



# Systems Engineering Research Center (SERC)

## Collaborator WebEx

May 6, 2015

This material is based upon work supported, in whole or in part, by the U.S. Department of Defense through the Systems Engineering Research Center (SERC) under Contract H98230-08-D-0171. The SERC is a federally funded University Affiliated Research Center (UARC) managed by Stevens Institute of Technology consisting of a collaborative network of over 20 universities. More information is available at [www.SERCuarc.org](http://www.SERCuarc.org)

- Old Business
  - Actions, Comments, and Questions from April 2015 Collaborator WebEx
- Program Development Update
- Research Task Status Update
  - New Research Tasks Awarded
- Upcoming Conferences and Events
- Technical Presentation: RT-134: Updates on RT-134: Purdue SoS Analytic Workbench, Presented by PI: Dan DeLaurentis, Associate Professor, Aeronautics and Astronautics Director, Center for Integrated Systems in Aerospace, Purdue University

- SERC Program Development Sponsor Liaisons
  - Congratulations to Tommer Ender and the Georgia Tech team – recent SERC task awarded from US Army ERDC in excess of \$1M
  - Upcoming award to Gary Witus at Wayne State from TARDEC for “SE M&S Integration Framework in the Digital Thread”
  - Still need Liaisons
    - DoD COIs: Autonomy, C4I, Cyber, Materials and Manufacturing Processes
    - BBP 3.0: Prototyping and Experimentation, Technology Insertion and Refresh in Program Planning
    - US Army RDECOM – ARDEC, CERDEC
    - US Navy – NAVAIR, NAVSEA, ONR, SPAWAR
    - US Air Force – Air Force Materiel Command, AFRL
- SERC Website
  - Doctoral Fellows page is live (under *People / SERC Doctoral Fellows*)
  - Working on SERC Doctoral Fellows Program description and information pages
  - Pending updates:
    - Job / Employment Opportunities
    - Undergraduate Research Opportunity Marketplace
- Communications
  - News articles for SERC website
  - SERC Quarterly Newsletter
    - Spring 2015 newsletter soon to be released

- Program Development Opportunity Updates
  - Office of Nuclear Regulatory Research, Nuclear Regulatory Commission
    - Interests in a Roadmap for Assurance Capability (of Cyber-Physical Systems) for Nuclear Power Plants
    - Discussions started between SERC PIs and NRC POC; Scoping first Research Task
  - U.S. Army Tank Automotive Research Development and Engineering Center (TARDEC)
    - Received budget/funding from ASA(ALT)
    - Research opportunities in “Autonomy Systems Engineering”
  - Department of Homeland Security (DHS)
    - Interagency agreement (IAA) delayed until first RT is identified (in process now)
    - High interest in Human Factors as related to Systems Engineering
  - US Veterans Administration
    - VA Center for Applied Systems Engineering (VA-CASE)
      - IAA still in process; First RT will involve Helix research
    - Future research opportunities involve “Healthcare Systems Engineering”
    - Current (internal) Request for Application re: Advancing Operations Research to Enhance Learning Healthcare System Initiatives
  - Energy-related Security with DOE [*Stagnant*]
    - Exploring opportunities with UTK Institute for Nuclear Security (INS) and National Nuclear Security Administration (NNSA)
    - Interested SERC Collaborators include Georgia Tech, Purdue, and Texas A&M
  - National Oceanic and Atmospheric Administration/National Weather Service (NOAA/NWS) and Office of the Federal Coordinator for Meteorology (OFCM)
    - Program Development meeting set for Tuesday, May 19

- Newly Awarded Tasks:
  - RT 140: Advanced Technical Leadership (Pennotti, Stevens)
- Pending Tasks
  - RT 114: Strategic Planning Science & Technology (Dillon-Merrill, Georgetown University)
  - RT 136: Security Engineering (Horowitz, UVa)
  - RT 146, continuation of RT-123: Experience Accelerator (Wade, Stevens)

# Upcoming Conferences and Events

START DATE	END DATE	EVENT	LOCATION	WEBSITE
5/4/2015	5/8/2015	WICSA 2015, 12th Working IEEE/IFIP Conf. Software Architecture	Montreal, Canada	<a href="http://www.wicsa2015.org">www.wicsa2015.org</a>
5/17/2015	5/20/2015	10 <sup>th</sup> International Conference on System of Systems Engineering (SoSE)	San Antonio, TX	<a href="http://sosengineering.org/2015/">http://sosengineering.org/2015/</a>
5/16/2015	5/24/2015	28 <sup>th</sup> IEEE Conference on Software Engineering Education and Training (CSEE&T) held in conjunction with 37 <sup>th</sup> International Conference Software Engineering (ICSE)	Florence, Italy	<a href="http://stardock.cs.virginia.edu/cseet/2015/">http://stardock.cs.virginia.edu/cseet/2015/</a> <a href="http://www.2015.icse-conferences.org">/ www.2015.icse-conferences.org</a>
5/21/2015	5/23/2015	I3M 2015 - The 12th International Multidisciplinary Modeling & Simulation Multiconference	Bergeggi, Italy	<a href="http://www.msc-les.org/conf/i3m2015/index.htm">www.msc-les.org/conf/i3m2015/index.htm</a>
5/30/2015	06/2/2015	IIE Annual Conference and Expo 2015 and 2015 Industrial and Systems Engineering Research Conference (ISERC)	Nashville, TN	<a href="http://www.iienet.org/Annual2/">http://www.iienet.org/Annual2/</a>
6/1/2015	6/4/2015	3rd Nordic Systems Engineering Tour (NoSE)	Hamburg, Copenhagen, Stockholm, Helsinki	<a href="http://www.nordic-systems-engineering-tour.com/content/">http://www.nordic-systems-engineering-tour.com/content/</a>
6/4/2015	6/5/2015	Kongsberg Systems Engineering Event	TBA	<a href="http://ksee.no/?p=1757">http://ksee.no/?p=1757</a>
6/8/2015	6/12/2015	27 <sup>th</sup> International Conference on Advanced Information Systems Engineering (CAISE 2015)	Stockholm, Sweden	<a href="http://caise2015.dsv.su.se/">http://caise2015.dsv.su.se/</a>
6/14/2015	6/17/2015	ASEE 122nd Annual Conference & Exposition	Seattle, WA	<a href="http://www.asee.org/conferences-and-events/conferences/annual-conference/2015">http://www.asee.org/conferences-and-events/conferences/annual-conference/2015</a>
6/22/2015	6/26/2015	AIAA Complex Aerospace System Exchange	Dallas, TX	<a href="http://www.aiaa-aviation.org/">http://www.aiaa-aviation.org/</a>
6/22/2015	6/25/2015	83rd Military Operations Research Society Symposium	Alexandria, VA	<a href="http://www.mors.org/Events/Symposium/83rd-Symposium">http://www.mors.org/Events/Symposium/83rd-Symposium</a>
6/22/2015	6/23/2015	83rd MORS Symposium – Virtual	Virtual Sessions	<a href="http://www.mors.org/Events/Symposium/83rd-Symposium">http://www.mors.org/Events/Symposium/83rd-Symposium</a>
7/6/2015	7/8/2015	19 <sup>th</sup> International Conference on Industrial Engineering and Operations Management / International Institute of Industrial Engineers Conference 2015	Aveiro, Portugal	<a href="http://www.icieom.org/">http://www.icieom.org/</a>
7/13/2015	7/16/2015	INCOSE 25th Annual Symposium IS 2015	Seattle, WA	<a href="http://events.incose.org/">http://events.incose.org/</a>
8/2/2015	8/7/2015	59th Meeting of the International Society for the Systems Sciences	Berlin, Germany	<a href="http://www.isss2015berlin.com/">http://www.isss2015berlin.com/</a>
9/29/2015	9/30/2015	First IEEE International Symposium on Systems Engineering (ISSE)	Rome, Italy	<a href="http://ieeessse.org/">http://ieeessse.org/</a>
10/26/2015	10/29/2015	18th Annual NDIA Systems Engineering Conference	Waterford at Springfield, VA	<a href="http://www.ndia.org/meetings/6870/Pages/default.aspx">http://www.ndia.org/meetings/6870/Pages/default.aspx</a>
11/2/2015	11/4/2015	Complex Adaptive Systems Conference: Engineering Cyber Physical Systems: Machine Learning, Data Analytics and Smart Systems Architecting	San Jose, CA	<a href="http://complexsystems.mst.edu/">http://complexsystems.mst.edu/</a>

# Monthly Research Topic Presentation

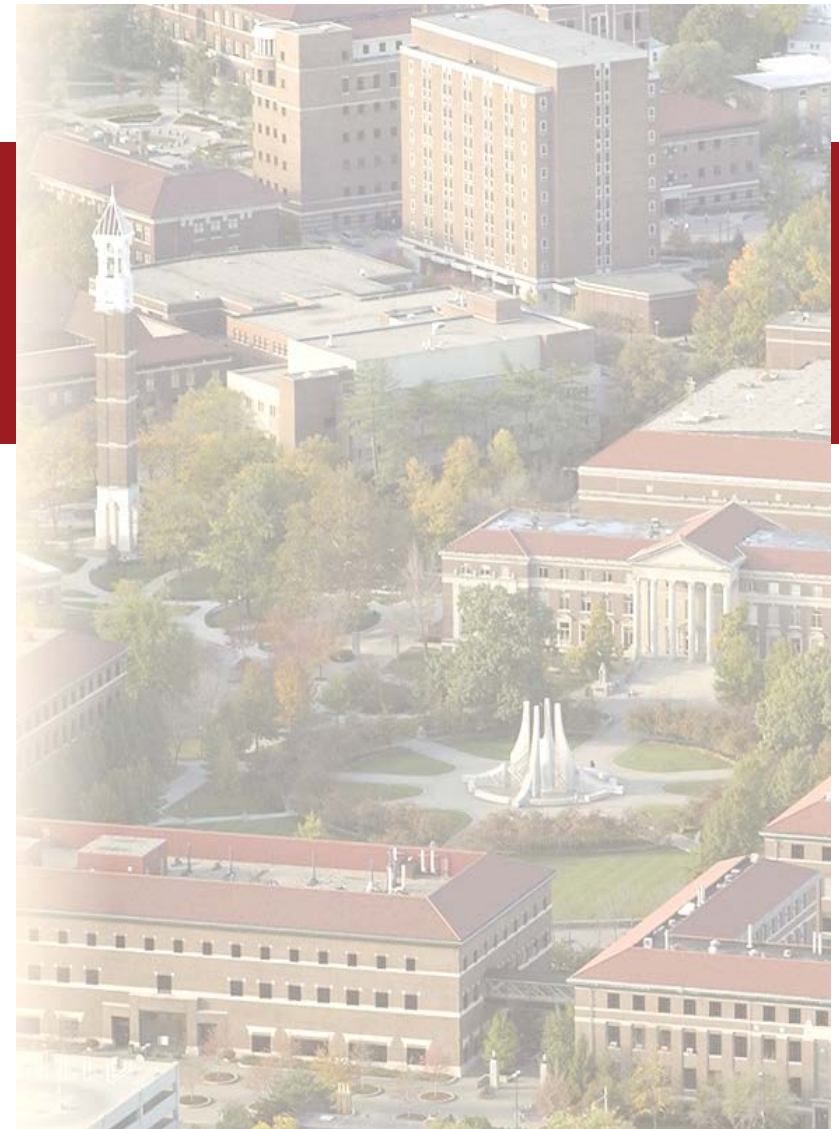
- Monthly Research Presentation Topic
  - **RT-134: Updates on RT-134: Purdue SoS Analytic Workbench;** Presented by PI: Dan DeLaurentis, Associate Professor, Aeronautics and Astronautics Director, Center for Integrated Systems in Aerospace, Purdue University
  - **Abstract:** RT-134 continues refinement and pilot testing of the SoS Analytic Workbench (AWB). This short update talk will briefly (very briefly!) review the SoS AWB concept and status followed by a reporting of insights and lessons learned from several pilot testing activities over the past year. The update will conclude with a glimpse of what lies ahead for the remaining project period.
- Looking for volunteers to present their research each month (Jun, Sep – Nov) of 2015
  - Summer (Jul, Aug) and Winter (Dec, Jan) typically have lower SERC Collaborator attendance at the WebEx, so no technical presentations are scheduled for these months
  - Contact Mitchell ([mkerman@stevens.edu](mailto:mkerman@stevens.edu)) or Mimi ([mmarcus@stevens.edu](mailto:mmarcus@stevens.edu)) if you would like to volunteer and get on the schedule



## RT-134: Analytic Workbench for System of Systems

**SERC Collaborator WEBEX**

Dan DeLaurentis,  
Karen Marais, Navin  
Davendralingam





- SoS Architectures are highly complex, with many interdependencies across diverse constituent systems
- Difficult to know how and when to add/remove/integrate systems or connections
  - Too big for one analyst
  - Too many contingencies and choices for simple tools
  - Too many stakeholders for top-down management

Pain Points	Question
<b>SoS Authority</b>	<i>What are effective collaboration patterns in systems of systems?</i>
Leadership	<i>What are the roles and characteristics of effective SoS leadership?</i>
<b>Constituent Systems</b>	<i>What are effective approaches to integrating constituent systems into a SoS?</i>
<b>Autonomy, Interdependencies &amp; Emergence</b>	<i>How can SE provide methods and tools for addressing the complexities of SoS interdependencies and emergent behaviors?</i>
<b>Capabilities &amp; Requirements</b>	<i>How can SE address SoS capabilities and requirements?</i>
<b>Testing, Validation &amp; Learning</b>	<i>How can SE approach the challenges of SoS testing, including incremental validation and continuous learning in SoS?</i>
SoS Principles	<i>What are the key SoS thinking principles, skills and supporting examples?</i>

Survey identified seven 'pain points' raising a set of SoS SE questions

*From: "Systems of Systems Pain Points", Dr. Judith Dahmann, INCOSE Webinar Series on Systems of Systems, 22-FEB, 2013*

**Can an organized set of Methods, Processes and Tools (MPTs), presented in a user-friendly way, solve these problems?**

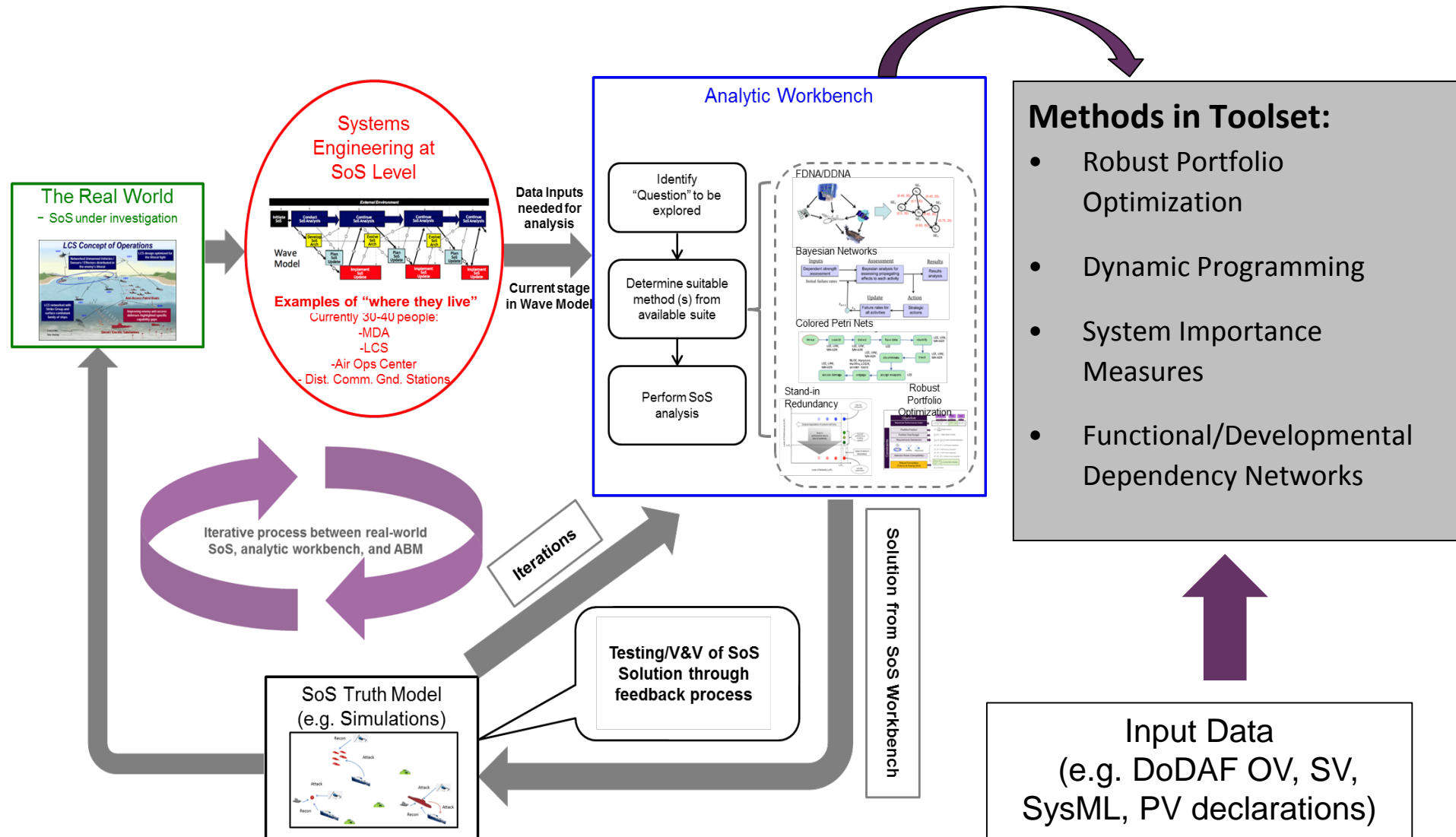
SERC RT-108/134 Projects have been pursuing this question

# Vision: A Useful SoS Analytic Workbench

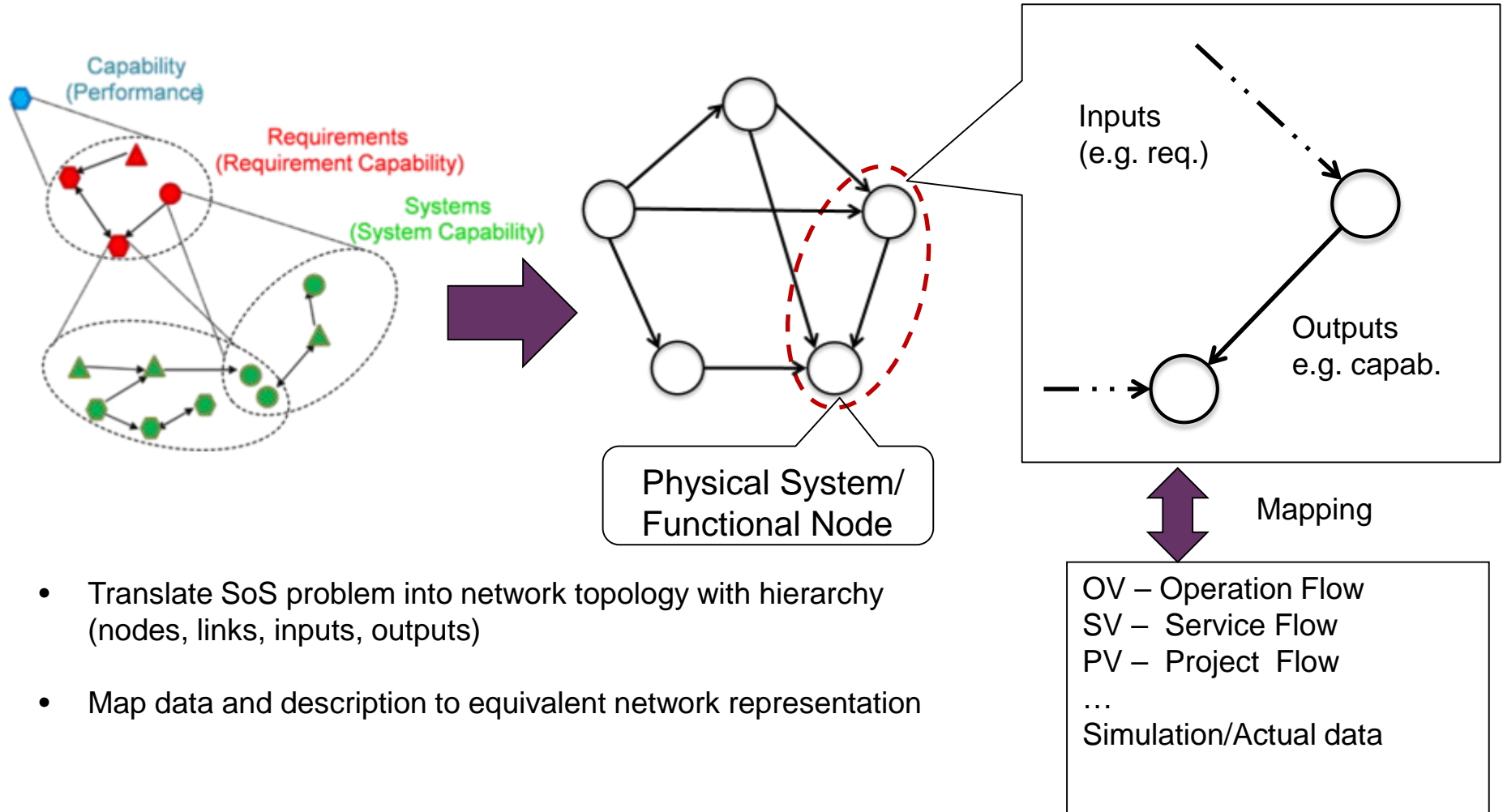
- Rational
  - Relegate complexities to methods
  - Delegate decision-making to users
- Open
  - Accommodates insertion of new SoS analytic methods (from Purdue or others)
- Interoperable
  - Outcomes produced in form suitable for additional SoSE phases
  - ‘Domain agnostic’, cross platform operations
  - Address uncertainty in data/simulation outcomes
- Useable
  - (Scalability) → reasonable scaling of computational need to problem sizes
  - (Ease of Use) → Users can translate problem to inputs required by relevant methods and tools



# Concept of Use: SoS Analytic Workbench



# Graph-basis Data Model / Representation



- Translate SoS problem into network topology with hierarchy (nodes, links, inputs, outputs)
- Map data and description to equivalent network representation



# Addressing the Archetypal Questions

Analyze and change a given architecture

System Importance Measures (SIMs)

Functional Dependency Network Analysis (FDNA/DDNA)

Analyze families of architectures

Robust Portfolio Optimization

Approx. Dynamic Programming

## • Capability

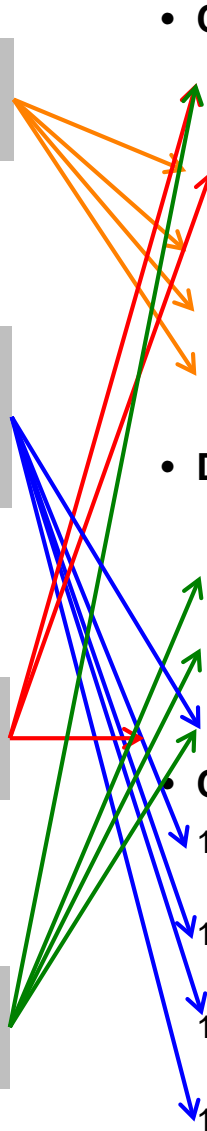
1. What combination of systems gives the desired aggregate SoS capabilities?
2. What changes to which systems offer the most (performance, resilience, etc.) leverage?
3. Which systems are critical to SoS performance? SoS risks?
4. Which parts of the SoS have excess or inadequate resilience?
5. Which design principles can improve SoS robustness and resilience?

## • Development

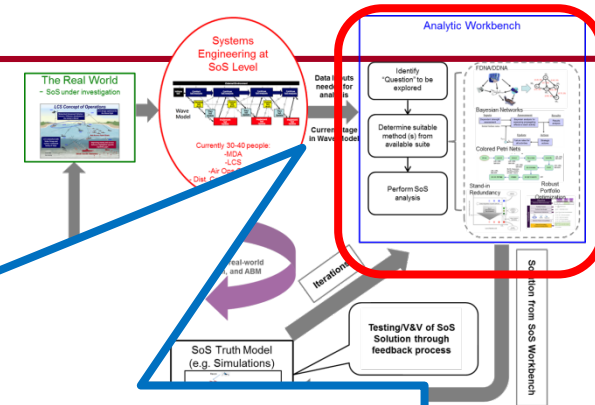
6. How do/should partial capabilities evolve over time?
7. How do we optimize multi-stage acquisitions in SoS development?
8. How do we coordinate planning between local and SoS-level stakeholders?
9. How do changes in system properties affect SoS development?

## • Critical System ID

10. What is the impact of partial/total system failures during operations?
11. What is the impact of partial/total failure of a system during development?
12. What are the most critical systems in a given operational (or developmental) network?
13. What is the impact of development delays in an interdependent network?



# Inputs for SoS Analysis

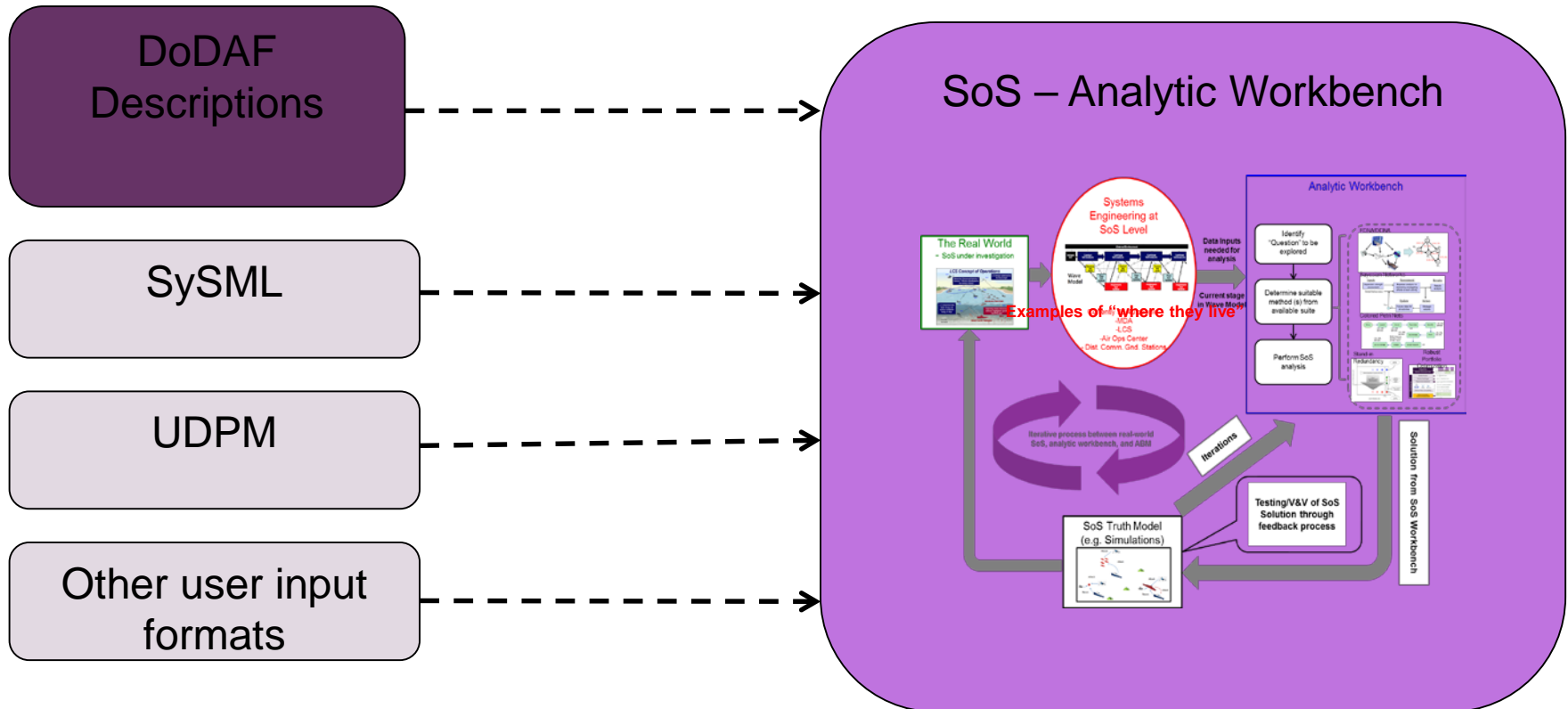


## Examining Current SoS AWB Methods

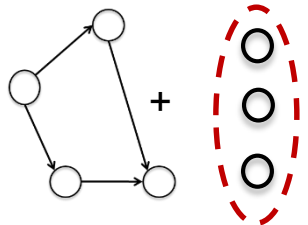
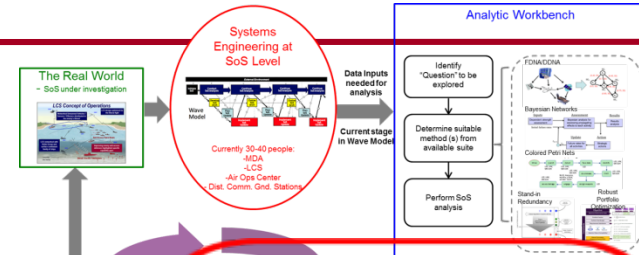
Translate user input into parameters of SoS AWB and data requirement

	User Input	AWB Parameter
<b>FDNA/DDNA</b>	Time to detect enemy / % of enemies detected	Operability
	Probability of radar node detecting an enemy	Self Effectiveness (SE)
	Scaled loss of operability when input missing	Strength of Dependency (SOD)
	Effects of total loss of input	Criticality of Dependency (COD)
<b>Robust Portfolio Optimization/ ADP</b>	Effective range of radar	System Capabilities
	Power req. of radar	System Requirements
	Types of compatible power supplies	System Compatibilities
<b>System Importance Measures</b>	Probability of radar loss	System Disruption Importance (SDI)
		System Recoverability Importance (SRI)

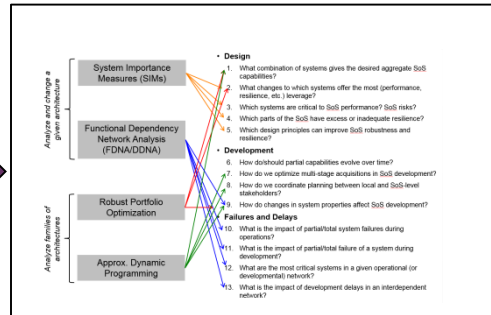
# Current and future input formats



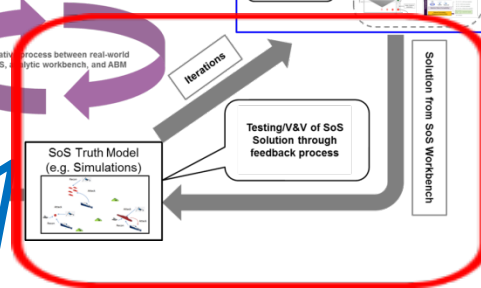
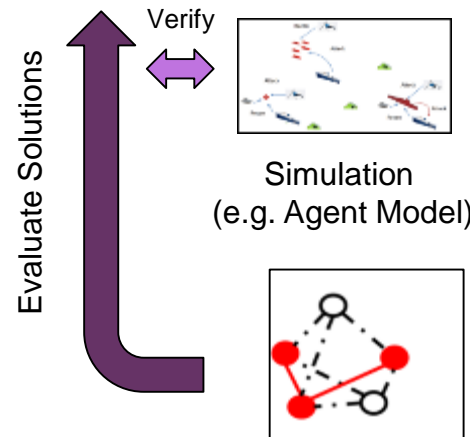
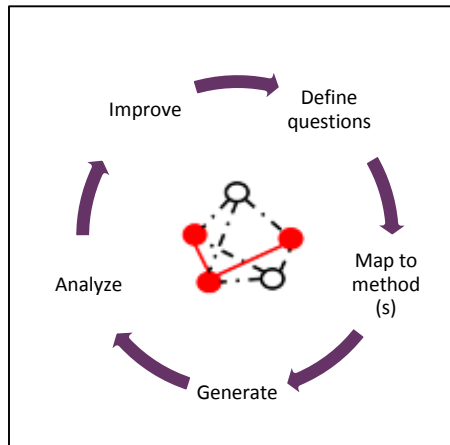
# Analysis & Verification



Initial  
Architecture + Candidates

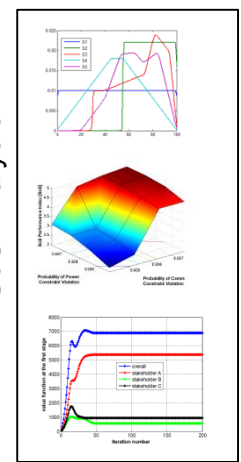


Map Questions & Data to Methods



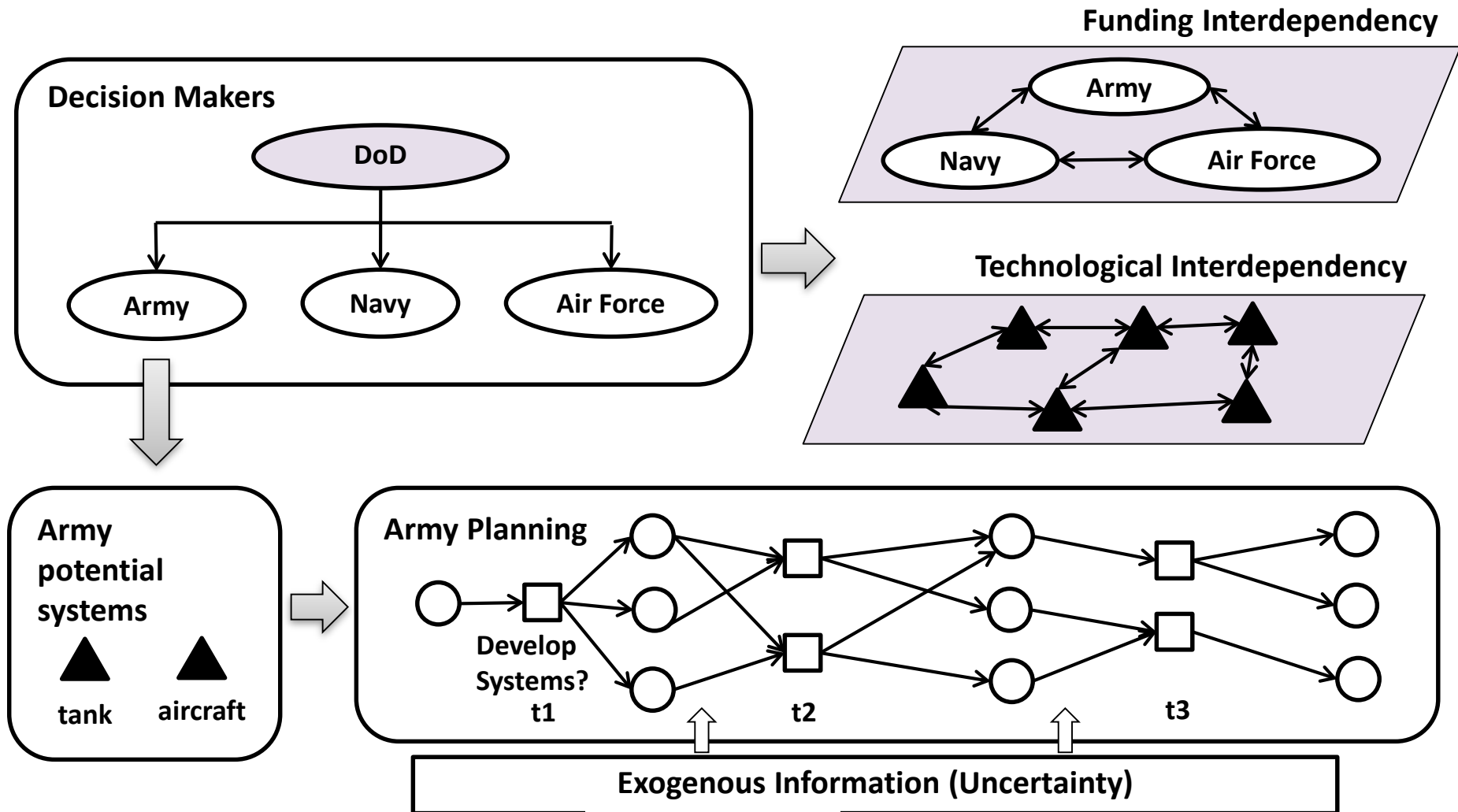
Iterative process to improve architecture

Use of simulation as a "truth model" and/or as data generator





# Multi-Stakeholder Dynamic Planning of System of Systems Development and Evolution- best student paper award, CSER 2015, Zhemei Fang



# SoS Analytic Workbench Demo. Software

Purdue SERC RT-108 Analytic Workbench Demonstration GUI Software  
Version: 30 November 2014

## User Manual for Analytic Workbench GUI

This manual aims at helping users learn the basic steps to conduct the analytic workbench Matlab GUI. It covers five methods, including Functional Dependency Network Analysis (FDNA), Development Dependency Network Analysis (DDNA), System Importance Measures (SIM), Robust Portfolio Optimization, and Decentralized Development Planning. Development and refinement of the workbench and tools within it are being continued under SERC RT-134.

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  - Option 1: Demo Scenario ..... 16
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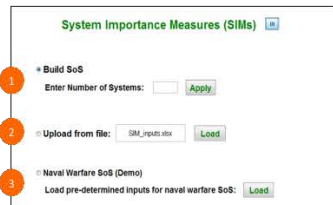
### System Importance Measures (SIMs)

- 1 Build SoS  
Enter Number of Systems:
- 2 Upload from file:
- 3 Naval Warfare SoS (Demo)  
Load pre-determined inputs for naval warfare SoS:

System SoS Capability	Sub-GP1	Sub-GP2	Sub-GP3	Power	Comm.	Req 1	Req 2
GeneralSystem1	0	0	0	100	0	0	0
GeneralSystem2	0	0	0	200	0	0	0
GeneralSystem3	0	0	0	400	0	0	0
GeneralSystem4	0	0	0	600	0	0	0
GeneralSystem5	0	0	0	800	0	0	0
GeneralSystem6	0	0	0	1000	0	0	0
SpecialSystem1	0	0	0	100	0	100	100
SpecialSystem2	0	0	0	200	0	200	200
SpecialSystem3	0	0	0	400	0	400	400
SpecialSystem4	0	0	0	600	0	600	600
SpecialSystem5	0	0	0	800	0	800	800
SpecialSystem6	0	0	0	1000	0	1000	1000
SpecialSystem7	0	0	0	100	0	100	100
SpecialSystem8	0	0	0	200	0	200	200
SpecialSystem9	0	0	0	400	0	400	400
SpecialSystem10	0	0	0	600	0	600	600
SpecialSystem11	0	0	0	800	0	800	800
SpecialSystem12	0	0	0	1000	0	1000	1000
SpecialSystem13	0	0	0	100	0	100	100
SpecialSystem14	0	0	0	200	0	200	200
SpecialSystem15	0	0	0	400	0	400	400
SpecialSystem16	0	0	0	600	0	600	600
SpecialSystem17	0	0	0	800	0	800	800
SpecialSystem18	0	0	0	1000	0	1000	1000

# SoS Analytic Workbench Demo. Software

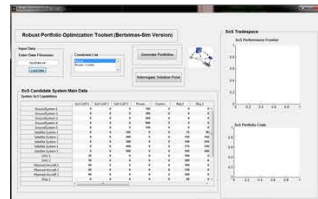
## System Importance Measures (SIMs)



System Importance Measures (SIMs)

- Build SoS  
Enter Number of Systems:  **Apply**
- Upload from file:  **Load**
- Naval Warfare SoS (Demo)  
Load pre-determined inputs for naval warfare SoS: **Load**

## Robust Portfolio Optimization

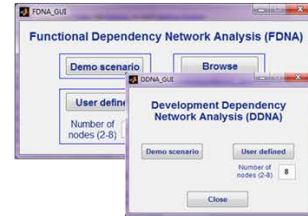


Robust Portfolio Optimization Toolset (Bertsimas-Sim Version)

System Not Guaranteed

System	SoS	SoS	SoS	SoS	SoS	SoS	SoS	SoS	SoS	SoS
System 1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
System 2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
System 3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
System 4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

## FDNA/DDNA



FDNA GUI

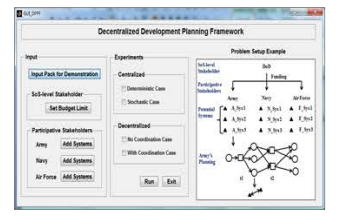
Functional Dependency Network Analysis (FDNA)

Development Dependency Network Analysis (DDNA)

Number of nodes (2-8)

Demo scenario | User defined

## Decentralized Planning (using ADP)



Decentralized Development Planning Framework

Input Pack for Demonstration

Experiments

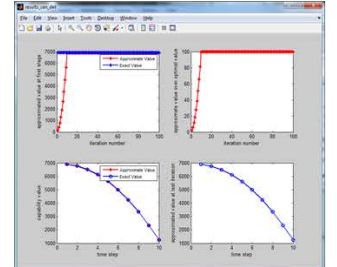
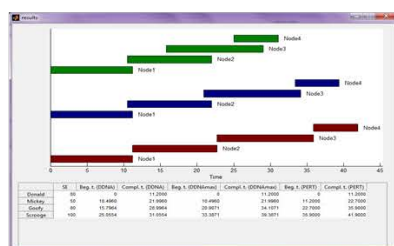
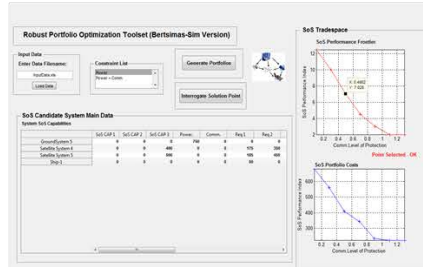
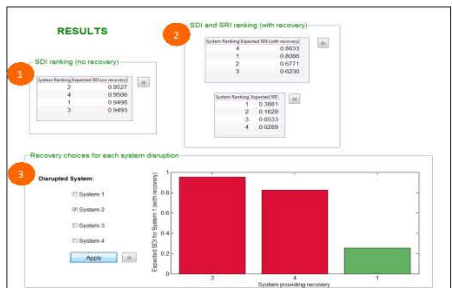
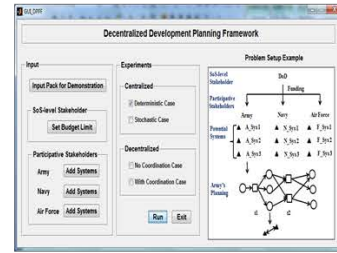
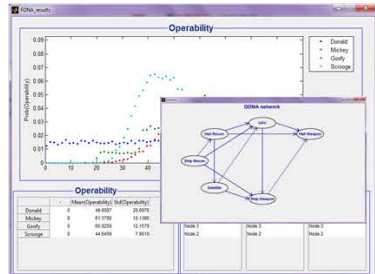
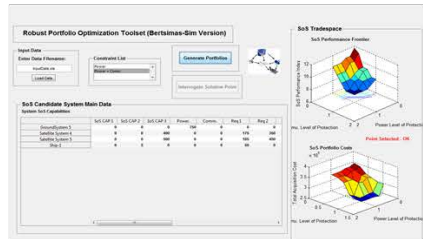
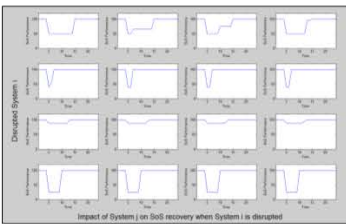
Centralized

- Deterministic Case
- Stochastic Case

Decentralized

- No Coordination Case
- With Coordination Case

Run | Exit



# Part of Pilot Effort for SERC Research Integration Project Demo

- Link together products from 3 SERC research projects
  - Purdue: The robust portfolio optimization model can find the optimal portfolio of constituent systems for an SoS given the performance risk level for each constituent system.
    - Purdue providing access through Hubzero technology that allows hosting at Purdue for ease of maturation and updating but accessibility (seamlessly, we hope) to SERC
  - Stevens: The counterfeit parts simulation can estimate the level of counterfeit part intrusion into a legacy system's supply chain
  - MS&T: The FILA-SoS simulation can estimate the effect of different agent behaviors (selfish, cooperative, etc.) on an SoS
- Work out the bugs, and find opportunities for, a widely accessible portal for DoD community to engage with SERC research products
- I encourage you to think carefully about being part of this.



# Pilot Studies

## Goal- Advance the AWB maturation from a user-centric perspective

- **Naval Surface Warfare Center Dahlgren Division (NSWCDD):** CRADA signed for collaborative work on development of AWB tools towards in analyzing interstitial spaces of SoSE engineering environments and assessing Navy's Integration & Interoperability initiatives.
- **MITRE Systems Engineering Technical Center:** 2-month activity to test usability of AWB on customer-inspired problems in the SoS space. Provide feedback to Purdue team on AWB and recommendations for enhancement
- **Army Always-On / On-Demand (AO/OD):** Initial problem set-up and on-site use of AWB to explore tailoring to support Army AO/OD initiatives for 2014-2015 period.
- **Johns Hopkins APL:** Two introductory WEBEX sessions, received good technical feedback, APL seeking potential customers to expose SoS AWB

- Usability
  - Use of version control
  - More detailed training material
  - Adding a capability to transfer data from one tool to another
- Perceived Value
  - Hard to quantify exactly how much value users will get out of the tools, at this time
  - In order for users to get the most out of these tools, they need to understand some key concepts
  - These tools force the engineers to dive deep into the interdependencies of systems in a SoS, and consequently provide meaningful analysis information that could be used to make smarter decisions early in the lifecycle of acquisition and modernization programs.
  - Just going through the process of determining the interdependencies is a useful exercise in itself. However, the Purdue SoS Analytic Workbench provides additional insight which based on this quick study may prove to be well worth the effort.