Assessing the Impact of Development Disruptions and Dependencies in System-of-Systems
Technical Report SERC-2015-RT-134
30th November 2015

Principal Investigator: Dr. Daniel A. DeLaurentis, Purdue University
Co-Principal Investigator: Dr. Karen Marais, Purdue University

Team Members
Navindran Davendralingam (Research Scientist)
Zhemei Fang (PhD Candidate)
Cesare Guariniello (PhD Candidate)
Demetrios Katsaduros (Undergraduate Assistant)
Yiqing Ding (Undergraduate Assistant)
Parth Shah (Graduate Student)
SUMMARY OF RT-134 ACHIEVEMENTS

Our work under RT-134 has resulted in an initial, functional concept for a SoS analytic workbench (SoS AWB) that uses a suite of computational tools to facilitate better informed decision-making for SoS architectural evolutions; the tools include: **(SODA/SDDA)** – System Operational Dependency Analysis/System Developmental Dependency Analysis, **MUSTDO** – Multi-Stakeholder Dynamic Optimization, **SIMs** – System Importance Measures, and **RPO** – Robust Portfolio Optimization.

The workbench provides a means of addressing SoS practitioners’ ‘archetypal questions’ in scenarios where size and/or interdependencies between systems are high. The workbench also enables analysis of capability and risk during the conduct of SoS evolution as patterned after the WAVE model. Our primary and common use case demonstration problem involves a Naval Warfare Scenario (NWS) that is based on the architecture of the Littoral Combat Ship (LCS). Each of the tools has used this common case study to illustrate the value in each tool performing various types of SoS level architectural analysis. While continuing basic research on each of the methods, our FY15 effort emphasized transitioning of the AWB for test in practical settings. Our efforts have resulted in the following areas of coordination and dissemination (details of these have been documented in RT-134 bi-monthly reports):

<table>
<thead>
<tr>
<th>Output</th>
<th>Description of Dissemination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conference Publications</td>
<td><strong>CSER 2015</strong></td>
</tr>
<tr>
<td></td>
<td>“Multi-Stakeholder Dynamic Planning of System of Systems Development and Evolution” – Zhemei Fang and Daniel DeLaurentis <em>(Won Best Paper Award)</em></td>
</tr>
<tr>
<td></td>
<td><strong>2015 IEEE Systems of Systems Engineering (SoSE) Conference</strong></td>
</tr>
<tr>
<td></td>
<td>“A Perspective on Decision-Making Research in System of Systems Context” – Daniel DeLaurentis, Navindran Davendralingam and Michael Jacobs (Purdue University, USA)</td>
</tr>
<tr>
<td></td>
<td>“A Conditional Value-at-Risk Approach to Risk Management in System-of-Systems Architectures”, Navindran Davendralingam, Dan DeLaurentis and Parth Shah (Purdue University, USA)</td>
</tr>
<tr>
<td></td>
<td><strong>INCOSE Systems Engineering Journal (accepted)</strong></td>
</tr>
</tbody>
</table>
**Engagement/Interaction Summary**

**SERC** - We have been actively participating in the SERC Demonstration Lab prototype with Stevens, including successful completion of counterfeit parts demonstration exercise over the summer for SERC sponsor. We have also worked with SERC sponsor to engage with Army (ARL).

**MITRE**
1) We have received the final report of findings from MITRE on the AWB. We have continued improvements on developing the interface of our workbench, based on the tenets of MITRE report, towards our collaborative efforts with the Naval Surface Warfare Center Dahlgren Division (NSWCDD)
2) We have been selected by DoD JOMIS program to be the one SERC-generated capability to be pilot tested by MITRE for use on MITRE’s execution of the JOMIS project.

**Naval Surface Warfare Center Dahlgren Division (NSWCDD)**
With our CRADA finalized with Navy NSWCDD, we made substantial progress (with Dahlgren POC Mary Ann Cummings) including the following:

- Series of phone calls on demos to establish understanding and requirements for use of the SoS AWB at Dahlgren.
- Hosted three Dahlgren persons (Mary Ann Cummings, Dahlgren engineer, and co-op) at Purdue Oct. 14-15 for in-depth, two-day deep dive demo and training on using the SoS AWB.
- Dahlgren has shared a missile defense case study that both sides can now work to configure for experimentation in SoS AWB (and further, investigate the synergy between the AWB and Dahlgren’s OSM agent-based simulation environment).
- Together, both sides continue to define and document outcomes from the experimentation/pilot evaluation, to continue into FY16.

**Software Dissemination and NanoHub Deployment**
We have made prototype version of our tools available through the nanohub.org portal, hosted here at Purdue University. The team worked on the development and compilation of tools for the hub environment, including necessary edits to relevant toolsets and GUI interfaces, to facilitate compatibility in this hosted environment. We have 15 users thus far, with a total of ~180 runs of the SoS AWB. (Please see attached file: nanohub-Dashboard-proof.pdf for global usage report and simulation runs statistics of our toolset) User can utilize the prototype version of tools by signing up for a free account at nanohub.org and looking for the System of Systems Analytic Workbench set of tools. Additionally, we are delivering a copy of our software to the DoD SERC, in accordance with the terms of our statement of work.
In summary, we have made progress in refining methods/fixing bugs through interactions with collaborator entities using demonstrative versions of our SoS AWB. Currently, we are focused on getting appropriate outputs from simulation and consolidating structuring of the various methods into an analytical workbench framework. We have a workbench 'concept of use' document that we are working on that is to be further reviewed and refined based on continued interaction with sponsors and collaborators.

I. **Guide to the Various Products attached to the Summary Final Report**

- **Papers**

- **Code documentation**
  - SODA_GUI_Manual.docx: description of the Graphic User Interface for SODA analysis, including possible inputs, choice of methods, resulting plots, output files.
  - SDDA_GUI_Manual.docx: description of the Graphic User Interface for SDDA analysis, including possible inputs, choice of methods, resulting plots, output files.
  - RPO_Manual_New_Version.docx: description of Graphic User Interface for Robust Portfolio Optimization toolset, including required inputs, choice of methods, output numbers and plots and other pertinent information.
  - MUSTDO_GUI_Manual.docx: description of the Graphic User Interface for MUSTDO framework, including possible inputs and resulting plots.

- **Technical Summaries of Methods**
  - SIMS: Development and Initial Implementation of SIMs, UdayEtAlNov2015.pdf
  - SODA/SDDA
    - SODA_SDDA_basics.pptx: Powerpoint presentation of the basics of SODA and SDDA, including motivation, goals, and applications.
  - RPO
    - RPO_basics.pptx: Powerpoint presentation on basics of 3 RPO sub-methods, including motivation, goals and applications.
  - MUSTDO
    - MUSTDO-Methodology.docx: summary of the MUSTDO methodology, including motivation, method description and applications.