by big projects developing already made discoveries in Guyana, Brazil and Mozambique.

Wood Mackenzie says the cost of developing new deepwater barrels has fallen by more than 50% since 2013, due to project downsizing, focus on subsea tiebacks and brownfield developments, project lead time and well count reduction,

n Deep

Deepwater drilling is back and targeting ever deeper waters, from South Africa to Pakistan. Elaine Maslin takes a look.

faster well completions, phased developments, better project execution and lower rig/service sector costs.

Exploration successes, particularly in Guyana, where more than 5 billion barrels has been found since 2015, with break-even oil prices in the $30s/barrel, is also driving interest. According to Wood Mackenzie, the number of risky deepwater frontier wells increased from six in 2016 to 21 in 2018, although only two made commercial discoveries and both were in Guyana. "The reality is that deep water is where the best opportunities are, because of lot of deep water, off the shelf basins are still relatively lightly explored," says Wood Mackenzie's Andrew Latham. Production from mature basins onshore and in shallow water is declining, leading operators into deeper waters. "The big untested prospects happen to be mainly in deep water or countries that are for various reasons more challenging to access. We are seeing NOCs explore non-deep water and for IOCs that want ready access to opportunities, deep water is where it is."

While deepwater exploration in 2019 isn't expected to outstrip 2018, operators are pushing the deepwater envelope. In January, Transocean signed a rig design and construction management contract, as well as a five-year drilling contract, with Chevron, for one of two DP ultra-deepwater drillships, currently being built at Sembcorp Marine's Jurong shipyard, Singapore. This will be the first ultra-deepwater floater rated for 20,000 psi operations and is expected to start operations in the Gulf of Mexico in the second half of 2021. Expected to be targeting high-pressure, high-pressure resources, the drillship will feature dual 20,000 psi blowout preventers.

Total is leading this game by a margin. "Most people transfixed by the success of ExxonMobil in Guyana and, before that, Eni in Mediterranean," says Latham. But, he says, Total is clearly a major player in this area. "Total has quickly been getting involved in a string of discoveries, both non-operated, including Ballymore in the US Gulf of Mexico (operated by Chevron), Calypso in Block 6 offshore Cyprus (operated by Eni), and its own. For a lot of our 'wild cats to watch' this year, their name keeps coming up."

AFRICA

Indeed, Total is leading the pack in African deepwater exploration. While West Africa hasn't been as busy as it used to be, it is due to be home to Total's ultra-deepwater exploration well on Block 48, which is Angola's current most outboard license and a potential play-opener. At 3,600 meters, it would be the deepest water well drilled to date. Block 48 is in the Lower Congo Basin, some 400 kilometers northwest of Luanda and 200 kilometers West of Soyo onshore facilities.

Success in Block 48 would come hot on the heels of Total's successful Brulpadda well offshore South Africa, completed in February. A reentry well, Brulpadda-1 is in 1,432 meters water depth in the frontier Outeniqua basin, 175 kilometers offshore, and was drilled using Odfjell Drilling's Deepsea Stavanger semisubmersible rig. Pegged as a play opener, Brulpadda has prospective volumes of around 1 billion BOE.

Total also has its sights on another deepwater target, the Venus-1 well in Namibia's ultra-deep Block 2913B (2,500-3,250 meters). Venus-1 has potential to be the year's largest discovery, says Latham. The ultra-deepwater wildcat will target 2 billion BOE in a giant Cretaceous fan play, close to the South African maritime boundary.

Total is also operator of the planned Rufisque Profonde-1 exploration well offshore Senegal, which is expected to be in about 3,000 meters water depth.

GULF OF MEXICO

The US Gulf of Mexico is in many ways an established basin, but there are big new plays being proven and tested – in deep water. "The last couple of years has seem some tremendous success in the Gulf of Mexico, including the Whale and Ballymore discoveries, driving further interest," says Latham.

Shell made the Whale discovery in 2017, in 2,400 meters water depth, in the Wilcox formation in the Perdido Fold Belt, in Alaminos Canyon Block 772, adjacent to Shell's Silvertip field and about 16 kilometers from the Perdido platform. Chevron's Ballymore find (in which Total is a partner), meanwhile, was made in 1,992 meters water depth in the Jurassic Norphlet play using Pacific Drilling's Sharav deepwater drillship. "Those two successes in last 18 months have really focused attention on the Gulf of Mexico and we expect we will

Stena Drilling's Stena IceMAX.

Source: Stena Drilling

see a string of important wells there this year," says Latham.

Latham highlights the Jurassic play. Shell's 2,250 meters depth Appomattox development, in Mississippi Canyon Block 392, due on stream this year, will mark the first production from a Jurassic reservoir in the US Gulf of Mexico, paving the way for future exploration and development from an area that had perhaps previously been overlooked.

"This area (the Jurassic) has surprised the industry," Latham says. "Despite the great depths at which they're buried, the Jurassic dune sand stones still have highly remarkable porosity causing people to think again about the potential of this play."

Chevron is due to spud Kingsholm-1 in the US Gulf of Mexico toward the end of the first quarter. The prospect is high-pressure, high-temperature (20,000 psi) and holds an estimated 300 million BOE of resource.

There are two main stories in the Gulf of Mexico, says Latham. Operators like LLOG are looking for 30 million barrell prospects, that are low risk and can add valuable barrels to core assets. Meanwhile, Chevron's Ballymore, containing some 500 million to 1 billion BOE recoverable, is a standalone project in scale, says Latham, found by targeting higher risk, harder to drill wells at 9,000 meters plus target depth.

MEXICO

While the next two oil and gas acreage auction rounds have been set back in the Mexican Gulf of Mexico, exploration activity hasn't, and new entrants are bringing a fresh approach into an established basin.

Exxon and Total are together targeting the ultra-deepwater Etzil prospect in Block 2 of the Perdido Fold Belt, awarded in Mexico's hydrocarbon auction Round 1.4 in 2016. It's been reported to cover some 80 square kilometers and potentially contains 2.7 billion BOE.

Equinor and Murphy Oil are also drilling wildcats; Equinor, with partner Total, in Block 3 in the deep waters of the Gulf of Mexico's Salina del Golfo Basin, and Murphy on the Cholula prospect, formerly known as the Palenque well, on Block 5.

"While Pemex has a reasonably long history drilling wells in the Mexican Gulf of Mexico, the deep water is very lightly drilled," says Latham. "Any basin that has been under a monopoly for a long time hasn't had a diversity of ideas. Fresh ideas and concepts are likely to lead to some success here."

BRAZIL

After a lull in exploration in recent years, activity is returning to Brazil. Results are expected soon on the Peroba well, targeting a giant pre-salt prospect in Brazil's Santos basin. Peroba, which lies on trend with the giant Lula discovery in 2,100-2,600 meters water depth, is estimated to hold recoverable volumes up to 1 billion BOE. "If the well is successful, partners Petrobras, BP and CNODC (China National Oil and Gas Exploration and Development Corporation) are likely to be sitting on a very significant find," says Latham. Going to press, operations were ongoing.

More wells are coming, with Shell, Equinor and BP lining up multiple targets and ExxonMobil with one well currently planned, says Latham. BP's prospects are expected to include the first Amazon Mouth well later this year.

Source: Wintershall

Odfjell Drilling's Deepwater Stavanger.

Source: BP

"It's definitely busier than it has been here," he says. "Brazil went through quiet phase as Petrobras focused on appraisal. Now we are entering another wave of exploration and these are all standalone-scale projects, mostly in the Santos Basin."

LATIN AMERICA

Brazil isn't the only game in Latin America; the Equatorial margin, especially Guyana and Suriname, have come under focus. In French Guiana, Total, again, is drilling the Nasua-1 well in 2,000 meters water depth, 150 kilometers offshore using the Ensco DS-9. Going to press, operations were ongoing.

There is also the Jethro prospect, in 1,350 meters water depth on the Orinduik Block, offshore Guyana. This well is on acreage adjacent to ExxonMobil's prolific Stabroek Block and will target a 200 million BOE prospect in the same play as the recent Hammerhead find.

MEDITERRANEAN

Having risen dramatically in prominence in recent years, the Mediterranean remains an active area. Recent developments in Israel, with the giant Tamar and then Leviathan discoveries, and, since then the fast track of Zohr, really put it the region on the map. Last year, Eni made the Calypso discovery in Block 6 offshore Cyprus, in 2,074 meters water depth, following Aphrodite in 2011.

This year, there are five potential wells in Cyprus, says Latham, three from Eni, following Calypso. Exxon has completed two deepwater wells, testing multi-Tcf in Block 10. It completed the Delphine well earlier this year and, late February, it completed Glaucus, in 2,063 meters water depth, using the Stena IceMax. Exxon said preliminary estimates suggest Glaucus contains 5-8 Tcf of gas in place resource.

The first well in Lebanon is due on Block 4 by Total, although the date has slipped. "This is a pretty big province and pretty lightly drilled," he says. "One of the attractions of discoveries that have been made is they can be developed with very few development wells. You get an enormous recovery rate from single wells, for that play; greater than100 million BOE a well. Egypt has a tremendous domestic gas market and the same with Israel, so there is a market. As volumes get bigger, the requirement to start exporting to Europe will emerge and there are various possibilities to get the gas to Europe."

OTHER REGIONS

Shell has lined up the Noble Globetrotter II drillship to sink a frontier exploration well in the Black Sea offshore Bulgaria in the first quarter of this year.

On January 6, Eni started drilling the Kekra-1 deepwater wildcat, in the Indus G Block, some 230 kilometers offshore Pakistan, using the Saipem 12000 drillship.

In Papua New Guinea, Total is targeting deep water this year, with the "giant" Mailu prospect well.

While not in the deepest water from a global perspective, Siccar Point's Blackrock prospect, West of Shetland, is a deepwater well in UK Continental Shelf terms, at 1,444 meters water depth. Siccar Point announced in March it commenced spudding an exploration well at Blackrock using the Diamond Offshore semisubmersible rig Ocean GreatWhite.

Three IMR Trends

Source: TechnipFMC

BY WILLIAM STOICHEVSKI

ROV Surveys: a TechnipFMC ROV during launch

For years, "maintenance and modifications" were catchwords for nearly everything that wasn't greenfield activity offshore. Two economic slowdowns later, subsea "M&M" might be seen as inspection, maintenance and repair (IMR), a segment that includes light well intervention, well monitoring and a range of subsea work offered as "life-of-field" and life-extending. Now, new transatlantic rules and best practices offer paths to future IMR earnings for operators and suppliers.

When the DNV GL call for well data went out to Norwegian operators and oil ministry managers about a decade ago, few would have imagined that it might one day help spawn new business streams. Back then, a DNV GL well integrity researcher seemed but a sign that Class was branching out into offshore structures, both surface and subsea.

Fast-forward about 15 years to 2019, and the new US Bureau of Safety and Environmental Enforcement (BSEE) has put out a similar call for well data. In the past year, BSEE has followed that up with revised rules for well design, well control, casing, cementing, real-time monitoring, asset integrity and subsea containment. There's even a new BSEE rule for 2019 governing field Life Cycle Management, 1st Edition.

Among the new rules is a requirement that an offshore facility have its own oceanic monitoring in real-time, and the use of a remotely operated underwater vehicle (ROV) or autonomous underwater vehicle (AUV) is recommended. Asset integrity for standing structures, subsea structures and wellheads has been codified into life-of-field canon, but knowing the strictures is a basis for future earnings. Some know them well, and today, large supplier-contractors known for their engineering procurement, construction and installation (EPCI) have recently taken shares in specialist subsea companies or formed joint ventures to do more of the inspection work today's robotic tech makes possible and today's rules make potentially lucrative.

An example of this is Subsea 7's inspection brand, i-Tech, now doing what the company calls IRM (IMR) work. February 2019 saw BP Exploration award them a contract for "construction, inspection, repair and maintenance" for all BP assets in the North Sea West of Shetlands and in the northern North Sea. iTech Services is slated to provide the operator with a life-of-field work vessel, Solstad's Normand Subsea, with "work class and observation class ROVs capable of inspection, survey, intervention" and light, subsea construction and two moonpools.

IMR GROUPING

While the award was a contract extension, 2018 was the year of IMR for Subsea 7. November saw Shell UK Ltd. join a seven-operator frame agreement that will see Subsea 7 provide IMR, construction and decommissioning services as part of its diving support vessel initiative.

In May 2018, Norwegian operator Equinor had also agreed to take a life-of-field support vessel, Seven Viking, from Subsea 7 to go with IMR performed by ROV, although the vessel also does light construction, as in module and tree installs managed from i-Tech Services in Aberdeen. "The award of this long-term [IMR] contract ac-

knowledges the capability and high standard of performance i-Tech Services has established over decades of providing [IMR] services to [Equinor]," states Steve Wisely, i-Tech senior vice president. IMR, however, hasn't always been called IMR, and even today, IMR assets are only now being grouped, hired or partnered with, as supplier consolidation coincides with the appearance of rules that allow longer field life via asset "recertification", a business stream shared by IMR vessel operators and EPCI experts.

Then there are the operators: in Norway, a local news report at press time noted that Equinor has, in just three years, secured more than 130 years of "extended field life" via rules-based recertification and life extension measures.

A decade ago, Island Offshore and Oceaneering collaborated to give Equinor inspection services that got everyone through the credit crunch post-2008. ROVs led the inspection work, mostly of rig moorings, and Island Offshore's new light well vessels awaited the new type of business they were built for. Today, TechnipFMC owns a 51% stake in new Island Offshore subsidiary, Island Offshore Subsea, the entity now in control of its light well intervention fleet. As with Subsea 7, TechnipFMC can now offer a construction vessel and riserless light well intervention (RLWI) and regular IMR to go with its subsea umbilicals, risers and flowlines (SURF), EPCI and subsea production systems. "Our current track record delivering RLWI services together with Island Offshore has significantly increased production from more than 500 subsea wells," said TechnipFMC's president of subsea, Hallvard Hasselknippe at the time of the merger. Add to that the "thousands" of wells Island Offshore CEO, Haavard Ulstein, told this writer are in need of plug and abandonment work — after new rules on plug depths — and there's a vast backlog of well intervention work that starts with IMR.

Today, Oceaneering is fresh from building and testing BP's programmable AUVs that will survey and inspect pipelines, fixed structures, subsea installations and do oceanographic work. Equinor, too, has Oceaneering contracted for inspection work aimed at recertifying subsea structures useful for field extensions and made necessary by some of those new rules mentioned. The three years of asset integrity inspection work will see Oceaneering design an IMR program of corrective measures, nondestructive testing, video inspection, vibration measurement, thermography and heat exchanger inspection for 14 Norwegian facilities.

The recertification work extends field life while also paving the way for the remote piloting from shore of ROVs and AUVs. So, just as a field's production tapers off and earnings are less, manning and travel costs can drop concurrently without a corresponding drop in safety: "One of our customers said it costs 17-times as much to have one of our employees working offshore as it does to have them working onshore," Oceaneering CEO, Rod Larson, said at a recent conference.

IMR Capable:
Island Offshore Subsea's Island Constructor

LIFE EXTENSION WAVE

Mostly, however, asset integrity via inspection is increasingly about extending field life past design life spans, something the new rules are being used for and the chief reason there is a surge in orders for this type of work.

A good, win-win example of this is Oceaneering's February 2019 award form Total to develop integrity management programs that de-risk via inspection the Tyra redevelopment project offshore Denmark. The 30-year-old installation will see a new lease on life for having "all its pressure systems and piping, topsides and jacket structures as well as pipelines" inspected and monitored under a regime managed from Aberdeen by Oceaneering's corrosion, inspection, structural and pipeline engineers." In the recent past, ROV video alone would not have been the path to longer field life. To do that, you need new, comprehensive standards, recommended practices and rules that say, "This is the way to extend field life based on risk-analysis."

"[Tyra] is defining the way in which integrity management is delivered, and our full suite of services will help to accomplish Total's goal of enabling remote operations of the future platform," Bill Boyle, Oceaneering's senior vice-president for asset integrity stated in February. And Tyra is uniquely important to a stalled Danish offshore sector, as it processes 90% of Denmark's gas production. Redevelopment and Oceaneering's inspection work will help secure production at the field for the

Source: William Stoichevski

Add to that the "thousands" of wells **Island Offshore CEO, Haavard Ulstein**, *told this writer are in need of plug and abandonment work — after new rules on plug depths — and* **there's a vast backlog of well intervention work that starts with IMR.**

next 25 years. Its newly recertified infrastructure "will enable operators to pursue new gas projects in the northern part of the Danish North Sea".

Oceaneering, BP and Equinor aren't alone in getting AUVs to cover both the asset — and environmental — integrity sides of inspection. Among others, Eni has combined on a cost-effective Clean Sea "drone" for deep water which is understood to do pipeline inspection, water sampling and visual inspection of subsea protection systems, jackets and cathodes. Others like Swire Subsea have invested in the capable payloads of Kongsberg Maritime's Hugin AUVs.

RECERTIFICATION WAVE

While recertification by IMR revives the Danish offshore industry and helps Aberdeen earn, it's also providing novel business streams in Norway for an unexpected segment: the coastal base. Armed with new best practices — specifically DNV GL's Best Practice No. RP-E101: Recertification of Well-control Equipment — the shore-based maintenance side of subsea IMR can also earn by recertifying wellhead equipment for compliance-minded rig owners, equipment resellers or operator field extensions. Compliance with new rules, or recertification, opens another path toward less risk and life extension.

The busy Norwegian CEO of CCB Subsea, Nils Frederik Fjaervik, can't talk to us when we call, but he confirms his coastal base, with the support of Danish NorSea Group, now offers recertification IMR work while serving as a base for rigs and taking on decommissioned structures from offshore. Supply chain manager NorSea is also understood to be marshalling interests and competence in Canada for a "one-stop shop" base like CCB Subsea.

Norwegian online business directories confirm CCB Subsea earnings are on the rise after acquiring engineering consultancy Logiteam and Logiteam Subsea. Equipped with engineers, including design engineers, the company can now recondition and redesign subsea wellhead equipment and drilling kit shoreside to meet recertification requirements.

"CCB Subsea understands recertification, and our engineers have extensive experience with recertification projects and the relevant standards governing the design and recertification of well control equipment," the company says, adding, "Together with DNV GL, CCB Subsea will ensure that your well control equipment is fit for another five years in service."

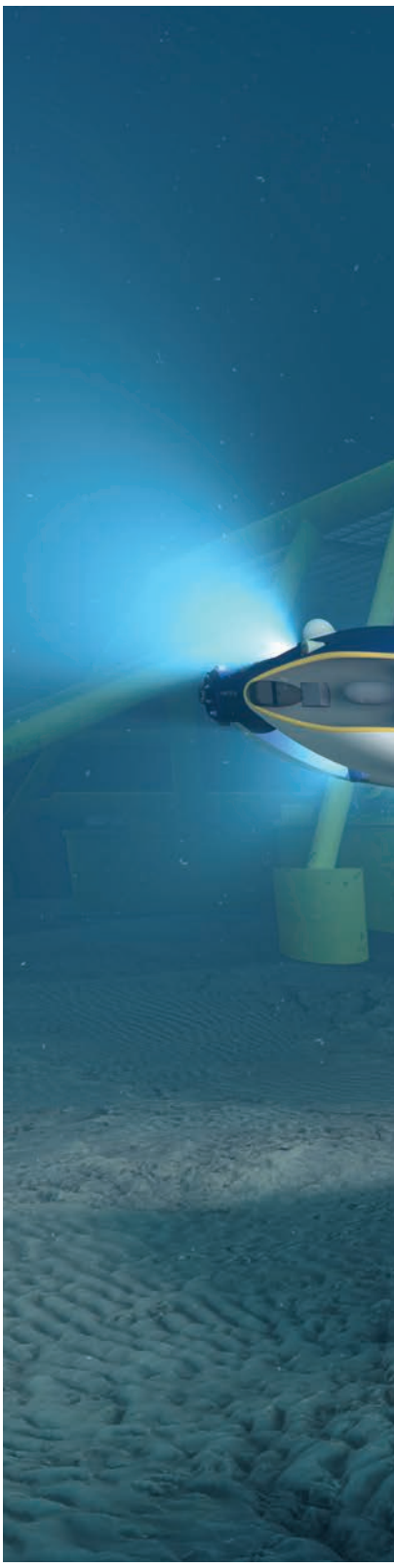
Meanwhile, in Canada, parent company, NorSea, appears to see the big picture offered by onshore maintenance and recertification of subsea assets. In a statement, Bruce Dyke, President of Integrated Logistics, comments, "The establishment of a Canadian Supply Base Company is a positive step towards developing the life-of-field support (including subsea services) the industry needs for continued development and growth in the offshore oil and gas sector."

The new strictures on IMR, it seems, are giving many a new lease on life.

A Sliding Scale of Residency

There are increasing moves toward subsea resident vehicles and an increasing range of options becoming available.

BY ELAINE MASLIN



Seabed deployed remotely operated underwater vehicles (ROV) are already here. Since early last year, IKM Subsea has been operating its Merlin UCV R-ROV (resident ROV) from a cage placed beneath Norwegian operator Equinor's Snorre B production facility offshore Norway. It's powered by and connected to, for communications and control, the Snorre B facility and deployed for three-months at a time before being retrieved for maintenance. By operating the ROV from the cage on the seafloor, launch and recovery operations are no longer reliant on the weather and the ROV can be on site faster when it's needed. Furthermore, it's able to be operated either by ROV operators on the facility or from an onshore control room near Stavanger, via fiber optic cable.

In April, Oceaneering's E-ROV (E for empowered) will take a different tack, working off vessels in Equinor's inspection, maintenance and repair (IMR) fleet. Using a concept demonstrated by Oceaneering using its e-Novus ROV last year, the battery-powered E-ROV will go out with the IMR vessels, be deployed at a site where it's required, together with a 600-meter tether management system and fiber optic cable to a surface communications gateway buoy. This will enable communication and control via 4G LTE from an onshore control room, leaving the IMR vessel free to do other work.

Not yet commercialized is an idea which would take these concepts a step further – ROV deployment from unmanned surface vessels (USV). Total and TechnipFMC have been exploring this idea for light subsea IMR activities working with France's ECA Group. ECA Group says that a successful demonstration of the ability to carry out an inspection task using its Hytec H300V observation class ROV deployed from a USV Inspector, using a wireless communication link (surface communications gateway), was demonstrated earlier this year. During the operation, an onshore operator conducted repetitive tasks on a simulated subsea asset, using the ROV, deployed from the Inspector 90 USV.

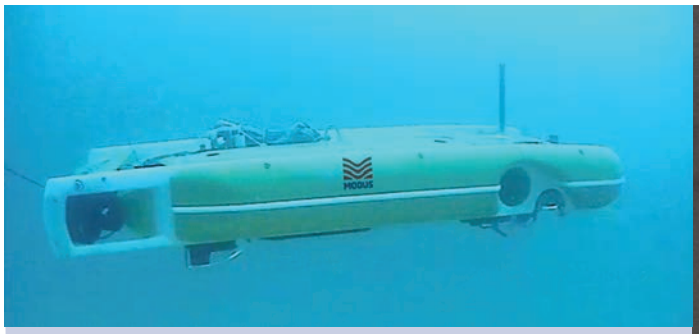
Cutting the Cord

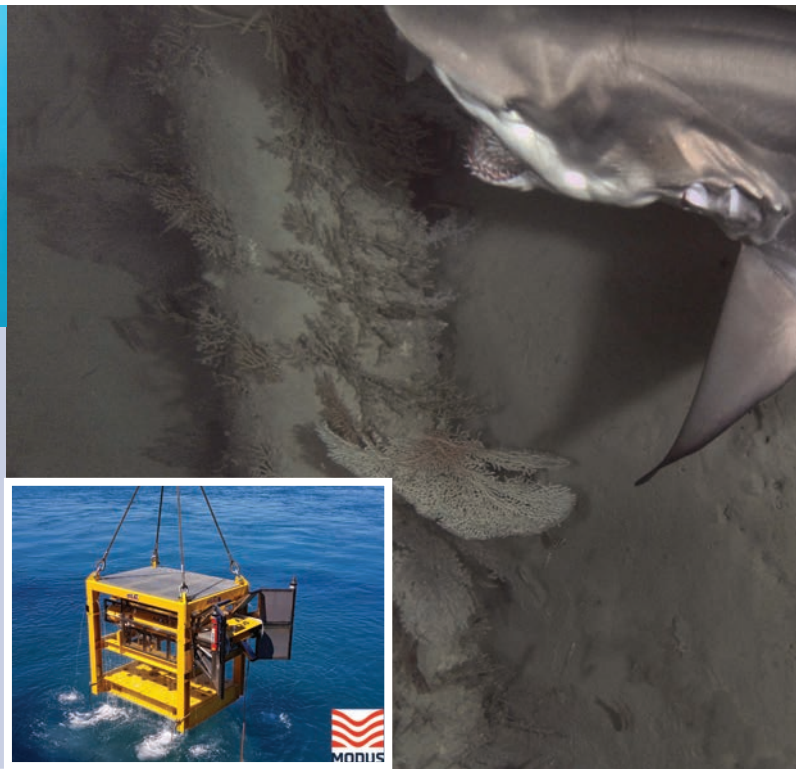
All of these systems so far rely on tethers for power and communications/control or, where the vehicle is battery powered, communications/control. For those wanting to shed the tether, autonomous underwater vehicles (AUVs) are the guiding light.

Earlier this year, Saab Seaeye says it achieved a world first by showing that underwater electric vehicles can dock at remote deepwater sub-resident resident docking stations for data transfer, assignment instructions and battery charging.

Oceaneering's Freedom concept, an artist's impression.

Source: Oceaneering





LAST YEAR, MODUD DEPLOYED A HAUV offshore northwest Australia to perform more than 200 kilometers of pipeline integrity survey, producing images and point cloud data, of both the pipeline and passing marine life using a Cathx laser and HD camera spread alongside a multibeam echosounder. "The survey time was half of what it would have taken using a traditional ROV to perform the survey and it could have been faster," says Modus CCO Nigel Ward. "Such a survey is possible without a tether, but it was performed with a tether on this occasion so that real time data could be collected." Modus has also been trialing Force Technology's FIGS system, which can do noncontact cathodic protection surveys at 4 knots, alongside while doing general visual inspection (GVI) survey. **Photos: Modus Seabed Intervention**

Its 3,000-meter-rated Sabertooth can already work remotely on preprogrammed or man-controlled missions, including IMR, research tasks and environmental monitoring. Now, fitted with a 2-kilowatt/80-megabits-per-second Blue Logic inductive charger and data transfer device, the hybrid AUV/ROV was able to dock, charge and download data in a trial in Saab Seaeye's test tank facilities. This means it can now dock, charge and up or download data at any docking station – including a standard design proposed by Equinor – where there's a respective Blue Logic connection, as well as change out tooling, says Jan Siesjö, chief engineer at Saab Seaeye.

"We have had the docking station and autonomous docking based on transponders and using BlueComm for quite a while, but power and data transfer hasn't been done before. This is the final missing piece for complete system that can do these resident jobs," Siesjö says.

Separately, Saab Seaeye is working with ocean energy technology firm Ocean Power Technologies (OPT), with which it has an agreement to jointly develop and market solutions for AUV and ROV charging and communications systems, using OPT's PB3 PowerBuoy as a power supply and surface data gateway. For Siesjö, a key enabler is surface communications. "There is 4G over most of the North Sea," he says. "With that, all of a sudden you can have a docking station with a communications buoy or a USV supporting an AUV with communication. All of the pieces are there."

Demonstrating Docking

Modus Seabed Intervention will take delivery of its second, deepwater-rated Sabertooth hybrid AUV (HAUV) this summer. In 2017, the company performed demonstrations and trials and its existing HAUV was ready for commercial operations in 2018. In one of the 2017 trial projects, the HAUV was launched from a quayside at a lake close to Saab's Facility in Sweden to perform a "mow the lawn" style pre-programmed survey collecting multibeam echosounder (MBES), side scan sonar (SSS) and sub-bottom profiler (SBP) data over about 15 kilometers, with no external aiding from a support vessel – just the vehicle's differential Global Positioning System (DGPS), inertial navigation system (INS) and doppler velocity log (DVL). "Having gone out and repeated the survey, it saw very little drift," says Nigel Ward, the firm's chief commercial officer. The vehicle was also successfully trialed multiple times, autonomously docking into its subsea garage.

In early 2018, a trial as part of an Innovate UK funded project for wind farm resident inspection performed out of the ORE Catapult facility in Blyth, England, involved indirect power coupling and data transfer using a Blue Logic inductive connector. In the final phase of this demonstrator project, later this year, in between its commercial commitments, Modus will trial a resident HAUV concept at an offshore wind farm in the UK.

Subsea 7's 3,000-meter-rated autonomous inspection ve-

hicle (AIV) is, like the Sabertooth, able to hover, (for close up inspection). It's an infield inspection vehicle with 24-hour endurance, says Alan Gray, from Subsea 7 company i-Tech 7. The 1.7-meter-long, 1.3-meter-wide, 0.8-meter-high vehicle (750 kilograms in air), with lithium ion batteries can do a 40 kilometers round trip, he told Subsea Expo in Aberdeen earlier this year, and performed 36 inspections during a single 18-hour period last year. It's done four offshore trials, including docking and has reached TRL5 (technology readiness level), he said. The AIV, which can communicate via acoustic, radio or 4G networks, could be used during simultaneous operations operating from a garage, to free up the IMR vessel for other work, says Gray. But, it's also been built with autonomy in mind. It uses a map combined with sonar to navigate and has an advanced planning system, with an intuitive map on which you can point and click to plan missions, says Gray. Using through-water communications could then bring the human in the loop for complex tasks, although there's

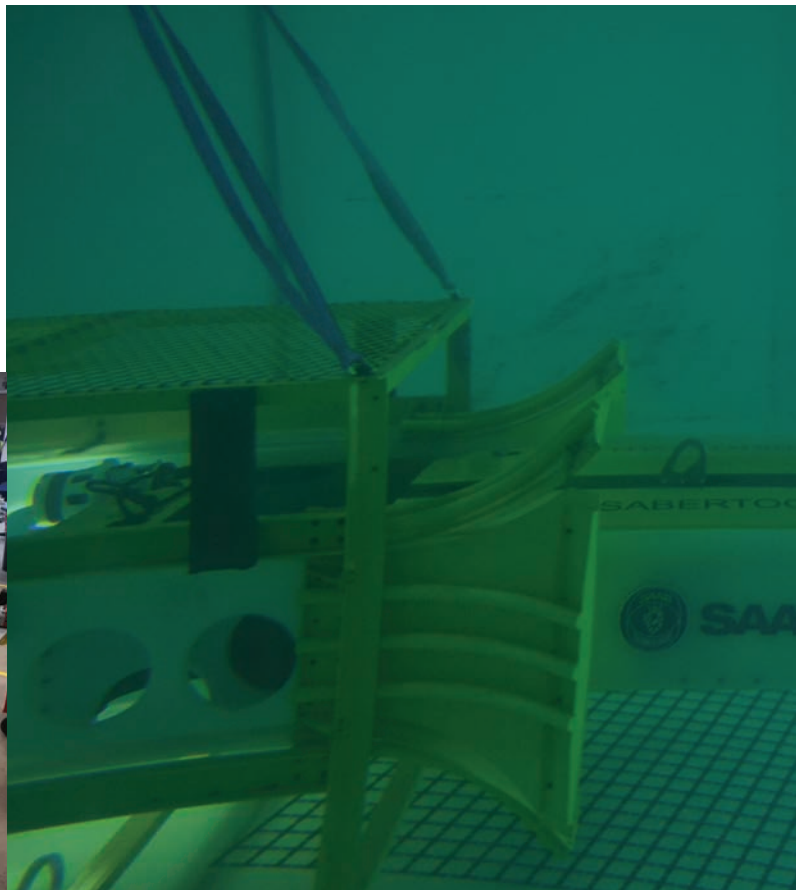
still some work to do here, he says.

Next into the water will be Oceaneering's Freedom vehicle. Oceaneering says that the 3.3-meter-long completely new design vehicle will be able to perform inspection, advanced survey and light intervention work, autonomously (out to 50 kilometers without a tether or 250 meters with a tether) or under remote control, using a modular design that means it can be configured for the mission it's required for. This will comprise a common center section with ends that can be interchanged. Freedom has a carbon fiber outer body, providing strength and encasing its buoyancy, instead of the traditional skeleton type structure of ROVs.

A prototype is being built in the US, ready to go on show at the Offshore Technology Conference in Houston, says Arve Iversen, ROV Operations Manager Special Projects at Oceaneering. After that, it will be shipped to Norway for testing in Trondheim fjord. Meanwhile a test vehicle has been built in Norway so that the control system and autonomy software, being developed with help from the Norwegian University of Science and Technology (NTNU), can be tested.

"This year we are focusing on control, obstacle avoidance, object recognition, and things like that. Docking will come and we will be able to dock with the docking station that Equinor has developed, and we will be using that for docking testing in Trondheim," says Iversen. Equinor's docking station is a standardized solution, also using inductive connectors, which it wants all subsea vehicles that it might want to use to be able to dock in to. "We think a standardized docking station is the way forward," says Iversen. "The business case is difficult if everyone is going to have their own." Iversen says with just 17 docking stations, the entire Norwegian continental shelf could be covered by Freedom, due to its range.

There are more hybrid AUV projects in the pipeline, including FlatFish, a resident autonomous vehicle which Shell licensed Saipem to develop last year and is expected to be qualified for commercial application by 2020. Saipem also has its Hydrone family of vehicles. Meanwhile, back in Trondheim, technology spin-out Eelume is set to test its latest 20-centimeter-diameter snake robot, EELY500, which

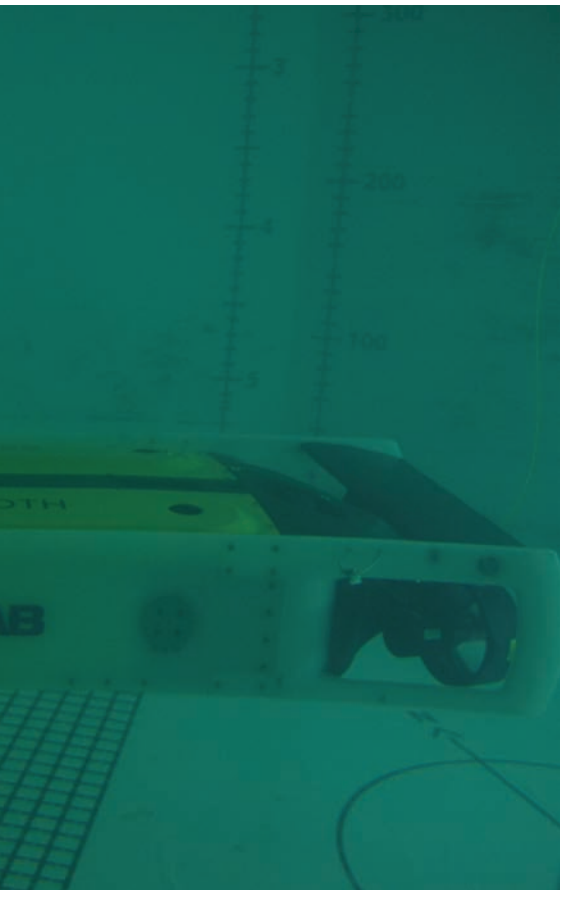


Saab Seaeye's Sabretooth (to the right, docking) has been fitted with a Blue Logic connector and proven inductive data and charging with it in its test tank (below).

Photos: Saab Seaeye

has eight thrusters for propulsion and stability. It's already been tested at 370 meters in a fjord near Trondheim. The next step is deployment from an Equinor designed docking station at the operator's Åsgard field, initially on a tether, where it can recharge its batteries and pick up tools.

Kawasaki Heavy Industries has launched a UK subsidiary, Kawasaki Subsea (UK), based in Aberdeen, that is focusing its efforts on developing AUVs for oil and gas pipeline inspection and later maintenance. A prototype of its vehicle, called SPICE (submarine pipeline inspection with close eyes), was tested at the now closed Underwater Center in Fort William in 2017 and is due to be commercially launched in 2020, with control software developed in cooperation with the UK's Heriot-Watt University. Testing included automated docking of the AUV to a prototype charging station, contactless charging and large-capacity optical communication operations.



Fleet Renewal

Source: Jumbo

It's been a tough market for heavy lift vessel operators – but that's not stopping them renewing and reinventing their fleets.

BY ELAINE MASLIN

Stella Synergy, an Ulstein-designed X-Bow heavy lift vessel for Jumbo, is expected to be delivered in the first quarter of 2020.

The offshore installation market has been tough, especially for those with installation vessels – resource and cash intensive assets. Depending on when you start counting from, there have been "three bad years for the installation market," Edward Heerema, founder and owner Allseas, said, "for everyone. Oil companies have been holding back investment. There is only low-cost development and there's heavy competition. Everyone has been going after the same job, and prices are very low."

Jack Spaan, expert heavy lift, at Boskalis Offshore Energy takes a stronger word, calling the last three years as terrible and added that, "When I count them it's about four. It's a difficult market and a lot of change has been going on for contractors. Looking for efficiency in operations is very important."

For Wout Janssens, Director Operations and Engineering, at Jumbo, "The last three to four years were horrendous in our industry. Those still standing recognize what we went through."

Whatever the words used, there's a theme. Operators have been reorganizing their assets and organizations and seeking new markets, from a full fleet color change (to grey, for Boskalis), to the likes of Seaway Heavy Lifting, now part of Subsea 7, looking to diversification into offshore wind and decommissioning.

The cause of this pain has been the drop in the oil price in 2014 and a slowdown in offshore installation. While some confidence has been returning to the market, it's not necessarily feeding through to fabrication work, as evidenced by the Heerema Fabrication Group's decision to close its Zwijndrecht yard in the Netherlands, after Italian fabrication group Rosetti Marino decided against acquiring the facility.

Yet, contractors, led by the Dutch, who have been the leaders in the offshore heavy lift market for some time, continue to evolve and adapt.

Allseas

The Pioneering Spirit, introduced by Allseas in 2016, and slated as the world's largest vessel, in terms of gross tonnage (403,342gt), breadth (123.75 meters), and displacement (900,000 metric tons), has proved its capabilities, both for lifting out decommissioned facilities in one fell swoop, to installing new topsides, such as the new 22,000-metric-ton drilling

Source: Equinor

Pioneering Spirit installs the processing platform topside for Equinor's Johan Sverdrup development

topside for Equinor's Johan Sverdrup project offshore Norway last year, as well as the 26,000-metric-ton processing platform topside and the 18,000-metric-ton living quarters for the same development this Spring.

The vessel has also left her mark on the pipelay market, with the installation of the two 930-kilometer-long, 32-inch Turk-Stream pipelines in 2,200 meters water depth. Never before has such large diameter pipe been laid at such depths, with the vessel exceeding lay rates of 6 kilometers per day.

In the first half of 2019, the vessel – the world's largest capacity heavy lift crane vessel with 48,000-metric-ton lifting capacity – will be equipped with a 5,000-metric-ton special purpose crane. Work on the vessel's jacket lifting system, which will go on the Pioneering Spirit's back deck, is also ongoing, with major fabrication contracts now awarded. Initial installation activities are planned to start toward summer 2019, with the delivery and installation of the main components expected late 2019, early 2020.

Despite the torrid environment of the past three or four years, Allseas is also continuing work on the Amazing Grace, a single-lift vessel even larger than Pioneering Spirit.

"No one took us seriously [with Pioneering Spirit] until we awarded the building contract for the hull in 2010. So, when we built it, we didn't know all of [the operator's] plans," explains Heerema. "Some facilities were too long, too high or wide, so we couldn't do them. We looked at what we would need to do all of these." The result is Amazing Grace, which will be able to reach around any platform in the world. "The design has not been finalized, but we are progressing very well," says Heerema.

Boskalis

While the 1980s song is "Fade to Grey", Boskalis isn't planning on fading at all, despite a rebrand to that color for all of its vessels. Boskalis has been breaking records, with the heaviest cargo record broken last year with the transport of the P-67 floating production, storage and offloading (FPSO) vessel aboard a semisubmersible heavy lift vessel, the Boka Vanguard (previously Dockwise Vanguard). The P-67, weighing 90,000-metric-tons, equivalent to Pioneering Spirit's displacement, was transported from China to its new home offshore Brazil, where it is operating for Petrobras.

The grey paint job is aimed at bringing all Boskalis' assets under a single brand. Following an extended period of acquisition, its fleet now includes assets from the legacy Dockwise (orange), Fairmount (green) and VBMS (black and yellow) businesses, as well as two large dive support vessels, from the former Harkand fleet (red).

Boskalis recently also broadened its renewables business, acquiring 11 survey vessels and 12 smaller vessels via the Gardline acquisition, three large cable laying barges via

Source: Van Oord

For the Walney Extension project, Van Oord perform installation activities from a floating vessel, the Aeolus.

the acquisition of Bohlen Doyen, and a trencher capable of burying cables down to 8 meters depth.

More broadly, Jack Spaan says the market conditions have meant older vessels have been made redundant and reorganization has been needed in the industry. "For Boskalis, we have had a combination of new vessels, procurement of vessels, discarding vessels or possible life extension," he says.

One of Boskalis' moves was to convert a former heavy transport vessel into a heavy lift vessel, by adding a 3,000-metric-ton Huisman crane and dynamic positioning capability. The 220-meter-long, 43-meter-wide Bokalift 1, which entered the market in 2018, is the result. "Before the conversion, Boskalis had to hire in external crane capacity," says Spaan. "The Bokalift 1 is able to transport, lift and install platforms and offshore wind turbine foundations." Boskalis is studying the potential for a second crane vessel and has added a construction support vessel to its fleet by taking out a multi-year charter on the Lewek Falcon. "We continue to assess our position in offshore and heavy lift transport," adds Spaan, "focusing on the top end of the market."

Jumbo

Wout Janssens, Director Operations and Engineering, at heavy lift and offshore transport and installation contractor Jumbo, says today we see developments in liquefied natural gas (LNG), offshore wind and subsea tiebacks, and tomorrow, it will be deepwater oil and gas fields, such as offshore Brazil, and remote areas, like remote parts of offshore Australia and East Africa.

Jumbo has its eye on some of this work for its newbuild vessel, Stella Synergy. The Ulstein-designed X-Bow heavy lift vessel (HLCV) is expected in the first quarter of 2020.

Janssens says the vessel reflects how Jumbo sees the future, which will remain driven by cost conscious final investment decisions on projects, which has seen operators, to date, halving the cost of projects like Shell's Vito and BP's Mad Dog in the US Gulf of Mexico. "It's not 'what do we want to do', it's 'what do we not want to do.'"

We were "Looking for economic and state of the art design, highest safety standards, low environmental footprint, high workability," he says. "Working with Ulstein, [we designed] light shipweight, LNG [power], a large deck area, and the X-Bow, which makes the vessel smaller and more comfortable when sailing at speed." The vessel has two cranes, one at 2,500-metric-ton capacity with a triple hoist for complex operations and high-capability heave compensation (AHC) for subsea lifting down to 3,000 meters, and a second at 400 metric tons with an AHC main hoist and lifting capability also down to 3,000 meters, with access to the vessel's moon pool. It will also have a dual remotely operated underwater vehicle (ROV) hangar and 22-meter-diameter carousel hold.

To date, most offshore wind turbines have been installed using jack-up vessels, due to the need for vessel stability during installation. However, **Van Oord has been proving the potential to carry out this work from a jack-up vessel in floating mode, a methodology that could save time.** On the Walney Extension offshore wind farm, Van Oord deployed both heavy lift installation vessel Svanen and offshore installation vessel Aeolus. "The 8,000-metric-ton [capacity] Svanen installed the 56 monopile foundations. The other 31 monopiles, as well as the transition pieces, were installed by offshore installation vessel Aeolus," says **Kevin van de Leur**, lead engineer at Van Oord, "Because the soil conditions at site were inadequate, a jack-up vessel wouldn't be able to jack-up."

The project, in 2017, meant "pushing the envelope," says van de Leur, working with the configuration of lifting gear and ballasting, allowing listing and working closely with the marine warranty surveyor and client. It was aided significantly by developments in computing power and the ability to model operations. "Nowadays we live in a virtual reality where the only boundary is imagination," says van de Leur. "'Virtually impossible' ceases to exist. The key is transforming that into a physical reality. How; the digital twin, high performance computing, artificial intelligence and very close cooperation with our colleagues on board. We want to make sure the [digital] vessel behaves as it does in reality."

"I personally would like to explore floating installation more. We know we can do it. For foundations, it's possible, but next generation 120-meter-height wind turbines on top of one of these towers? Over the coming three to five years, I think the industry will come up with smart ideas to make it possible to install these from a floating vessel."

To meet the demands of the offshore wind market, the Aeolus, which can also work as a jack-up in up to 45 meters water depth, was modified to achieve an increased loading capacity, accommodation and a helicopter deck, as well as a new 1,600-metric-ton crane.

SEABED SURVEILLANCE ENTERS AGE OF AUTONOMY

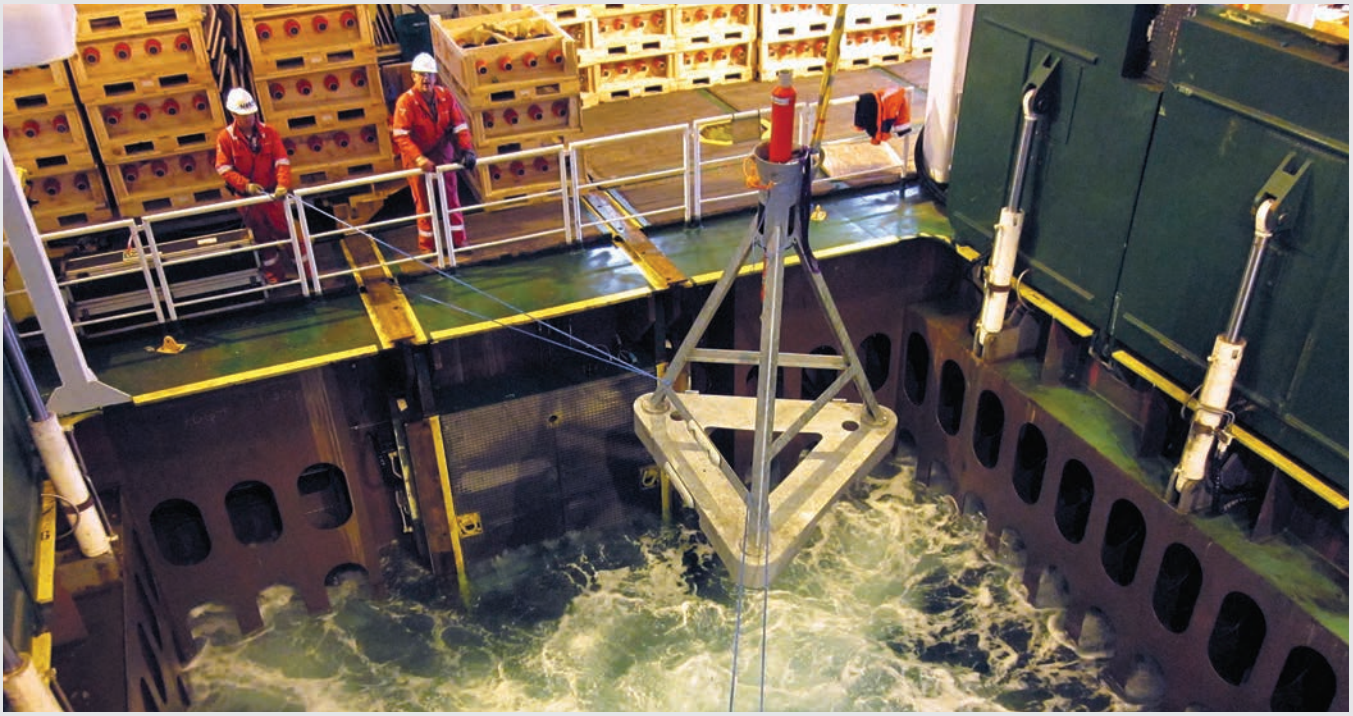
Seabed deformation monitoring is moving into new realms of capability, as self-calibration, autonomous deployment and data collection open up new possibilities for extending the life of oil fields.
Shaun Dunn, *Sonardyne's Global Business Manager, Exploration & Surveillance, explains.*

In the recent downturn, one of the measures oil companies took to sustain production was to focus more on improved oil recovery (IOR) programs at existing fields rather than exploring new frontiers.

Proactive management of existing reservoirs to maximize recovery, without the need for major upfront capital investment that developing new fields requires, was and remains a profitable way to get more product out of the ground, using less resource and reduced environmental impact. Yet, with IOR comes additional risks including fault-reactivation and other geohazards, such as seabed fractures, deformation or subsidence. Seabed movement is often to be expected above reservoirs as they are produced and pressure levels fall. Several centimeters of movement a year is quite typical. As pressure levels in a production zone reduce, so does the ability of the reservoir rock to support the rock layers or overburden above it, leading to seafloor deformation phenomena such as a gradually increasing subsidence bowl.

While this movement might not cause a major hazard in itself, knowing how much movement there is, in what direction and how fast it's happening helps operators to learn more about how their reservoirs are performing, and therefore how to operate them more productively.

The ability to measure seafloor movement laterally and vertically over time enables geophysicists to fuse this information with other production data to infer fluid flow, pore pressure, reservoir level compaction, etc., and then tune their reservoir management plans and improve recovery rates accordingly. During drilling and production activity, seafloor monitoring can also help to avoid geohazards, such as fault reactivation and mud slips.



AMT deployment during the Ormen Lange project, offshore Norway.

All images courtesy Sonardyne

German research vessel Sonne and a Wave Glider unmanned surface vessel (USV) were used to harvest data from AMTs. USVs can now also perform GPS-Acoustic measurements.

What works onshore, doesn't work offshore

However, in the past, it hasn't been easy to measure these small movements offshore. Onshore, GPS positioning, laser ranging and satellite altimetry systems can be used to determine the positions of, and distances between, objects on land to within centimeters or even millimeters. These techniques don't work subsea.

Traditionally, bathymetric sonars have been used to measure subsidence offshore, but their precision is severely limited, particularly in deep water, and the deployment logistics involved hinders their practical application for detecting slow subsidence rates, where long duration measurements are required. Portable gravimeters are also used to detect changes in density brought about by water replacing gas for example. But, these sensors have to be moved between permanently deployed seafloor monuments using a remote operated underwater vehicle (ROV), and repeated gravity and pressure measurements taken at each location. It's a lengthy, personnel, asset-intensive and therefore costly process and is only usually undertaken at multi-year intervals, which limits the usefulness of the data.

Over the last decade, a more cost-effective alternative has been developed, thanks to an idea Shell research geophysicists Dr. Paul Hatchell and Dr. Stephen Bourne had in 2006. They were aware that, because seabed deformation causes vertical and horizontal displacements, a more continuous method of monitoring subsidence could be possible by taking vertical and horizontal measurements using long-term deployed subsea instrumentation. At the time, suitable long-endurance and highly sensitive monitoring equipment was not available, so Shell approached Sonardyne, because of our long history in high-precision instrumentation design.

Introducing seabed deformation monitoring

Working with Shell, we developed the first seabed deformation monitoring system, which was deployed at Shell's Ormen Lange field on the Norwegian continental shelf in 2007. The system measured the horizontal distances between two locations on the seafloor using acoustic ranging and made vertical depth measurements using pressure sensors. These techniques are not new in underwater survey. Indeed, Sonardyne has provided these technologies to the offshore oil and gas industry for more than four decades. However, to create a seabed deformation monitoring system, a number of innovations were required.

To measure horizontal displacement, acoustic waves are transmitted as signals between pairs of our Autonomous Monitoring Transponders (AMT), which are separated by hundreds of meters, and two-way round trip time of those signals is determined. The wave speed is also measured locally and in real time

using integrated sound velocity sensors, so that the distance between AMT pairs can be monitored very accurately. Vertical displacement is measured using integral pressure sensors. By comparing the results from multiple AMTs, the effects of tide, water column density and barometric pressure changes can be removed from the results leaving only the relative seabed depth changes remaining.

Sounds simple? It's not. A lot of hard work has gone in to developing this system so that it can provide both the sensitivity and long-duration service needed, at the seafloor depths required. This has included innovations in high-performance acoustic signaling, pressure sensing, low power electronics, waterproof pressure tolerant and corrosion resistant marine housings, battery technologies and acoustic transducer designs. We've also added an in-situ pressure sensor calibration in a process known as Ambient Zero Ambient (AZA) to address the inherent drift that pressure sensors experience without having to retrieve them to surface.

These systems are field-proven. Following first sea trials at Ormen Lange, we conducted a longer-term deployment at the same site, from 2010 to 2015. During this deployment, nearly 220 AMTs were deployed, enabling five and a half years of continuous subsidence monitoring over the site, collecting more than 600 million range observations. Versions of the system have been deployed by operators in UK North Sea, the US Gulf of Mexico and offshore Asia.

L to R:
An AMT tripod frame assembly

AMTs and their frames following recovery after more than five years deployment

An AMT variant installed subsea for subsidence monitoring in the US Gulf of Mexico

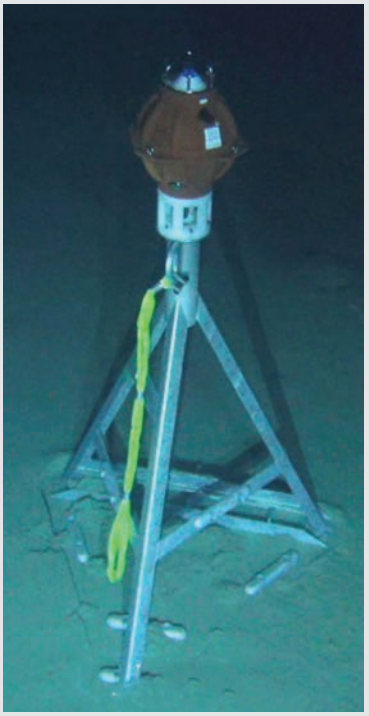
Leveraging moves into marine autonomy

But, we have not stood still. Using unmanned vehicles, we have been able to take this system even further: we can localize the precise positions of our AMTs using GPS-Acoustic box-in (GPS-A) and then perform wireless data retrieval using unmanned surface vessels, such as Liquid Robotics' Wave Gliders. Using unmanned systems saves cost, as they typically have running costs that are one or two orders of magnitude lower than average manned vessels.

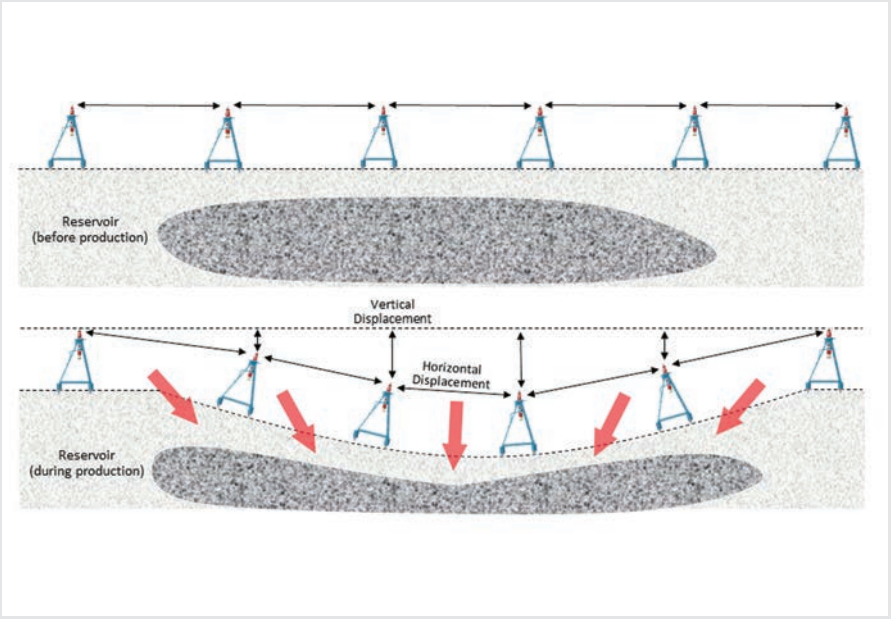
The result is that we now have instruments that are fully autonomous; can be deployed to the seabed, remaining in place for 10 or more years without any direct intervention; make highly precise measurements of horizontal and vertical movement; and, using remote unmanned wireless data gathering capabilities, can routinely report information back to a user sat at his or her desk. It can therefore be used for the most challenging and high sensitivity settlement monitoring projects globally.

Improving accuracy, improving results

The work doesn't stop. We're also continuously looking to improve the precision of our seabed settlement monitoring equipment. Through our work to enable regular in-situ calibration, as well as a research program to select and pre-characterize the best pressure sensors, and to localize the positions of equipment from surface drones, we have



All images courtesy Sonardyne



Sonardyne AMTs measure vertical and horizontal displacement to detect any production induced seabed deformation.

been able to achieve close to 1cm/year measurement sensitivity.

This is exciting – it could revolutionize seabed settlement monitoring because it unlocks a whole new global capability for monitoring fields that subside very slowly, including deepwater fields, such as those in the Brazilian pre-salt and the Gulf of Mexico.

What's more, this technology is also providing data that ocean scientists previously couldn't access, for subduction zone and tectonic plate movement monitoring. Until recently, scientists almost exclusively depended on the use of manned research vessels to undertake observations at sea. This meant they only had sporadic and limited data acquisition projects, which in turn meant that they were unable to satisfactorily model subduction zones. These are areas where an oceanic crust submerges under a denser continental crust and creates the frictional energy build-up that is typically associated with the world's most damaging earthquakes and tsunamis. Now, they not only have the ability to acquire this subsidence data, but, with the ability to perform GPS-acoustic box-ins, we can precisely locate the absolute positions of each AMT so that this data can be used with models. This data has previously been out of reach to scientists.

Enabling tsunami and earthquake research

GEOMAR, among others, have deployed Sonardyne's seabed deformation monitoring system in a number of European and South American locations to measure the build-up of strain associated with tectonic plate movement. For one deployment along the Nazca-South American tectonic plate off the coast of Chile, GEOMAR were specifically interested in the build-up of horizontal strain that can be used to predict when large displacements might occur in the subduction zone. This system is unique in being configured with lower frequency acoustic signals that propagate readily over considerable distances, a setup required for effective wireless communication in the extreme depths (greater than 5,000 meters) in which some of these instruments have been deployed.

Scripps Institute of Oceanography, which first used this technology in 2013-14, is working with the United States Geological Survey (USGS) to better understand the Cascadia Subduction Zone in order to better predict when a major event is more likely to occur. It is using Sonardyne's Fetch instrument (functionally equivalent to the AMT, but with a much bigger battery that enables deployments of up to 10 years) for the seabed component of the study.

The technology is also the basis of a Japanese Government funded collaboration between the University of Kyoto, Universidad Nacional Autónoma de México and New Zealand's GNS Science; "Hazard Assessment of Large Earthquakes and Tsunamis in the Mexican Pacific Coast for Disaster Mitigation". Further significant programs are also being proposed.

Precise, accessible insight

Our seabed deformation monitoring system is giving operators and scientists centimetric detail of seafloor movement, to help manage and maximize their resources and monitor submarine plate tectonic movements in far greater detail than they have ever been able to do before, all at a fraction of the cost of previous methods.

BOOSTING OIL RECOVERY IN THE GULF OF THAILAND

By Isma Mohd Ismail from Tendeka and Muhammad Triandi, Ikenna Chigbo and Thanudcha Khunmek from Mubadala Petroleum

The Jasmine field, operated by Mubadala Petroleum, is located 200 kilometers south of Bangkok. This field has a sandstone reservoir and is highly complex and compartmentalized. Many good sands have a thickness of about 30 feet to 40 feet, reservoir pressure is supported by a strong aquifer, and most wells have high productivity.

The field has been producing since 2005 and reached a cumulative production of 70 million stock tank barrels (MMSTB) from five platforms in 2018. The very early wells were initially drilled with vertical or deviated trajectories without any artificial lift in the crestal areas. They were later drilled as horizontal wells or multizone completions with electrical submersible pumps (ESP) as the artificial lift.

In the particular fault block of interest, a large gas cap above and below the water was present, which is normally not apparent in other fault blocks. This reduces the oil sand thickness to about 20 feet as shown in figure 2 and poses a significant risk of free gas production, particularly in this undeveloped reservoir where the degree of aquifer support is unproven.

Too much gas production can lead to gas lock problems for the ESP, causing pump or motor failure, and could potentially render the well inoperable. In the last five years, five wells have been shut-in due to ESP failure, with an average of 10 months to remediate. Although recent completion modifications have improved gas tolerance in ESP wells, the risk of gas production becomes higher when you target a thin oil rim, as the gas will tend to have early breakthrough at the heel section. This has limited the development of thin oil rims in the Jasmine field. Therefore, Autonomous Inflow Control Device (AICD) sand screens were examined to restrict some of the produced gas and water.

Increasing oil production with AICD completions

The AICD is an active flow control tool that delivers a variable flow restriction in response to the properties (viscosity) of the fluid flowing through it and works on the principle of a levitating disk[1]. When gas or water flows through the AICD valve, the velocity of the water and gas will increase, hence reduce the dynamic pressure and levitate the disk toward the inlet to choke the flow. The flow path through the device is marked by arrows (figure 3). The AICD valve is assembled as part of the sand screen joint (figure 4). The flow path from the reservoir is marked by arrows. The reservoir fluids enter the completion through the sand screen filter and flows into the inflow control housing where the AICD is mounted. The fluids then flow through the AICD and into the production stream and flows to surface together with the production from the rest of the screens. Swell packers are also installed along the open-hole section to isolate the water/gas bearing zone and to provide zonal compartmentalization to the production zone. Spacing between the packers were 100 to 150 feet.

Controlling gas production

One of the key issues is relatively thin oil rims in the placement of the well. With the AICD technology, the wellbore trajectory inside the sandstone has been moved slightly higher in new wells to move away from the water zone and located 10 feet below the gas-oil contact. Although this will bring the wellbore closer to the gas cap, the AICD valves will be choking the gas if conning and minimize the risk of gas breakthrough in this 2,000-foot horizontal well.

Incremental volume evaluation

The incremental recoverable oil volume resulting from using an AICD completion is investigated though dynamic reservoir simulation as shown in figure 5. In this case, the success of the completion was evaluated by comparing production performance to the existing nearby well in the same block. The difference of cumulative volume is the potential gain realized by using devices in the horizontal well. In addition to predicting cumulative production, the gas-oil-ratio (GOR) of the AICD completion is also investigated to determine if the gas breakthrough is controlled sufficiently to prevent ESP problems. The forecast GOR is valuable input for designing the well ESP. The potential cumulative difference is approximately 15% incremental as per simulation result in figure 5. The analysis demonstrates that GOR can be controlled and constant throughout the well life. The incremental AICD completion cost adds 12% to the total well cost.

Figure 1 The Jasmine field name is commonly used to represent both the Jasmine and Ben Yen Fields in the B5/27 Block

Figure 2 AICD flow path

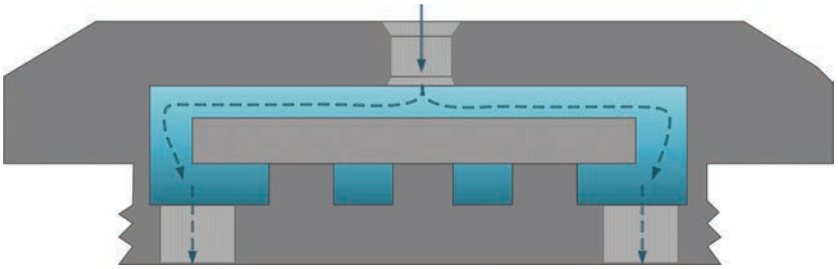


Figure 3 AICD unit mounted into sand screen joints.

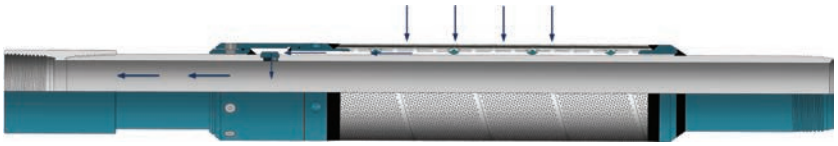


Figure 4: Cumulative oil comparison

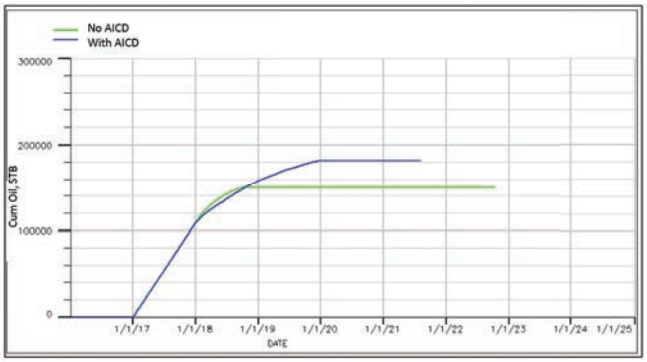
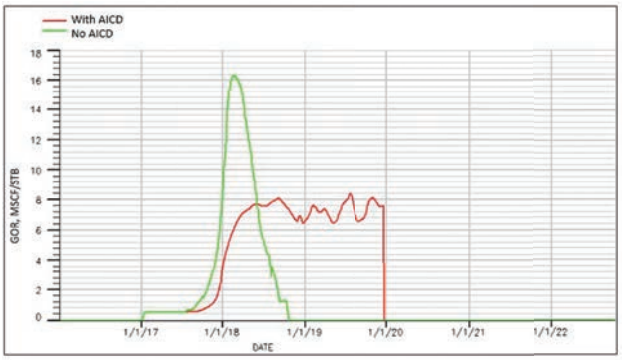


Figure 5 GOR trend comparison



Production performance

The AICD well completion has been successfully implemented as a pilot project in horizontal wells at the Jasmine and Ban Yen fields to reduce gas breakthrough. Post AICD implementation, the AICD well has shown reduction in GOR compared to the adjacent well. The initial production rate for the AICD well is 430 barrels of oil per day (BOPD) with 0% water cut. After more than six months, the gas production was less than 1 million standard cubic feet per day (MMSCFD) with GOR of 2 million standard cubic feet/stock tank barrel (MSCF/STB). Comparing the adjacent well, the AICD well oil production has increased from 190 BOPD to 430 BOPD, a rise of 126% more oil production. This is due to the reduced GOR from 17.5 MSCF/STB to 2 MSCF/STB, a decrease by a factor of eight.

With the achieved success of this project, similar thin oil rim opportunities are now being investigated in the Jasmine field. The AICD well has now been producing for more than one year and is currently producing as expected at low GOR levels.

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THE INTEGRATED APPROACH

Source: TechnipFMC

TO DRIVE LOWER COSTS, FASTER DELIVERY

The Energian Power floating production storage and offloading (FPSO) unit will work 90 kilometers offshore to enable the tieback of Karish field.

By Willy Gauttier, TechnipFMC, Executive Project Director, Karish

An integrated approach to subsea services is the driving force behind a major project being performed by UK-based TechnipFMC at the deepwater Karish field, offshore Israel, in the Mediterranean Sea.

The integrated engineering, procurement, construction and installation (iEPCI) award for Energean Oil & Gas' Karish development at 1,750 meters water depth marks the largest iEPCI project the company has undertaken to date.

The $1.4 billion Karish gas project is one of 12 iEPCI projects TechnipFMC has been awarded throughout the globe. The company's approach to comprehensive integrated solutions is designed to strengthen the economics of subsea projects and help unlock first oil and gas faster.

The integrated full-field subsea offer includes subsea architecture design; subsea development and integrated project execution; and optional performance enhancement via inspection, maintenance and repair.

"Bringing together complementary skills and advanced technologies through integrated solutions can boost efficiency, lower costs and accelerate schedules," said Senior Project Director Steve Duthie.

Streamlining the process

The technologically differentiated approach of iEPCI better manages the complete work scope and streamlines every part of the process. Among the benefits:

- One global contractor promotes a lean execution of one project and one team, avoiding duplication in position and competency.
- Integrated project planning compresses project delivery schedules.
- Seamless infrastructure delivery reaches installation faster, eliminating handovers and float between contracts.
- Reduced project interfaces mitigate risks and complexity and improve coordination.
- Streamlined procurement processes enable faster project kick-off.

To support its integrated efforts, the company has built

high-tech facilities near the world's main offshore oil and gas producing basins. The facilities include subsea hardware, flexible pipe, umbilical and reeled rigid pipe welding/spooling manufacturing plants, plus a fleet of specialized vessels for pipeline installation, subsea construction, diving support and heavy lift.

Seabed to FPSO

TechnipFMC has been a partner in the Energean Karish project since the concept stage in 2017, delivering an offering that extends from seabed to offshore producing facility. First gas is expected in the first quarter of 2021.

"Karish is an excellent demonstration of an efficient integrated approach and showcases the added value it provides," Duthie said.

"The iEPCI approach means that one company takes care of all the interfaces. And that means the client no longer has to worry about that, so the cost and schedule can be reduced."

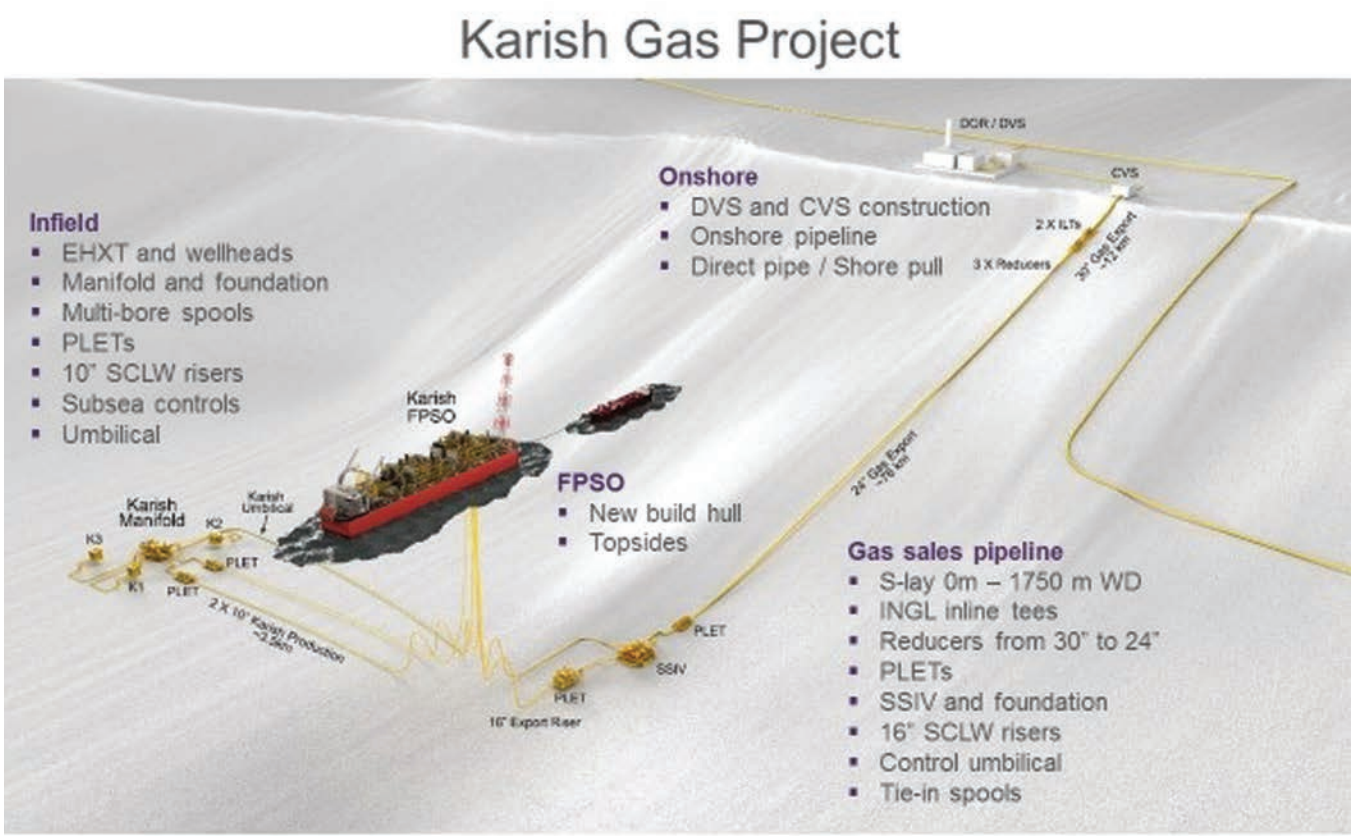
The execution of the Karish iEPCI contract covers the design, procurement, construction and installation of the complete subsea system, a floating production storage and offloading unit (FPSO) 90 kilometers offshore named Energian Power that will enable the tieback of the Karish field, the pipeline system, and the onshore pipeline and valve station at the receiving station.

The Karish project is an example of working collaboratively across several different businesses to provide an integrated solution.

Duthie is responsible for both the subsea and onshore elements and leads the Karish team based in Aberdeen, UK. "This is the first project where we are responsible for the onshore parts of the work alongside an FPSO facility, the full subsea production system and the subsea, umbilical, riser and flowline installation," he said.

The FPSO is being handled through the company's Paris operations with some of the topside modules being designed and managed at the Lysaker, Norway office. The onshore scope is

The Karish gas field development, located in the Mediterranean Sea in 1,750 meters of water, marks TechnipFMC's largest iEPCI project to-date.



Source: Technip FMC

being delivered by operations in Rome and subsea umbilicals from Newcastle, UK. The trees and the wellheads are coming from Dunfermline, UK, while the subsea production system work and drilling tools support are being performed in Kongsberg and Bergen, Norway. Other elements are being provided by US-based affiliate Genesis in Houston, Texas.

"We are supplying a cost-effective, integrated iEPCI solution displaying product lines, service hardware installation and engineering and project management capabilities," Duthie said.

Marginal fields

The iEPCI model also can be used to unlock marginal fields. The shallow water systems offer turnkey, cost-effective solutions for tieback wells in jackup water depths to open revenues in marginal fields.

This is accomplished through enhanced design, optimized installation and a lean project team.

iEPCI satellite tieback systems provide a competitive solution for marginal fields and stranded assets. It's a pre-engineered solution for developing smaller fields close to existing infrastructure.

Early engagement

The energy industry is beginning to appreciate the benefits from an early engagement, technology-enabled iEPCI model. More industry specialists are talking about integration, but the benefits to the operator are dependent on the degree of project integration. Full integration requires early engagement at the FEED stage to optimize field design and remove interfaces and schedule waste. It requires having all capabilities under one roof to manage the trade-offs inherent in optimizing solutions.

More than surface level, the integrated approach goes deeper by merging two subsea leaders in SPS and SURF to deliver a full water column solution. Integrated services can simplify development solutions, optimize subsea architecture, reduce contractual risks, deliver cost savings and enhance overall value.

PUSH-THE-BIT RSS

BY JENNIFER PALLANICH

Two service companies known for point-the-bit rotary steerable systems (RSS) each decided in 2016 to create their own push-the-bit tools. Their offerings are aimed at increased tool reliability, utilization, smoother wellbores and higher levels of drilling performance consistency from well to well, the companies say.

Halliburton's Geopilot point-the-bit RSS was a "workhorse" but the company sought to develop a push-the-bit system that could handle complex wells, be reliable and provide consistent results. Because of a variety of factors involved in drilling, says Paul Bond, Halliburton RSS product manager, drilling performances for multiple wells in the same field may not match up.

"You can drill one well in an offshore field, and it's a record, but the next well may not go so well," he says.

Halliburton decided to harness the leaps in technology – electronics packaging, sophisticated algorithms and high speed processor – that had come since previous systems had been developed.

"We took advantage of that technology to put into the tool to drive some of those improvements in reliability and steerability, and to be able to drill fast with the tool," he says.

The result was iCruise, which launched in the third quarter of 2018. The "i" in iCruise is for intelligence, Bond explains. The exterior of the tool "looks simple and robust," but the interior has the ability to capture large amounts of data in real time and transmit it to the operator.

Three pads come out of the tool once per rotation, so at 400 revolutions per minute, each pad will come out at the same point six times per second to push the bit in the direction the driller wants to steer the wellbore. A complex control system takes into account 1,000 measurements of the tool face per second to determine when to send the pad out.

"That's the type of intelligence we put in it," Bond says. "We store a lot of information in the tools, and we use the information to improve overall reliability."

Those measurements of the tool's voltages, temperatures and vibrations are also taken per second, and stored in the system's memory, allowing for real-time smart diagnostics. The massive amount of data generated from every run can be used to "work out when to retire certain components of the tool before they fail based on the history of those components," Bond says. "This takes diagnostics to a new level."

Halliburton's design process incorporated the use of digital twin modeling. "It gives us a good idea of how it would work in the digital space before we even drill the well."

The digital twin can be used with well plans to help make drilling more predictable, repeatable and consistent than when using a manual directional driller alone, he says.

"We could put models into a surface computer and well plan and criteria around avoiding other wells, and develop an automation platform where the surface system generates commands to the tool for the tool to follow the well plan," Bond says.

Halliburton ran that trial on a test rig, with a computer generating commands directly to the iCruise tool in November 2018 in Texas.

"We planned it with a build and an 11-degree turn, and it followed the plan precisely," he says, adding confidence in this technology could reduce the requirements for having so many directional drillers on location.

The system itself can handle doglegs of 18 degrees. iCruise is available in 4 3/4 inch, 6 3/4 inch, 8 inch and 9 1/2 inch.

According to Halliburton, the modularity of the iCruise BHA and its precise steering capabilities have delivered smooth wellbores with less tortuosity, which has resulted in faster tripping speeds after drilling laterals in excess of 2 miles long.

To date, Halliburton has drilled 250,000 feet with iCruise in multiple basins across North America, the Middle East and Argentina. It is slated for deployment in the Gulf of Mexico and offshore Norway later this year.

"This will be our workhorse going forward," Bond says.

Magnus

When Weatherford set its sights on creating a push-the-bit offering, the service company moved rapidly through the development process by bringing on engineers familiar with push-the-bit systems, carrying out information sessions with customers to fully understand their needs and wants in a push-the-bit RSS, and concurrently designing and manufacturing a tool.

Less than a year later, in April 2017, Weatherford had a fully functional tool

Halliburton engineers prepare the iCruise Intelligent Rotary Steerable System for a run on a test rig.

BELOW:
Halliburton's iCruise push-the-bit RSS.

Source: Halliburton

on a test rig in Oklahoma, and in April 2018, Weatherford commercialized its Magnus push-the-bit RSS with a 6 3/4 inch collar. As of February, the company had drilled more than 200,000 feet with Magnus across the US, Mexico and the Middle East.

Etienne Roux, Weatherford's president of drilling and evaluation, says the company invested in developing a push-the-bit system for a number of reasons, including that Magnus opens up the offshore market for the service company while driving greater tool utilization efficiency due to the inherent design difference between point- and push-the-bit systems.

"All rotary steerable systems are complex," he says. "Push-the-bit systems are less complex, though."

Part of the driving challenge for the push-the-bit system design, he says, is that customers want costs to come down on well construction. For years prices hadn't decreased for push-the-bit RSS operations, he says, largely due to a duopoly in the push-the-bit space. Additionally, when a system failed, it often had to be sent far away for repairs causing capital inefficiency and costly availability constraints. Customers wanted a streamlined system to minimize chances for stuck pipe, and they wanted a system that delivered a smooth wellbore which could be maintained and turned as close to operations as possible.

Magnus is intended to reduce overall well construction costs, Roux says. The tool itself is able to drill further, longer and deeper with fewer maintenance requirements compared to other systems, he says.

Source: Weatherford

> "MAGNUS ELIMINATES MICRODOGLEGS AND TORTUOSITY,
> THE THINGS THE COMPLETION GUYS HATE THAT COST A LOT OF MONEY OVER THE LIFE OF THE WELL AND WHICH CAN SOLVE LONG-TERM PRODUCTION PROBLEMS."
>
> ETIENNE ROUX
> WEATHERFORD

Magnus is a robust tool, and its streamlined design minimizes stuck pipe issues, according to the company.

One of the key design features of Magnus is its trio of independent pads, which Weatherford developed in response to customer pleas for a method of RSS that would result in a smoother wellbore, he adds. The pads come out at predetermined intervals to move the bit in the required direction. All three pads can be switched off on demand, allowing, for the first time, true independent pad control driving smoother wellbores and allowing for more efficient casing exits, he says.

"Magnus eliminates microdoglegs and tortuosity, the things the completion guys hate that cost a lot of money over the life of the well and which can solve long-term production problems," Roux says.

The system has a dogleg capability of 10-plus degrees when needed to build a curve, according to the company, while high-speed sampling verifies toolface position. Weatherford has commercialized its 950 tools size for 12 1/4 inch hole sections and an 11 inch collar version of Magnus will be available later this year.

Weatherford ran Magnus in the Mexican sector of the Gulf of Mexico shelf in November 2018 for a client. In that application, Magnus was replacing a competitor's push-the-bit RSS tool for a well in 161 feet water depth.

"We managed to exceed the competitor's delivery in rate of penetration and time to total depth," Roux says.

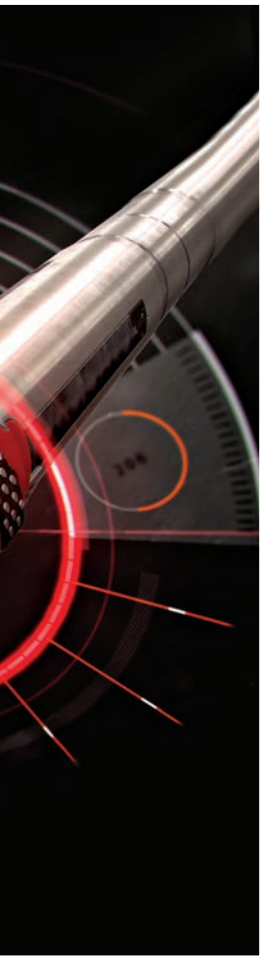
Client KPIs called for an ROP at or above 9 m/hr through the section, and Magnus delivered more than 16 m/hr, according to Weatherford. In addition, the company says, it was critical that the buildup rate was maintained at less than 3.75 DLS, which Magus delivered on, maintaining at 3.67 DLS.

Looking forward, Weatherford aims to more fully automate Magnus. For example, Weatherford is fine-tuning software that makes it possible to automatically measure the direction and azimuth in a similar fashion that inclination is being controlled, allowing for real-time adjustments to be made to stay on a predefined well trajectory and azimuth.

"We're doing a lot of work to make it possible to run Magnus autonomously," Roux says.

RIGHT
Weatherford engineers deploy the Magnus push-the-bit RSS.

BELOW
Weatherford's Magnus push-the-bit RSS.



Source: Weatherford

Magnetic Drive System

Upwing

Upwing Energy, a Calentix Technologies spinoff created with backing from Equinor Technology Ventures, has developed a Magnetic Drive System (MDS) aiming to transform the century-old topology for electric submersible pumps (ESP).

The Upwing MDS leverages the characteristics of permanent magnet (PM) motors in terms of higher efficiency and power density. The PM motor is used as a magnetic coupling. The stationary part, the motor stator, is integrated within the completion of the well, where it is hermetically sealed together with all other electrical components, including the least reliable components: connectors and cables. The motor rotor is part of the retractable component and deployed via slickline together with all the other mechanical rotating components like the axial bearing and pump section. This approach provides complete wellbore access and eliminates any vulnerable electrical or mechanical connections.

The new topology offers reliability through hermetically sealed electrical components, which are isolated from the production fluids, and quick retrievability via slick line of the rotating components. It also eliminates the ESP protector and its associated seals, pressure compensation, dielectric fluids and other auxiliary components.

Source: Upwing Energy

Upwing Energy's MDS, with hermetically sealed electrical components outside of the tubing.

Industry 4.0

Automated MPD Riser System

Weatherford launched its automated managed pressure drilling (MPD) riser system. Billed as Industry 4.0, the system combines with artificial intelligence, condition-based maintenance and additional sensors to help speed up operations.

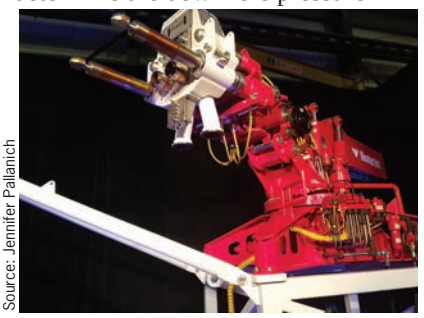
MPD provides an active approach to well control that can be used to optimize the performance of drilling operations in any well.

By using a closed-loop system to determine the downhole pressure limits and manage the annular pressure profile accordingly.

Its automated MPD riser system features a robotic arm that can connect a single subsea control umbilical and flowlines in a matter of 20 minutes or less.

According to Weatherford, it's the industry's first hands-free flow spool for all weather conditions and harsh environments, so no personnel must work over the moonpool to make the connection, and the need for remotely operated underwater vehicles (ROV) is also reduced or eliminated.

It is expected to see its first deployment in the Caspian in the second half of 2019.



Source: Jennifer Pallanich

Weatherford launched its automated managed pressure drilling (MPD) riser system. Pictured is the flow spool.

Monitoring the Health of Subsea Systems

Jupiter AIM: Asset Integrity Monitor

The recent drive for permanently deployed remotely operated underwater vehicles (ROV) highlights the need for monitoring their operational state.

Jupiter AIM provides inputs for up to 10 x 3 Axis 2g/8g accelerometers to continually monitor the physical health of subsea systems.

Vibration data is digitized at 12kHz and displayed at the surface in the time or frequency domains. Data is stored in a secure Structured Query Language (SQL) database for later display or analysis and can be shown with current data for comparison.

Users can set alarm conditions for each channel in the time or frequency domain and create alerts if any limits are exceeded. Acoustic feedback from any sensor is also available via the PC audio channels. Jupiter AIM can support multiple surface PCs visualizing differing combinations of present or historic data on a client server basis.

Source: Zetechtics

Jupiter AIM also interfaces to the Jupiter ICM fluid contamination sensor to add hydraulic status data to the record. Other sensors, including pressure, temperature and strain may also be integrated with the system.

Jupiter AIM operates from 24V, 15W DC, is a compact 4,000-meter rated titanium housing, and connects to a conventional PC or laptop at the surface via Ethernet.

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ClassNK is a classification society with technical expertise to support all industry sectors, from oil and gas carriers to offshore structures. ClassNK also works in partnership with the industry to develop new cutting-edge technological solutions aimed at securing a safer, greener future.

Daido Steel
OTC Booth #7053
www.daido.co.jp
Daido Steel Co., Ltd., founded in 1916, has expanded its specialty steel business throughout the years to contribute innovation in various industries, including offshore oil and gas. The company supports growth, through the creative development of technologies to make the most of the specialty steel properties.

Daihatsu Diesel
OTC Booth # 7053
www.dhtd.co.jp
The new 8DEL-23 is a long-stroke version of the eco-friendly DE-23, designed to save space, while offering greater power and low fuel consumption. The engine is a response to the trend of increased power consumption due to more prevalent installation of new environmental devices and the increased use of electronic equipment on board. Space savings and increased output are achieved without compromise to environmental performance.

Fuji Trading
OTC Booth #7045
http://www.fujitrading.co.jp
Marine supplier Fuji Trading Group supplies machinery equipment, spare parts, marine stores, provisions, catering, engineering, marine logistics and marine safety services. The group recently strengthened its global network, having established GSM-Fuji, LLC in Houston last year.

Hien Electric Industries
OTC Booth # 7145
http://www.hien.co.jp/e_index
Having provided shipboard cables for 65 years, Hien has delivered around 200 types of cables such as power, control, instrumentation and telecommunication cables for any kind of merchant ship. Halogen-free, flame-retardant, fire-resistant, cold-proof cables are available. The company also manufactures coating materials, lamination, printing and coating for functional film used in electric cables and on electric wires.

INPEX

Inpex Corporation
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www.inpex.co.jp/english/index.html
INPEX is Japan's largest oil and natural gas exploration and production (E&P) company, and a mid-tier E&P player just behind the world's oil majors. INPEX is currently involved in approximately 70 projects across more than 20 countries, including the Ichthys liquefied natural gas (LNG) project in Australia as operator. Its top business targets include sustainable growth of its oil and gas production business, development of a global gas value chain business and reinforcement of renewable energy initiatives.

KNG KONGO COLMET MFG.

Kongo Colmet Manufacturing
OTC Booth # 7145
http://colmet.co.jp/wp2/en/
Kongo Colmet Manufacturing supplies white metal ingots and bearings that provide the ultimate in casting and bearing performance. The components work for diesel engines, turbines, generators, compressors, pumps, electric motors and other types of machinery.

Nippon Paint Marine Coatings
OTC Booth #7045
www.nipponpaint-marine.com
Nippon Paint's self-indicating technology, NOA, is engineered to ensure paint is applied to the correct thickness. Nippon Paint Marine has created high performance antiabrasive epoxy schemes with pigments that have various opacities depending on it thickness. If you can see through it, NOA's thickness is too low. This remarkably simple concept enables owners and yards to literally see when

Fuji Trading

Hien Electric

Kongo Colmet

Nippon Paint Marine Coatings

Tokyo Seiko Rope

Ushio Reinetsu

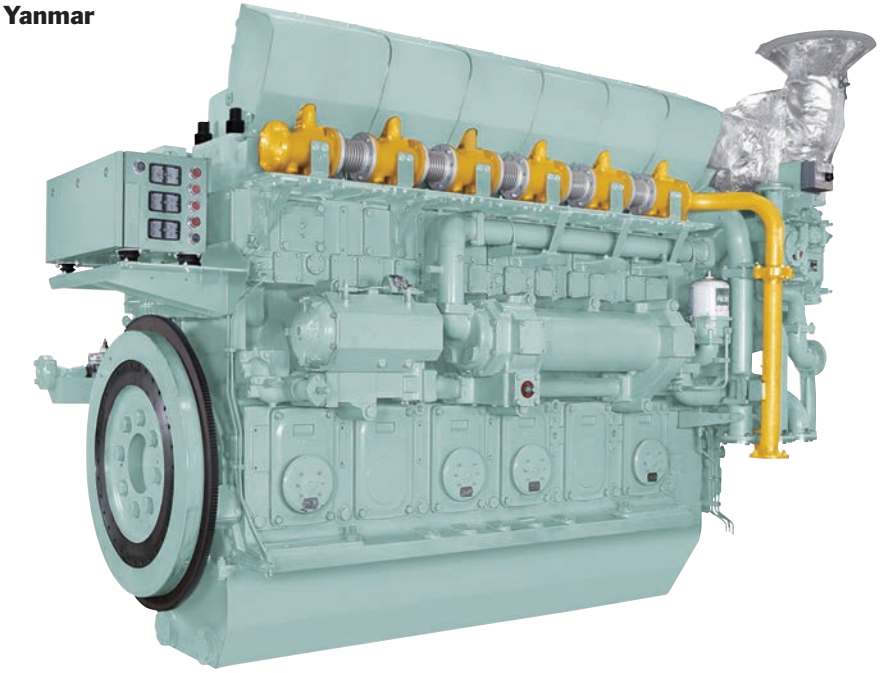
the coating has been applied to the correct thickness, even if it can't be measured conventionally. Since 1998 NOA has been applied to improve application accuracy and performance, and new NOA versions are now available for different parts of the ship according to the anticorrosive needs of that area.

Tokyo Seiko Rope
OTC Booth #7045
www.fiber-tokyorope.jp
Since its establishment in 1887, Tokyo Seiko Rope has been a leading ropes manufacturer. The company produces ropes that are both safe and easy to use for various vessel types as well as marine and offshore construction. The company has also developed a myriad of advanced technologies within this field thanks to the emergence of many new high performance fibers.

Ushio Reinetsu
OTC Booth #7145
http://ushioreinetsu.co.jp/english
USHIO provides complete heating, ventilation and air conditioning (HVAC) and elevator services including engineering, procurement, design, installation and completion, with 40 years experiences in the marine and offshore industries. The company has supplied equipment for offshore facilities such as FPSOs, FSOs and jack-up rigs.

Yanmar
OTC Booth #7145
www.yanmar.com/global/marinecommercial/
The use of LNG is attracting attention within the marine engine sector, both as a means of addressing fluctuating fuel costs, and as a way of reducing the burden on the environment. YANMAR has developed the 6EY26DF dual fuel engine that can use both diesel and gas, which complies with IMO NOx Tier3 regulations as well as SOx Emission Control Areas (ECA).

Yanmar



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caspianoilgas.az

Data Driven Drilling & Prod. Conf.
June 11-12
Houston, USA
www.upstreamintel.com/data

Underwater Technology Conference
June 11-13
Bergen, Norway
www.utc.no

Global Petroleum Show
June 11-13
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https://globalpetroleumshow.com

Brasil Offshore Conference & Expo
June 28-28
Macae, Brazil
www.brasiloffshore.com/en

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www.spe.org/events

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www.offshore-europe.co.uk

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www.gastechevent.com

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September 26-28
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www.asiaoec.com/

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September 30-October 2
Calgary, Canada
www.atce.org/cfp2019

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October 2-3
Houston, USA
www.atce.org/welcome

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October 7-9
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www.offshore-energy.biz/home

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