RPSEA 3300-05 Program: Phase I
Autonomous Inspection of Subsea Facilities

PROJECT OBJECTIVES:

In response to initiative #4 – In-Water Intervention Services

— Maturity of Autonomous Underwater Vehicles (AUVs) open new capabilities to the offshore industry
  • Pre/post hurricane inspection by an AUV
  • Reliable operation of a subsea valve

Phase I Objective:

— Develop, integrate & test autonomous technology needed to conduct pre/post hurricane inspection of a facility
  • Autonomous imaging and real-time 3D re-construction of underwater facility
  • Detection & highlighting of changes to underwater facility
  • Feature based navigation
  • Local offshore testing from Lockheed Martin facility in Florida
RPSEA 3300-05 Program: Phase I
Autonomy Integration Sequence & Status

Current Phase
RPSEA 3300-05 Program: Phase I
Execution Schedule

<table>
<thead>
<tr>
<th>3300-05 PROGRAM (Phase I)</th>
<th>2010</th>
<th>2011</th>
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</thead>
<tbody>
<tr>
<td>Autonomous Inspection of Subsea Facilities</td>
<td>Jun</td>
<td>Jul</td>
</tr>
<tr>
<td>Key Program Milestones</td>
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<tr>
<td>Contract Award</td>
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<tr>
<td>Conduct Program Kickoff Mtg</td>
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<tr>
<td>Submit Program Management Plan (Draft)</td>
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<tr>
<td>Submit Technology Assessment Report</td>
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<td>Submit Technology Transfer Plan</td>
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<tr>
<td>Lab Run #3 (Verification Test Ready)</td>
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<tr>
<td>Sim Lab Demo (for RPSEA/Chevron)</td>
<td>Sep 24</td>
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<tr>
<td>Submit Program Management Plan (Final)</td>
<td>Sep 10</td>
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<tr>
<td>Submit Integration Test Plan</td>
<td>Oct 5</td>
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<tr>
<td>Lab Run #4 (Vehicle Ready)</td>
<td>Oct 24</td>
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<tr>
<td>Local Offshore Demo</td>
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<td>Submit Final Test Report</td>
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<td>Project Progress Reports (by 7th day of the month)</td>
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<td>TAC Quarterly Meetings</td>
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Phase I Research & Development

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<tr>
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<th>2010</th>
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<tr>
<td>Autonomy Design Development</td>
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<tr>
<td>Hardware Design Development</td>
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<tr>
<td>Support Equipment Design/Fab</td>
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<tr>
<td>Sim Lab Integration &amp; Test (Integration Phase)</td>
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<tr>
<td>Sim Lab Integration &amp; Test (Test Phase)</td>
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<tr>
<td>Sim Lab Demo (Vehicle Ready)</td>
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<tr>
<td>System Integration &amp; Test (Integration Facility Phase)</td>
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<tr>
<td>System Integration &amp; Test (Dockside Phase)</td>
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<tr>
<td>System Integration &amp; Test (Offshore Phase)</td>
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<tr>
<td>Prepare Final Test Report Report</td>
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<td>Prepare Public Technical Report of Work Performed</td>
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Secure Energy for America
RPSEA 3300-05 Program: Phase I
Marlin™ Offshore Platform Inspection System Mission Profile

Lockheed Martin Marlin™ AUV

AUV Launch & Recovery (>150m Stand-off) -> Ingress

Adaptive Path Planning

Inspect

Dive to Next Slice

Detect/Acquire Platform

The Platform Inspection mission profile involves successive passes around the platform at a 15m standoff, with 50% overlap of 3D sonar scans between passes.
RPSEA 3300-05 Program: Phase I Simulation Lab Run Results – Change Detection

Successful Detection of Large Scale Anomaly Types  
Successful Import & Display of Platform Inspection Data into ArcGIS Tool

- Bent Members Detected
- a priori Model
- Sonar-based Scanned Model
- Detected Positive Anomalies
- Detected Negative Anomalies
RPSEA 3300-05 Program: Phase I
Marlin™ AUV Launch – Feb 2, 2011
RPSEA 3300-05 Program: Phase I
GoM Sonar Data Collection – Risk Mitigation

• Collected **Ship mounted** 3D sonar data on various oil & gas platforms in the Gulf of Mexico for Perception algorithm evaluation & risk mitigation (model building & pose estimation)
RPSEA 3300-05 Program: Phase I
Initial Results: 3D Models Built from GoM Sonar Data

Fixed Platform ~ 80 ft.

3D Sonar Imagery

Resulting 3D model

Sonar Data Set Represents One Pass Around Platform at a Single Depth
RPSEA 3300-05 Program: Phase I
Initial Results: 3D Models Built from GoM Sonar Data

Sonar Data Set Represents One Pass Around Platform at a Single Depth
RPSEA 3300-05 Program: Phase I
Local Offshore Testing (Palm Beach, Florida)

- Conducted Initial Data collection Runs (30 meter offset) on an Offshore Structure of Opportunity (Cross Current Barge Reef) and Generated Coarse Model from 3D Sonar Data

- Conducted Model Building Runs (15 meter offset) on an Offshore Structure of Opportunity (Cross Current Barge Reef) and Generated Higher Resolution Base (a priori) Model to be used for Inspection/Change Detection Runs
RPSEA 3300-05 Program: Phase I Local Offshore Testing (Palm Beach, Florida)

- Introduced Changes into the Base (*a priori*) Model and Conducted Inspection Runs (15 meter offset) to Detect/Localize Changes
RPSEA 3300-05 Program: Phase I Project Deliverables

Status of Project Deliverables:

- Project Status Reports
  - Oct 2010 Report – 7 Oct (Delivered)
  - Nov 2010 Report – 8 Nov (Delivered)
  - Dec 2010 Report – 7 Dec (Delivered)
  - Jan 2011 Report – 14 Jan (Delivered)
  - Feb 2011 Report – 7 Feb (Delivered)
  - Mar 2011 Report – 7 Mar (Delivered)
  - Apr 2011 Report – 7 April (Delivered)
  - May 2011 Report – 7 May (Delivered)
  - June 2011 Report – 7 June (Delivered)
  - July 2011 Report – 7 July (Delivered)

- Project Management Plan (Draft) – 10 Oct (Delivered)
- Project Management Plan (Final) – 16 Nov (Delivered)
- Technology Status Assessment Report – 10 Oct (Delivered)
- Technology Transfer Plan – 24 Oct (Delivered)
- Integration Test Plan (Draft) – 29 Nov (Delivered & Approved w/Comments)
- Integration Test Plan (Final) – 14 Jan (Delivered)
- Final Test Report (defining the results of the test program) – 31 Jul
RPSEA 3300-05 Program: Phase II GoM Demonstration Objectives

**Demonstrate Inspection of US Gulf of Mexico Platform**
- In cooperation with a major oil and gas company conduct a demonstration of a platform inspection

**Capability Demonstrated**
- Baseline inspection
- Introduce physical changes and re-inspect
- Demonstrate API TRL level 5 capability
  - Mission planning & execution
  - Operational safety
  - Ability to operate in typical Gulf of Mexico conditions
  - Autonomous inspection
  - Autonomous change detection
  - Feature based navigation
  - Post inspection analysis
  - Launch and Recovery from a Typical Support Vessel
RPSEA 3300-05 Program: Phase II GoM Demonstration Scope of Work

LM Scope of Work:

- GoM Demo Test Procedures
- System Mobilization / Demobilization
- On Board Demonstration Testing & Evaluation
- RPSEA Project Reporting & Documentation

Major Oil Company Scope of Work:

- Test Planning Support
- Demonstration Support (includes provision of the vessel, equipment, facilities, personnel, services and technical information)

A Major Oil Company is Sponsoring the RPSEA 3300-05 Phase II GoM Trials, Supplying Key Personnel, Vessel Services, and Access to Offshore Facilities
## RPSEA 3300-05 Program: Phase II Schedule GoM Demonstration

### 3300-05 PROGRAM (Phase I)
Autonomous Inspection of Subsea Facilities

<table>
<thead>
<tr>
<th>Activity</th>
<th>2010</th>
<th>2011</th>
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<tbody>
<tr>
<td>GoM Demo</td>
<td>In 24</td>
<td>In 16</td>
</tr>
<tr>
<td>Test Procedure Development</td>
<td>Jun</td>
<td>Jul</td>
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<tr>
<td>Gom Testing/Demo Readiness Reviews</td>
<td>Aug</td>
<td>Sep</td>
</tr>
<tr>
<td>Pack/Ship/Mob/Shakedown</td>
<td>Oct</td>
<td>Nov</td>
</tr>
<tr>
<td>Testing (GoM)</td>
<td>Dec</td>
<td>Jan</td>
</tr>
<tr>
<td>Demo Execution (GoM)</td>
<td>Feb</td>
<td>Mar</td>
</tr>
<tr>
<td>Contingency/Demob/Pack/Return Ship</td>
<td>Apr</td>
<td>May</td>
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### Offshore Testing is Underway and Progressing Ahead of Schedule
Technical Progress is Outstanding

**Launch of Lockheed Martin Marlin™ AUV for Offshore Platform Inspection Mission**

**Lockheed Martin Marlin™ Equipment Mobilized Onboard ACO Jessica Moore**
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(Cell) 561-662-5742