Luna Innovations Incorporated

Processes for Condition Monitoring and Prognostics at the Sensor Node

Luna Innovations Incorporated (Luna) has developed a framework to design, test and deploy condition monitoring computational processes that track the health of shipboard equipment. Signal processing and modeling techniques are robust, efficient and tailored to conserve energy when run on battery-powered sensor nodes like Luna’s condition-based maintenance hardware. This allows nodes to operate as edge computing resources that diagnose faults locally, report relevant damage features or transmit entire data histories for higher fidelity models that operate on shipboard computers to verify predictions and reduce risk. Performance has been demonstrated for the Navy through relevant environment testing, using both industrial and submarine-grade equipment in partnership with the original equipment manufacturer of hydraulic systems. The ultimate goal is to inform maintenance practices and lower total ownership costs.

Technology Category Alignment:

Satellite Communications (SATCOM)
Robotics/Automated Material Handling Equipment
Shipyards/Shipbuilding
Supply; Storage
Satellite Communications (SATCOM)
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Supply; Storage
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Satellite Communications (SATCOM)
Satellite Communications (SATCOM)
Shipyards/Shipbuilding
Robotics/Automated Material Handling Equipment
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Robotics/Automated Material Handling Equipment
Robotics/Automated Material Handling Equipment
Protection, Sustainment, and Warfighter Performance
Medical Chem-Bio Defense
Military Infectious Diseases
Propulsion and Extreme Environments
Fixed Wing Vehicles (includes UAS)
Survivability
Maintainability/Sustainability
Unmanned Ground and Sea Vehicles
Corrosion
Advanced Computing/Software Development
Networks and Communications
Modular/Open/Reconfigurable Architectures
RF Components for sensing, transmission and communication
Electronics Integration
Broadband/Multispectral Components and Systems
Sensors, Electronics and Photonics
Radio Frequency (RF) (non-EW)
Survivability
Broadband/Multispectral Components and Systems
RF Components for sensing, transmission and communication
Radio Frequency (RF) (non-EW)
Networks and Communications
Guidance, Navigation & Control (GN&C) and Data Links
RF Components for sensing, transmission and communication
Networks and Communications
Cognitive/Adaptive Capabilities
Preemptive/Proactive Effects
Broadband/Multispectral Components and Systems
Advanced Computing/Software Development
Networks and Communications
Personalized Assessment, Education, and Training
System Interfaces & Cognitive Processes
Aircraft Propulsion, Power and Thermal
Modeling, Simulation & Test Infrastructure
Rotary Wing Vehicles
Fixed Wing Vehicles (includes UAS)
Fixed Wing Vehicles (includes UAS)
Acoustic, Seismic and Magnetic
Rotary Wing Vehicles
Structures and Protection
Energy storage
Unmanned Ground and Sea Vehicles
Mobility
Power and Energy
Synthesis/Analytics/Decision Tools
Information Collection/Management
Advanced Computing/Software Development
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Power Generation/Energy Conversion
Energy storage
Power and Energy
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Maintainability/Sustainability
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Microelectronics and Nanoelectronics
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None

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SYSCOM: NAVSEA
Contract: N00024-17-C-4008

Corporate Brochure: https://navystp.com/vtm/open_file?type=brochure&id=N00024-17-C-4008

Tech Talk: https://atsi.adobeconnect.com/pr4a9ty17e3q/
Department of the Navy SBIR/STTR Transition Program
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Naval Surface Warfare Center Port Hueneme Division

**WHO**

**SYSCOM:** NAVSEA  
**Sponsoring Program:** PMS 450  
**Transition Target:** PEO Submarines  
**TPOC:** (215)897-8358

**Other transition opportunities:** Unmanned underwater vehicles, weapon system survivability, hull and mechanical equipment for military and commercial ships, and naval systems.

**Notes:** Luna Innovations has developed an embedded CBM technology for diagnostics of hydraulic valve and pump actuation in partnership with the Army Corps of Engineers.

**Contact:** Kevin M. Farinholt, Senior Research Engineer  
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**WHAT**

**Operational Need and Improvement:** The U.S. Navy is investing in new technologies to monitor the health and performance of machinery onboard submarines and surface ships. These tools inform CBM+ to improve operational availability and reduce maintenance cost through condition assessments that drive overhaul and repair schedules. Widespread adoption requires robust and efficient models and software that can run on low-power sensing hardware. Luna has developed a framework to design, test and deploy eCBM algorithms that can be implemented using battery powered electronics.

**Specifications Required:** The Navy is seeking to develop computational processes that correlate transient and steady-state operational condition of equipment to known and predictive failure modes. Algorithms must be suitable for processors that capture data at the equipment level where sensor nodes are used to wirelessly communicate with network resources. Models need to track damage state and accumulation for core shipboard operations like, but not limited to, actuation of valves and engines, linear and rotary actuators, pumps, motors or compressors.

**Technology Developed:** Luna’s eCBM process development environment provides the ability to design, test and deploy data processing and classification algorithms using embedded wireless sensor nodes. The framework allows users to analyze features from a range of sensors and apply computationally efficient models that can be compiled and deployed using battery powered sensing hardware. Extensive laboratory experiments have shown these algorithms can accurately assess equipment health, damage type and extent, and failure severity. Tests have been performed on industrial and Navy grade valves and actuators in support of the original equipment manufacturer (OEM).

**Warfighter Value:** CBM enabled equipment will perform self-inspections, monitor for known failure modes and inform maintenance schedules to minimize time spent in depot. This will increase operational availability, reduce maintenance cost and allow warfighters to focus on mission-related objectives through automation of routine inspections.

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**WHEN**

**Contract Number:** N00024-17-C-4008  
**Ending on:** December 31, 2019

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Risk Level</th>
<th>Measure of Success</th>
<th>Ending TRL</th>
<th>Date</th>
</tr>
</thead>
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<tr>
<td>Develop framework to identify data features and generate machine learning algorithms for damage classification</td>
<td>N/A</td>
<td>Provide workshop to NSWC personnel</td>
<td>3</td>
<td>April 2017</td>
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<tr>
<td>Perform failure mode analysis of industrial rotary hydraulic actuators with multiple damage states and severities</td>
<td>N/A</td>
<td>Datasets with baseline and damage states</td>
<td>4</td>
<td>June 2018</td>
</tr>
<tr>
<td>Perform relevant environment testing on Navy grade actuator in partnership with OEM</td>
<td>N/A</td>
<td>Model prediction using embedded sensor nodes</td>
<td>5</td>
<td>March 2019</td>
</tr>
<tr>
<td>Extend data collection, analysis and modeling approach to linear hydraulic actuator</td>
<td>Low</td>
<td>Accurate prediction of operating state</td>
<td>6</td>
<td>February 2020</td>
</tr>
<tr>
<td>Test performance on shipboard hydraulic components</td>
<td>Med</td>
<td>Accurate prediction of operating state</td>
<td>7</td>
<td>December 2020</td>
</tr>
</tbody>
</table>

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**HOW**

**Projected Business Model:** Luna’s goal is to deliver robust condition monitoring systems that inform maintenance decisions for critical equipment and machinery. The technical and commercial development team is working to market the eCBM line of technology to complement our existing products in corrosion monitoring. Luna supports low-rate production and will use the process development framework to generate software and firmware that will provide intelligent sensor nodes that can locally diagnose and predict equipment health. Luna is also working with OEMs and system integrators to discuss licensing of the eCBM technology to provide detection of equipment health, condition-based maintenance and alert operators of maintenance needs. Luna is also pursuing licensing options with the Navy to determine how the process development environment can be used to analyze and model existing data streams already being generated by shipboard equipment.

**Company Objectives:** Luna’s creative scientists and engineers collaborate with prime contractors, government, industry and federally funded R&D centers and universities, advance R&D and provide the technology to customer needs. Luna’s Performance Systems and Analytics group focuses on advanced, high performance sensors and measurement technologies for extreme environments and long operational life to improve safety, reliability and operating cost. Luna is at the forefront of corrosion monitoring technologies, and the eCBM technology will expand our presence in equipment health monitoring. Luna has established strong relationships with prime integrators and original equipment manufacturers, and we are actively discussing how the eCBM can be integrated into new equipment designs.

**Potential Commercial Applications:** Luna’s eCBM technologies will provide local health monitoring capabilities for a variety of equipment systems used by defense, industrial and energy customers. Direct applications would include hydraulic actuators used in dams and navigational locks, oil and gas drill rigs and off-shore platforms as well as military and commercial ships. The technology can also be used to monitor HVAC systems and equipment used in government, commercial and private facilities.

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