OIL & GAS

Risk Based Inspection (RBI) Planning for Hull Structures of Mobile Offshore Units (MOUs)

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Why do we inspect ?

Degradation (fatigue cracking, corrosion…)

Fabrication defects or installation damage

Does the structure have adequate structural integrity ?

Design errors

Environmental overload

Accidental loads or damage

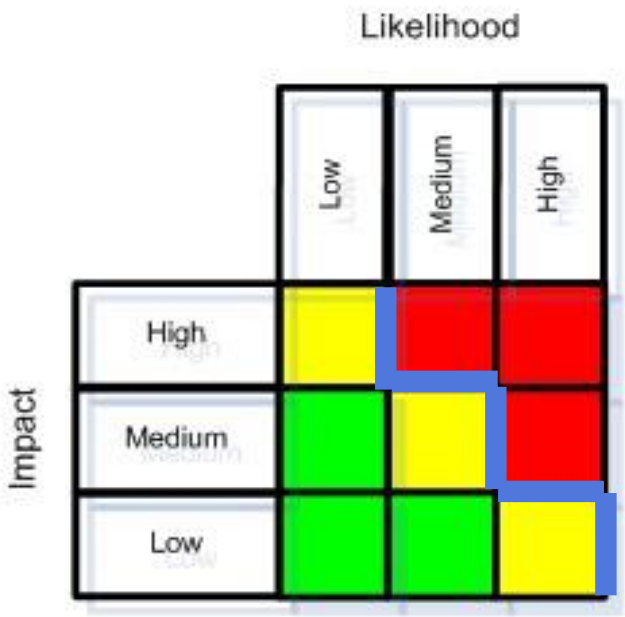
When do we inspect MOU Hull Structures?

Time based approach

- Fixed interval
- Key areas
- CLASS or other prescriptive regulatory requirements
- Renewal survey every **5 years**, or every **2.5 years** beyond fatigue design life

Risk based approach

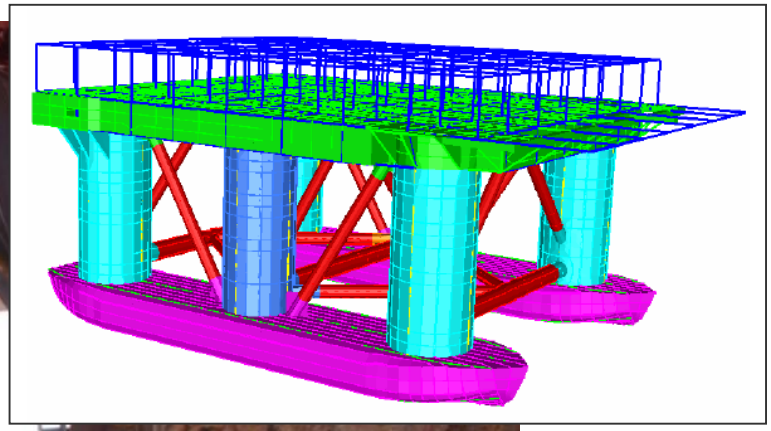
- Variable intervals (probability and consequence of failure)
- Qualitative or Quantitative approaches
- DNVGL-RP-C210: Fatigue cracks
- DNVGL-OTG-17: Coating and Corrosion



What do we inspect ?

What do we inspect ?

Where do we inspect ?

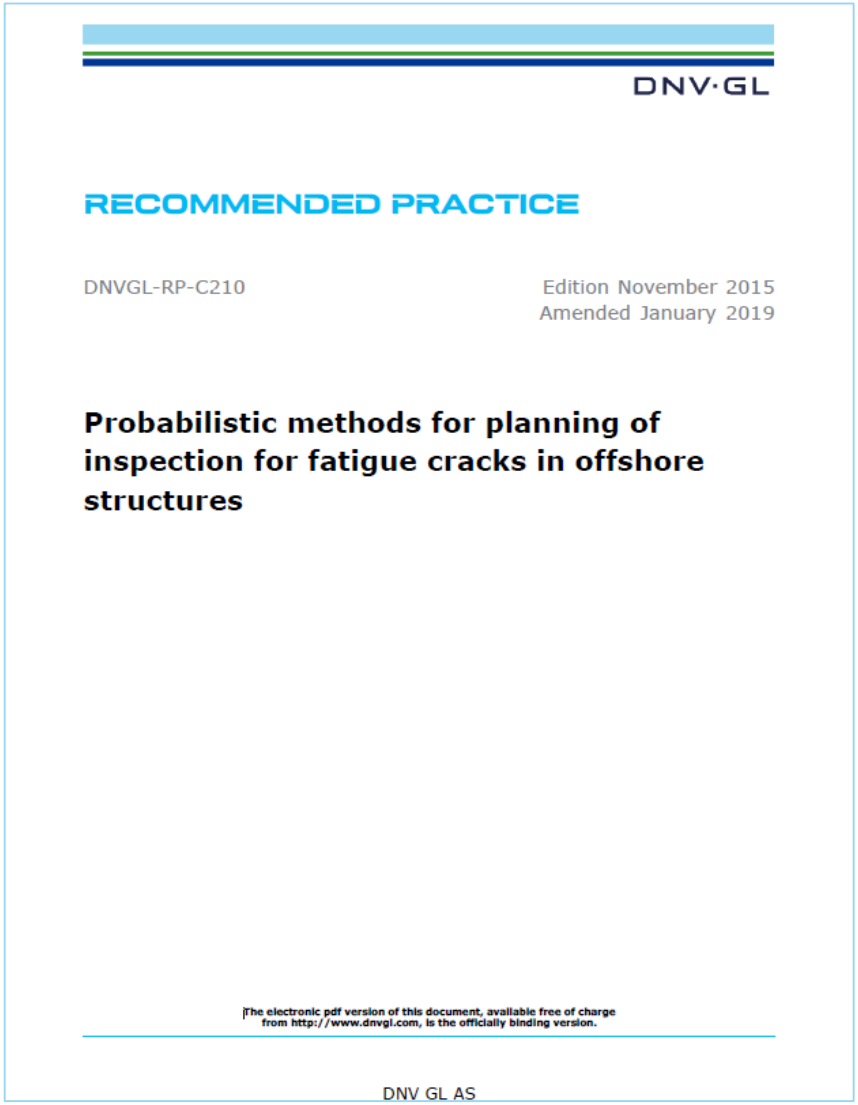


How do we inspect ?

What else can be done ?

Background : DNVGL-RP-C210

- Specific guidance for:
  - Jackets
  - Semisubmersibles
  - FPSOs
- Focuses on **fatigue** cracking
  - SN-Data
  - Fracture Mechanics
  - Assessment of Probability of Fatigue Failure
  - Target Reliability
  - Probability of Detection
  - Determining requirements for NDT at fatigue hotspots
  - Inspection Planning
  - Examples



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RECOMMENDED PRACTICE

DNVGL-RP-C210

Edition November 2015
Amended January 2019

Probabilistic methods for planning of inspection for fatigue cracks in offshore structures

The electronic pdf version of this document, available free of charge from http://www.dnvgl.com, is the officially binding version.

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Background: DNVGL-OTG-17

- Guidelines for how to apply RBI Methodology for MOUS classed in DNVGL worldwide for the following:
  - Semi-submersible
  - Jack-up
  - FPSO
  - Deep Draft Floater
  - Buoy
  - TLP
- The developed in-service inspection plan (IIP) shall be approved by DNVGL CLASS before the plan is implemented as part of the class in-service inspection plan.
- Damage Degradation Mechanisms:
  - Fatigue (Section 3)
  - **Coating and Corrosion** (Section 4)


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Offshore Technical Guidance

DNVGL-OTG-17 Edition August 2019

Inspection planning of MOUs in-service by use of RBI methodology

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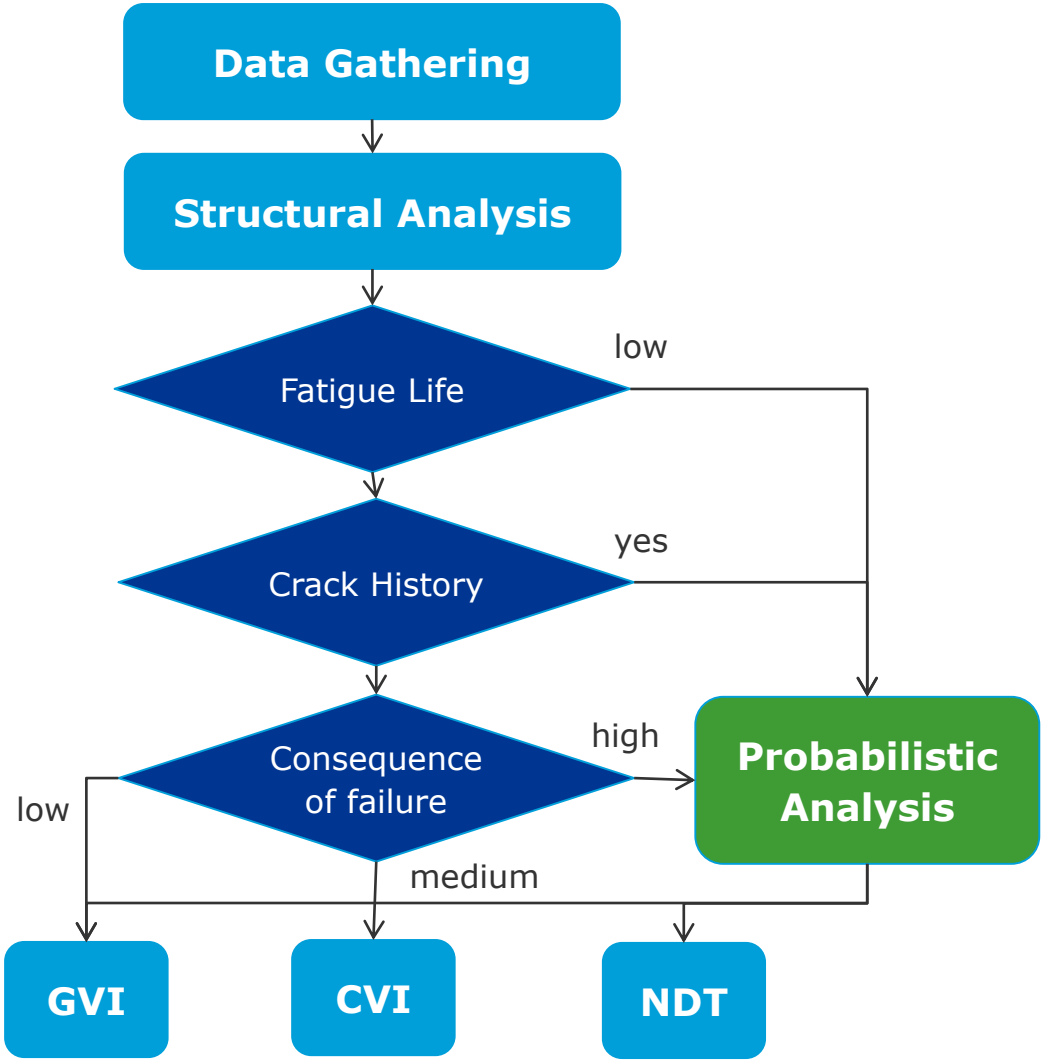
Typical methodology (overview) for Fatigue RBI

- Data Collection:
  - Drawings, inspection history, operating history, etc.
- Perform structural analysis (if not already available)
- Perform quantitative RBI at selected hotspots (low fatigue life, history of cracking or high consequence)
- NDT intervals determined by RBI
- Visual inspection of other details



Qualitative Screening - Overview

- **Develop** structural hierarchy of inspectable elements
- **Identify** relevant failure modes and damage mechanisms
- **Evaluate** Probability ranking for relevant mechanisms
  - linked to inspection history, results of fatigue analysis, type of coating, fluid corrosivity etc.
- **Evaluate** Consequence ranking for safety, environment or business impact
- **Evaluate** Risk level using agreed risk matrix
- **Develop** inspection plan for different inspection activities based on risk
- Typical Inspection intervals are as shown below

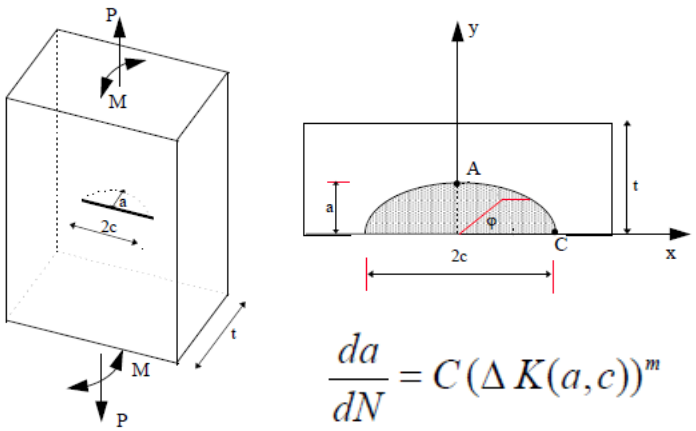
Risk Category	Level I Inspection	Level II Inspection	Level III Inspection	Level IV Inspection
High	Annual	Annual	2 Years	2 Years[1, 2]
Medium	Annual	3 Years	5 Years	As required
Low	Annual	5 Years	As required	None

Quantitative Analysis

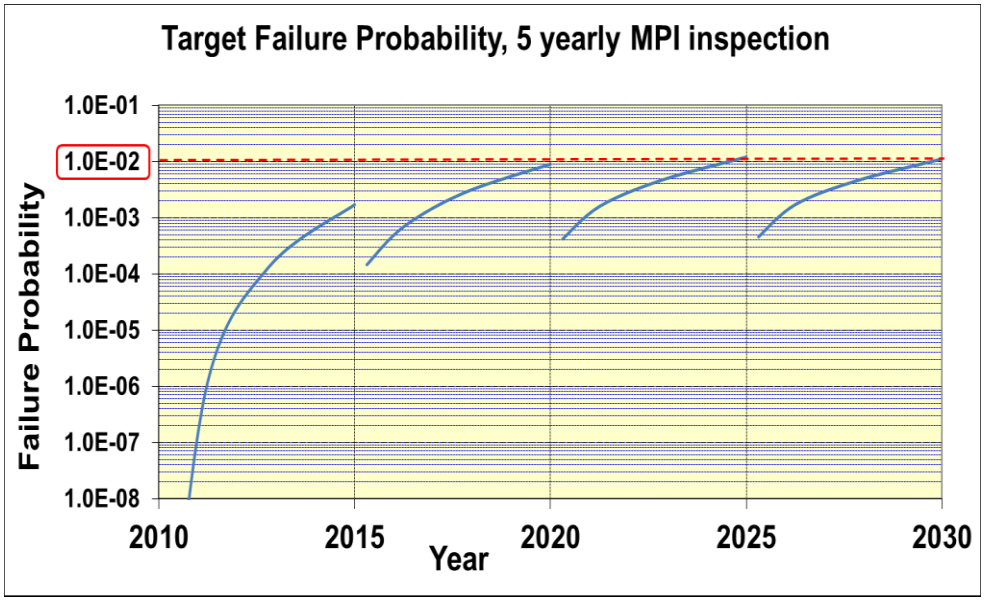
- For high risk items or where there is a desire to optimize inspection frequencies beyond those given by screening assessment
- Quantitative assessment of fatigue in accordance with DNVGL-RP-C210
- Quantitative assessment of corrosion in accordance with DNVGL coating degradation model and DNVGL-OTG-17

Quantitative analysis of fatigue

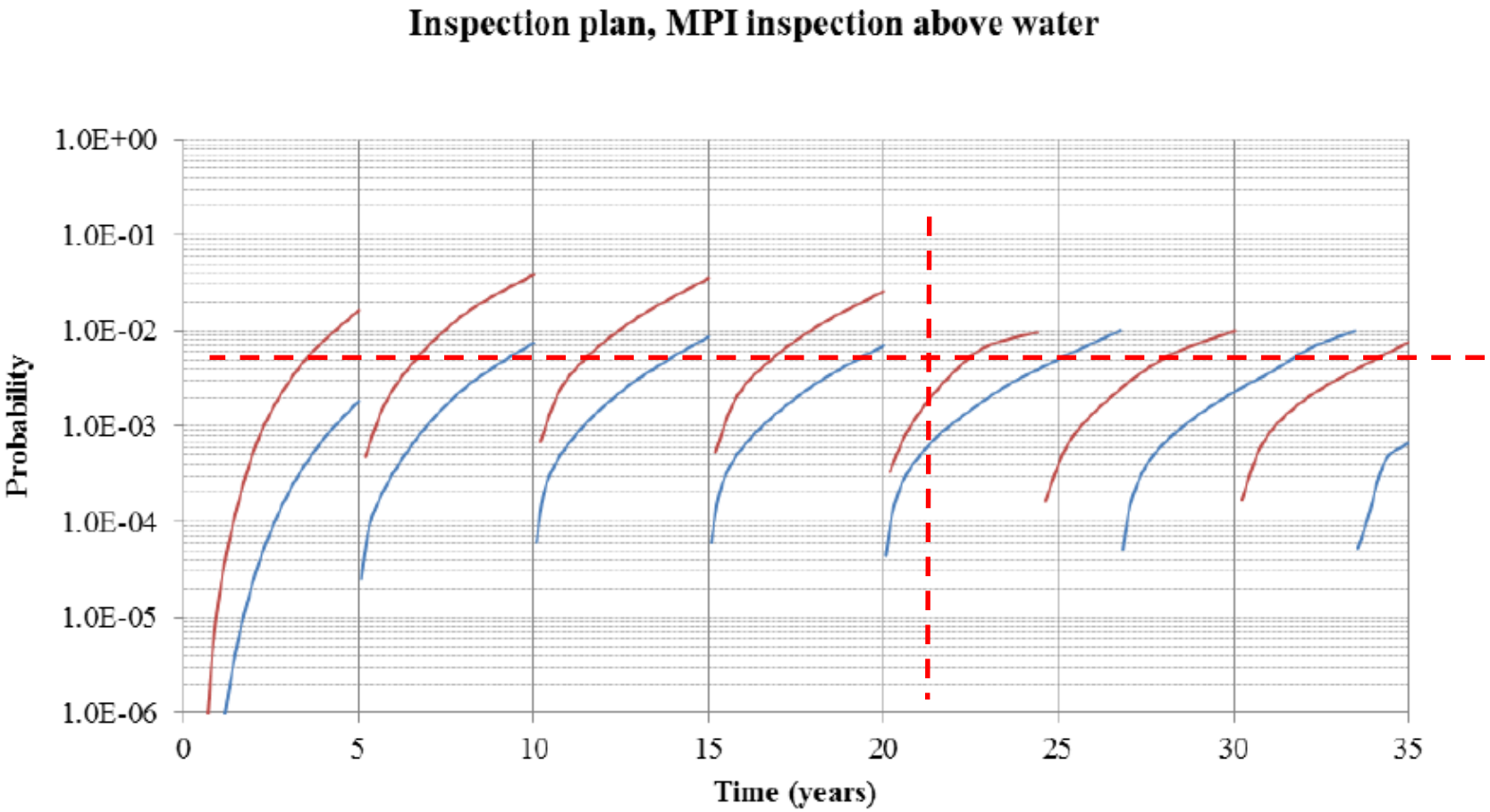
- Fracture mechanics Model
- Probabilistic approach: probability of failure as a function of time, taking account of uncertainties in loading and material properties, as well as inspection history
- Calibrated against S-N life to ensure consistency
- Optimum inspection frequency to keep POF below target level (target level depends on consequence of failure)
- Structural improvements, toe-grinding etc., where appropriate



$$\frac{da}{dN} = C(\Delta K(a,c))^m$$



Probabilistic Crack Growth Analysis



Optimal inspection plans for details with different fatigue lives (time between NDT inspections)

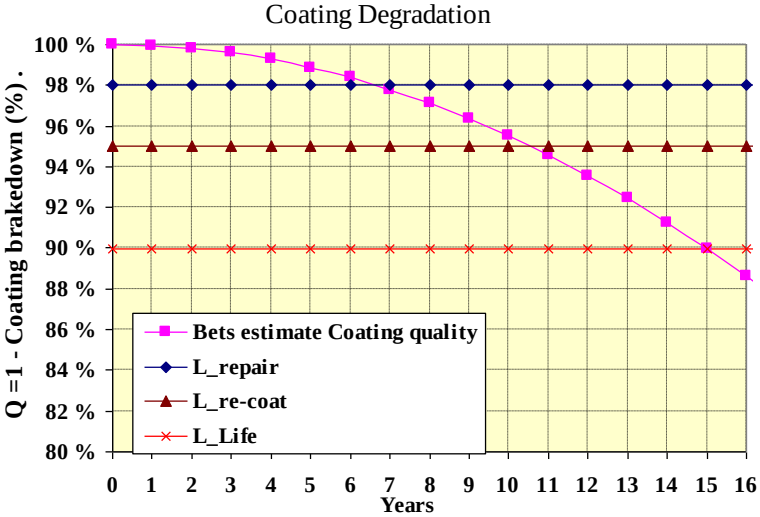
Quantitative analysis for Corrosion / Coating degradation

POF associated with coating degradation modelled using parameters such as:

- Target life (depending on coating specification)
- Surface preparation factor (cleanliness)
- Environmental exposure factor (type and temperature of tank contents)
- Osmosis factor (salts on surface or solvents in paint)
- Cathodic disbondment (type of coating and test results)
- Other factors: such as flexibility of coating, resistance to shrinkage etc.

Inspection frequency:

- Time at which expected coating quality falls below target
- Time at which the probability of unacceptable coating quality exceeds target
- Cost optimal criteria depending on cost of re-coating and/or patch repairs

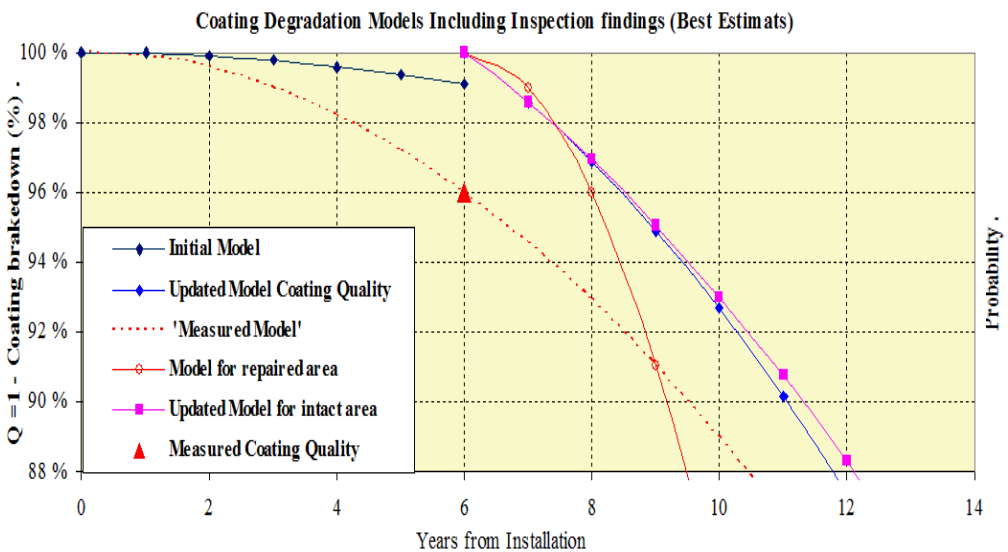


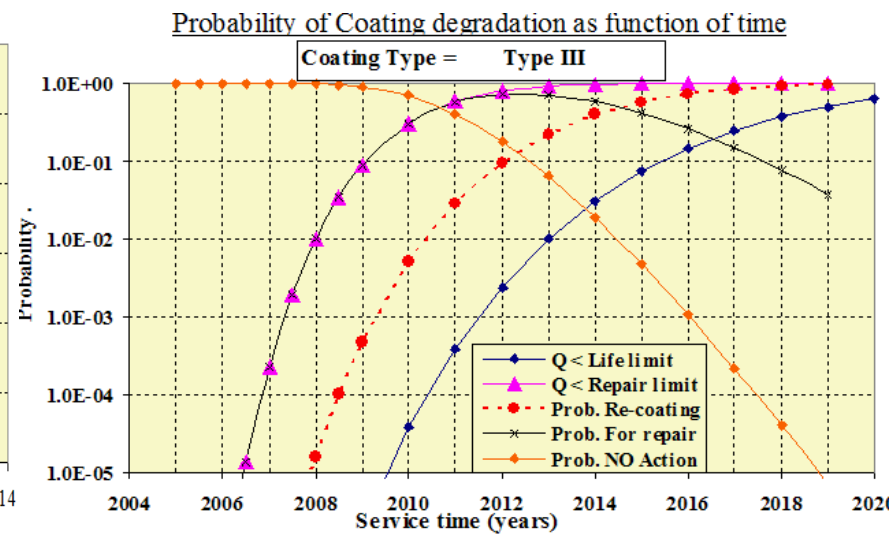
Methodology – Corrosion / Coating degradation

- Update of Models based on Inspection Data
- Update of inspection plans for future condition
- Inspection updating procedure is similar to that used for fatigue cracks
- Classification of the condition of the coating in the ballast tanks based on IACS:
  - GOOD: Condition with only minor spot rusting
  - FAIR: Condition with local breakdown at the edges of stiffeners and weld connections and/or light rusting over 20% or more of areas under consideration, but less than as defined for POOR condition.
  - POOR: Condition with general breakdown of coating over 20% or more of areas or hard scale at 10% or more of areas under consideration

Methodology – Corrosion / Coating degradation

- Acceptance criteria for inspection planning:
  - Expected coating condition falling below threshold, or probability of certain condition exceeding the target
  - Alternatively, plans can be developed to minimize cost (while maintaining adequate safety)
    - cost of inspection versus cost of patch repairs, re-coating, etc.

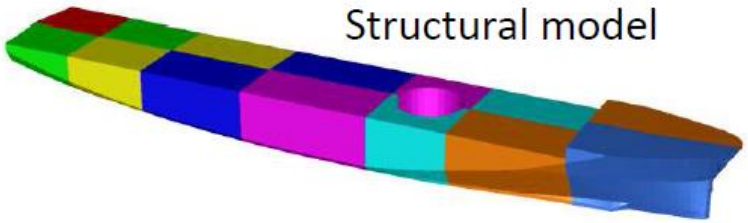


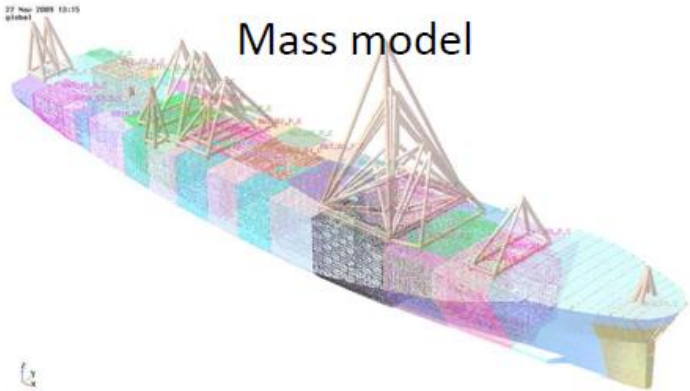


Case Study – FPSO

Phase 1

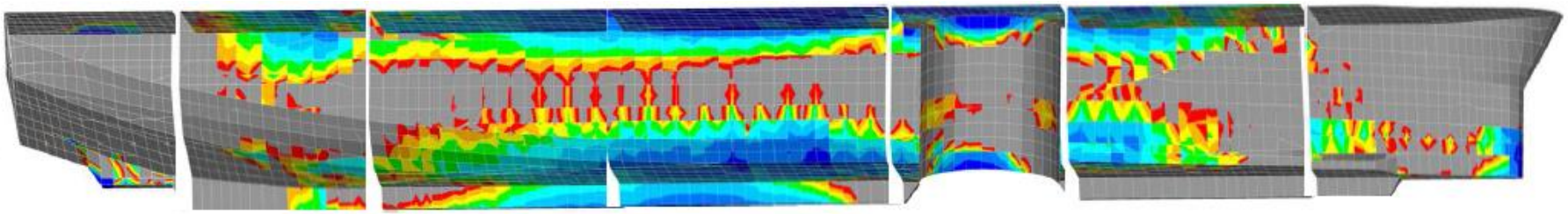
- Global structural model and analysis
- Global screening
- Refined fatigue analysis at selected hotspots





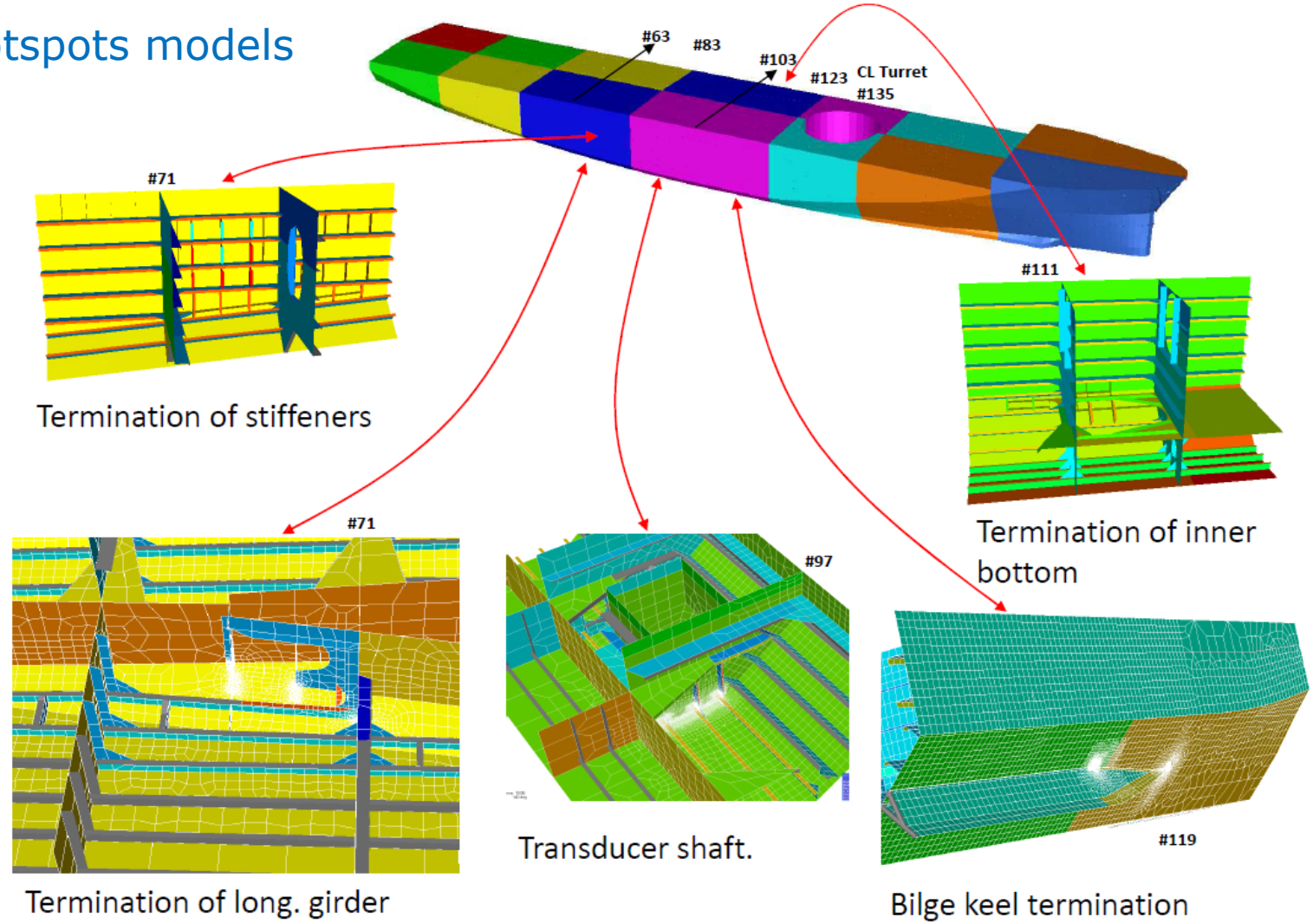
Phase 2

- Detailed fatigue analysis of additional hotspots
- Quantitative RBI analysis
- Recommendations



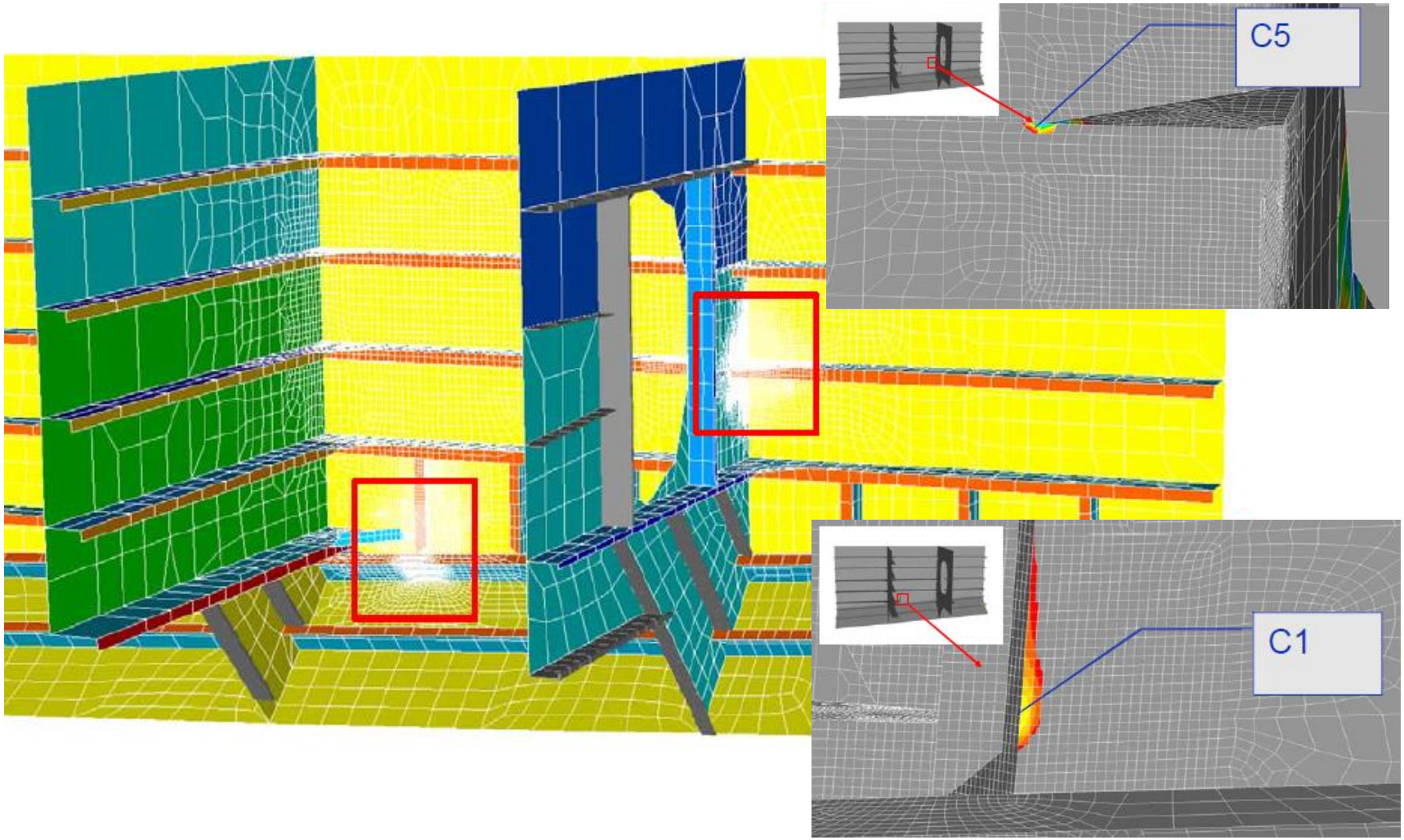
Case Study – FPSO

- Hotspots models



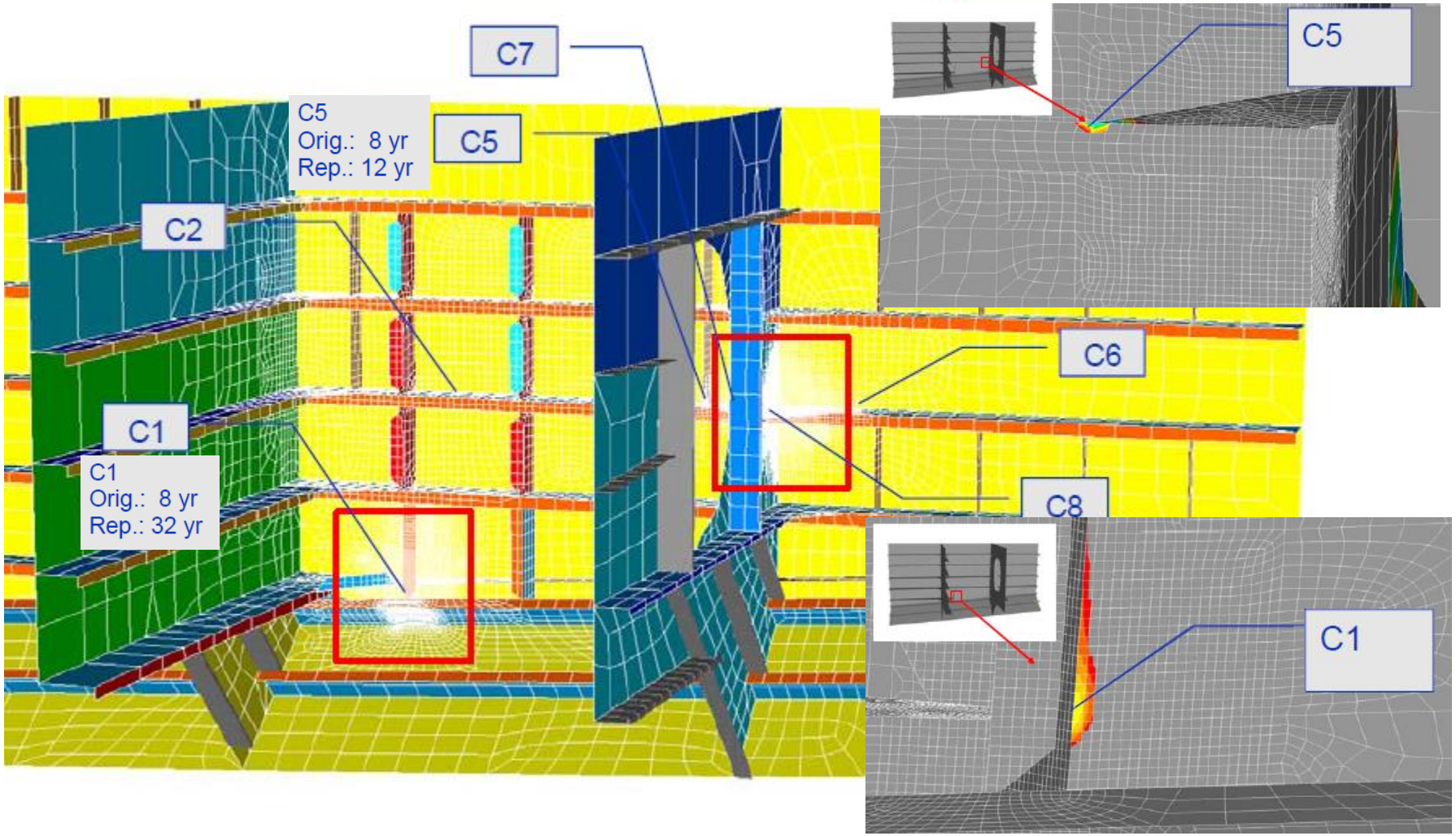
Case Study – FPSO

- Hotspot Model C – Termination of Stiffeners - Frame #A - #B Starboard



Case Study – FPSO 1

- Hotspot Model C – Repaired



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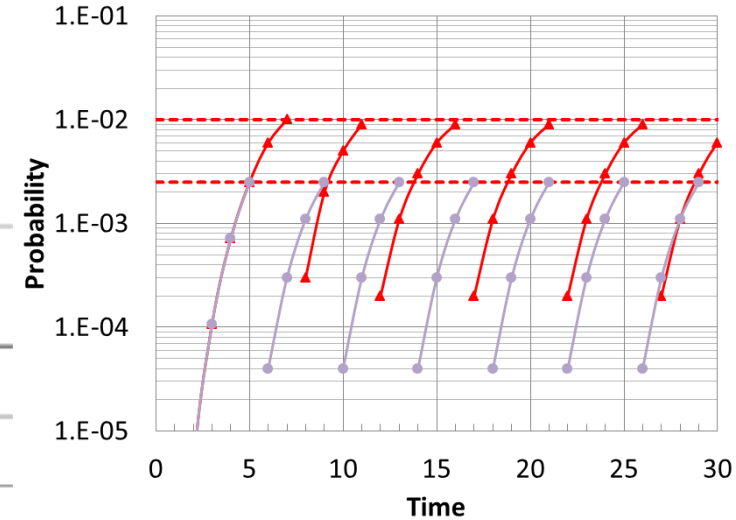
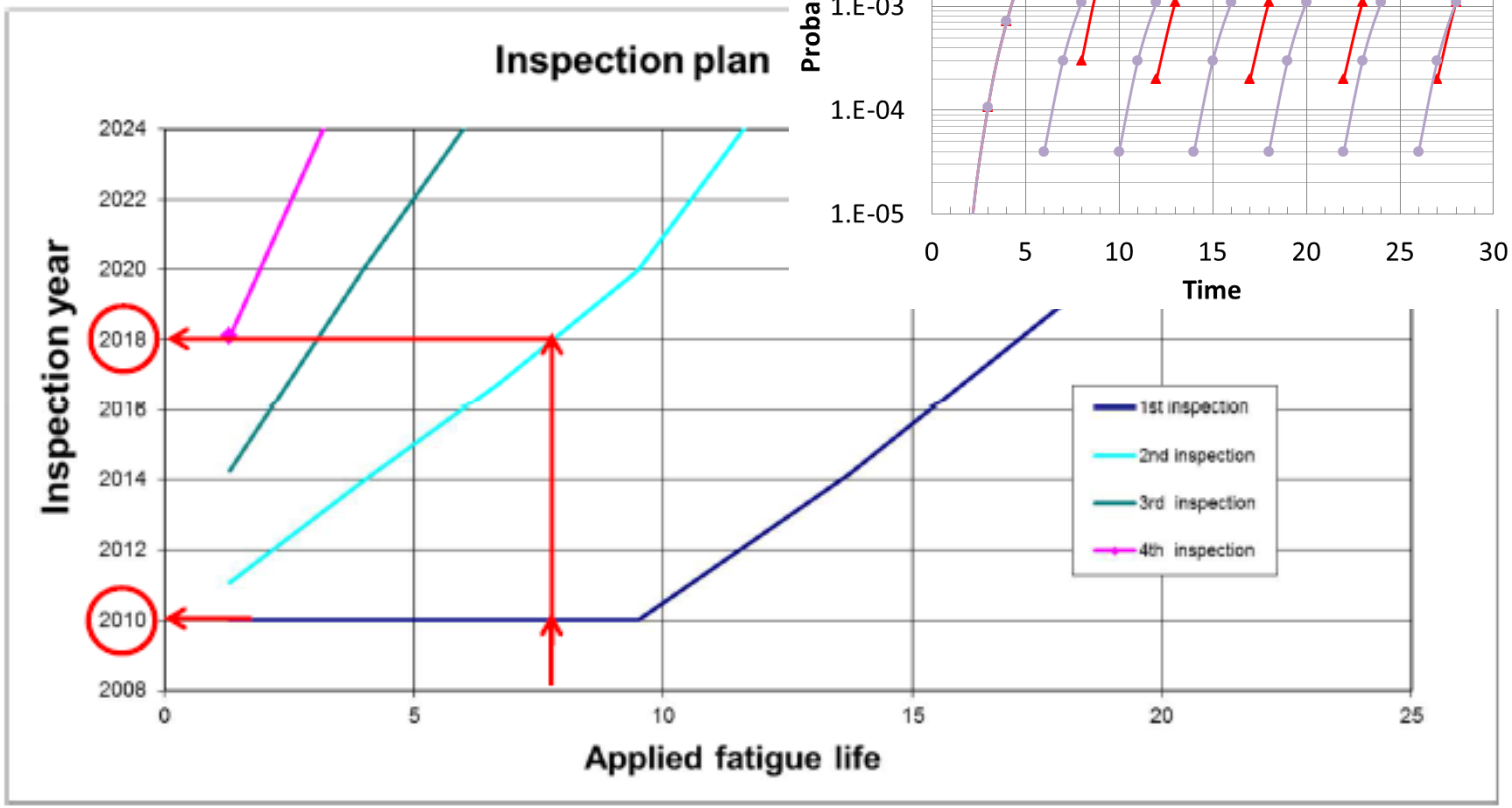
Case Study – FPSO 1

- RBI Analysis: Fatigue Degradation Mechanism
  - Generic inspection plans



2nd inspection

1st inspection



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Case Study – FPSO 1

- RBI Analysis: Fatigue Degradation Mechanism
  - Detailed inspection plans produced for each hotspot area (e.g. C5 to C8)
  - Repair from one side in 2004 moves C1 hotspot onto outside
  - EC unable to detect cracks on outside. Crack growth analysis (of through wall crack) demonstrates 6-monthly GVI (leak detection) is sufficient in this instance.

Tank	Hotspot	Side of plate	Fatigue life (Original)	Fatigue life (Repaired)	Inspection Method	Insp. 1	Insp. 2	Notes
A	C1	Internal	8	32	GVI*			Crack / repair 2004 Toe grinding 2006
		External	4137	20	GVI*			
	C5	Internal	8	12	EC	2010	-	
	C7	Internal	11	11	EC	2010	-	
	C8	Internal	2	2	EC	2010	2012	

Case Study – FPSO 1

- RBI Analysis: Coating Degradation Mechanism
- Total life correction factor: product of the critical coating factors, i.e. surface preparation, environmental stress, Osmosis, Cathodic disbonding, Coating type and maintenance factor
- Repair of coating and repair of the corrosion damages in this tank is advised if the unit shall be used for the next 5 to 10 years

Assumptions:

- Inspection in 2018, coating breakdown as FAIR, between 5% - 20%

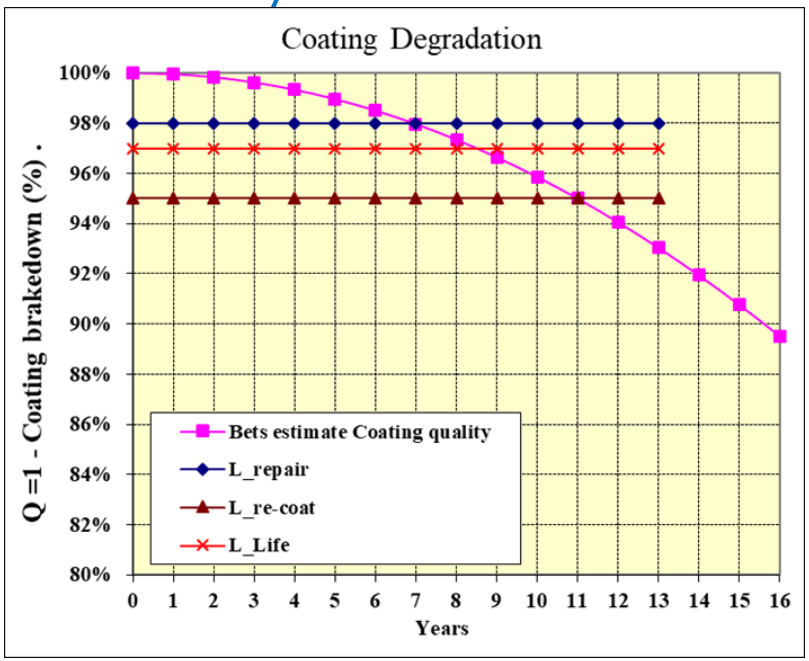

Figure: Simulation of Coating Degradation for COT A

Summary

- Background info for RBI
- Brief Methodology
  - Fatigue (DNVGL-RP-C210)
  - Corrosion (DNVGL-OTG-17)
- Sample Case Study

Thank you for your attention…

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