Riser Lifecycle Monitoring System (RLMS) for Integrity Management

11121-5402-01
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GE Global Research

Ultra-Deepwater Floating Facilities and Risers & Systems Engineering TAC meeting
June 5, 2014
Greater Fort Bend Economic Development Council Boardroom, Sugar Land, TX
Agenda

- Industry Challenges & Conventional Approach
- Program Overview
- Phase I Status & Plans (2014)
  - VOC and WPG
  - Task 5 – RLMS Subsystems: RFID, Subsea Platform, Vibration & Fatigue Analysis, Rig Test Plan
  - Task 6 – Alternative Approach to RLMS Communication Subsystem
- Demo
- Phase II Plans (2015)
Industry Challenges & Conventional Approach

Challenges for Drilling and Production

- Drilling in deep water and hostile environments (VIV/loop currents and hurricanes):
  - Riser curvature
  - Fatigue loading damage
  - Hang-off deflections
  - High tensions at BOP and base
- Exploration in deepwater environments (10,000 ft+)
- Safety, Environment and Compliance

Conventional Approach

- ROV systems (post process analysis) – limited actionable information
- Too much data – not enough information
- Limited information for reliable fatigue models

Needs

- Real Time Operations Visibility
- Lifespan Monitoring for Optimized I&M
- Asset Management Tools

Maintain Uptime and Improve ROI
Program Overview

Riser Lifecycle Monitoring System (RLMS)

Program Goal: Develop, Test and Field Trial Integrated, Commercially Viable and Industry-Accepted RLMS Solution
Innovation

- Modular Subsea Platform approach
- Economical number of Sensor Nodes
- Continuous Calculation of Fatigue Damage
- Enhanced Operations Reliability
- Performance-based Inspection
Program Status

<table>
<thead>
<tr>
<th>Project Cost Summary</th>
<th>Period of Performance</th>
<th>Date</th>
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<tbody>
<tr>
<td>Phase I budget</td>
<td>$1.1M</td>
<td>Phase I, Award 11/22/13</td>
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<td>Spend</td>
<td>$236K</td>
<td>Phase 1, Kickoff 12/12/13</td>
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<td>Phase I, End 11/21/14</td>
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<td>Projected End 11/21/14</td>
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Phase I Updates Since Kickoff:
- Tasks 1-3: Project Mgmt. Plan, Technology Status Assessment, Tech. Transfer
- Task 5 – Overall RLMS System Design using High TRL Subsystems
- Task 6 – Alternative Technology Development for RLMS Communication Subsystem

Financial processes in place to manage project metrics
# Phase 1 Program Plan – Tasks 5 & 6

<table>
<thead>
<tr>
<th>Program Activities</th>
<th>Phase I (12 months)</th>
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<tbody>
<tr>
<td><strong>Phase 1 Technology Development</strong></td>
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<tr>
<td><strong>Task 5.0 - Overall RLMS System Design using TRL 5 &amp; 6 Subsystems</strong></td>
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<td>Subtask 5.1 – Voice of the Customer</td>
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<td>Milestones:</td>
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<td>VOC workshop</td>
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<td>Framework for cost-benefit analysis</td>
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<tr>
<td>Subtask 5.2 – Preliminary system design &amp; risk analysis for key subsystems (RFID, Sensing/telemetry, Vibration &amp; fatigue analysis, Topside SW)</td>
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<tr>
<td>Milestone: Preliminary system design and risk analysis for RLMS subsystems</td>
<td>J F M A M J J A S O N D</td>
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<td>Deliverable: Preliminary Design Report [Tasks 5.1, 5.2], Draft &amp; Final</td>
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<td>Subtask 5.3 – Design &amp; conduct sub-system lab validation &amp; sub-scale rig testing</td>
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<tr>
<td>Subtask 5.3.1 Sub-System Laboratory Validation</td>
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<tr>
<td>Milestone: Laboratory testing of RLMS sub-systems at GRC-Niskayuna</td>
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<td>Subtask 5.3.2 Sub-Scale Rig Testing</td>
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<td>Milestone: Rig testing of RLMS system at UFRJ with GRC-Brazil</td>
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<td>Deliverable: Sub-scale Rig Design Validity Testing and Analysis Report [Task 5.3], Draft &amp; Final</td>
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<tr>
<td>Deliverable: Generic riser life-cycle reliability model Report, Draft &amp; Final</td>
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<td>Subtask 5.4 Phase 1 Final Reporting, Presentation &amp; Phase 2 Recommendation</td>
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<tr>
<td><strong>Task 6.0 – Alternative Tech. Development for RLMS Communication Subsystem</strong></td>
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<tr>
<td>Subtask 6.1 – Test Plan and Equipment Set-up</td>
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<tr>
<td>Milestone: Test plan for alternative RLMS communications approach</td>
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<tr>
<td>Subtask 6.2 – System Tests</td>
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<td>Milestone: Laboratory system tests</td>
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<td>Subtask 6.3 – Quantitative Comparison and Documentation</td>
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<tr>
<td>Milestone: Communication architecture and Trade-off Analysis</td>
<td>J F M A M J J A S O N D</td>
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<tr>
<td>Deliverable: Statement of Requirements Report [Task 6.3], Draft &amp; Final</td>
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2014 Program on target to meet deliverables
Customer Needs and WPG

Summary
Translate industry stakeholder/SME VOC to RLMS design specs;
Gap analysis

Focus Topics
- Value
- Installation & Operationalization
- Economics

Status
Translating initial customer KPI’s to RLMS subsystem design specs

<table>
<thead>
<tr>
<th>Customer Expectations (Y’s/ WHAT’s)</th>
<th>Importance</th>
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<tr>
<td>Enhance operations reliability</td>
<td>5</td>
</tr>
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<td>Impact I&amp;M schedules</td>
<td>4</td>
</tr>
<tr>
<td>Easily retrofit &amp; install on existing risers</td>
<td>5</td>
</tr>
<tr>
<td>Real time loads &amp; tension near wellhead</td>
<td>5</td>
</tr>
<tr>
<td>Cost effective</td>
<td>3</td>
</tr>
<tr>
<td>Rugged, reliable &amp; accurate system</td>
<td>5</td>
</tr>
<tr>
<td>Intuitive UI; Actionable Information</td>
<td>5</td>
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House 1 Pareto

Operator Engagement on Roadmap
Task 5: Overall RLMS System Design using high TRL Subsystems

Functional System Components

- Asset Identification using RFID
- Subsea Sensing & Acoustic Telemetry
- Vibration & Fatigue Analysis Methodology
- Topside SW

Laboratory and Rig Scale testing

Focus on Preliminary System Design and Risk Analysis for Key Subsystems
5.2.1 Asset Identification using RFID

**Technical Approach**

**Use Case**
- Ruggedized RFID system to identify joints from staging area
- Build up riser string
- All analytics based on unit riser joint

**Initial Design Specs**
- Read range 18 inches minimum
- Ruggedized for handling, subsea T & P

**Technology**
- 125 KHz, 915 MHz
- System evaluation against Use Case & Design Specs
- Expand to 915 MHz EPC, if needed

**Status**
- Tradeoff Analysis COTS RFID technologies
- Down selected 2 vendors for lab testing

**Plans for 3/4Q**
- Obtain RFID systems & testing for capabilities and survivability

Core Technology to Automate Processes, Enables Analytics & Riser Pedigree; Leverage COTS
5.2.2 Subsea Sensing & Acoustic Platform

Technical Approach
- Modular Platform
- Acoustic telemetry
- "Plug and go" & battery powered
- Open OS on microprocessor

Status
- Vision & strategy for Platform
- Lab testing HW platform with WHOI
- Identified & procured sensors
- Initial plan for topside modem connectivity & data storage
- Initial QFD/model

Plans for 3/4Q
- Enhance SW for customized app development
- Build optimization model for battery life
- System integration testing on riser joint
- System marinization & installation plan

Modular Open Platform Approach for Industry Acceptance
5.2.3 Vibration & Fatigue Analysis Methodology

**Technical Approach**
- Vibration & fatigue damage prediction with marine riser analysis packages - Id sensor node location & number
- Continuous calculation of fatigue damage - economical Sensor Node configuration

**Status**
- Assessment of Industry accepted riser analysis packages
- Shear7 procured, building model & running test cases
- Initial RLMS SW for UI, Analytics, DB

**Before deployment**
- Surface Waves, Currents, VIV, Vessel Drift, Tensioning
- Riser Mat, Joint Types, Buoyancy, Mod., Hydrodynamics, Soil Props, Mud Density, Materials & Properties

**After deployment**
- Accelerometers
- Sensor Locations and Outputs

**Plans for 3/4Q**
- Assess capability to obtain fatigue damage at any location using acceleration data
- Generic Riser Life-cycle Reliability Model

**Goal - Generic Riser Life-cycle Reliability Model**
Task 5.3 Rig Scale Testing

Test Goals
• Subsea Sensing Platform attachment
• Sensor validation
• Structural testing under loads

Sample Development

Test Value Estimation by Simulation
• Maximum force
• Oscillation (Frequency)
• Loading conditions

GRC-Brazil & UFRJ Collaboration

Industry Standards
• DNV – OS – F201- DYNAMIC RISERS
• API RP 16Q - Recommended Practice for Operation, Inspection of Drilling Riser

Test plan and Collaboration in place; Testing 3/4Q
### Task 5 Risk Mitigation Strategy

<table>
<thead>
<tr>
<th>RLMS Subsystem</th>
<th>Risk</th>
<th>Rating</th>
<th>Mitigation Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.2.1 RFID for Asset Identification</strong></td>
<td>HW require ATEX certification</td>
<td>L</td>
<td>Evaluate companies with ATEX certification</td>
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<tr>
<td></td>
<td>Integration with existing COTS SW</td>
<td>M</td>
<td>Assess options to integrate COTS SW tracking solutions</td>
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<tr>
<td><strong>5.2.2 Subsea Sensing &amp; Acoustic Platform</strong></td>
<td>Data interface from “surface” acoustic modem to topside DAS</td>
<td>M-L</td>
<td>Identify suitable topside DAS; develop interface accordingly</td>
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<td></td>
<td>Battery life, power consumption</td>
<td>H</td>
<td>• QFD flow down: CTQ’s affecting battery life</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Build transfer function &amp; optimize battery life w.r.t. system parameters</td>
</tr>
<tr>
<td></td>
<td>System Marinization/Installation</td>
<td>H</td>
<td>Partner with academic &amp; industry experts</td>
</tr>
<tr>
<td><strong>5.2.3 Vibration &amp; fatigue analysis</strong></td>
<td>Economical number of sensor points for desired fatigue life accuracy</td>
<td>M</td>
<td>Testing and validation of fatigue life prediction accuracy vs. number of sensors</td>
</tr>
</tbody>
</table>
Task 6 – Low TRL, Alternative RLMS Communication Subsystem

Technical Approach

Deliverable:
Feasibility study to define technology viability

Test Plan

Variables:
• Amplitude
• Distance
• Carrier Frequency
• Orientation of the fiber cable
• Length of receiving fiber cable

Preliminary Results

11kHz carrier
SNR=17dB

Risk
Acoustic Reflections

Next Steps:
• Install acoustic absorbers
• Run acoustic telemetry tests

Test plan, preliminary results complete; final setup in progress
RLMS Demo

RiserLife – Riser Lifecycle Monitoring System

- Continuous calculation of fatigue damage from sensor measurements
- Identify life-limiting riser joints
- Performance-based inspection – Refine inspection interval & remaining useful life
- Enhanced operations reliability – Real time visibility into drilling operations & optimization of riser configuration following extreme events

Intuitive UI
Intelligent Algorithms
Real time Transmission
Edge Decisioning
Modular Sensing Platform

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Imagination at Work
Load Riser Configuration from RFID File
View Riser Model

Complete riser model with motion sensor locations
## Riser Lifecycle Scenarios

<table>
<thead>
<tr>
<th>Lifecycle ID</th>
<th>Year 1</th>
<th>Year 2</th>
<th># Years</th>
<th># Drilling Campaigns</th>
<th>Damage Rates</th>
<th>Description / Action</th>
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</thead>
<tbody>
<tr>
<td>---</td>
<td>2000</td>
<td>2000</td>
<td>0</td>
<td>---</td>
<td>---</td>
<td>Installed riser configuration is brand new</td>
</tr>
<tr>
<td>A</td>
<td>2000</td>
<td>2010</td>
<td>10</td>
<td>40</td>
<td>Average</td>
<td>Max damage levels in riser joints progress as expected (compared to damage from design currents)</td>
</tr>
<tr>
<td>B</td>
<td>2010</td>
<td>2012</td>
<td>2</td>
<td>6</td>
<td>High</td>
<td>Riser string moved into a field with higher-than-average currents</td>
</tr>
<tr>
<td>C</td>
<td>2012</td>
<td>2012</td>
<td>0</td>
<td>0</td>
<td>---</td>
<td>Repair 5 riser joints as recommended by the RiserLife tool</td>
</tr>
<tr>
<td>D</td>
<td>2012</td>
<td>2015</td>
<td>3</td>
<td>12</td>
<td>Average</td>
<td>Riser string is in a new field with more moderate currents</td>
</tr>
<tr>
<td>E</td>
<td>2015</td>
<td>2018</td>
<td>3</td>
<td>10</td>
<td>Low</td>
<td>Riser string is in a shallower field with below-average currents</td>
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</table>

### Damage Calculation Workflow

1. Accelerometer readings collected periodically (every few minutes to an hour)
2. VIV software solves “inverse problem” to obtain stresses consistent with the acceleration histories
3. VIV software uses S-N curves associated with riser joints to calculate fatigue damage rates and damage increments
4. Fatigue damage levels are updated for each riser component and stored in a database
Lifecycle Part A – 40 Drilling Campaigns In Years 1-10
Current Levels ≈ Design Current Levels
(→ Average Damage Rates)
Lifecycle Part A -- Display Damage Along Riser String
@ t = 10 yrs
Lifecycle Part A – Riser Damage vs. Time

Assessment: Damage rates have been just slightly above average in the first part of the lifecycle.
Recommendation: If the trend continues, the next inspection can take place as planned at t = 15 years.

Recommendations
- No action required at this time
- Inspect as planned at 15 years
Lifecycle Part B – 6 Drilling Campaigns in Years 11-12
Current Levels > Expected (i.e. Design) Levels
(⇒ Above Average Damage Rates)

New riser damage calculated from sensor data in years 11 and 12.
Assessment:
The riser string has been moved into a field with above average current levels. Damage rates have increased.

Recommendation:
An inspection is due to the increased damage rates; 6 years of usable riser life have been lost. Repair the five riser joints with the highest damage (or swap them with joints that have much lower damage).
**Lifecycle Part C – Repair the 5 Recommended Riser Joints**

**Action:**
The riser string was inspected as per the recommendation.
The maximum damage is now down to acceptable levels (compared to the expected damage from the design currents). The remaining useful life is now back to normal.

Riser Joints that were Repaired:
- 23007404589
- 23008448640
- 23006560175
- 23002784237
- 23004781880
Lifecycle Part D – 12 Drilling Campaigns In Years 13-15

Current Levels are Moderate

Assessment: Damage rates are slightly above average in this period.
Recommendation: If the trend continues, the next inspection can take place as planned at $t = 20$ years.

Recommendations – No action required at this time
– Inspect as planned at 20 years
Lifecycle Part E – 10 Drilling Campaigns In Years 16-18
Current Levels are Below Average

Assessment:
The riser string is moved to a new field where current levels are considerably lower than in the past. Damage rates are below average.

Recommendation:
If the trend continues, skip the planned inspection at $t = 20$ years and inspect next at $t = 25$ years.

Recommendations – No need to inspect at 20 years
– Inspect as planned at 25 years
## Phase II Program (2015)

### Program Activities

<table>
<thead>
<tr>
<th>Task 7.0 – Conduct RLMS System Field Trial, Final Design Specifications for Integrated Deepwater RLMS &amp; Develop Commercialization Plan from Pilot Test</th>
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<tbody>
<tr>
<td><strong>Subtask 7.1</strong> – Determine Operator Commitment and Test Site, and Safety, Regulatory, and Documentation Requirements</td>
</tr>
<tr>
<td><strong>Milestone:</strong> Field Trial customer commitment and requirements definition</td>
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<tr>
<td><strong>subtask 7.2</strong> – Develop Pilot Charter (e.g. team, schedule, costing)</td>
</tr>
<tr>
<td><strong>Milestone:</strong> Pilot charter</td>
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<tr>
<td><strong>Subtask 7.3</strong> – Develop final design specifications for integrated deepwater RLMS</td>
</tr>
<tr>
<td><strong>Milestone:</strong> Final RLMS system specifications and field trial operational procedures</td>
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<tr>
<td><strong>Deliverable:</strong> Field Trial Project Management Plan - Draft, Final</td>
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<tr>
<td><strong>subtask 7.4</strong> – Conduct pilot</td>
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<tr>
<td><strong>Milestone:</strong> Pilot execution</td>
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<td><strong>subtask 7.5</strong> – Integrated Test Plan Results Report and Final Presentation</td>
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<tr>
<td><strong>Deliverable:</strong> Field Trial Technical Report - 90 days after Phase 2 approval, Draft; Final</td>
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<tr>
<td><strong>Task 8 – Business model analysis and cost vs. benefit assessment</strong></td>
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<tr>
<td><strong>Milestone:</strong> Business model and cost-benefit analysis</td>
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<td><strong>Task 9 – Define integrated generic solution for industry</strong></td>
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<tr>
<td><strong>Milestone:</strong> Commercially viable RLMS solution design</td>
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<tr>
<td><strong>Deliverable:</strong> Technology Readiness Report – Draft, Final</td>
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<td><strong>Deliverable:</strong> Phase 2 Final Presentation materials - 14 days after RPSEA comments</td>
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### Phase II (12 months)

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**Partner identified for Phase II trials**
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