DECOMMISSIONING & INTEGRITY MANAGEMENT

WILL ROWLEY
28 NOVEMBER 2017

ACTEON FLS
Why am I speaking here today?

• The opportunity to meet some great people (you!)

• Share the latest activities and some ideas & examples of change & innovation (technical, process & commercial) that are **delivering positive change** and **notable cost reductions** within various areas of offshore decommissioning and integrity management

• To be clear, both decommissioning & integrity management are two areas under significant change & evolution and this is challenging convention, custom and practices
  
  • *You may not agree or like some of the examples or case studies, but focus on the outcomes*

• I have been asked to challenge and stimulate, hopefully I will achieve both
Introduction

Will Rowley MBA (Dip), Law (Cert)

• Market Strategist, Analyst & Economist (not an Engineer)
  • Market development, supply/demand, economics/costing, complex modelling, assessments, positioning, drivers/impacts, business growth, investments, commercials etc…..
  • Provider of key data inputs & influence behind policy or investment decisions, alongside technical evaluation & inputs
• An Offshore Oil & Gas Specialist including Decommissioning for >20yrs
• Currently working for Acteon Group, one of the largest privately owned subsea services companies globally; active in >100 locations with x21 operating companies
• Director of Decom North Sea (largest global trade body focused on decommissioning)
• Advisor to Oil & Gas UK on decommissioning market development
• Worked with/for major operators & contractors and Governments & departments globally from US Congress, US Coastguard, UK/Norway/Australia Gov’ts, Shell, BP, CNOOC, Petronas, Saudi Aramco, TechnipFMC, Subsea 7, Saipem, McDermott etc…..
Acteon FLS

- Acteon Group companies provide services, equipment & expertise in support of dynamic & critical offshore infrastructure
- Acteon FLS (Field Life Service) is the central corporate unit responsible for integrated solutions involving multiple Acteon Group companies;
  - Focused on **decommissioning, integrity management** and **installation support**
  - Global coverage with access to; x21 companies, x101 locations, x247 product/service lines and unparalleled domain knowledge & experience in key specialist areas of activity

<table>
<thead>
<tr>
<th>Company</th>
<th>Domain</th>
<th>Description</th>
<th>Market Position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mooring &amp; Installation</td>
<td>World-leader in innovative mooring and installation technology. The company designs, supplies and deploys technically advanced mooring systems and provides rig-move and back-of-the-boat installation services worldwide</td>
<td>[#1]</td>
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<tr>
<td>UTEC</td>
<td>Survey &amp; Monitoring Services</td>
<td>Largest independent provider of survey, geotechnical &amp; positioning services with global coverage. Operates the world's largest fleet of autonomous underwater vehicles (AUVs) for pipeline &amp; platform survey &amp; inspection</td>
<td>[#2]</td>
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<td>Menck</td>
<td>Foundation Services</td>
<td>Provides specialised hydraulic pile driving solutions and project management for customers in oil, gas renewables and civil engineering</td>
<td>[#1]</td>
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<tr>
<td>aquatic</td>
<td>Mooring &amp; Installation</td>
<td>Globally renowned for laying and retrieving flexible and semi-rigid products on the seabed. The company has proven ability in shallow and deep water, and extensive experience of off- and onshore installations, transpooling, recovery and decommissioning</td>
<td>[#1]</td>
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<td>Seatronics</td>
<td>Survey &amp; Monitoring Services</td>
<td>Firmly established as a global supplier of electronic subsea equipment to the hydrographic, environmental, geophysical, metocean, remotely operated vehicle (ROV) and diving industries</td>
<td>[#1]</td>
</tr>
<tr>
<td>2H offshore</td>
<td>Riser Services</td>
<td>Specialises in the engineering design, monitoring and integrity management of offshore risers and conductors</td>
<td>[#1]</td>
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We are organised in ‘clusters’ with complimentary capabilities & skills
Acteon delivers decommissioning…

amongst others…
Decommissioning – a complex challenge

Cost uncertainty
- Cost delta or differential is too large
- Cost increases averaging ~15% p/a

Reputational risk
- Oil companies have heightened public interest & media attention
- Environmental implications of decommissioning are a key influencer

Limited experience & lack of best practice
- Significant technical & commercial challenges with few examples of best practice
- Limited ‘in-house’ experience

Lack of investor returns
- Zero sum game competing against E&P capital investment

Track record of cost & schedule overruns
- >80% of projects overrun on costs
- Too many contractual disputes around ‘unknowns’ and risks

Oil price & macro financial pressures on supply chain
- Cashflow, supply chain financial stress are impacting innovation and commercial flexibility
Decommissioning – some background statistics & comments

>80% of decommissioning projects have exceeded their original cost estimates

Not uncommon to overrun in excess of 100%

Cost estimating & uncertainty ranges are too excessive

Differential for best practice vs worst practice for similar activities is >200% (exc. Outliers!)

This is why Gov’ts & regulators, who are part payers through tax relief, increasingly involved with decommissioning.

Cost reduction themes

- Low levels of in-house expertise & experience (technical & commercial) in decommissioning
- Procurement policies & strategies
- Contracting & execution strategies

UK Govt – decommissioning cost estimates

It is also starting to be realised that some of the ‘soft’ issues have a significant impact on out-turn costs;

- Low levels of in-house expertise & experience (technical & commercial) in decommissioning
- Procurement policies & strategies
- Contracting & execution strategies
Is this a technical or commercial challenge?

Need to take a different approach to decommissioning projects.
<table>
<thead>
<tr>
<th>Category</th>
<th>Initiatives</th>
</tr>
</thead>
</table>
| Regulatory     | • Increased clarity of responsibility; new guidance on strategies and pathways to decommissioning  
|                | • Revised processes for environmental appraisal of decom activities (fit-for-purpose)  
|                | • Evaluation of liability transfer  
|                | • Tax reform  
|                | • Insurance product development  
|                | • Detailed operator reporting of costs  
| Technical      | • Revised well P&A guidelines – to reflect technical changes & actual results  
|                | • Revised & updated methodology for OSPAR 98/3 for derogation cases  
|                | • Development of a cost reduction opportunity tool for benchmarking  
|                | • Enhanced recording of case studies for best practice  
|                | • Development of risk-based approach to pipeline monitoring  
| Commercial     | • Supply chain capacity reports  
|                | • Evaluation & development of innovative business models  
|                |   • e.g. campaigning & multi-asset/multi-operator [MAMO] projects
The biggest challenge in decommissioning?
Digital decom – an emerging trend

Decommissioning data, benchmarks and activities are poorly reported.

Few Operators have a sufficient portfolio of assets or projects to capture experience or lessons learnt.

The diversity of technical challenges and approaches makes comparisons difficult.

Even when ‘successful’ it is hard to identify in detail the success factors or influences...

Acteon is expanding & enhancing its internal data recording to share data with operator clients and regulators…for collective good..
What are we doing differently?

- Delivering lower costs & risks
- Applying proven technology
- Challenging conventional processes
- New commercial models
- Proactive collaboration
- Open-loop thinking
- Applied processes
- Data management
- Subsea vessel based
- Combined campaign
- Rig SIMOPS
- Batching
- Platform rigless

Challenging conventional processes

Delivering lower costs & risks

New commercial models

Proactive collaboration

Aligned Target

Alliance

Digital decom

Data collection

Analysis

Learnings

Execution

Update process

Output driven

Cross-silo activities

Applying proven technology
Digital decom

Real data

Real understanding

Useful outputs

Work in progress

Looking for additional operator partners
Digital decommissioning

Hard issues:
- Processes
- Costs
- Technical solutions
- Time reporting
- Asset used
- Suitability etc…

Soft issues:
- Interfaces
- External influences
- Behaviours
- Levels of integration
- Contractual implication analysis

Project led by a data scientist (impartial & dispassionate)
DECOMMISSIONING – WELL P&A
20 MIN + 10 MIN Q&A
Well P&A – typically half of all decom expenditure

Average days/well currently sit at ~ 26 days/wells

Biggest influencers are; rig rates & nos. rig days

Sounds simplistic and is it correct? Depends who you are asking?
According to some operators…

**Activity**
- Reduce the number of well barriers
- Improve front-end learning
- Improve platform system reliability during P&A ops
- Use campaigns for efficiency
- Use LWIV instead of rigs

**Impact**
- Saves between 4-6 days/well
- Reduces ‘problem’ wells by 25-50%
- Save 3-5 days/well
- Save 10-17 days/well
- Save equivalent of 15% of rig time ratio

But is this the whole picture?

*Notice the largest saving (campaigning) is not purely technical or commercial but Process Engineering*
Some additional examples of further developments

- Rigless abandonment
- Asset substitution
- SIMOPS

- Eliminate the rig & associated costs
- Match activities to fit-for-purpose asset
- SIMOPS to compress rig schedule
Rigless well plug & abandonment

**Market applications**

- Subsea vessel based
  - Combined campaign
    - SWAT
    - P-SWAT
  - Rig SIMOPS
    - Batching
    - P-SWAT
  - Platform rigless
    - P-SWAT

**Operations**

Campaign and/or batched activities

- SWAT
- SWAT
- SWAT
- SWAT
- RIG (JU/SS)
- SWAT
- SWAT
- P-SWAT
- P-SWAT
- P-SWAT
- P-SWAT

Move well to suspended status with rig then go rigless

**Proven benefits**

**COST**
- Lower net cost/well
- Reduced rig schedule
- Reduced mob/demob
- Reduced crew
- Campaign efficiencies
- Batched efficiencies
- Applied learnings
- Shared costs
- New commercial models

**RISK**
- Proven technology
- Reduced weather risk
- Increased schedule flexibility
- Reduced operational risk

**OPERATIONS**
- Experienced crews
- Proven processes
- SIMOPS opportunities
- Contingency flexibility
- Reduced crew numbers
- Reduced equipment footprint
- Light, compact equipment

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**SWAT** – Subsea well abandonment tool

**P-SWAT** – Platform SWAT

**SIMOPS** – Simultaneous operations
Campaign process…

- Review well suitability
- Determine schedule & status
- Determine optimized host asset (platform, JU, JULB, vessel)
- Evaluate campaign optionality
- Then consider procurement strategy

Not all wells suitable
Aim to get multiple wells included
Ensure asset partner involved and aligned
Other wells, assets to include? Other operator wells?
Align outcomes first then figure out best delivery mechanism

Objectives: reduce mob/demob time per asset (well), reduce WoW & associated time risk per asset (well), reduce carried risk per client (operator) through shared contractual alignment

Simple principle, hard to execute, main challenge is client alignment
SWAT™ provides an alternative to using rigs for the abandonment of suspended subsea wells. The system permits perforation, circulation and cementation of multiple casing annuli while maintaining appropriate pressure control barriers.
SWAT™ WITH DECK SPREAD

SWAT’s modular deck spread offers operational flexibility

Notice the ‘small’ scale of the vessel

Whilst cost savings/well can be <80% within a campaign the lower cost base also means the risks of cost overruns are dramatically reduced;
- Directly through lower asset costs
- Indirectly through schedule flexibility within a campaign
Asset substitution

Principle is simple, execution is simple; **process alignment** is challenging.

Objective is match fit-for-purpose asset & equipment to the activity;

- Decom has enhanced schedule flexibility to use time as an advantage (don’t use the usual ‘project’ or ‘drilling’ approach)
- Split activities into ‘packages’ that balance capability & risk
- Substitute cheaper assets as soon as feasible; use incentives to align schedule discipline
- Savings are in the detail…

*Need to maintain positive tension & challenge in the process*

*Avoid “the rig is there, let the rig do it” drilling dept approach*
SIMOPS

Break a workstream down into components and run some in parallel as SIMOPS rather than in traditional series. **Important** to align all parties to outcome objectives. Aim is to shorten on-hire schedule to reduce costs.

Example 1: Rig plugging with SIMOPS rigless severance & recovery

Example 2: SIMOPS rig & rigless P&A
Example 1: Rig P&A, rigless severance & recovery

Objective – reduce JU rig time on location

Wells were batched within skidding distance of the rig

Solution – Rig system focuses on plug setting; separate severance system on side of rig

Process; JU plugs well 1 then moves to well 2, Acteon sever/recovery well 1 then ‘follows’ rig process

Result: rig schedule reduced by 27% against series schedule, net financial savings of 18%
Example 2: SIMOPS rig & rigless P&A

Play Centrica video…[4 mins long]
DECOMMISSIONING – SHALLOW WATER STRUCTURES

20 MIN + 10 MIN Q&A
Identify the ‘true’ costs

Decommissioning has both direct & indirect costs – especially evident with facilities

- The most progressive operators include ALL of their associated opex costs
- This most include direct/indirect overhead costs and associated ‘opportunity’ costs

For many smaller facilities the true opex costs can be greater than the ‘decom’ costs

As indicated earlier the biggest impact on net costs is ‘process engineering’

- When do you start late-life/decom planning?
- What is your approach; conventional technical solution led or output led?
Costs & uncertainties

Cost disparities all weighted towards the approach, not the technical solution.

What is clear is separate P&A and facilities..

FACILITIES INPUT UNCERTAINTIES

Inputs Ranked by Effect on Output Mean

-10% -8% -6% -4% -2% 0% 2% 4% 6% 8% 10%

- VNS Post-CoP Opex years for platform-based P&A work
- Post-CoP unmanned period
- Uncertainty over Average Annual Post-CoP Opex
- Uncertainty over the number of Jacket Lifts
- Market Rate Uncertainty for Marine Vessels
- Uncertainty over the number of Topsides Lifts
- Subsea pipeline decommissioning scope
- Topsides Offshore Preparation Costs
- Topsides Grillage/Seafastening Costs
- Post-CoP cleaning & preparatory work

OUTPUT FACILITIES DECOMMISSIONING COSTS

- P&A POST COP OPEX 22%
- JACKET LIFT & TRANSPORT 10%
- TOPSIDES PREP 10%
- TOPSIDES LIFT & TRANSPORT 10%
- PIPELINES 6%
- OTHER 42%
Spoke previously about asset substitution; using cheaper rigs, liftboats or rigless.

Planning & executing well P&A prior to CoP utilising operational facilities & reducing asset requirement i.e. unlocks cheaper P&A solutions.

**EXAMPLE COST SAVINGS OPPORTUNITIES FOR FACILITIES**

<table>
<thead>
<tr>
<th>Facilities Opportunities</th>
<th>Assumptions/Rationale</th>
<th>% Red Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>P&amp;A platform wells prior to CoP</td>
<td>Save on post-CoP Opex by plugging &amp; abandoning wells prior to CoP. Saving of 25%/35%/50% range was applied to P&amp;A platform days.</td>
<td>8%</td>
</tr>
<tr>
<td>Minimise the Post-CoP unmanned period</td>
<td>Save 25%/50%/75% range compared to P50 estimate from minimising the post-CoP period.</td>
<td>3%</td>
</tr>
<tr>
<td>Transfer Duty Holder for cleaning and preparation phase</td>
<td>Transfer Duty Holder from Operator to contractor to save cost. Percent saving for phase in range 30%/40%/50%.</td>
<td>2%</td>
</tr>
<tr>
<td>Flotel in lieu of HLV for accommodation during topsides preparation</td>
<td>Percentage range of 60%/65%/72% is the saving by using flotels compared with the NNS and SNS HLV rates.</td>
<td>2%</td>
</tr>
<tr>
<td>Additional derogation for NNS jackets</td>
<td>Percentage range of 12%/15%/20% saving if greater derogation is allowed for NNS jackets.</td>
<td>2%</td>
</tr>
</tbody>
</table>
Eugene Island Platform 322 A was left with severe structural damage following hurricane Lilli. The Platform was 80 miles offshore in 235ft of water.
CASE STUDY
EUGINE ISLAND

We provided:

Abrasive cutting operation, managed from adjacent platform

Worked with 15’ incline in the conductor

Internal single-pass cutting of the 7” – 26” conductors

Cutting achieved 100ft below surface

15 wells cut successfully without incident

The Result:

The project was completed and BP reefed the structure as planned.
CASE STUDY
LEMAN A1

A 38-year-old well on a normally unmanned platform in the Leman field, was identified as having suffered a corrosion/fatigue failure of the 20” conductor.

Complete failure of the 20” conductor and partial fracture and wear to the 13 3/8” caisson.

The failure was approximately 20 ft below sea level.

The well was immediately shut in and a strategy to plug and abandon the well had to be agreed.
Timing and cost prohibited the use of a jackup rig

…Therefore, all of the following activities had to be performed via rigless operation, the first of its kind:

• Downhole perforating & cementing operations
• Xmas tree removal and tubing severance & recovery
• Severance of the casing strings below mudline
• Recovery of the casing strings
• Recovery of the 20” conductor below the fracture point
• Back loading of the cut casing sections – due to deck restrictions.
CASE STUDY
LEMAN A1

InterAct developed the downhole programme for wireline perforation and cementing of the well. Due to contractual agreement, this was carried out by the existing contractors for cementing, wireline and perforating.

Claxton designed and manufactured a bespoke conductor reaction recovery system to interface with the Leman platform comprising of:

- Load spreader beams
- False rotary work platform
- Hydraulic reaction jacking system complete with reaction slips and suspended false rotary.
- Material handling telescopic cranes
- Positive-grip tension ring used in the reaction recovery system
- Hydraulic power units (HPU)
- Drilling & pinning
- Bandsaws
- SABRE™ abrasive jet cutting
- Lifting equipment and equipment to recover the production tubing with the platform crane.
Claxton combined our cutting equipment with a bespoke interface.

Using a novel equipment package we recovered the conductor in sections – cutting, securing and lifting each piece via a hydraulic reaction system.
CASE STUDY
LEMAN A1

Operation was performed on schedule, to budget

The bespoke equipment package performed as expected in the field

316 man hours were recorded offshore with no incident – the only time lost was due to inclement weather

Perenco commented that the total costs were less than half of a comparative rig-based solution.
Claxton provided abrasive cutting (using the proprietary SABRE system) for 16 wells on Shell’s Indefatigable field.
SABRE being tested on Inde – the jet, a mixture of water, air and garnet, operates at 15,000psi and exits Claxton’s in-house nozzle technology at transonic speeds.
The cutting was completed to schedule and the project ended with Claxton being praised by both Shell and Halliburton.
DECOMMISSIONING – DEEPWATER
(SUBSEA & FLOATERS)
20 MIN + 10 MIN Q&A
Deepwater & floater issues & trends

- Wellhead fatigue
- Riser recovery (see later case study)
- Late life operations
  - Flowline & umbilical flushing, cleaning & fluid recovery
  - NORM identification
- Contractual delineation with leased units (FPSOs, FSOs & Buoys)
  - Responsibilities, especially on interfaces
  - Contractual ‘conflicts’ on priorities
Contractual delineation

Major Operator & leased FPSO case study

- Mid-size deepwater FPSO with x20 subsea wells
- Leased FPSO
- >3yrs pre-COP decommissioning planning
- Operator ‘believed’ he had alignment with the leasing company but some issues emerged....
Deepwater FPSO decom issues

Decom optimisation study concluded;

- Significant cost savings if flushing/cleaning commenced prior to FPSO sail away
  - Lease suggested sail away at production suspension – lack of alignment
- If flushing/cleaning fluids returned to the FPSO – who is responsible for the fluid?
  - If the fluids were required to cross borders, who is responsible?
- Anchor recovery is lease company responsibility whilst risers are operators – interface?
- Combined anchor/riser recovery could save >$1m in an integrated contract – how to execute?
- Lease contract was ‘silent’ on environmental responsibilities around interfaces
- >$20m of potential savings were identified in areas where contractual differentials (silent or mis-aligned)
  - Operator set about to find a ‘working solution’ to fill the void
Red Hawk Spar and Kuito FPSO Decommissioning

Lessons Learned
Kuito FPSO & CALM Buoy Decommissioning

WORK SUMMARY

Project Mgmt, Engineering & Offshore Services for Kuito FPSO and CALM Buoy riser and mooring disconnect and laydown;

Offshore labor onboard MSV Maersk Achiever and FPSO during disconnect including Tow Masters;

Offshore Phase 1 – disconnect and laydown of 20 risers & umbilicals from FPSO;

Offshore Phase 2 – disconnect of 12 mooring lines from Kuito FPSO;

Offshore Phase 3 – disconnect and laydown of 2 risers and 6 mooring lines from CALM Buoy followed by the towing to shallow waters.

SITE DETAILS

Location: Kuito Field
Region: Angola Block 14
Water depth: 1,260 ft
Kuito FPSO Decommissioning - Challenges

OLD ASSET

The FPSO had been installed in the field for 15 years

The client was looking for alternative solutions in case reversing the original pull-in method for the risers and umbilicals was not feasible.
InterMoor developed conventional and non-conventional procedures to disconnect and laydown the risers and umbilicals, and release the mooring lines.

Five riser and umbilical disconnection methods:

- two (2) base case methods,
- two (2) alternative methods
- one contingency method.

One umbilical was disconnected using one of the alternative methods – a subsea riser clamp.
For the alternative and contingency cases, InterMoor proposed the use of subsea clamps. These were designed by sister company 2H Offshore, under InterMoor’s supervision, and fabricated in InterMoor’s fabrication facility in Morgan City, La. As a contingency for the subsea clamp, InterMoor procured and delivered Chinese fingers to ensure and achieve a safe and efficient operation.
Red Hawk – Spar Decommissioning

WORK SUMMARY

Ballasting Operations
• Proj Mgmt, Engineering, Procurement, Procedure Development, and Offshore Execution for all ballasting activities

Mooring Disconnect & Recovery
• Proj Mgmt, Engineering, Procurement, and Offshore Execution for Mooring Disconnect and Recovery operations

Towing & Reefing
• Proj Mgmt, Tow Analyses, Engineering, Procurement, and Offshore Execution for Towing and Reefing Operations

SITE DETAILS

Location: Red Hawk Field
Region: GoM – Garden Banks 876
Water depth: 1615 m (5,300 ft.)
Red Hawk - Project Challenges

First decommissioning/reefing of a spar
Complexity of ballast system requirements
Limited access to spar during key activities required a remote ballast system for all operations
Hose management
Mooring equipment was integrated into topsides
Water depth at reef site dictated minimum draft requirements
Vertical tow configuration of hull
Ballasting Operations

Key Ballasting activities:

- Ballast spar down for topsides lift (Provisional and variable)
- Remove water from provisional tanks
- Pump air into variable ballast tanks

Required 3 distinct systems on both DB 50 and the spar to facilitate the above:

- Air ballast/de-ballast system
- Water ballast system
- Water de-ballast system
Ballast System - Spar

Air Ballast Sys

Water Ballast Sys

TOP OF SPAR - EQUIPMENT & HOSE ARRANGEMENT
Ballast System – DB 50

Air Ballast System  Water Ballast System
Hose Management
Mooring Disconnect and Recovery Operations

Disconnect utilized both DB 50 and Kirt Chouest

- Kirt grappled fairlead chain and took majority of load
- DB 50 used pendant w/sacrificial sling to lower chain to fairlead
- ROV cut sacrificial sling at fairlead
- Kirt recovered chain to deck and temporarily laid preset on seabed
- Kirt recovered moorings once spar left the field
Vertical Tow

70 nautical mile tow route chosen to:

• minimize pipeline crossings
• maximize hull’s distance from other platforms, and
• maintain adequate bottom depth clearances during the final approach to the proposed reefing site

Tow route pre-surveyed several months ahead of tow to verify public database depths at 700 ft and shallower and observe seabed objects
Vertical Tow

Tugs engaged for station keeping at GB-876 during mooring line disconnect, vertical tow to EI-384, and station keeping at reefing site
Vertical Tow

Average tow speed: 1.5 - 2.0 knots
Duration: ~44 hrs
Signet Thunder and Signet Lightning tow tugs with Titan trailing
DB 50 followed tow and its ROV surveyed tow path once water depth was >500 ft
Reefing

While station keeping with tugs, personnel transferred to the hull.

Hull was placed vertically on seabed.

Rope access crew connected ballast tanks.

Rope access crew cut flooding holes in hull exterior.

All air valves for variable ballast tanks opened.

Main tugs paid out work wire and pulled spar the direction of initiation hole to start flooding.

Hull allowed to submerge gradually into horizontal position on seabed.

ROV disconnected tug work wires from tow rigging.
Reefing
Keys to Success for Both Projects

Early involvement

Integrated project team

• Good communication
• Active participation of all relevant parties

Extensive planning

• Base case
• Contingency
• Spares
ASSET INTEGRITY

- DEEPWATER ASSET INTEGRITY
  - MOORINGS & RISERS
- SUBSEA INFRASTRUCTURE

70 MIN + 20 MIN Q&A
Technology Limits?

Failures Trends
- Umbilical
- Mooring
- Flex Risers
- SCM/Choke
Mooring Line Failures

- 137 mooring incidents from 92 facilities across the industry (1997-2016)
- >60 single line failures – x11 multiple line failures
- 38 pre-emptive replacement events – 12 reports of severe degradation
- >172 lines replaced/repaired since 2001
Failure Overview

Failure Mechanisms
- Wear
- Fatigue
- Abrasion
- Corrosion
- Damage
- Strength
- Excessive Tension
- Operational

Failure Locations
- Chain: 47%
- Connector (shackle, H-link, Triplate, etc): 19%
- Wire Rope: 24%
- Polyester Rope: 5%
- Chain Connector (shackle, H-link, Triplate, etc): 5%

Failure Locations
- Vessel drift
- Riser damage
- Replacing mooring line
- Production shutdown
- Hydrocarbon release

Variety of detailed problems…

Figure 1—Degradation Encountered in a Chain Mooring System
Inspections are throwing up multiple problems on related lines.

Figure 2—Pictorial Representation of Chain Degradation Mode Impact on Chain Cross Section
Figure 1—Typical operational FPSO responses with intact (left) and one mooring line broken (right)
Issues go beyond material sciences and understanding requires highly complex data analysis of direct & in-direct influences…. 

Figure 9—Mean offsets of a CALM buoy for intact (red) and broken mooring lines (blue)

Figure 10—Falsely predicted broken lines based on type of type of instrumentation — a CALM buoy case
Mooring is going digital….

Real time activity, real time response, real cost savings…

Move from prescriptive IM to risk-based IM

- will lead to increased data collection & management costs
- savings come in reduced vessel activity

This is not theory but recorded best practice….not ‘rocket science’ or unproven approach

Difference now is this is evidence based.

In the UK the HSE (Health & Safety Executive) recently required an operator with an increasing failure record to switch from prescriptive to risk based inspection on an FPSO & Buoy, and utilise InterMoor’s Mooring Failure Database for reference
Data Integrity

- iCUE & iSITE offer secure, global access to asset data
- Decentralized, live information for all parties to stay up to date
- Access control, customized log-ins
- Using right people for documentation (Dr diagnoses, technician gathers)
- Full time database management ensures data is easily available and well organized
- Other systems are often poorly populated, managed, and only available to select few
Design Intent

- Shift from local applications based data storage to cloud based.

- Shift from getting ‘software installed’ by IT to getting a username/password

- Transition from design (organized by vendor/project) to operations (organized by equipment/location)

- All design, fabrication, installation and commissioning information available online

- Starts record for lifecycle of asset which will be available throughout (Similar to a medical history file)

- Software with specialty focus on Moorings & Subsea Life of Field

- Feed in information from manufacturer, designer, installer, survey, operator & other 3rd party.
The cornerstone of knowledge management is sharing best practices and lessons learned.
- Uniform access to information
- Align employee and client perspectives in real time
- Incentivize exchange of information

Companies (all of our clients) collect large amounts of data,
- Content accessibility and organization become pressing issues.
- The magnitude of content has increased dramatically, but the time to find and understand it should not.

Savings examples from the early 90’s reported 15% direct cost reduction.
- Schlumberger: $150MM/yr; Resolution of tech queries by 95%; Reduction of time to update engineering modifications by 75%
- “BP Amoco documented $700 million in savings”
- Chevron: “savings from 1991 to 1999 were $650 million from just one community effort;” “I believe this priority was one of the keys to reducing our operating costs by more than $2 billion per year”
Risk Based Mooring IM Plan

<table>
<thead>
<tr>
<th>No.</th>
<th>Mooring Threat</th>
<th>Inspection</th>
<th>Inspection Frequency</th>
<th>Monitoring</th>
<th>Monitoring Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wear</td>
<td>CVI, Gauge</td>
<td>3yr</td>
<td>Link position</td>
<td>1yr</td>
</tr>
<tr>
<td>2</td>
<td>External Corrosion</td>
<td>GVI</td>
<td>1yr</td>
<td>Tension</td>
<td>Ongoing</td>
</tr>
<tr>
<td>3</td>
<td>Defective Link</td>
<td>N/A</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Pile Scour</td>
<td>GVI</td>
<td>1yr</td>
<td>N/A</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Failure Probability in Field Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact</td>
</tr>
<tr>
<td>Low</td>
</tr>
<tr>
<td>Medium</td>
</tr>
<tr>
<td>High</td>
</tr>
<tr>
<td>Very High</td>
</tr>
<tr>
<td>&gt;$100,000,000</td>
</tr>
<tr>
<td>$10,000,000 to $100,000,000</td>
</tr>
<tr>
<td>$1,000,000 to $10,000,000</td>
</tr>
<tr>
<td>&lt;$1,000,000</td>
</tr>
</tbody>
</table>

Frequency of Assessment

<table>
<thead>
<tr>
<th>Criticality</th>
<th>Inspection (yrs)</th>
<th>Monitor (Mos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4-5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>6 monthly</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Reduce Risk</td>
<td></td>
</tr>
</tbody>
</table>

Note: Designed to withstand single failures; replacement plan/spares in place reduces the consequence of failure and required inspection
Practical MIM Programs should address the following:

- **Inspection & Maintenance (I&M)**
  - Identify weakened or damaged mooring components (on and off-vessel)
  - Lubrication, payout adjustments to avoid excessive wear, etc.

- **Mooring Repair Plans (MRP)**
  - Development of “Preliminary Repair Procedures”
  - Identification of long lead items, installation vessels, installation aid requirements, staging and mobilization locations, import and export restrictions, etc.

- **Probability of Failure & Life Expectancy Estimates**
  - Based on the actual condition (measurements), degradation rates (inspection records), and anticipated loading conditions

- **Spare Mooring Component Philosophy**
  - Procurement, fabrication, storage, and maintenance of the mooring components needed to repair or replace a failed mooring line
Integrity Management Plan

- Operations set out to manage risks to prevent incidents while meeting production targets

- IM/IRM (in medical terms)
  - General practitioner recommends visits & intervals based on maintained history
  - Surgeon/physical therapist rehabilitates system when risk is too high

- Throughout life
  - Have a plan
  - Execute IRM
  - Manage the risks

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Life of an Asset</th>
<th>Managed Risk Level</th>
<th>Re-assess Risk Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early Life Risks</td>
<td>Baseline RA</td>
<td>Early Life Risks</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strategy in Place</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Higher than expected water cut</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Splashzone corrosion under insulation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flexjoint Elastomer Degradation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Managed Risk Level</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>End of Life Risks</td>
<td></td>
</tr>
</tbody>
</table>
From Design to Life Extension

Inspection & Monitoring
- General visual, CP
- In-line Inspection
- Monitoring

As-Built Design

System Analysis
- Fatigue analysis
- ECA/FFS
- Soil Data
- Metocean
- Vessel Motion
- Software

Modifications
- Critical component replacement
- Coating repairs
- VIV Suppression device cleaning
Process Overview

Balance the costs and benefits

Implement thorough knowledge transfer

Ensure knowledge continuity

Design Phase

- Mooring Design Analyses
  - Define operating limits
  - Corrosion rates
  - Mooring layout

- Operating Parameters
  - Expected offsets
  - Tension monitoring
  - Failure scenarios

Integrity Management Plan

- Inspection Plan
- KPI Monitoring Plan

Knowledge Transfer

- The Need
- The Risks
- The Consequences of Deviation

Operations Group

- Plan for inspection and monitoring to manage risks
- Update the IMP based on current system status
- Share & Understand the system health status through routine integrity review meetings

Designated Responsible Party

- Execute plan
  - Inspect & Maintain mooring components
- Assess & Verify KPIs and mooring health, alert if deviations occur

Production Phase

- Record & Report KPIs & mooring health as part of periodic system integrity validation

Operations Group

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Key Performance Indicators

Vessel Relocation Stations vs. Date
(Mooring Link Counts)

Amber Limit = 41.7 (ft)

Tropical Storm Lee
Tropical Storm Debby

Wave Height (ft)

North Hs East Hs South Hs West Hs

Date

Northing (ft)

Eastings (ft)
Integrity Management Plan

- Run to failure
- Manage Change
- Gather Data
- Defined IM Plan
- Interpret Data
- Understand Risks
- Predictive & Measured Responses

- Leading KPIs
- Optimized IMR
- Optimized corrosion plan
- SEED strategy in place & tied to operating condition

- Risk based IM plan
- Annual review meetings across teams (wells, SURF, FS, topsides, Corr)
- Spares management phil.
- IM data management
- Engineering KPI limits

- Operational history known
- Defined anomalies and responses
- Inspection engineering assessment reports
- Pragmatic inspection
- Work scopes
- FFS Assessments

- Pass regulatory audits
- Structured program (RACI & phase gates)
- Defined inspection intervals (typically 1-2yrs)
- Standard corrosion and chemistry team in place

- ROV inspections
- Gather corrosion data quickly, globally, access to design and as built data
- Change management
- As-built data somewhere
- Respond to failures

- Operational as designed

- Relative Cost
- Relative Risk Exposure
- Value
# Changing Behaviors

<table>
<thead>
<tr>
<th>Inefficient Behaviors</th>
<th>Efficient Behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Just one more item while the boat is there”</td>
<td>Have a plan, get the tools, execute the scope</td>
</tr>
<tr>
<td>Using a work class ROV as a platform a standard definition camera</td>
<td>Right vehicle for the job [IM, Survey, IRM]</td>
</tr>
<tr>
<td>The work is done when the boat is done</td>
<td>Document &amp; communicate findings. Lessons learned to team and community</td>
</tr>
<tr>
<td>It’s too complicated, just inspect it all annually. “The boat will be out there anyway”</td>
<td>Prioritize activities with risks. Ensure most resources are on highest risks</td>
</tr>
<tr>
<td>Engineer doing a technicians job and vice versa</td>
<td>Properly trained personnel supporting common objectives</td>
</tr>
<tr>
<td>“I’ll just keep this video here on my desk if anyone needs it”</td>
<td>Data is readily available and easy to manipulate</td>
</tr>
</tbody>
</table>
Wellhead fatigue

Show conductor VIV video from 2H Offshore in GoM
Wellhead Fatigue Mitigation

Drilling riser and conductor system response is highly dynamic and fatigue sensitive.

Driven by: rig selection, water depth, wave response, VIV in currents > 2 knots and BOP size and stack natural period.

Reducing BOP motions is one means of mitigating conductor system fatigue issues.
History

NeoDrill CAN (no affiliation with 2H)

- Deployed offshore Norway and UKNS
- Employed by numerous operators: Statoil, Eni, Centrica, Lundin, Det Norske, Endeavour UK
- **BOP Anchoring to subsea template** - Employed on BP Shah Deniz wells in UKNS

BOP Anchoring using Suction Piles

- Patented by BP / Trendsetter
- Concept developed by 2H - Used on Quad 204
- **BOP Anchoring by Clump Weights**
  - Employed by Chevron in North Sea - Uses hydraulic winches
  - 2H developed an improved tether concept with Clump Weights
  - Low cost system
# 2H Track Record

<table>
<thead>
<tr>
<th>NeoDrill CAN</th>
<th>Tethered Suction Pile</th>
<th>Tethered BOP to Template</th>
<th>Improved Tether System with Clump Weights (2H Concept)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wellhead fatigue analysis for Endeavour East Rochelle field in 445ft</strong></td>
<td>Created the initial conceptual design</td>
<td>Wellhead fatigue analysis for Shah Deniz</td>
<td>Concept design of low cost solution with simplified tether tensioning with ROV interface</td>
</tr>
<tr>
<td><strong>Wellhead fatigue analysis for Centrica Energi Ivory field in 4,690ft water depth</strong></td>
<td>Detailed design of BOP attachments</td>
<td></td>
<td>Turnkey solution for rental or sale</td>
</tr>
<tr>
<td></td>
<td>Managed tether and winch load testing</td>
<td></td>
<td>Awaiting Acteon funding until a project award</td>
</tr>
</tbody>
</table>
Tethered BOP System

Improves conductor system fatigue by a factor of >10

Reduces wellhead loads

16 week delivery time

2H developed the concept, designed the BOP attachments, managed tether and winch load testing

Suction pile foundations

Installation requires work boat with 150 ton crane
Improved Tether System (2H Concept)

- Designed for deployment and installation from drill rig
- Simpler tether tensioning system and ROV interfacing
- Ballasted concrete clump weight foundations
- Lower cost - turnkey rental or sale
- Acteon solution: 2H, InterMoor, Mirage Subsea

ROV Operated Tension Compensator (Confidential)
Reducing Cathodic Protection (CP) inspections

Use of FiGS (Field Gradient Sensor)

FiGS is a non-contact CP inspection tool, and the only tool on the market of its kind that:

- Detects coating damages on exposed and buried pipelines and structures
- Accurately measures anode performance
- Helps optimise CP retrofitting, offering substantial cost savings
- Reduce inspection time
Exposed subsea structures & buried pipelines…

<table>
<thead>
<tr>
<th>Exposure Type</th>
<th>FIGS</th>
<th>Twin Cell (fixed sensors)</th>
<th>Buried structures and pipelines</th>
<th>Twin Cell (fixed sensors)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode Current</td>
<td>Suitable in most cases</td>
<td>Possible with some constraints *</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
</tr>
<tr>
<td>Cathodic Current Density</td>
<td>Suitable in most cases</td>
<td>Possible with some constraints **</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
</tr>
<tr>
<td>Calculated Anode Wastage</td>
<td>Suitable in most cases</td>
<td>Possible with some constraints *</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
</tr>
<tr>
<td>Calculated Potentials</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
</tr>
<tr>
<td>Detection of Coating Damages</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
</tr>
<tr>
<td>Accurate Current Drain to e.g. Piles, Wells and Substructures</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
</tr>
<tr>
<td>Detection of Damages to Flexible Pipes Outer Sheet</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
<td>Suitable in most cases</td>
<td>Normally not suitable</td>
</tr>
</tbody>
</table>

* Fly-by measurements and stab measurements (with lower sensitivity)

** Stab measurements (with lower sensitivity)
CP computer modelling

✓ Provides a distribution of the electric field enabling interpretation of FiGS data

✓ Simulates past, present and future performance of the CP system

✓ Applicable to all structures

✓ FiGS data is used to calibrate CP computer models
Why is FiGS interesting?

Reducing the time & risk of CP inspection

But also….

By linking real time data output to a combination of on-vessel pre-processing and 24hr onshore analysis we are able to ascertain if intervention is required, whilst the survey vessel is on location.

The ‘on-location’ response allows for either extra data gathering (CP, video etc.) or light intervention such as replacement anodes

Saving = reduction in necessary return trips (>A$4m saving in one IMR programme alone)

Risk = reduced risks of ‘missing’ key data input plus reduced activity is lower risk

Behaviour = vessel operating incentivised to shorten job if aligned with objectives
Life Cycle Cost of Typical Deep Water Asset

Cost include: CAPEX, RISKEX, IM & IMR

Risk expense dominates the total cost based on a net present value calculation for deferred production

$45/bbl, 50kBOPD, Discount rate of 0.1, and 100% of field shut-in

Risk matrix of a TLP is used to determine total life cycle cost

GoM reduced cost by 60% over 9yrs (mainly RISKEX reductions)

Shah Deniz IM developed by Clarus and will reduce cost by 60% within 2yrs (mainly RISKEX reduction)

Methodology can be applied to all other BP regions and assets

2/3rd IM inspection reductions on BP SDA through RBI
Life Cycle Failure Rates

Common bath tub plot shows failure rates increasing as assets approach service life of field.

North Sea is experiencing this right now.

Failure Rates can be reduced by applying the lessons learned from the assets in the North Sea to all other BP regions and assets.

Savings are based on the following:

- Mitigating observed threats that occur during end of life
- Monitoring common failures within equipment
- Aligning Integrity Management Plans to incorporate lessons learned
- Optimizing inspection campaigns to inspect critical equipment near end of life
- Repairing equipment when necessary
Existing Inspection & Reporting Process

**Scheduling**
- ~20 weeks
- 8 manwks

**Execution**
- ~10 weeks
- 7 manwks

Gaps in Inspection Data are often identified during Anomaly Assessment and reporting.

~$500k to $1M
### Examples of Ineffective Inspections

<table>
<thead>
<tr>
<th>Issue</th>
<th>Remediation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extensive Corrosion</td>
<td>Cathodic Protection Measurements</td>
</tr>
</tbody>
</table>

**Small gap**: gap < 1-inch  
**Large gap**: gap ≈ 1 - 3-inch  
**Exposed pipe**: gap > 3-inch
Inspections with iCUE

Enhancing inspections by:

- Optimizing creation of scopes of work and work packages
- Maximizing information gathered during inspections
- Reducing reporting time
Streamlined Inspection & Reporting Process

- **Scheduling**
  - ~12 weeks
  - 4 manwks
  - BP: Schedule Inspections based on BP Inspection Plan
  - IM Contractor: Develop and Issue SOV

- **Planning**
  - ~6 weeks
  - 6 manwks
  - BP: Review Cycle, Approve Scope of Work (SW) for use by IM Contractor
  - IM Contractor: Develop and Issue Workpackage

- **Inspection**
  - Inspection Contractor Not Required
  - 8 wk reduction of Planning Time
  - More effective Inspection at the same cost
  - BP: Approve Work Package for use by IM Contractor, Pre Job Meeting
  - IM Contractor: Inspection Execution Start, Inspection Execution End

- **Reporting**
  - 2 wk reduction of Reporting Time
  - BP: Schedule and Conduct Post Job Meeting if required
  - IM Contractor: Conduct Engineering Assessment, Anomaly Process/Anomaly Reporting
  - Vessel Contractor: Mobilize crew and equipment, Support and execute inspection
Automation of Subsea Condition Monitoring

iCUE Automated Processor

Data Screening
Data Visualisation (Plots)
Degradation Rate Calcs

Generates alerts for further evaluation.

QA'd by Clarus

Offshore
Environ. & Vessel Data
Corrosion & Erosion Data
Subsea Controls Data

Riser Integrity Team
Corrosion Team
Controls Team

Reducing manual processing of data allows focus and evaluation of priority risks.
Riser Response Monitoring

Eliminates manual data QA and processing.

Efficiency in alerting relevant teams of limit exceedance.
Chemical Injection Availability

25% Reduction in data collection
- Digital device data input synced to iCUE

Eliminates manual data processing
- Auto CI Availability calculations
- Real time reporting

iCUE Automated Processing

Water Production Rate (Sensor)
Oil Production Rate (Sensor)
Gas Production Rate (Sensor)
Daily CI Dosage (Manual)
Corrosion Modelling

25% reduction in data collection.
- Digitized offshore data entry using handheld devices synced to iCUE;

Eliminates manual input and calculations.
- Automated corrosion modelling and calculations;

Efficiency in alerting relevant teams of anomaly.
- Generates alerts for corrosion rates exceeding allowable.

Calibrate Corrosion model with measured corrosion rates.

- Digitized offshore data entry using handheld devices synced to iCUE;

- Automated corrosion modelling and calculations;

- Generates alerts for corrosion rates exceeding allowable.

iCUE Automated Processing
Subsea Controls Performance

Value added using existing data. Advanced planning of replacement.
Dynamic Risk Assessment Module

- Interface with BP FLRA and CTALA
- Auto generate baseline assessment - New Projects
- Reduced man hours in execution and update
- Interactive access to Inspection/ Monitoring results
- Input from global historical anomaly database

Risk Assessment Module
Global Historical Anomaly Database and Asset Metrics

Anomalies - Equipment Type

- Subsea Production Hardware 17%
- Controls Equipment 13%
- Below Water Risers 23%
- Misc. Equipment 15%
- Flowlines/Jumpers 26%
- Above Water Risers 6%

Anomalies - Threat Type

- Equipment Failure (Misc.) 7%
- External Mechanical Damage 7%
- Fatigue 10%
- Leaks 5%
- Incorrect Operations 4%
- Overstress 9%
- Wear 3%
- Overload 2%
- Control System Failure 3%
- CP/Anode Depletion 15%
- Cracking 4%
- Internal Corrosion 3%
Offshore IM catching up with the digital generation…