RT-134: Analytic Workbench for System of Systems

Transitioning Systems Engineering Research into Practice

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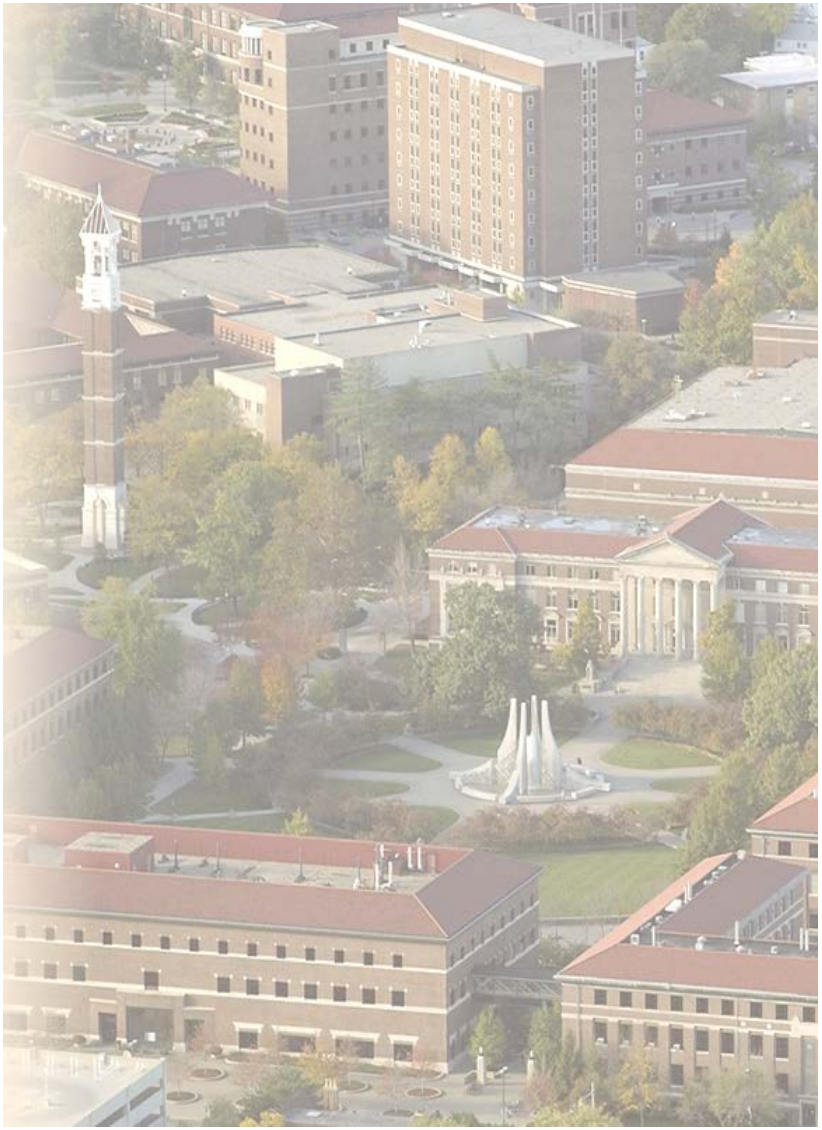


Problem Statement

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

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

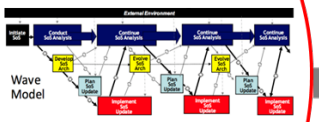
Vision: A *Useful* SoS Analytic Workbench

- 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

The Real World
- SoS under investigation

Systems Engineering at SoS Level



Examples of "where they live"
Currently 30-40 people:
-MDA
-LCS
-Air Ops Center
- Dist. Comm. Gnd. Stations

Data Inputs needed for analysis

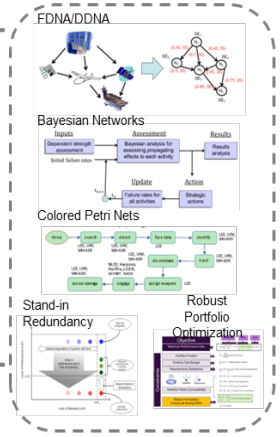
Current stage in Wave Model

Analytic Workbench

Identify "Question" to be explored

Determine suitable method (s) from available suite

Perform SoS analysis



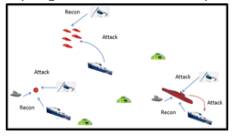
Methods in Toolset:
- Robust Portfolio Optimization
- Dynamic Programming
- System Importance Measures
- Functional/Developmental Dependency Networks

Iterative process between real-world SoS, analytic workbench, and ABM

Iterations

Testing/V&V of SoS Solution through feedback process

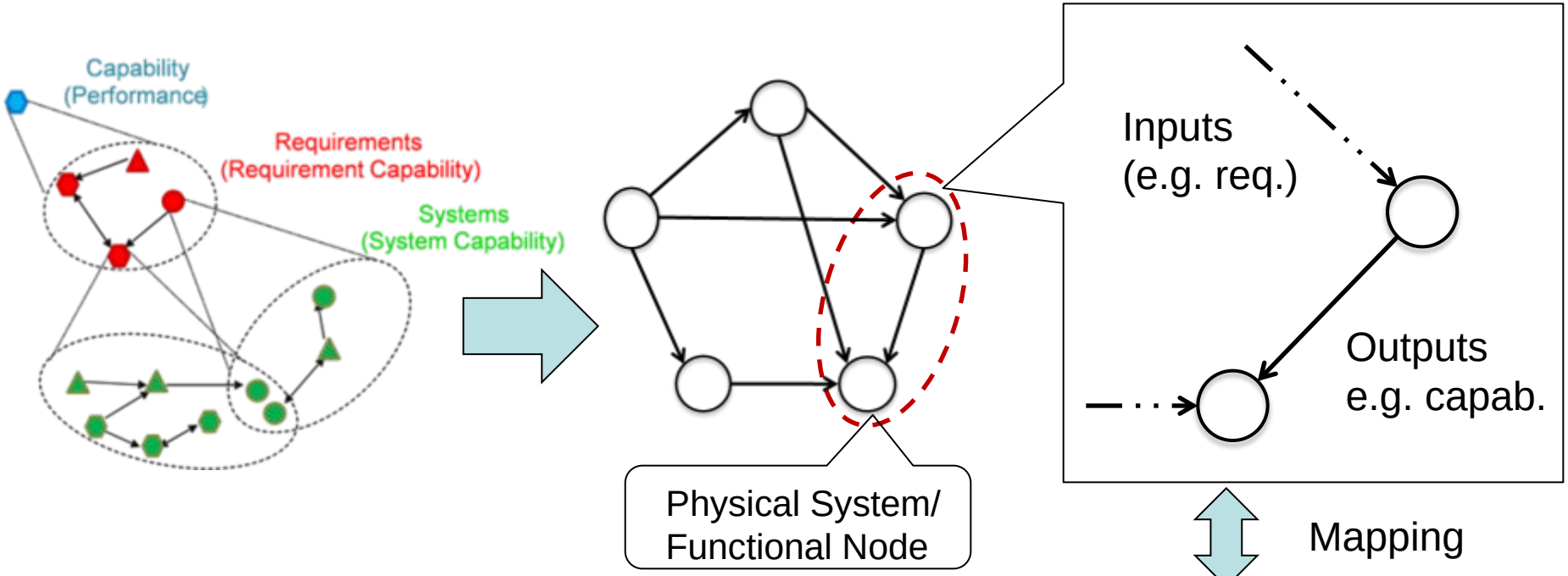
SoS Truth Model (e.g. Simulations)



Solution from SoS Workbench

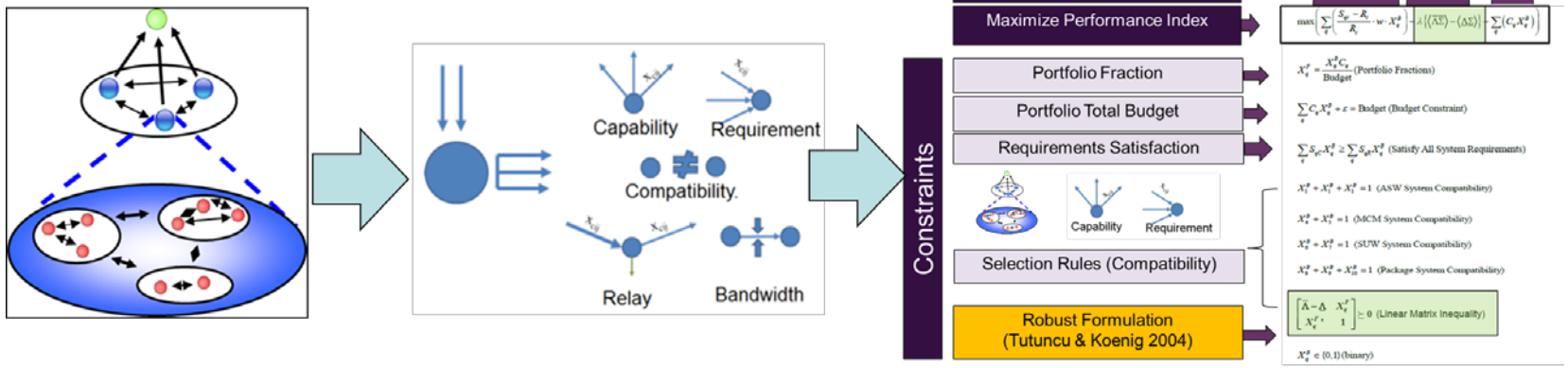
Input Data
(e.g. DoDAF OV, SV, SysML, PV declarations)

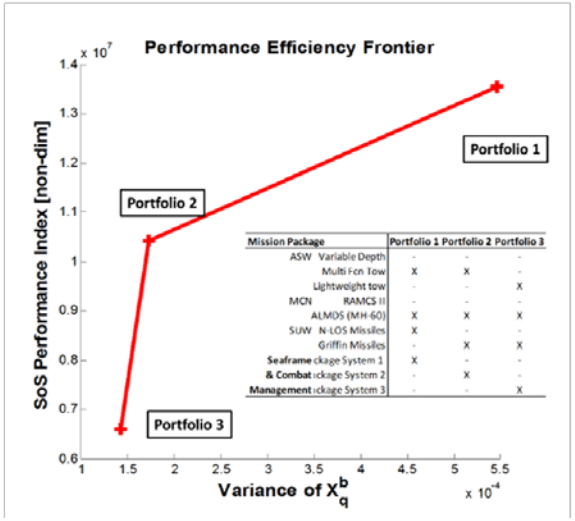
Graph-basis Data Model / Representation

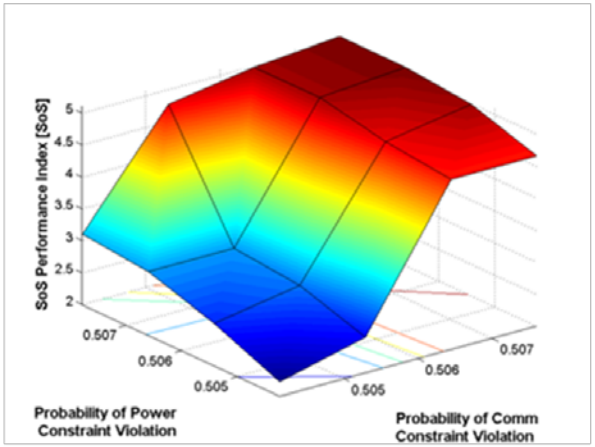


- Translate SoS problem into network topology with hierarchy (nodes, links, inputs, outputs)
- Map data and description to equivalent network representation

Decision Support for SoS







Addressing the Archetypal Questions

Analyze and change a given architecture

System Importance Measures (SIMs)

Systems Operational / Developmental Dependency Analysis (SODA/SDDA)

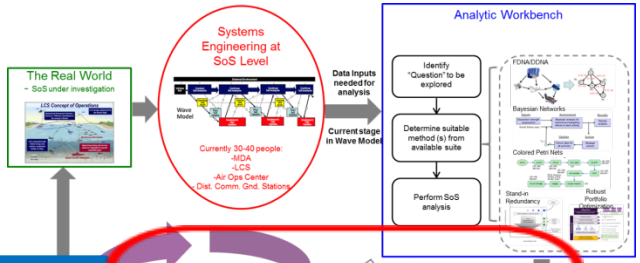
Analyze families of architectures

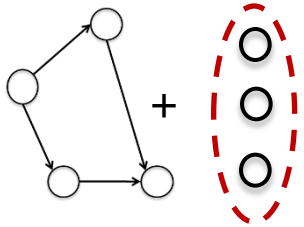
Robust Portfolio Optimization

Approx. Dynamic Programming

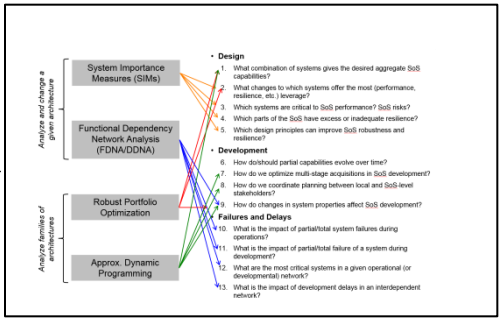
- **Design**
  1. What combination of systems gives the desired aggregate SoS capabilities?
  2. What changes to which systems offer the most (performance, resilience, etc.) leverage?
  3. Which systems are critical to SoS performance? SoS risks?
  4. Which parts of the SoS have excess or inadequate 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?
- **Failures and Delays**
  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?

Analysis & Verification

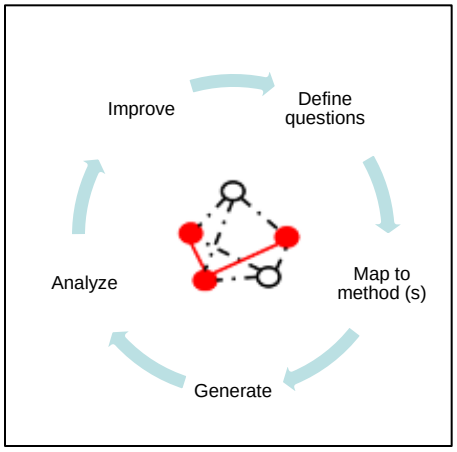


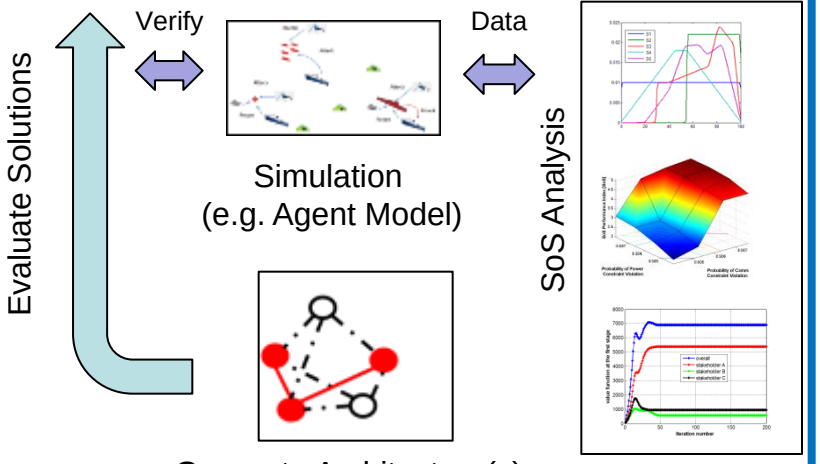


Initial
Architecture + Candidates



Map Questions & Data to Methods





Iterative process to improve architecture

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

Pilot Studies & Collaboration

- **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 initiative

- **Johns Hopkins APL**: Two introductory WEBEX sessions, received good technical feedback, APL seeking potential customers to expose SoS AWB

- **SERC Integration Project**: Connecting research tools with other RTs for counterfeit parts case study

- **Conferences:** CSER, NDIA, IEEE SoSE

MITRE Review Summary

- Usability
  - Use of version control
  - More detailed training material
  - Adding a capability to transfer data from one tool to another
- Perceived Value
  - 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.

HubZero Implementation

- Deployment for broader DoD-SE community using HubZero technology → tighter integration with data input definitions (e.g. DoDAF)
- Web based virtualization of SoS AWB for broader community use.
- nanohub.org implementation – sign up for free account