Damage Detection and Verification System (DDVS) for In-Situ Health Monitoring

PROBLEM / NEED BEING ADDRESSED

There is a need for the assessment and image characterization of damage for monitoring structural system health. The problem that is being addressed is the detection, inspection, and characterization of damage caused by Orbital Debris (OD) and Micrometeoroid (MM) impacts through the development of the DDVS. DDVS is an integrated damage detection system with autonomous inspection capability which can be used to detect OD and MM damage in an ISS environment.

PROJECT DESCRIPTION/APPROACH

Establish the concept of operations, formulate design requirements for a potential ISS flight experiment, and develop a preliminary design of an autonomous inspection system that will be demonstrated as a 1st generation ground based damage detection and inspection system.

- Develop concept of operations and requirements documentation for an integrated approach of designing and developing a Damage Detection and Verification System (DDVS).
- Technology concepts will include an imaging system for autonomous inspection and verification of damage in combination with a sensory panel architecture that is able to locate and identify damage size and could be demonstrated as an external ISS Flight Releasable Attachment Mechanism (FRAM) flight experiment.
- Ground-based testing will be used to verify and validate the imaging inspection requirements. A 1st generation demonstration in a relevant environment will be conducted in FY15 leveraging other KSC project capabilities with existing sensory panels designs and the Advanced Inspection System (AIS) robotic camera.
- The robotic camera system along with upgraded computer vision and image processing software will be used to analyze the physical features of the current existing sensory panels to determine and verify damage location and certain physical characteristics such as size.
- Feasibility studies for flexible circuitry use in sensory panel architecture and system modeling tools will also be conducted.

QUANTITATIVE IMPACT

- Reduces the cost of OD and MM damage detection monitoring
- Could significantly reduce life cycle cost and increase safety and system reliability
- Technology demonstration that could close gaps needed for future missions
- Significant impacts for in-situ health monitoring for deep space exploration and habitation missions, as well as satellites, military, and commercial aviation needs

PROJECT GOAL

- Establish the concept of operations and architectural design
- Formulate system requirements
- Develop a preliminary design of an autonomous inspection/capability system.
- Demonstrate a proof-of-concept, preliminary ground-based damage detection and inspection system using imaging processing software upgrades.
- The proof of concept demonstration will raise the TRL of this technology (sub-systems) from a 3 to a 4.

2015 GCD MYR
Detection and Verification System (DDVS) expands the Flat Surface Damage Detection System (FSDDS) sensory panels’ damage detection capabilities and includes an autonomous inspection capability utilizing cameras and dynamic computer vision algorithms to verify system health. Objectives of this formulation task are to establish the concept of operations, formulate the system requirements for a potential ISS flight experiment, and develop a preliminary design of an autonomous inspection capability system that will be demonstrated as a proof-of-concept ground based damage detection and inspection system.

### Integration with other projects/programs and partnerships
- Early development of FSDDS technology was funded by KSC IRTD and AES programs
- AES and KSC R&T investment funds
- KSC intellectual property, patent application and actions with Patent council and Technology transfer office
- JSC for potential ISS flight experiment opportunity
- LaRC for potential partnership with MASH in out years

### Technology Infusion Plan:
- Potential customer: AES, ISS flight experiment, commercial and military uses
- Technology development and demonstration – in-situ damage detection and verification system
- Who is the infusing potential customer: STMD, AES, Technology Demonstration Mission (TDM), and Space Mission Directorate (SMD)
- Anticipated uses: future aircraft, inflatables and habitation, military and industry

### Key Personnel:
- **Program Element Manager:** Kevin Kempton
- **Project Manager:** David Moore LaRC/Nancy Zeitlin (KSC)
- **Lead Center:** KSC, Martha Williams, Ph.D. and Mark Lewis/PI/PM/System Architect
- **Supporting Centers:** LaRC/LMAM
- **NASA NPR:** 7120.8
- **Guided or Competed:** Guided
- **Type of Technology:** Push

### Key Facts:
- **GCD Theme:** LMAM
- **Execution Status:** Year 1 of 3
- **Technology Start Date:** February 2015
- **Technology End Date:** September 2015
- **Technology TRL Start:** 3
- **Technology TRL End:** 4
- **Technology Current TRL:** 3
- **Technology Lifecycle Phase:** Formulation
Damage Detection and Verification System (DDVS) and Key Members

Principal Investigator/Project Manager:
Martha K. Williams, Ph.D.

System Architect: Mark Lewis

Software Imaging Processing: J. Szafran and C. Shelton

Flexible Circuitry: L. Ludwig

System Requirements (also leveraged KSC R&T funds) - T. Gibson, Ph.D. and J. Lane, Ph.D. and T. Trautwein

NASA KSC DDVS
**Program Milestones**

1.0 Project Management

2.0 Health Monitoring Concepts

2.1 System Concepts Requirements

2.2 Autonomous Design

3.0 Ground System Demonstration

3.1 Test Requirements

3.2 Imaging Process/Computer Vision Demo

**FY2015 Milestone Schedule**

<table>
<thead>
<tr>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>Feb</td>
<td>Mar</td>
</tr>
</tbody>
</table>

- **Task Agreement Complete 1-22-2015**

- **High-level Design of FLEX-DSVS System Complete 3/2015**

- **90% ConOps Complete 3/2015**

- **9/2015 GCD Quarterly Status Review**

- **Close-out Report 9/2015**

- **90% Design Requirements Document Complete 9/30/2015**

- **Initial Software Complete 8/2015**

- **Draft Proposal for Flight Consideration 8/2015**

- **Preliminary Test Plan Complete 9/2015**

- **Preliminary Ground Demonstration 9/15/2015**

**Status as of 5/31/2015**

- **GCD End Year Review 10/2015**

- **Milestone Slip**

- **Project Key Milestones Complete**

- **Project Milestones Deliverables Complete**