OIL & GAS

MI@NUS ASSET INTEGRITY & RISK MANAGEMENT R&D WORKSHOP 2014

CURRENT DEVELOPMENTS IN MOORING INTEGRITY MANAGEMENT

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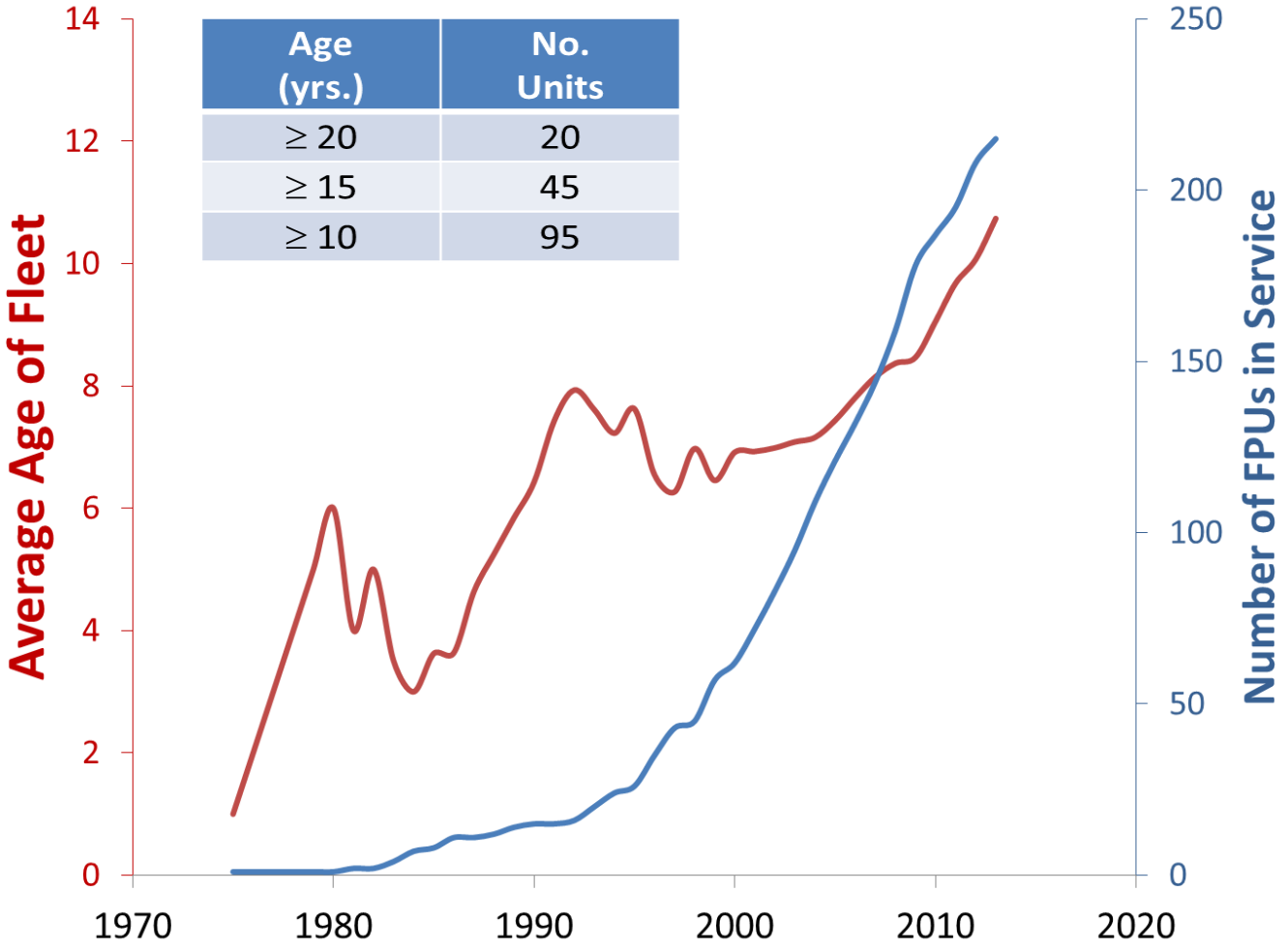
Introduction

- Moored Floating Production Unit (FPU) fleet is experiencing rapid growth
- Moored FPU fleet is aging and life extension is often a consideration
- Many different operating areas, environments and water depths
- Mooring incidents have been occurring at a relatively high rate
- Incidents have resulted in the following:
  - Vessel drifting
  - Riser ruptures
  - Hydrocarbon release
  - Production shutdown

Aging FPU Fleet

Age (yrs.)	No. Units
≥ 20	20
≥ 15	45
≥ 10	95

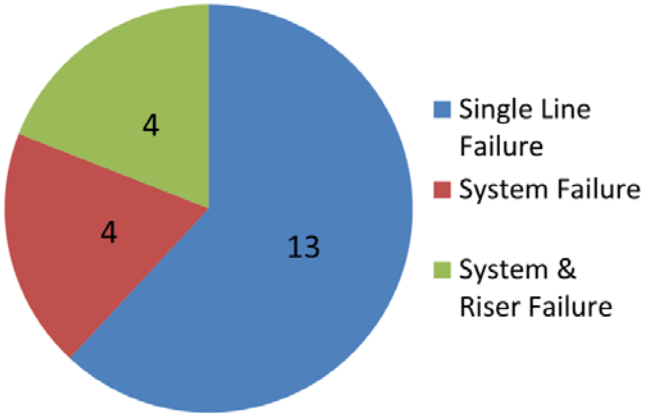


SOURCE: Offshore Magazine

Permanent Mooring Incidents

Actual mooring system failure probability ~30 times greater than Industry target

Mooring Failures 2001-2011



SOURCE: OTC 24025

High rate of mooring replacement and/or repair

No. of Mooring Lines Replaced/Repaired 2001-2011

150

SOURCE: OTC 24181

Is a single line repair or break a failure?

- Mooring typically designed to last the life of the field development
- Line replacement / repair is frequently required prior to end of field design life
  - Costly, especially if no spare exists or the field is in a remote area
- Can an FPU continue production with one mooring line missing?
  - Criteria require adequate SF for 1-line damage case in design environment
  - Safety case regimes (NMD, UK HSE) now requesting 2-line damage case
  - However, once a line is missing, mooring system has reduced reliability
  - Experience has shown that line replacement can take one year or more
- Clearly there is an incentive to prevent premature line failures

FPU Mooring Incident Claims (2006 – 2012)

Type of Loss	Claims Paid
Property Damage	US$ 2.20 Billion
Business Interruption	US$ 0.66 Billion
Total	US$ 2.86 Billion

SOURCE: Matthews Daniel

Actions

- Industry is collaborating to improve understanding of causes of offshore failure
- Currently limited guidance available on Mooring Integrity Management (MIM)
- MIM recommended practice for industry in progress
  - Oil & Gas UK Mooring Integrity Guidance (Draft) – Issue 2, June 2014
  - DNV GL Recommended Practice for Mooring Integrity – In Progress
  - Floating Production System Mooring Integrity JIP – Phase 2 (Ongoing)

Confidential

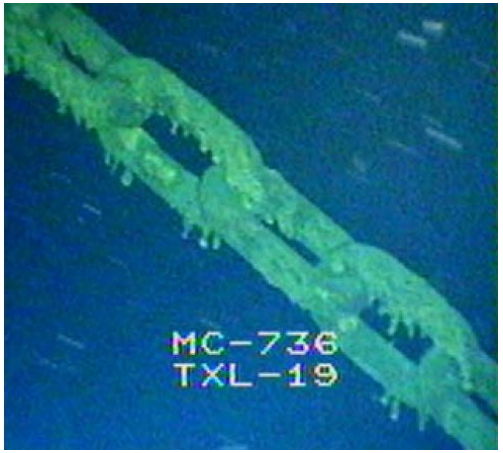
Why do moorings fail?

Overload (Deepsea Atlantic 2012)

Fatigue (Transocean Spitsbergen 2012, Transocean Leader 2011, Norne 2012)

Heavy Narrow Wear (OTC 20613)

Corrosion (Africa)



MIC (1800m WD)

Recent Industry Advances

- Fatigue
  - Fatigue test data for large diameter R5 chain (e.g. TWI JIP in progress)
  - Improved understanding of OPB impact on chain fatigue (e.g. SPM OPB JIP)
  - Improved understanding of chain fatigue crack growth (e.g. Lassen, 2005)
  - Improved FEA models of chain SCFs (e.g. Vargas, 2004)
- Wear
  - Improved chain wear models (e.g. NDE MIM JIP)
- Corrosion
  - Improved chain and wire rope corrosion models (e.g. SCORCH JIP)
  - Improved models of corroded chain residual strength (e.g. FEARS JIP in progress)
  - Improved reliability models accounting for corrosion deterioration over time

SOURCE: DNV GL OTC 25134

Ongoing Research Issues

- Fatigue
  - Effect of chain twisting not adequately understood
- Wear
  - No universal wear model
- Corrosion
  - No universal corrosion model

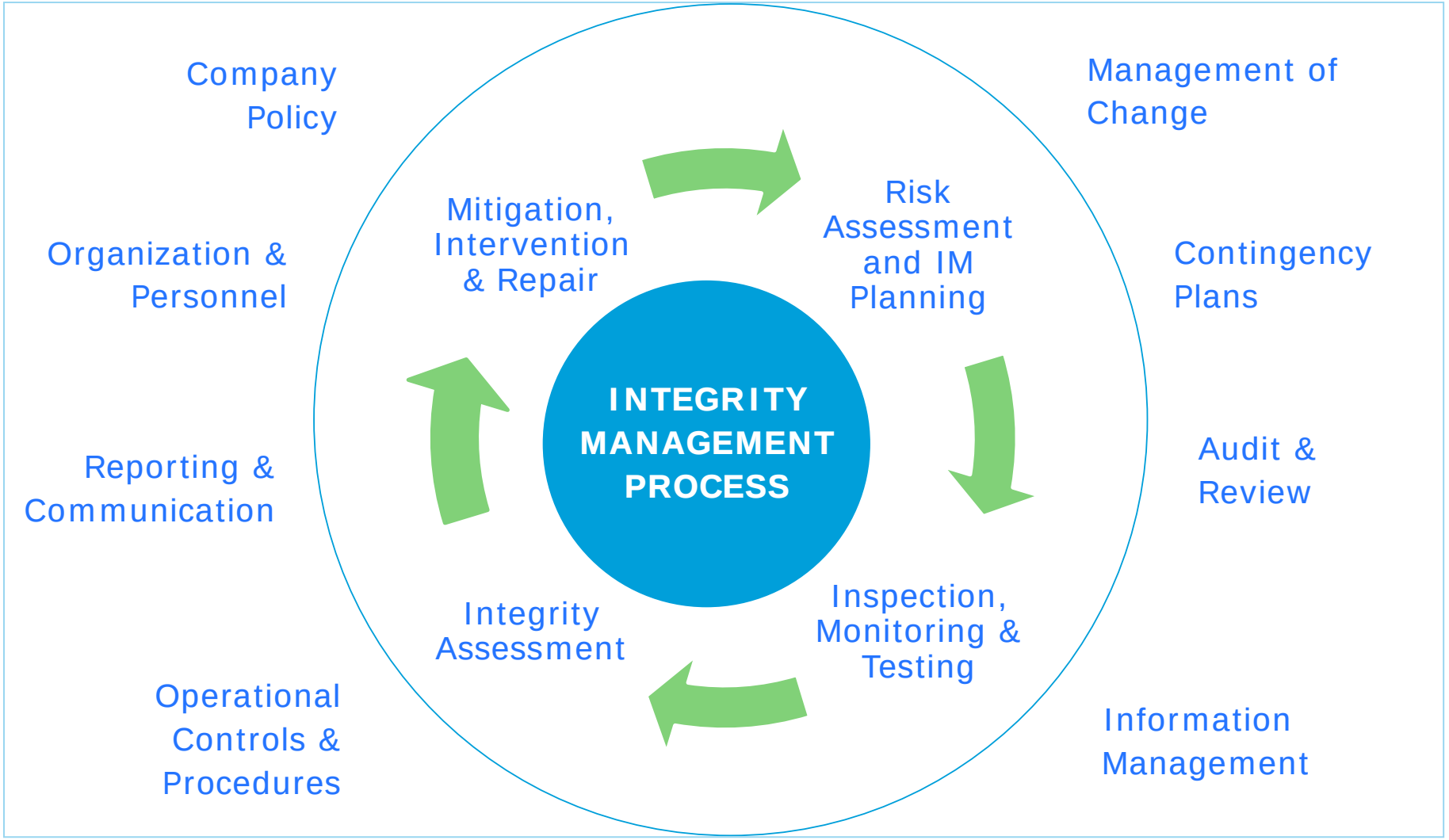
SOURCE: DNV GL OTC 25134

Other Contributing Factors

- Manufacturing Defects
  - Low toughness mooring components
  - Chain post heat treat weld repairs
- Installation and Accidental Damage
  - Jacket damage on spiral strand rope during installation
  - Polyester rope accidental damage (e.g. from ROV umbilical)
- Design Shortcomings
  - Design codes require updating
  - Connecting hardware contact with seafloor
- Pollution

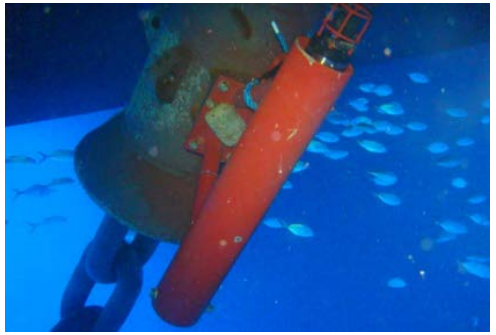
PREVENTABLE!

Mooring Integrity Management



Monitoring Advances

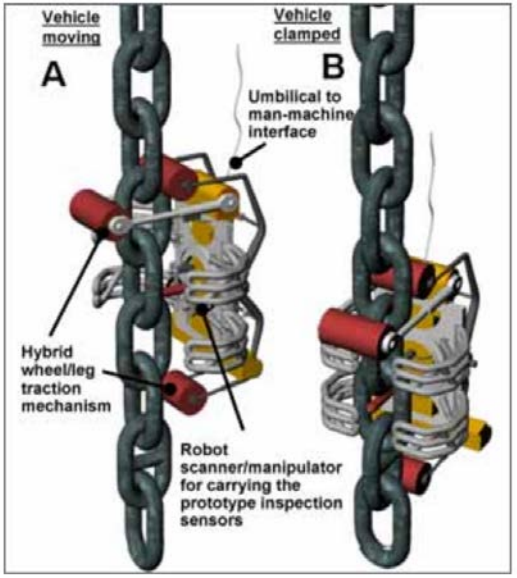
- Position Monitoring
  - DGPS can detect change of movement behaviour
- Tension Monitoring
  - Innovative instruments and acoustic data transmission have made long term line monitoring viable
  - Needed to monitor for failed line
  - Used to assess mooring performance
- Material Monitoring (under development!)
  - For long term monitoring of line corrosion



Inspection Advances

- In-situ inspection of mooring line is difficult and costly
  - Most inspections are General Visual Inspections (GVI) made using ROV camera
- Some Specialised Inspection Techniques
  - Chain
    - Mechanical & optical calipers
    - Alternating Current Field Measurement (ACFM)
    - Under development
  - Rope
    - Optical
    - Magnetic
  - Connectors
    - 3D HD video

Optical Caliper
(Welaptega CMS™)



TWI ChainTest™
(under development)

Concluding Comments

- Overall safety performance of industry is good but with room for improvement
- Many joint industry research activities ongoing to understand failure mechanisms
- Class and Industry are working together to create recommended practice for MIM
- Technological developments are improving monitoring and inspection methods
- Open sharing of mooring failure data through forums such as the Mooring Integrity User Group is very important toward improving mooring performance
- **Moorings systems, unlike vintage wines, do NOT improve with age!**

Thank you for your kind attention

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