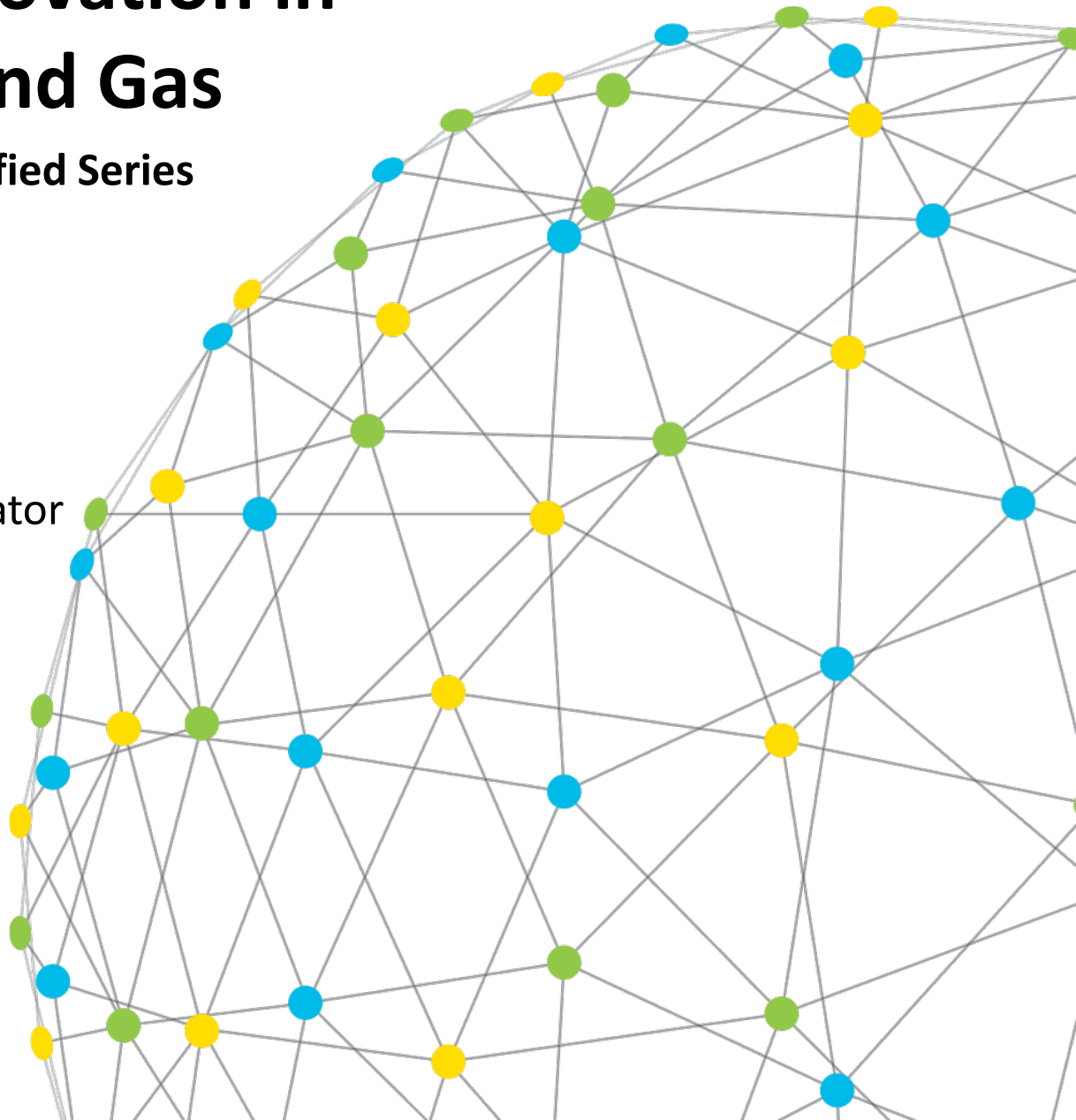
Technology Innovation in Upstream Oil and Gas

Presentation at SPE Simplified Series
13th September 2017

Patrick O'Brien,
Chief Executive,
Industry Technology Facilitator



Presentation Agenda

- Oil and gas industry has a strong record in technology development and innovation
  - Evolution of Riser Technology
  - Drilling of Wells
  - Subsurface imaging
- Our challenges today and emerging solutions
  - Technology is needed to make us perform better
- Innovation
  - What are we doing and can we do it better
  - ITF's specific role in innovation support
- Draw out some conclusions

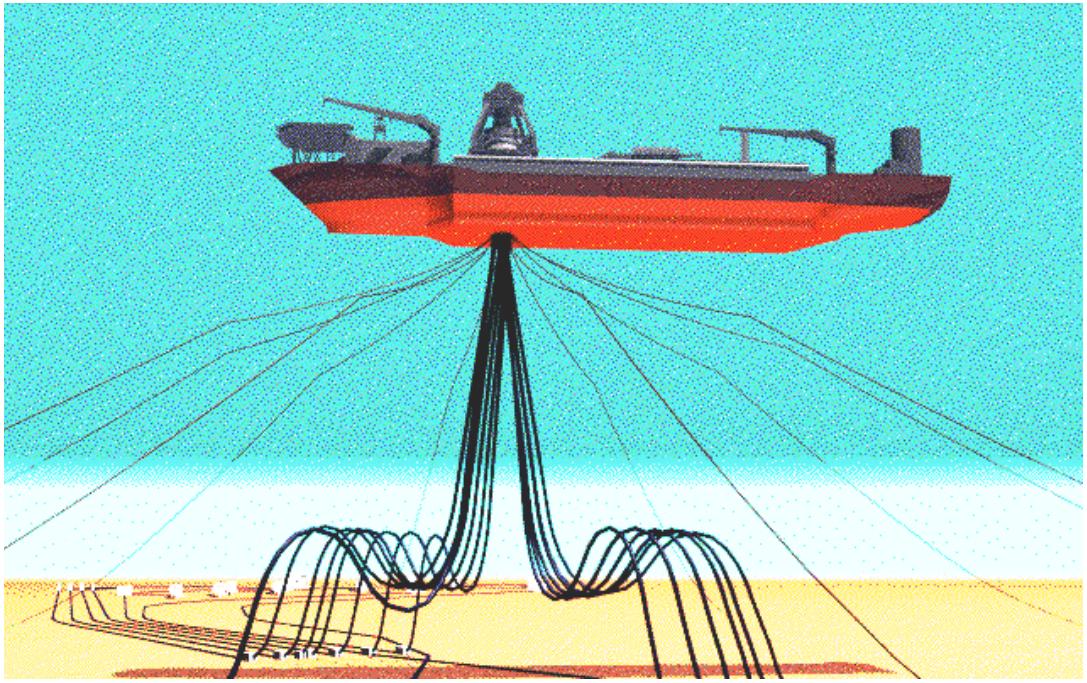
Evolution of Riser Technology with Water Depth

Top Tensioned (Rigid) Risers

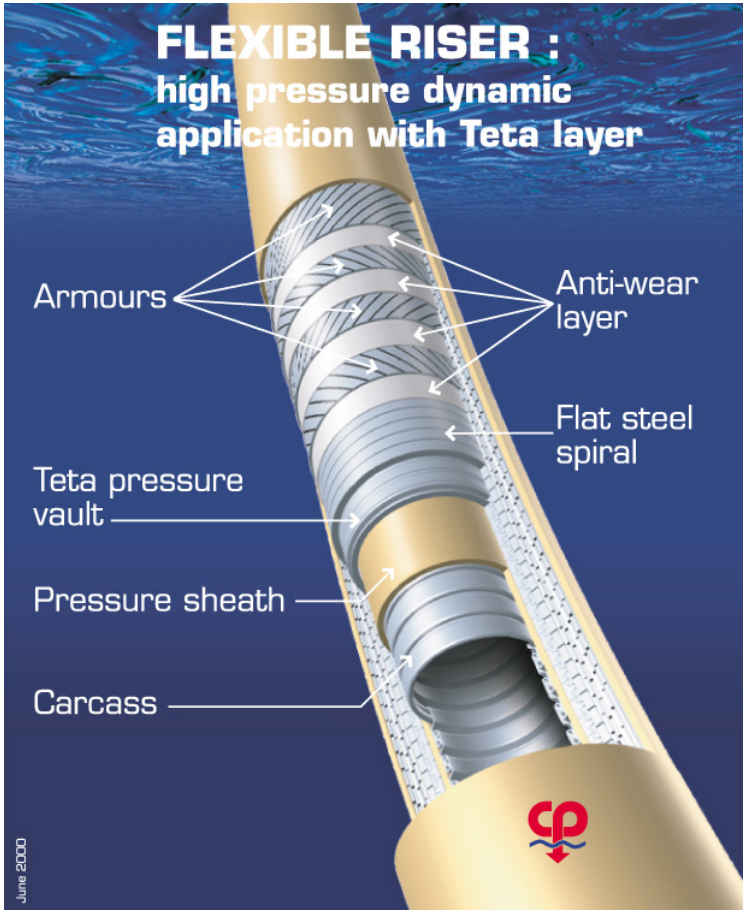
Tension Leg Platform Evolution

- First TLP:
  - Hutton in 1984
  - 486 ft (148m) water depth, North Sea
- Currently designing world's deepest TLP:
  - Big Foot Development
  - 5,187 ft (1,581m) water depth
  - Planned installation 2016 / 2017

Flexible Riser Technology



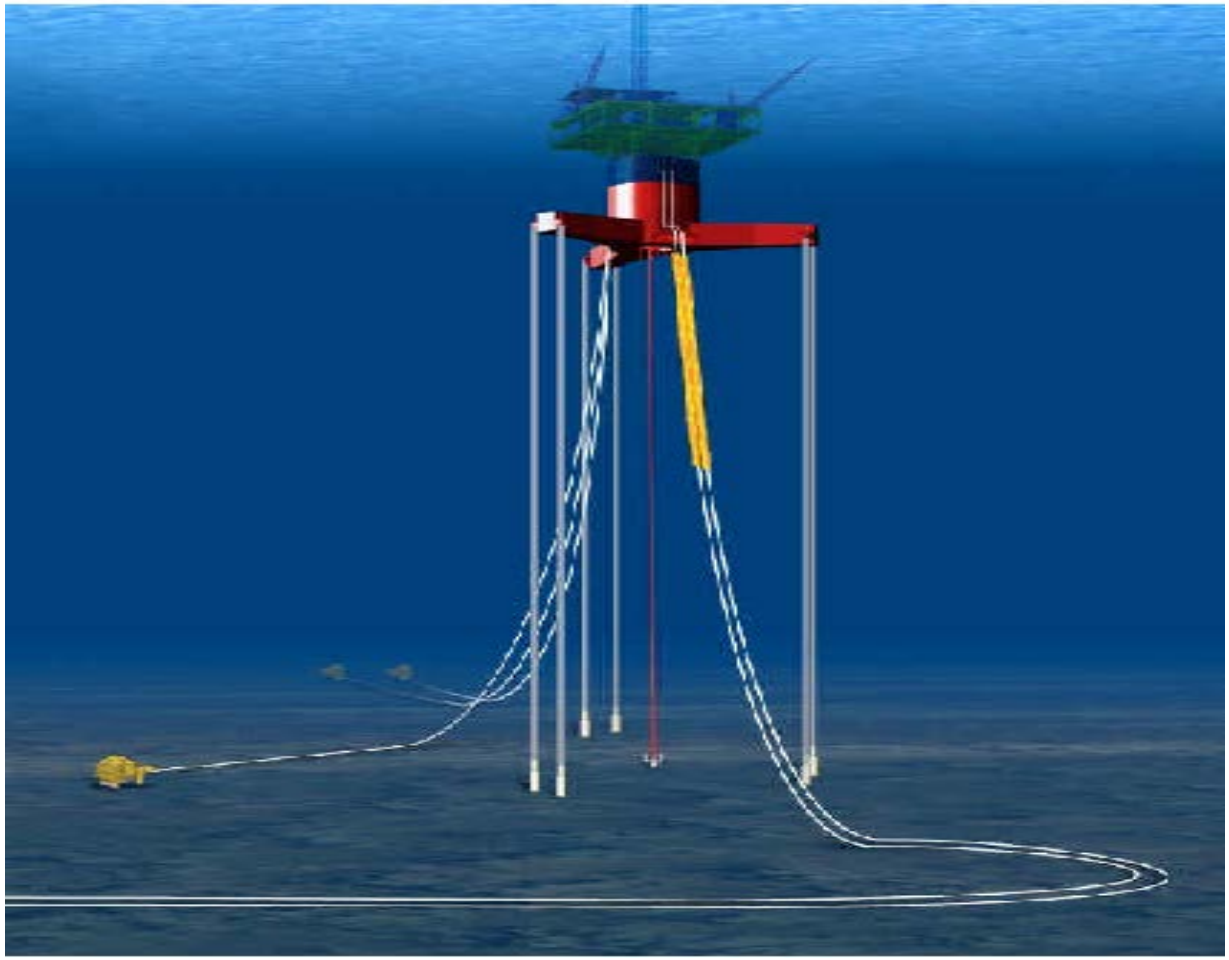
BP Foinaven Field, First Oil 1997



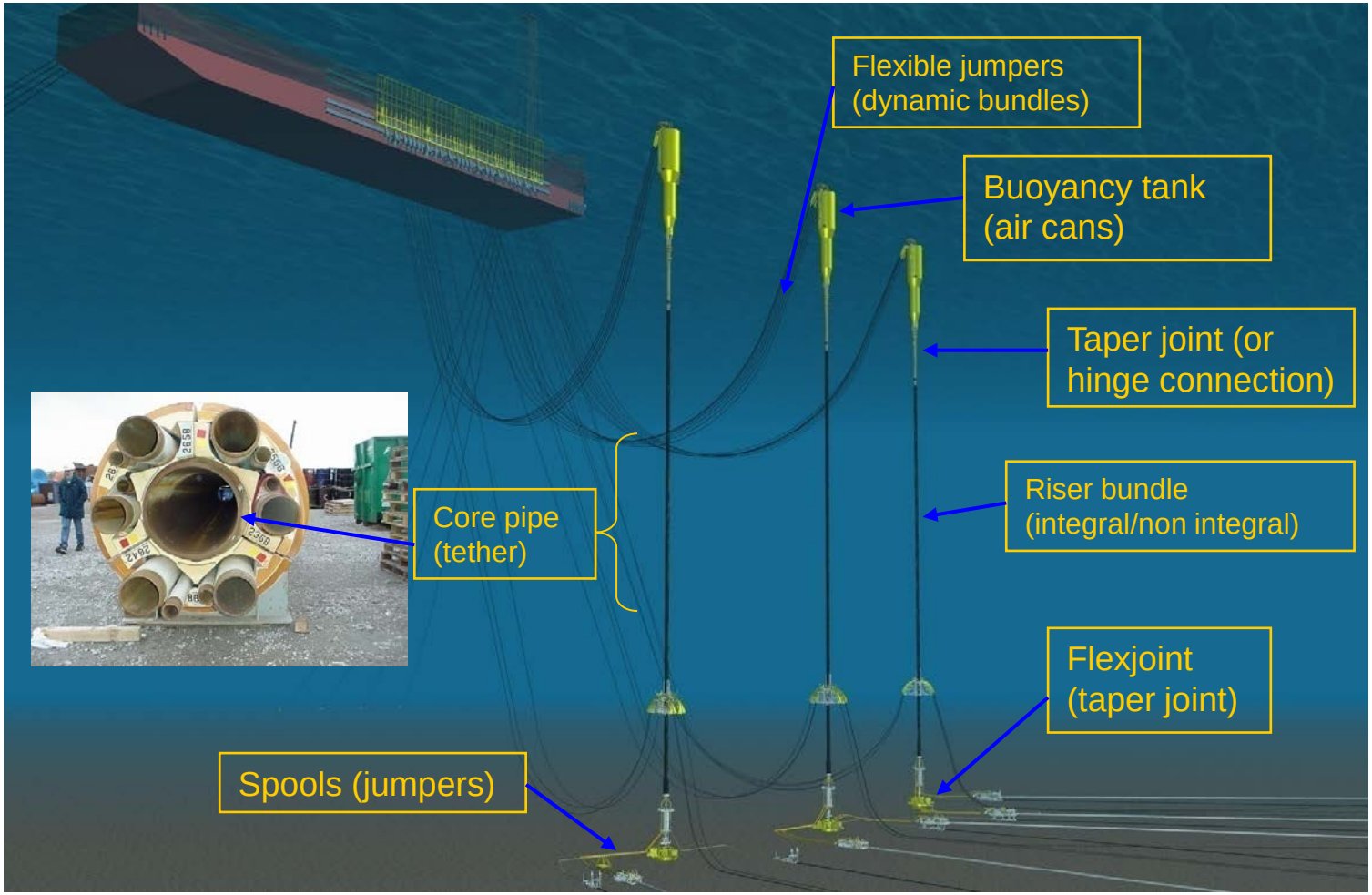
Other pioneering floating production platform fields include Balmoral (onstream 1986) and Ivanhoe Rob Roy (onstream 1989)

Steel Catenary Risers

- Shell Auger TLP, 1994, GOM, 2,860ft water depth
- Petrobras, Marlim, 1997, first SCR to a Semi, 910m water depth



Hybrid Riser Technology

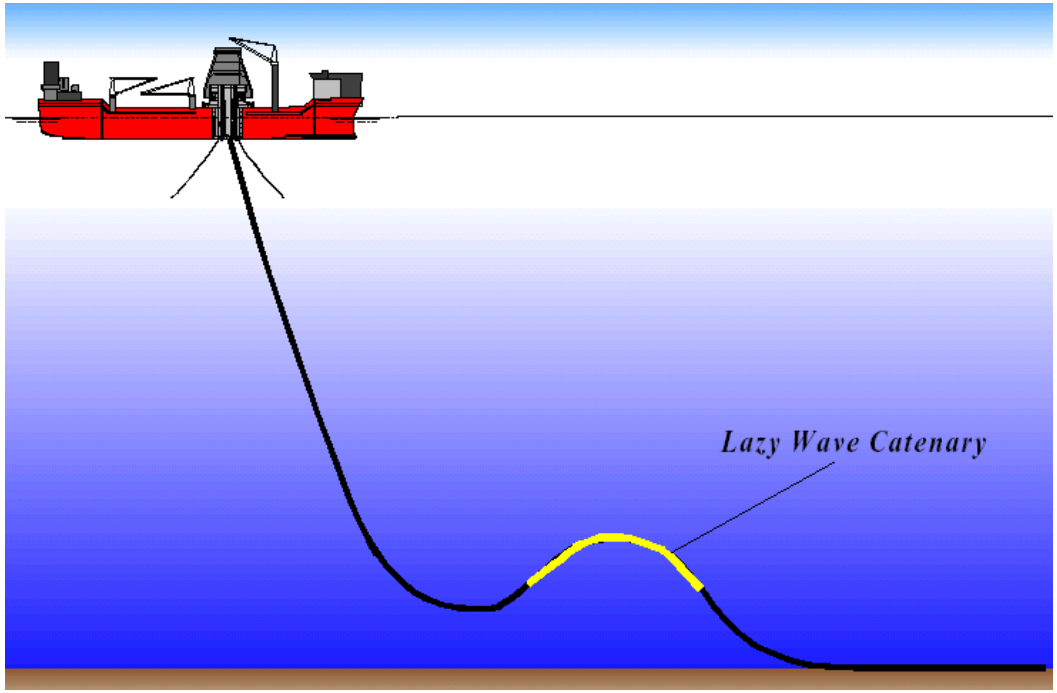


Girassol Field, Offshore Angola, onstream 2002

Steel Lazy Wave Riser

Shell BC 10 Project:

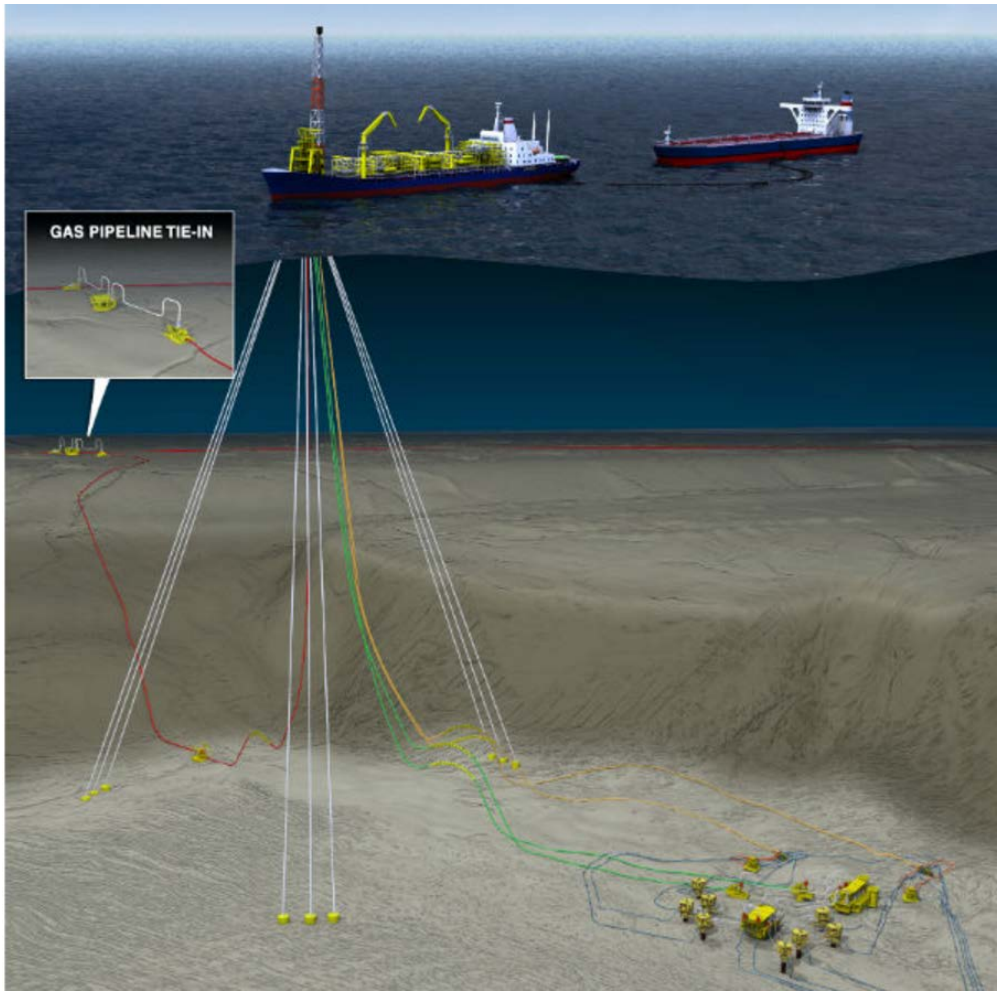
- Offshore Brazil
- Water Depth: 1,780m
- 7 SLWRs totalling 21km of pipe
- Installed in 2009
- World's first SLWR



SLWR – Latest Development

Shell Stones Project:

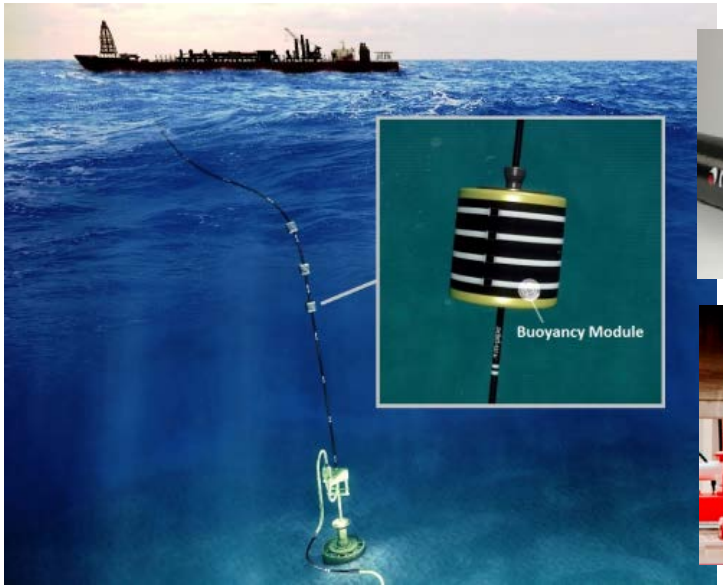
- Offshore Gulf of Mexico
- Water Depth: 2,900m
- First phase:
  - Two 8-inch production and one 8-inch gas SLWRs
- World's deepest FPSO and risers
- World's first SLWR to a disconnectable turret
- On stream September 2016

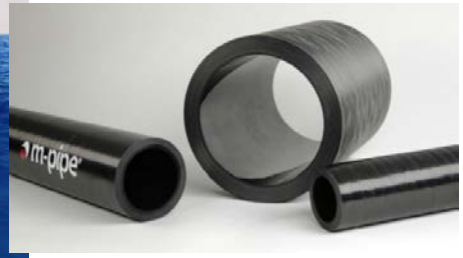


Thermoplastic Composite Risers

Key Benefits:

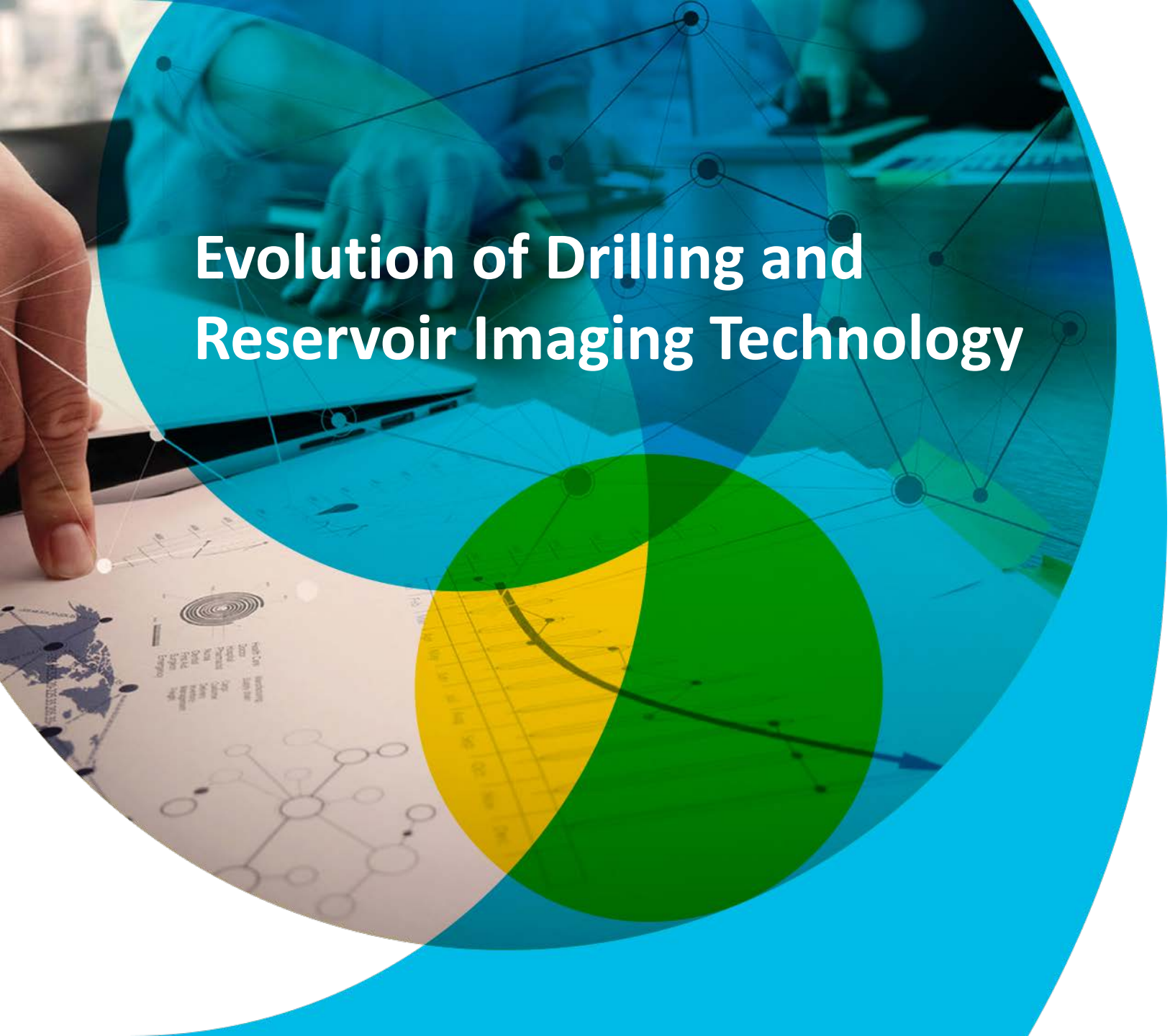
- Lightweight
- High Strength-to-weight ratio (much higher than steel)
- Bonded composite solutions vs traditional flexible pipe solutions with composite armours
- Corrosion and fatigue resistant
- New DnV Recommended Practice for Composite Thermoplastic Pipe just published
- Emerging technology
- Frontier deep waters 3,000m to 4,500m





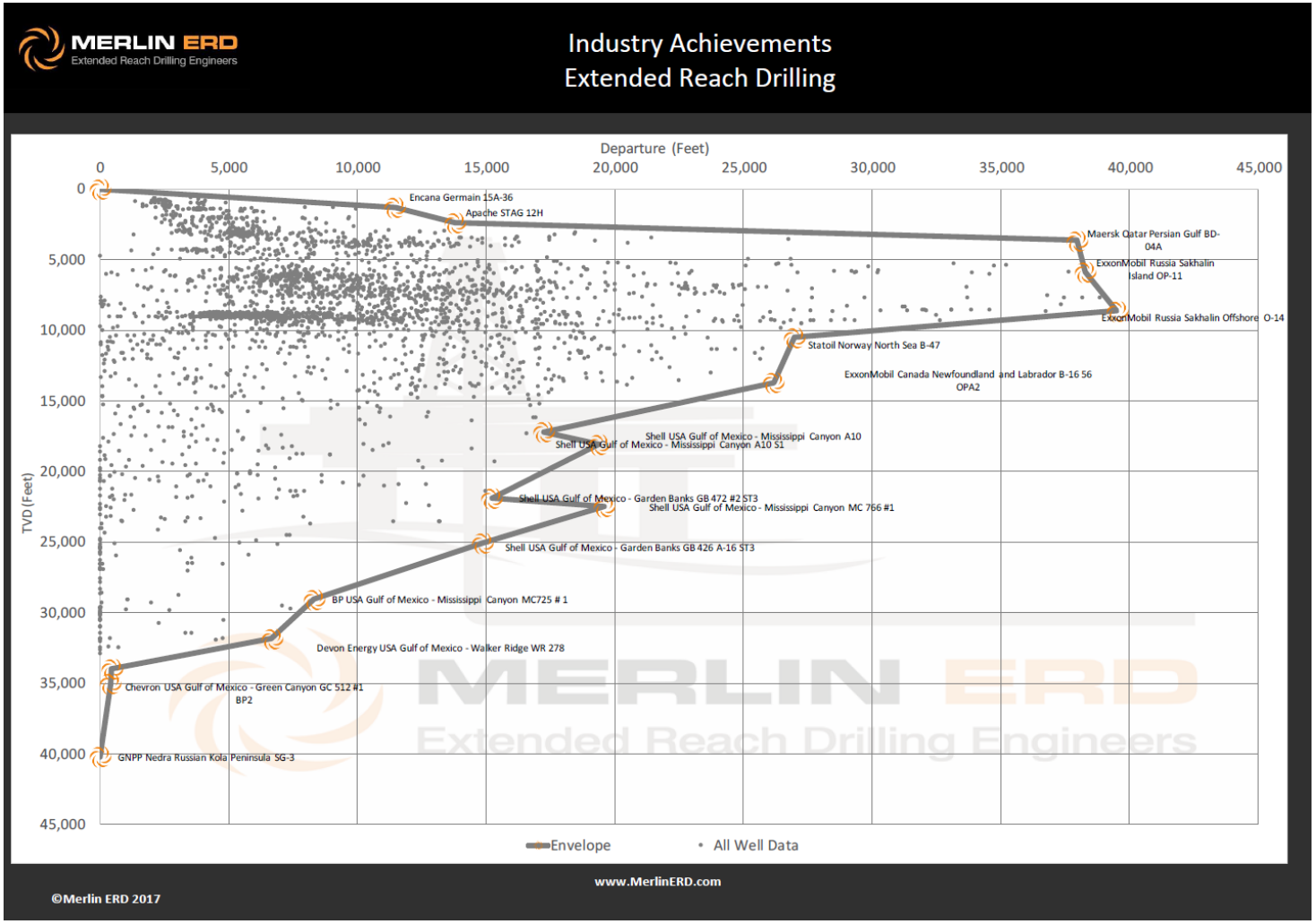
Source: www.magmaglobal.com

Source: www.airborne-oilandgas.com



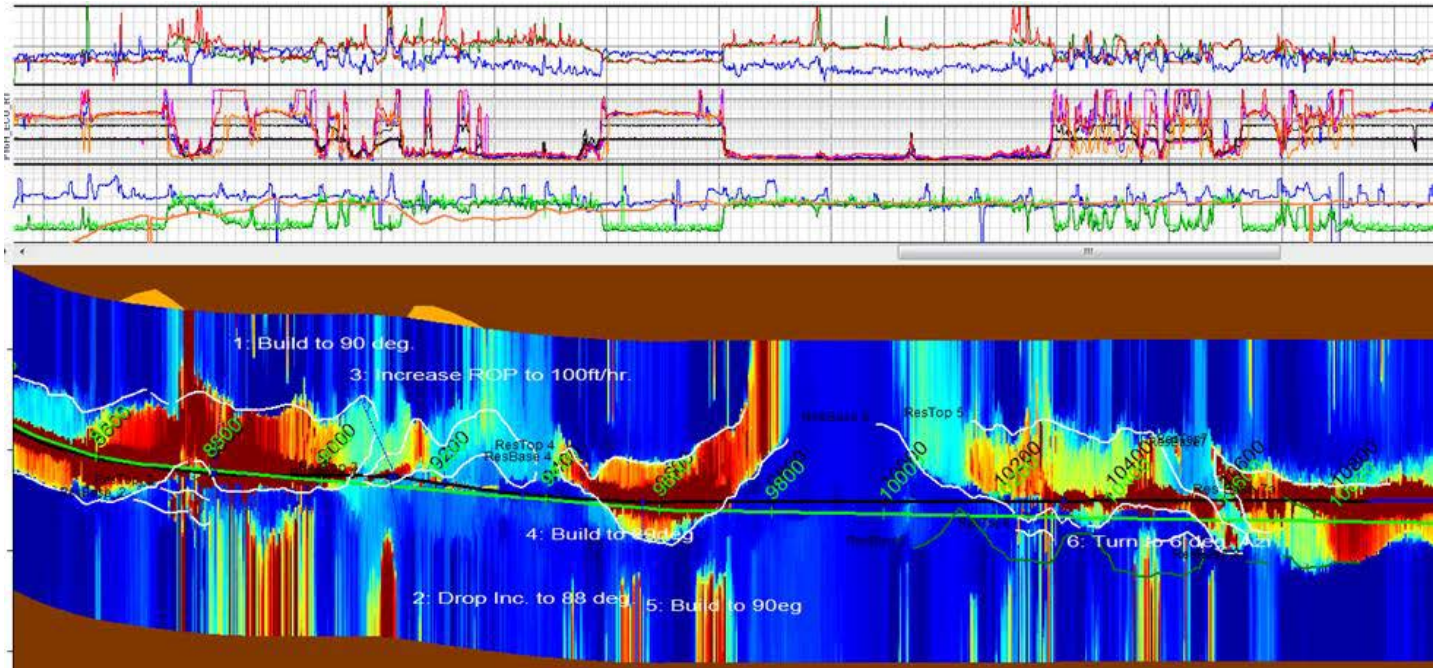
Evolution of Drilling and Reservoir Imaging Technology

Extended Reach / Horizontal Drilling



Source: www.MerlinERD.com

Geosteering to Maximise Reservoir Contact



- *From Mat Gibson et. al. (Premier Oil) and Mike Bower et. al. Schlumberger, Paper No. SPE-186136, Offshore Europe 2017*
- Deep Directional Resistivity (DDR) tool technology

Fullwave Inversion Analysis Technology Subsurface Imaging

Acoustic Wave Equation:

$$\frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} - \nabla^2 p = s$$

$$\underline{\boldsymbol{A}}\,\boldsymbol{p} = \boldsymbol{s}$$

Model Parameters:

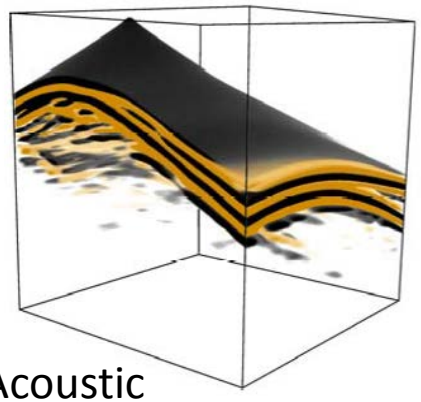
$$\boldsymbol{G}(\boldsymbol{m}) = \boldsymbol{p}$$

Objective Functional:

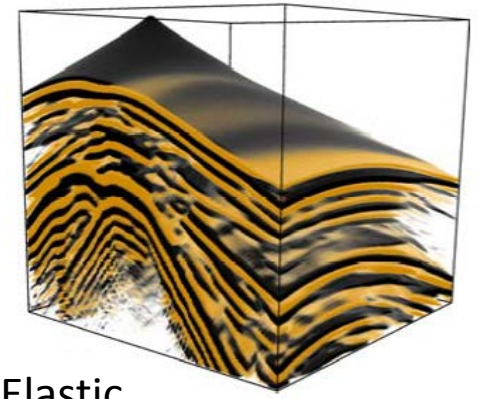
$$f(\boldsymbol{m}) = \frac{1}{2}\sum^{n_s}\sum^{n_r}\sum^{n_t}|d_{calc} - d_{obs}|^2 = \frac{1}{2}\|\delta\boldsymbol{d}\|^2$$

Solve for Model Parameter Increment:

$$\delta\boldsymbol{m} = -\left(\frac{\partial^2 f}{\partial \boldsymbol{m}^2}\right)^{-1}\frac{\partial f}{\partial \boldsymbol{m}}$$



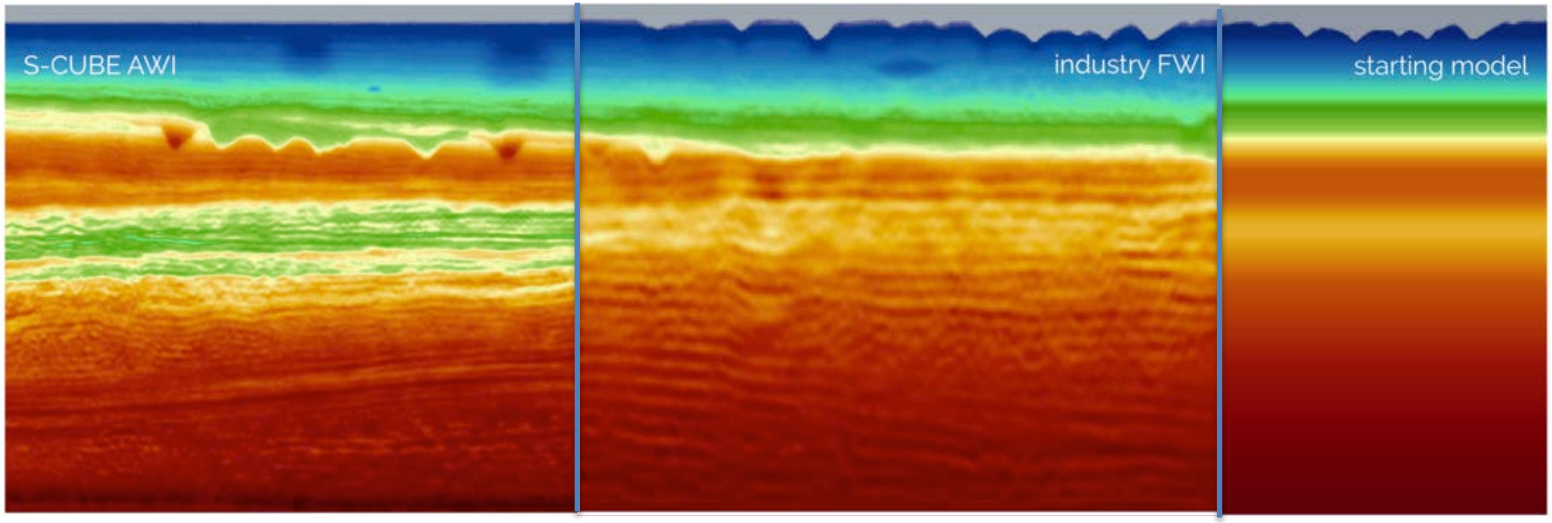
Acoustic



Elastic

- 50 GB for each source, 70 TB for whole set

Fullwave GameChanger by Imperial College London



Courtesy: www.s-cube.com

- 10 years, 15 industry participants, £7.5m ITF Member investment
- Leading edge research and analysis technology now emerging into industry and transforming our ability to image the subsurface
  - Commercial engagement of CGS, PGS, TGS-NOPEC
  - Spin-off company S-Cube now formed www.s-cube.com
- Great project to run as a Joint Industry Project
  - Participants submit individual datasets but share outcomes in a non-attributable manner
  - The developer gets to continuously improve his technology aligned to industry needs
- JIP Outcomes have already influenced 100 drilling / well placement decisions amounting to some $500m dollars of value

Technology Challenges and Potential Solutions Proposed Today

Our Technology Challenges Today

- Reduce Costs
- Add Value
- Increase Efficiencies
- Maximise Performance

McLaren Applied Technologies

Learning from Motorsport

- Geoff McGrath, CIO, McLaren Applied Technologies at ITF Technology Showcase, March 2017:
  - High performance sport maximising marginal gains to win
  - Advanced simulation capability with empirical data and data analytics capabilities enables rapid scenario planning leading to accurate predictive capabilities and data driven decision making
- Key messages from Geoff:
  - Model the whole system
  - Measure what you can manage
  - Keep the human in the loop

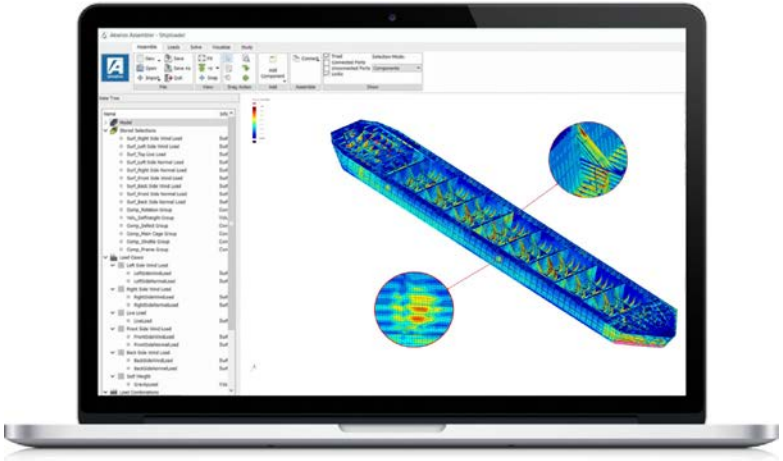
Applications to Offshore Oil and Gas:

- Production Efficiency & Optimisation
- Marine Logistics
- Seismic data analysis
- Asset Integrity

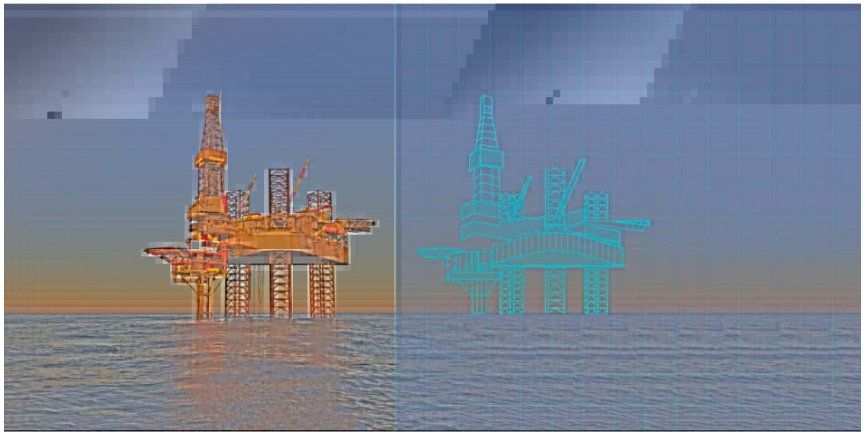
Akselos Digital Guardian JIP

- Reduced Basis Finite Element Analysis (FEA)
  - 1000 times faster than standard FEA
  - Technology from MIT
  - Rapid multi-scenario modelling
- Sensored asset with Data Analytics leads to “Digital Guardian”
- Predictive based asset integrity management
  - Reduced inspection costs
  - Extended asset life

ABB Paper at OTC 2017:
- Paper No. OTC-27788-MS
- 1969 research work showed that 89% of failures had a failure distribution uncorrelated to age



Model Complex Whole Systems in Detail



Akselos Digital Guardian

ConocoPhillips Integrated Operations

- All to support offshore operations
- Bring together process, plant, logistics
- Whole system modelling, monitoring with data analytics
  - Enables data driven decision making
- Maximise performance, reliability and extend life

Courtesy: ConocoPhillips

Robotics Offshore

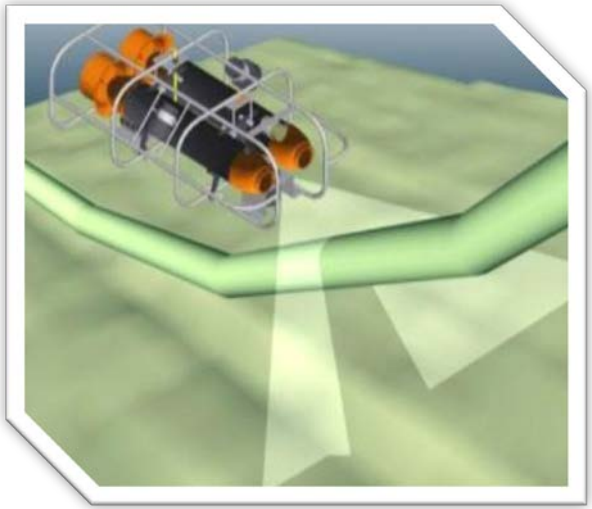
- Edinburgh Centre for Robotics

Source: www.edinburgh-robotics.org

- Robotic Drilling Systems
  - http://www.rds.no/home

- Total ARGOS Challenge
  - http://www.argos-challenge.com/en

Autonomous Subsea Inspection
Seebyte Ltd



Courtesy www.subsea7.com

- 12 month, £524k JIP sponsored by BP, ConocoPhillips, Subsea 7, DTI and Scottish Enterprise
  - Seebyte founder Professor David Lane, Director Edinburgh Centre for Robotics, Heriot Watt University recently awarded CBE
- Demonstrate the use of an Autonomous Underwater Vehicle (AUV) to automatically inspect a riser
- Shell adoption of the AIV concept for subsea inspection of their worldwide deepwater facilities
  - AIV developed as a collaboration between Subsea 7 and Seebyte
  - https://www.youtube.com/watch?v=iRdWzsUAH-w

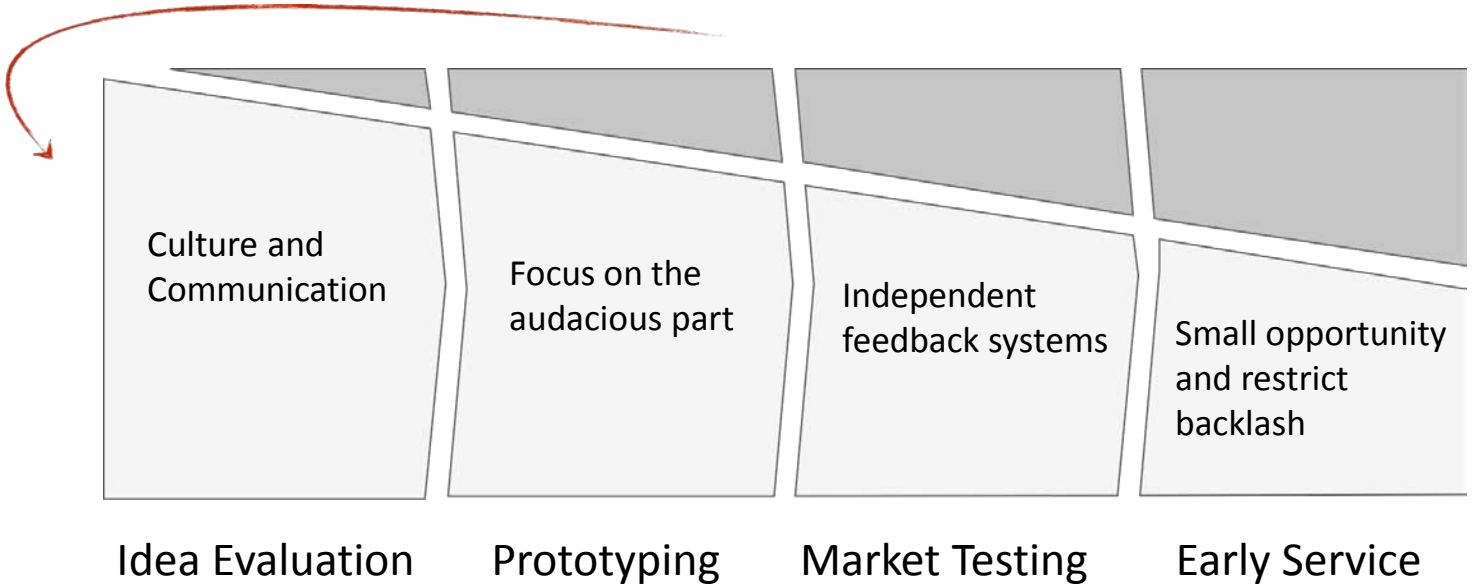
Innovation and Role of ITF

Technology Development and Innovation in Oil and Gas Industry

- Stakes are high as:
  - Safety is paramount
  - Offshore costs are high
  - Operators have strong obligations and high liability
- Field trialling new technology is difficult
  - Frustrating for technology developers
- New Technology Implementation
  - Significant operator focus on technology qualification bars, which could be better shared
  - Poor practice on innovation and how to introduce it

What is Innovation?

- *"Innovation is the process of executing on new ideas"*
  Josh Valman, CEO, RPD International at ITF Technology Showcase, March 2017
- *"Create an environment that suits the necessary failure of innovation"*



Courtesy: Josh Valman

Government Role on Innovation

- Advanced Economy
  - Cannot just copy others; must do things in a different and better way
  - Higher levels of investment in R&D and innovation correlate with faster growth and higher income
    - Improves productivity
    - New products and services
    - More effective processes
    - Be competitive and leading on the international scale
    - Essence of economic growth and the reason why government must support innovation

- UK Industrial Strategy
  - Government is putting in place an industrial strategy to support investment in science, research and innovation
  - UK invests 1.7% GDP in public and private R&D which is less than OECD average of 2.4%. Government is to increase its spending in R&D and innovation.
  - Investments in particular technologies such as batteries and robotics
  - Set up of sector deals to support specific industries that can give UK competitive edge internationally
  - Putting in measures to support better commercialisation of existing strong R&D capability

UK Technology Structure

- Oil and Gas Authority (OGA)
  - Regulates, influences and promotes UK oil and gas industry
  - Has a specific technology function:
    - ✓ Co-chairs UK Technology Leadership Board (TLB)
    - ✓ Engages with operators on Field Technology Plans
    - ✓ Monitors progress on technology implementation
- UK Technology Leadership Board (TLB)
  - Be the single industry voice on UKCS technology priorities; set the technology strategy
  - Provide industry stewardship on progress of technology agenda
  - Communicate, engage with and influence industry with regards to its activities
  - Co-chaired by industry and OGA
- Oil and Gas Technology Centre (OGTC)
  - Executes technology strategy of TLB
  - Has £18m per annum Government funding to be matched by industry
  - Will focus on technology implementation through field trials and other mechanisms
- Supporting Technology Organisations
  - ITF, Oil and Gas Innovation Centre (OGIC), National Subsea Research Initiative (NSRI)

UK Technology Support Organisations

- ITF
  - Joint Industry Project is key mechanism to deliver
  - Member driven; global technology themes
  - Developers are an important source of innovation for our members
    - Little direct support for innovators
- OGTC
  - £18m Government funding for industry with matched engagement by industry (in-kind or cash)
  - Focused on delivering technology solutions for MER UK and unlocking potential of the North Sea
  - Create a culture of innovation in North East Scotland
- NSRI
  - Technology focused arm of Subsea UK
  - Direct support to UK subsea supply chain
  - Connecting industry and academia to encourage collaboration
- OGIC
  - Funded by Scottish Government
  - Connecting universities with companies on technology development projects

ITF Mission

“Make Technology Impact and Bring Innovation to our Members”

The Joint Industry Project (JIP)

- Well established in the oil and gas industry
  - Project sizes can vary from $100,000 to $10,000,000
- Stimulates technology development and demonstrates industry need
- Gets cold face industry input to the development of the technology
  - Vital insight for the developer
- Enables good knowledge transfer
- Shares development costs
- Encourages additional venture capital investment

- ITF Intervention:
  - Projects are strategic and meet industry needs
  - Captures wide industry innovation and enables development of competing solutions
  - ITF plays an ongoing care and maintenance role for its JIPs to promote best outcomes for its members and the wider industry
  - Establish best practice JIP execution and use the JIP model appropriately

ITF Members & JIP Participants

Current Joint Industry Project Participants:

- ADNOC
- Anadarko
- BP
- ConocoPhillips
- CGG
- Chevron
- Dong Energy
- EBN
- ENI
- ExxonMobil
- Hess
- Husky Energy
- Maersk
- Marathon
- Nexen
- PDO
- Petronas
- Premier
- QP
- Repsol
- Shell
- South West Energy
- Statoil
- Suncor
- Total
- Tullow
- Woodside
- Wintershall

ITF in Numbers

18 years in business

13 members

28 JIP participants

82 collaborative investors

2,103 developers

216 collaborative initiatives

9 countries

15 currently running projects valued at **£9m**

£77m invested

£4.5m average per year

Maximum annual of **£9m**

£7.5m seismic imaging project

100 well placement decisions amounting to **$500m** in value

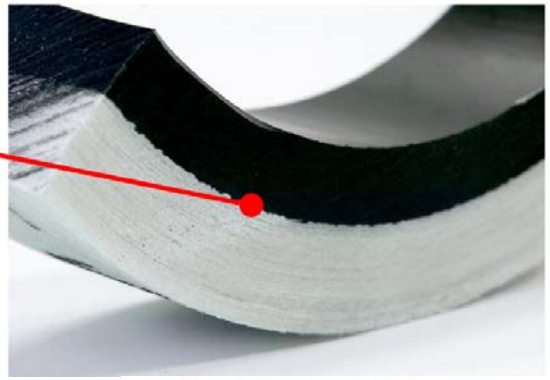
20 times leveraged private investment

89 open proposals valued at **£58m**

Airborne Oil and Gas
Thermoplastic Composite Pipe (TCP) / Riser

Airborne

Fully bonded flexible pipe (melt-fused): one solid wall



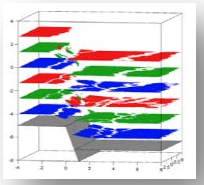
- 18 month €2m JIP to test and demonstrate feasibility of TCP
- Attracted private investor to build new factory
  - Subsequent oil company investors include Chevron, Shell and Saudi Aramco
  - Recently announced €10m investment from Saudi Aramco plus another €13m from existing shareholders
- Recent Implementation:
  - Petronas award TCP flowline for hydrocarbon transport with highly corrosive fluids
  - Chevron install TCP jumpers on its North Sea Alder project
  - Total qualifying TCP jumper spools for deepwater West of Africa application

Sponsors

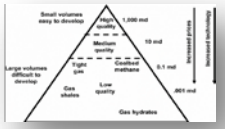
PETROBRAS BG GROUP Statoil bp Chevron subsea 7 TOTAL Schlumberger

Currently Running Subsurface JIPs

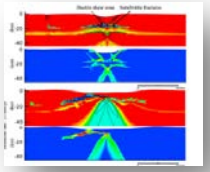
QUAFF



PetGas



COMPSTRUCT



Structural Geology

Petrophysics

Basin Modeling

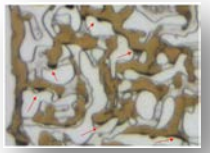
Subsurface

EOR

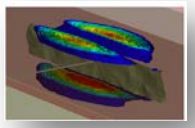
Fracture Modeling

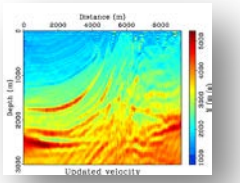
Geophysics

Low Sal EOR



FracGas

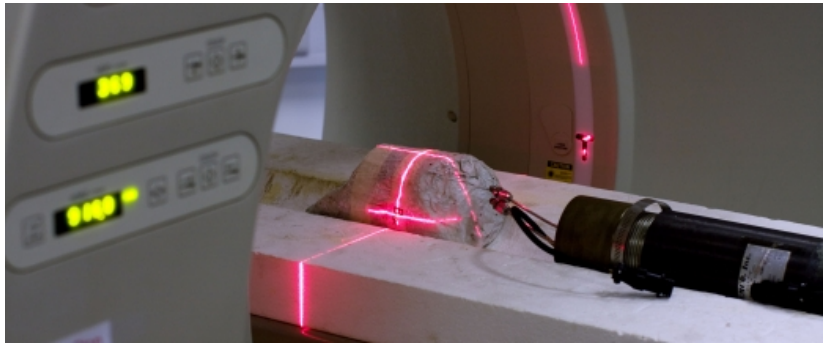




FWGC

Tight Gas Reservoirs

- PETGAS III – University of Leeds
  - Rapid petrophysical characterisation
  - Database and data mining software
  - State-of-the-art testing equipment
  - EBN and Petroleum Development Oman



Core Analysis by University of Leeds

- FRACGAS II – Rockfield Software
  - £4.5m investment in FRACGAS I and II projects
  - Participants include Repsol, Marathon, BP, Nexen, Chevron, Southwestern Energy and previously Total, Statoil, Noble Energy
  - Leading edge analysis technology calibrated to test samples and now in commercial use by industry

Courtesy www.rockfieldglobal.com

Quantification of 3D Fault Zone Geometries (QUAFF)

Phase 2

Developer: University College Dublin

Project Purpose: Reservoir modelling risk reduction.

Sponsors: Shell (BG), ExxonMobil, Conoco Phillips, Total, Statoil, Woodside, ENI P… Anadarko Petroleum.

Total Project Funding: £1,6… €36,666 **Duration:** 36 mont…

Project Description & Obje…

The fault zone characterisat… QUAFF resulted in a compre… fault zone structure from ou… library of 3D fault zone moc… using different internal and… mechanical boundaries, and… applying the database to pr… management issues. The ob… project is to apply and develop this body of work, packaging the result in the 'Faultmaker' plugin and standalone software.

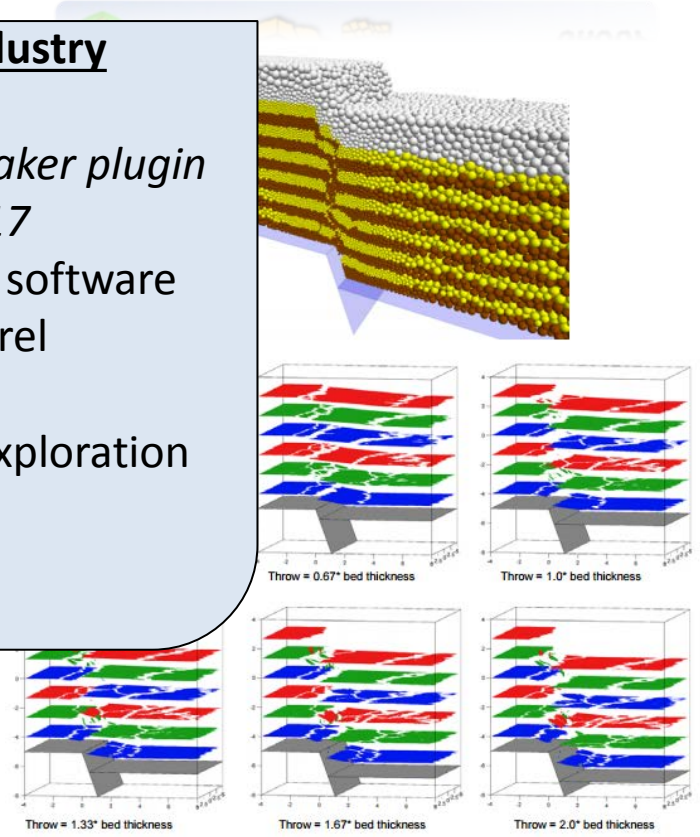
End Date: 31.12.18

Status and Value to Industry

Status – *β version of FaultMaker plugin and standalone released 2017*

Value - Stand alone industry software

- Commercial plugin to Petrel platform
- Reduced uncertainty in exploration and appraisal
- Reduced drilling risk



EOR by Low Salinity Water Injection

Activation of Natural Surfactants of Crude (LowSalEOR) Phase 2

Developer: Heriot Watt University

Project Purpose: Low salinity water injection; prediction of incremental EOR based on reservoir fluid analysis.

Sponsors: Shell (BG), BP, To
Wintershall, Maersk, OGA.

Total Project Funding: £1,2
£50,000

Duration: 36 months.

Project Description & Obje

In a phase one Heriot Watt
explanation for the mechar
enhanced oil recovery by lo
Their mechanism links the i
to the activation of the natu
compounds of crude oil by low salinity water injection.
The aim and deliverable of this project is to develop a robust and reliable tool for evaluating reservoirs suitable for low salinity water injection and to predict the size of potential incremental oil recovery.

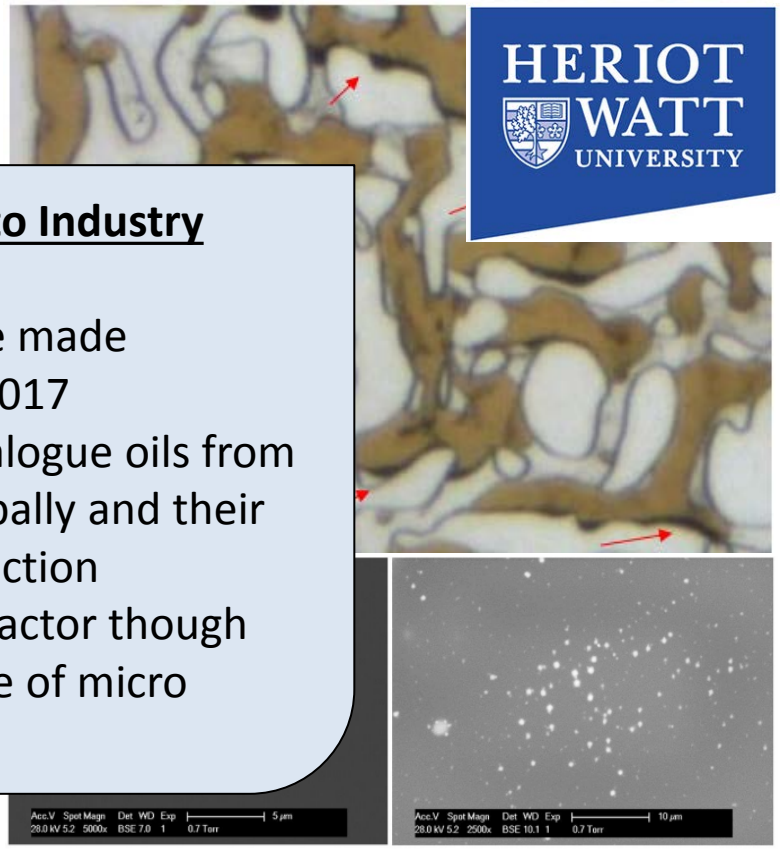
End Date: 31.12.17

Status and Value to Industry

Status – Database to be made available to members 2017

Value - Database of analogue oils from different reservoirs globally and their response to LowSal injection

- Increased recovery factor though increased knowledge of micro dispersion effect

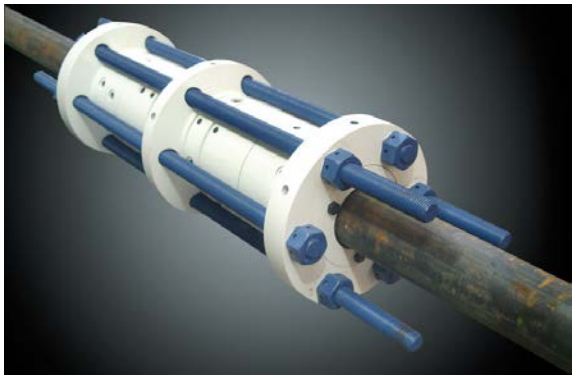


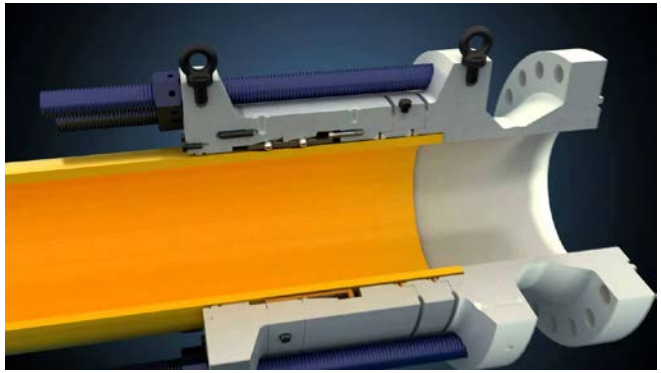
CLIP-MC Joint Industry Project

- CLAD & Lined Pipe Mechanical Connector
  - CRA lined pipe for highly corrosive internal fluids (CO2, H2S)
  - Mechanical connector repair mechanism
- Collaborative approach to put in place an emergency infield repair solution
- Mechanical connector to avoid welding
- £1.1m JIP supported by: Chevron woodside
- Hydratight will build, test and qualify full scale prototype connector that is capable of sealing CRA liner-to-liner
- **UK developer with Australian operators**

Inner Lined CRA Pipe

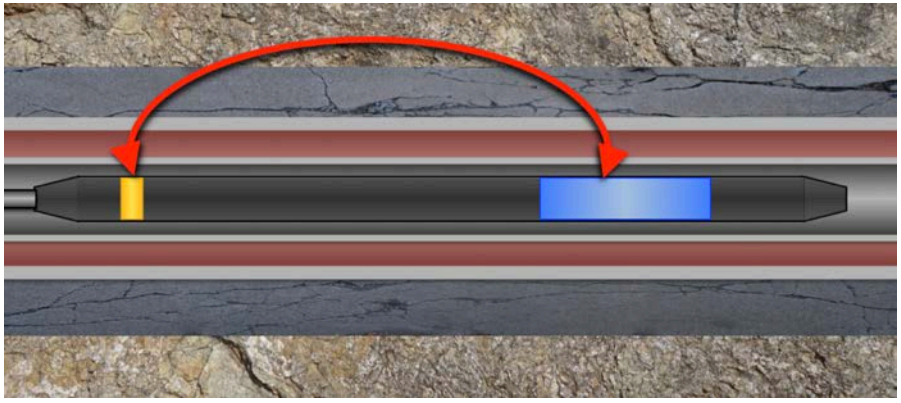
Mechanical Connector





MagnaBond Vortexx R&D Technology

- Ferromagnetic particulate additives for cement
- Magnetically permeable cement allows for later inspection by a Pulsed Eddy Current EM logging tool
- New sensor downhole EM tool concept:
  - Sensitive enough to detect MagnaBond cement through production tubing and multiple strings of casing
- Well integrity at construction
- Seal integrity at abandonment
- Project to develop, lab and field test



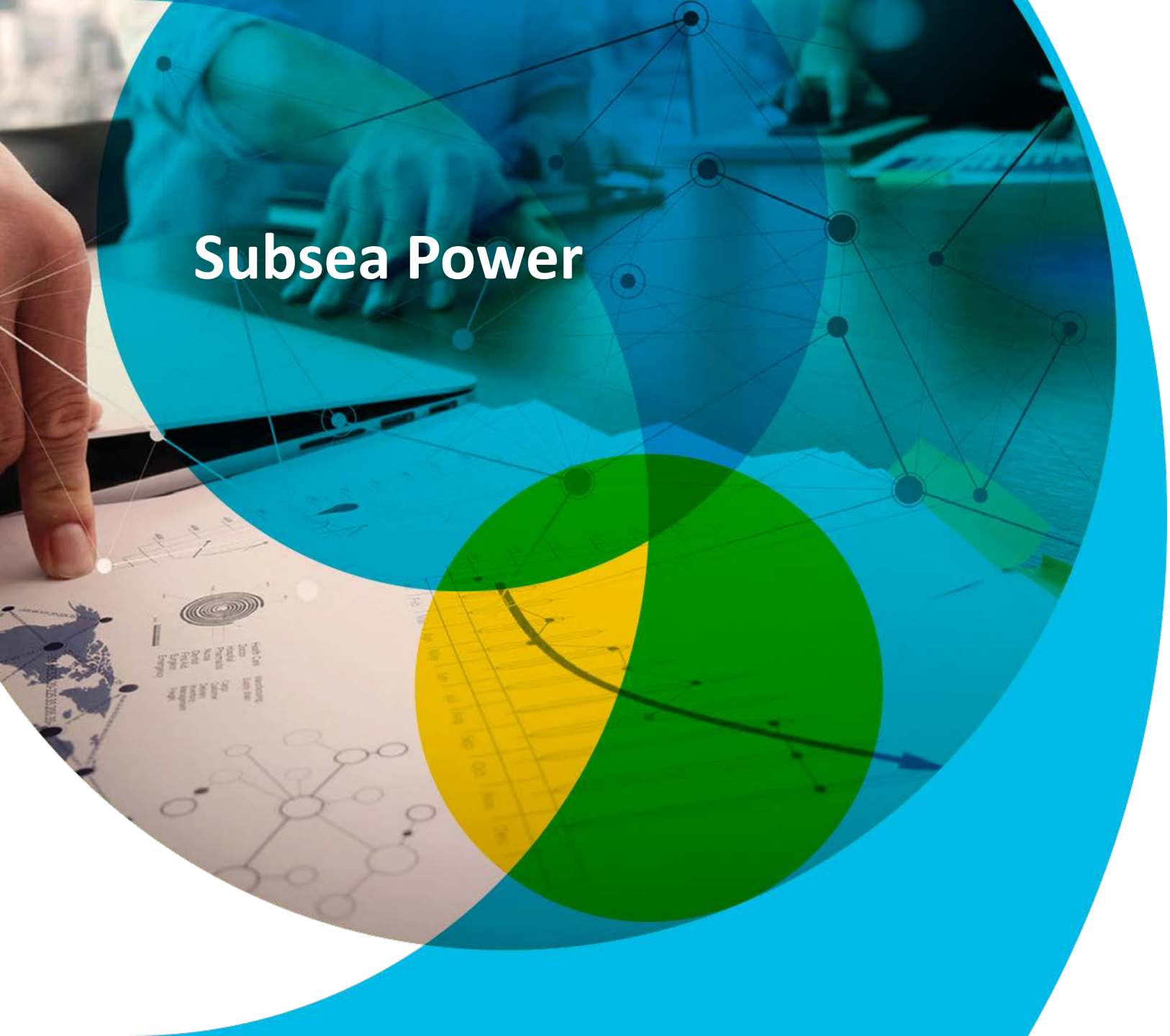
Vortexx

Specific & Direct JIP Initiatives

- Statoil One-Trip Steerable Liner Drilling & Completion Technology
  - Drill, secure and cement simultaneously
  - Technology developed jointly with Baker Hughes
  - Statoil planning field trials latter half of 2017
  - ITF establishing a Qualification and Early Adopt Network with five operators and Statoil

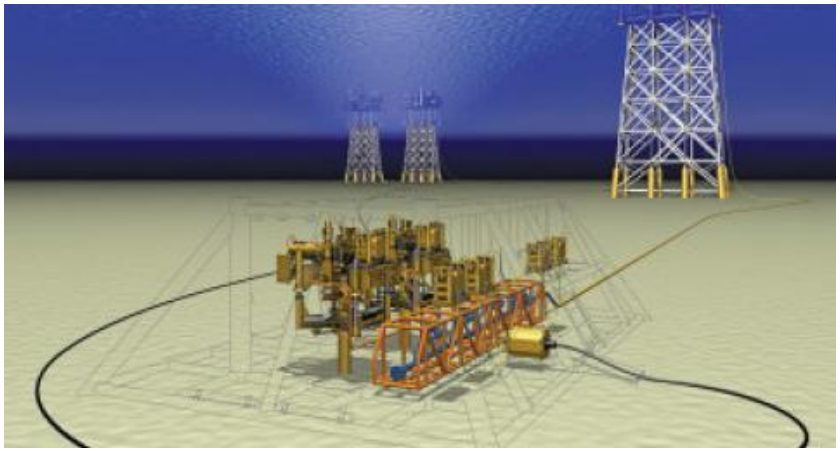
- Neodrill Suction CAN Technology
  - Replace traditional conductor in well drilling & construction
  - Reduced well construction costs and potential to integrate subsea equipment and pipelines to reduce time to production
  - Needs operator input to prove feasibility across a range of soil conditions
  - Speed up adoption of an already tried technology

Subsea Power



World-First All-Electric Subsea Well

- K5F3 well, Offshore Netherlands, the world's first all-electric Subsea Well opened to production August 2016
- Initially two electric subsea Christmas trees has been successfully operating on the K5 field since 2008
  - Surface controlled subsurface safety valve still hydraulic
- All-electric system removes topsides Hydraulic Power Unit and reduces size of umbilical with the removal of all hydraulic lines associated with the traditional multiplexed electro-hydraulic control system
- Cost savings of between 7% and 15% can be achieved
- Radically improved potential for:
  - Communications standardisation
  - Data monitoring and retrieval
  - Subsea power



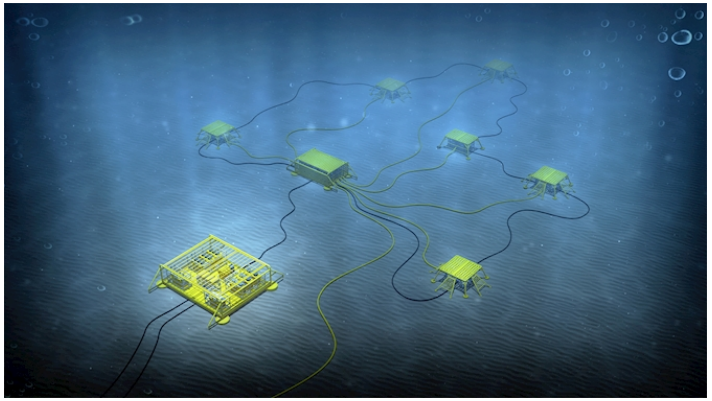
Source: *http://www.ep.total.com/en/expertises/deep-offshore/deep-offshore-first-all-electric-subsea-well*

ABB Subsea Power Joint Industry Project

- $100m joint industry project (JIP) funded by:
  - ABB, Statoil, Total, Chevron and Research Council Norway
- Subsea Power and All-Electric Control and Production
  - Power levels up to 100 MW
  - Water depth up to 3000m
  - Tieback distances up to 600 km

Subsea Transformers Model

Source: *www. http://new.abb.com/oil-and-gas/sectors/offshore-oil-and-gas/subsea/subsea-power/subsea-power-gird*



To Conclude…..

Final Conclusions and Observations

- The oil and gas industry has a strong track record in technology development and innovation
- ITF has a specific role in the innovation landscape
  - Facilitating collaborative technology development projects (JIPs) working on global themes and using our industry connections both with operators and developers
  - Working with other technology organisations, but need to do a better job at articulating our industry roles
- Innovation
  - All of us need to be better at it and recognise it as a discipline
  - Creating space for and executing on innovation
  - Are supply chain incentivised?
- Government see technology innovation as key to sustaining our industry for the long term
  - OGA Role and set up of OGTC
- Articulating the business case for action
- Commercial readiness level for technology development

Thank you for listening……