Monaco Engineering Solutions

Development and Implementation of Systematic Subsea Reliability Strategies
Wednesday 5th February 2014
Presenter: Dr. Mehran Pourzand
Overview

• Subsea Reliability Challenges

• Reliability, Availability and Maintainability Definitions

• Subsea Reliability Strategy using PLASMA – Based on API RP 17N

• Reliability Strategy Summary
Subsea Reliability Challenges

- Maximise Oil and Gas production
- Minimise environmental impact
- Minimise risk to assets and personnel
- Maximise profit

These can be accomplished by improving reliability of subsea systems and optimising maintenance costs and thus:

**Maximising Subsea Production Availability**
System Production Availability

Reliability

Production Availability

Maintainability
The main focus of Reliability is understanding the failure patterns of equipment/components throughout life of field.
Early life failures are also known as infant mortality and burn-in failures.

Manufacturing defects: Welding flaws, cracks, defective parts, contaminations, poor workmanship and poor quality control.

Minimised by good design, fabrication and testing philosophy and implementing a Reliability Strategy.
• Aiming to reduce early life failures

![Reliability – Bathtub Curve diagram](image)

- Early Life
- Useful Life
- Wear out

Uncertainty

Failure Rate vs. Time
Aiming to reduce early life failures

What are the uncertainties in the equipment failure rates
- Environmental conditions
- Operating conditions
- Suitability for Service (e.g. Is it operated within design conditions?, Is it designed to appropriate standards? Is it being used beyond its capability?)
- Lack of dependable subsea reliability data
Maintainability

- Maintenance downtime profile for a single failure
• Maintenance downtime profile for a single failure
Maintainability

- Maintenance downtime profile for a single failure

Repair Time (No Production)

Repair Time comprises:
- Access
- Diagnosis
- Replacement/Repair
- Verification and Alignment
Maintainability

• Maintenance downtime profile for a single failure

Restart or Ramp-up
1. Corrective Maintenance (CM) i.e. repair or replace when failure occurs.
2. Planned Preventive Maintenance (PPM) i.e. time based maintenance or replacement.
3. Condition based maintenance (CBM) i.e. monitoring the performance and perform maintenance/replacement when condition deteriorates.

For ultra-deepwater, the preferred strategy is Corrective Maintenance (CM) i.e. repair or replace when failure occurs.

However, the CM strategy itself when implemented is still not cost-effective. There’s a need to eliminate potential failures when possible.
Typical Production Output

- Reducing frequency of failures = **Improving Reliability**
- Reducing repair or downtime = **Improving Maintainability**
- How do we quantify production availability?

![Diagram showing Typical Production Output]

Assuming a constant production profile

- 10 failures
- 6 weeks downtime
Production Availability Definition

Production Availability = \frac{Actual Production Vol}{Potential Production Vol}

Assuming a constant production profile
How can we optimise the production availability?

- Optimise reliability and maintainability and adopt the asset management strategy based on API RP 17N.

- Use specialised tools that implement Subsea Reliability Strategy into design:
  - The tool should be designed to conform with API RP 17N and ISO 20815.
  - Platform for Operators, Contractors and Vendors to understand and review R&M as an iterative and continuous process
  - Allow all parties to work together to meet R&M goals and remain up-to-date on Reliability targets
  - Ensure R&M goals are carefully considered throughout all life-cycle phases
  - Formulate a Reliability Assurance Document (RAD) which summarises the findings from various analyses from the Reliability Strategy program such as RAM, FTA, FMECA, TRC and TRL and demonstrate whether production availability targets have been met.

- This paper investigates the implementation of Subsea Reliability Strategy using PLASMA software.
API RP 17N provides a structured approach which organisations can adopt to manage uncertainties throughout the life of a project.
The reliability activities have been arranged into a cycle of four basic steps.

Based on 12 key reliability processes as defined by ISO 20815 for production assurance and reliability management.
The changes to the Goals can be tracked through each iteration.
Goals and Requirements

- Define project specific goals, strategies and requirements
- Define high level reliability and maintainability goals
  - Overall Production Availability
  - Probability of achieving a maintenance free operating period
  - Probability of achieving a minimum failure free operating period (non-maintainable items)
**Goals and Requirements**

- Allocation of availability
  - Topside system
  - Subsea system

- Define project strategy
  - Minimise time to restore failed equipment to an operable state (Maintainability Strategy)
  - Extend equipment life before failure (Reliability Strategy)
  - Combination of both
Technical Risk Categorisation

- Define project requirements
  - A high level technical review using Technical Risk Categorisation

<table>
<thead>
<tr>
<th>Technical Risk Category</th>
<th>Risk Level</th>
<th>Nature of Assessment Work</th>
<th>Effort Expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>High</td>
<td>Quantitative</td>
<td>More</td>
</tr>
<tr>
<td>B</td>
<td>Medium/High</td>
<td>Mostly Quantitative</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Medium/Low</td>
<td>Mostly Quantitative</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Low</td>
<td>Qualitative</td>
<td>Less</td>
</tr>
</tbody>
</table>
## Technical Risk Categorisation

<table>
<thead>
<tr>
<th>Key Words</th>
<th>Reliability</th>
<th>Technology</th>
<th>Architecture / Configuration</th>
<th>Environment</th>
<th>Organisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High (A)</td>
<td>Significant Reliability Improvements (technology change)</td>
<td>Novel technology or new design concepts</td>
<td>Novel application</td>
<td>New environment</td>
<td>Whole new team</td>
</tr>
<tr>
<td>High (B)</td>
<td>Significant Reliability Improvements (design change)</td>
<td>Major modifications</td>
<td>Orientation and capacity changes</td>
<td>Significant environmental changes</td>
<td>Significant team changes</td>
</tr>
<tr>
<td>Medium (C)</td>
<td>Minor Reliability improvements</td>
<td>Minor modifications</td>
<td>Interface changes</td>
<td>Similar environmental conditions</td>
<td>Minor team changes</td>
</tr>
<tr>
<td>Low (D)</td>
<td>Unchanged Reliability</td>
<td>Unchanged Technology</td>
<td>Unchanged</td>
<td>Same environmental conditions</td>
<td>Same team as previous</td>
</tr>
</tbody>
</table>
Reliability Activities

- Allocate leadership and resources to the required reliability activities
  - resources (people, software/hardware, etc.);
  - roles and responsibilities;
  - deliverables for each activity;
  - schedules and milestones.
Reliability Activities

- Planning philosophies and tasks
  - Operators should initiate reliability plans as early as possible in feasibility and concept selection stage
  - Plans should be adopted by contractors in consultation with the operators
## Reliability Activities

<table>
<thead>
<tr>
<th>Reliability Activity</th>
<th>Task Notes</th>
<th>Responsibility</th>
<th>Timing</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability Data</td>
<td>Establish data for RAM Model - initially use OREDA</td>
<td>RAM Specialist</td>
<td>Ongoing</td>
<td>PLASMA Database</td>
</tr>
<tr>
<td>Define/update/monitor R&amp;M Goals</td>
<td>Achieve availability of $A_i%$ within CAPEX of $C_i$ and OPEX of $O_i$</td>
<td>Project Manager</td>
<td>Before ITT</td>
<td>Update Basis of Design</td>
</tr>
<tr>
<td>Update qualification plan &amp; schedule</td>
<td>Update and manage Reliability Plan and schedule for qualification</td>
<td>Reliability Lead</td>
<td>Ongoing - Quarterly</td>
<td>Qualification plan and schedule</td>
</tr>
<tr>
<td>System functional FMECA</td>
<td>Identify unacceptable system failure modes</td>
<td>Reliability Lead / RAM Specialist</td>
<td>Before ITT</td>
<td>HAZOP report and actions; input into the RAM model</td>
</tr>
<tr>
<td>Fault Tree Analysis</td>
<td>Identify the causes of failure and failure modes. Applicable to Unrevealed Failure Modes</td>
<td>Reliability Lead / RAM Specialist</td>
<td>Ongoing</td>
<td>Quantify the Probability of Failure on Demand for the TOP Events</td>
</tr>
<tr>
<td>System RAM Analysis</td>
<td>Use PLASMA to examine Production Availability and look at impact of design change</td>
<td>RAM Specialist</td>
<td>Ongoing – Final completion in X months</td>
<td>RAM Model</td>
</tr>
<tr>
<td>Lessons Learned</td>
<td>Verify lessons learned have been considered in the design</td>
<td>Project Manager</td>
<td>Ongoing</td>
<td>Design review report</td>
</tr>
<tr>
<td>Reliability Assurance (RAD)</td>
<td>Ongoing collection of evidence for assurance</td>
<td>Reliability Lead</td>
<td>Ongoing – Final completion in Y months</td>
<td>Subsea RAD</td>
</tr>
</tbody>
</table>
Project implementation should keep R&M at its core:

- potential failure modes that could affect system performance have been analysed and managed
- all design decisions are consistent with the R&M goals
- the qualification of equipment has addressed the R&M required by the project
- all documented lessons learnt from previous projects have been incorporated
- the supply chain is fully integrated into the reliability and technical risk management program
Feedback

• Lesson learnt from operations regarding reliability performance of equipment should be included as an input into projects.
The purpose of Reliability Assurance is to demonstrate that the Availability requirements have been met and the extent to which the availability goals will be achieved.

This contains statements on:

- Goals, requirements and strategy
- Project technical risk category
- Description of work carried out and findings
- Recommendations for the project
- Lessons learnt
Process Flow Diagram (PFD)

Reliability Block Diagram (RBD)
Fault Tree Analysis (FTA)
Probability of Failure on Demand
Top event frequency
Failure Mode Effects and Criticality Analysis (FMECA)
<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
<th>Failure Mode</th>
<th>Failure Mode ID</th>
<th>Failure Cause</th>
<th>Consequences</th>
<th>Failure Rate (per mil hours)</th>
<th>Method of Detection</th>
<th>Risk Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP Pumping Sub-System</td>
<td>Generate pressurised dual redundant High Pressure hydraulic supplies for subsea equipment</td>
<td>Leakage</td>
<td>1.1</td>
<td>Component failure</td>
<td>Local depressurisation of failed pump output</td>
<td>15</td>
<td>HPU Instrument displayed at OS</td>
<td>4</td>
</tr>
<tr>
<td>HP Accumulators</td>
<td>Provide pressurised fluid storage to optimise pump cycle times</td>
<td>Leakage</td>
<td>2.1</td>
<td>Fitting or component failure</td>
<td>Potentially resulting in eventual closure of subsea tree &amp; manifold valves</td>
<td>8</td>
<td>HPU Instrument displayed at OS</td>
<td>6</td>
</tr>
<tr>
<td>HPA or HPB Output Supply Line Components</td>
<td>Control of one of HP Outputs including ESD Solenoid Valve operation</td>
<td>Leakage</td>
<td>3.1</td>
<td>Internal mechanical failure</td>
<td>ESD not carried out on specific hydraulic supply</td>
<td>0.1</td>
<td>HPU and/or subsea Instrument displayed at OS</td>
<td>4</td>
</tr>
<tr>
<td>Umbilical Termination Unit</td>
<td>Conduct for pressurised dual redundant LP hydraulic fluid supplies for subsea control</td>
<td>Leakage</td>
<td>4.1</td>
<td>Fitting or component failure</td>
<td>Loss of System Redundancy</td>
<td>0.2</td>
<td>HPU Reservoir Low Level Alarm</td>
<td>3</td>
</tr>
</tbody>
</table>

Failure rate data is dynamically linked with other Reliability Activities to ensure consistent use of data.
1. The subsea system has an average production availability of 97.4% ± 1.4% over its 30 year design life.

2. This is equivalent to an average production rate of 10,700,000 sm$^3$ per year and average production loss of 270,000 sm$^3$ per year.

3. The estimated production volume over the design life is 321,000,000 sm$^3$ per year.

4. The average production availability does not meet the production availability target of 98.5%.

5. A breakdown of the contributor to overall unavailability.
1. The PAPD is based upon 500 simulation runs.
2. There is a 6.8% probability that the production availability target of 98.5% shall be achieved over its 30 year design life.
3. There is a 50% probability that the system shall achieve an average production availability of 97.4% or above over its 30 year design life.
1. The main system relative contributors to overall unavailability are Production (36.9%), MEG DS (22.4%) and HIPPS (17.1%).
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2. The main Production relative contributors to system unavailability are Pipelines (54.7%), Wells (37.5%) and Hydrate (7.8%) respectively.

Overall System > Production
1. The main system relative contributors to overall unavailability are Production (36.9%), MEG DS (22.4%) and HIPPS (17.1%).

2. The main Production relative contributors to system unavailability are Pipelines (54.7%), Wells (37.5%) and Hydrate (7.8%) respectively.

3. The main Wells relative contributors to system unavailability are X-Tree (37.6%), Tubing (24.4%) and SCSSV (18.0%) respectively.

Overall System > Production > Wells
• How much Reliability and Maintainability should be designed into a product?
• **Acquisition cost** includes cost of implementing and operating a reliability program in addition to the overall development and production costs associated with the product (Material, labour, taxes, insurance, admin, marketing etc.)
• **Failure Cost** includes warranty costs, liability costs, replacement or repair costs and loss of market share.

$$\text{Total Cost (t)} = \text{Acquisition cost (t)} + \text{Failure Cost (t)}$$
• **Planned Maintenance (PM) Cost** includes labour and equipment required. This will capture any incipient failures.

• **Corrective Maintenance Cost** includes costs associated with downtime, repair crews, equipment required and parts required.

\[
\text{Total Cost } (t) = \text{CM cost } (t) + \text{PM cost } (t)
\]
Reliability Assurance Document (RAD)
Reliability Assurance Document (RAD) Contents

- Executive Summary
- Introduction
- Process Description
- Availability Requirements and Strategy
- Reliability Activities
- RAM Analysis
- Fault Tree Analysis (FTA)
- Failure Mode Effects and Criticality Analysis (FMECA)
- Technical Risk Categorisation (TRC)
- Technology Readiness Level (TRL)
- Availability Evidence
- Availability Claims
- Conclusions & Recommendation
1.0 EXECUTIVE SUMMARY

The purpose of Reliability Assurance is to demonstrate whether the Availability requirements have been met and the extent to which the availability goals have been achieved for the project.

1.1 Production Availability Targets

The production availability targets set during the “define phase” and the current production availability achieved are described in Table 1.1.

<table>
<thead>
<tr>
<th>Production Availability</th>
<th>Production Availability Target</th>
<th>Production Availability Achieved</th>
<th>Target met?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>95.7%</td>
<td>95.2%</td>
<td>x</td>
</tr>
<tr>
<td>Topside System</td>
<td>97.2%</td>
<td>97.5%</td>
<td>✓</td>
</tr>
<tr>
<td>Subsea System</td>
<td>98.5%</td>
<td>97.5%</td>
<td>x</td>
</tr>
</tbody>
</table>

The overall production availability target has not been met. The Topside System has achieved its production availability target, but the Subsea System has not met its production availability target.

The R&M strategy for this project is focused on Reliability Strategy. This primarily focuses upon extending equipment life before failure.
10.0 CONCLUSIONS & RECOMMENDATIONS

The availability model indicated that the production availability of the subsea water injection system was predominantly influenced by the intervention vessel mobilisation delay and the number of spare Subsea Control Modules (SCM).

- It was recommended that an operational commitment to be obtained to an ROV Support Vessel availability of 31 days throughout field life. This amounted to an upgrade in the system availability of +3%;
- It was recommended that an operational commitment be explored with respect to achieving a MODU Support availability of 91 days throughout field life. This exercise amounts simply to the performance of a cost analysis to weigh in the balance whether or not it is economically attractive to enter into such a commitment with the prize in mind of achieving an upgrade in system availability of +4.2%.
- It was recommended as a minimum to store in-country the following equipment, maintained in a "ready-for-use" condition:
  - A 600M long section of Spare 8" Subsea Flexible Flowline plus four Spare End Fitting Flanges suitable for offshore termination
  - A 900M long section of Spare Subsea Control Umbilical plus two Offshore Re-termination Kits
  - Four Spare SCM's plus all necessary test stands
  - Three Spare Subsea Choke Inserts
Reliability Strategy Summary

- API RP 17N is a structured approach which can be used to optimise R&M goals.
- Reliability Strategy is an iterative process which is used throughout all project phases.
- Reliability Assurance Document (RAD) records the findings from various reliability activities (RAM, FTA, FMECA, TRC, TRL etc.) and demonstrates whether the production availability targets have been met.
- PLASMA is an integrated reliability tool which provides a live platform for Operators, Contractors and Vendors to understand and demonstrate that R&M goals have been met.
Contact Us

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