Modeling and Simulation Support for the Systems Engineering of Systems of Systems

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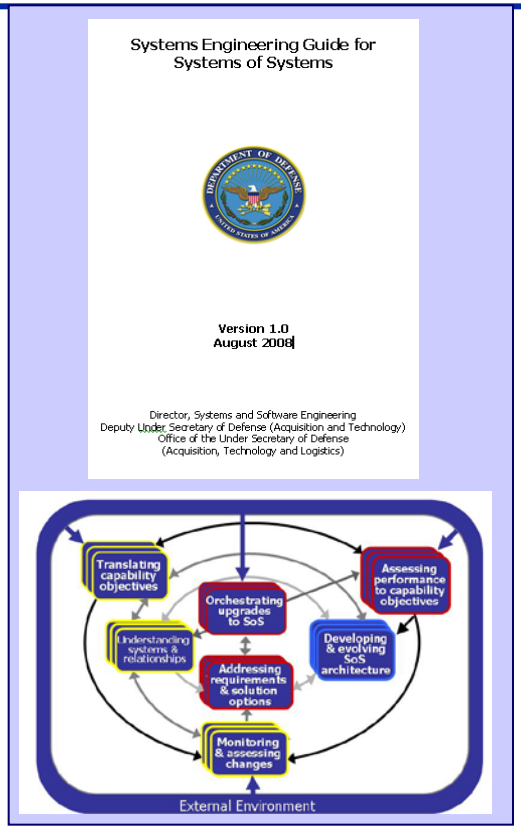
Systems Engineering for Systems of Systems



SoS: ***A set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities***

- **AT&L Released "Systems Engineering for Systems of Systems" Version 1.0 in August 2008**
- **How does the SoS SE Guide address M&S?**
  - Initial .9 Version included M&S throughout the draft
  - The practitioner reviews indicate limited use of M&S
    - Main place where M&S was cited is in the emulation of systems not otherwise available for testing
  - Consequently the 1.0 Working Draft limited M&S to this area
  - Comments on the draft identified more uses of M&S
  - The final 1.0 Version has an M&S section and added places where M&S is discussed
- **Requested M&S Committee provide input on use of M&S to support SE for SoS**

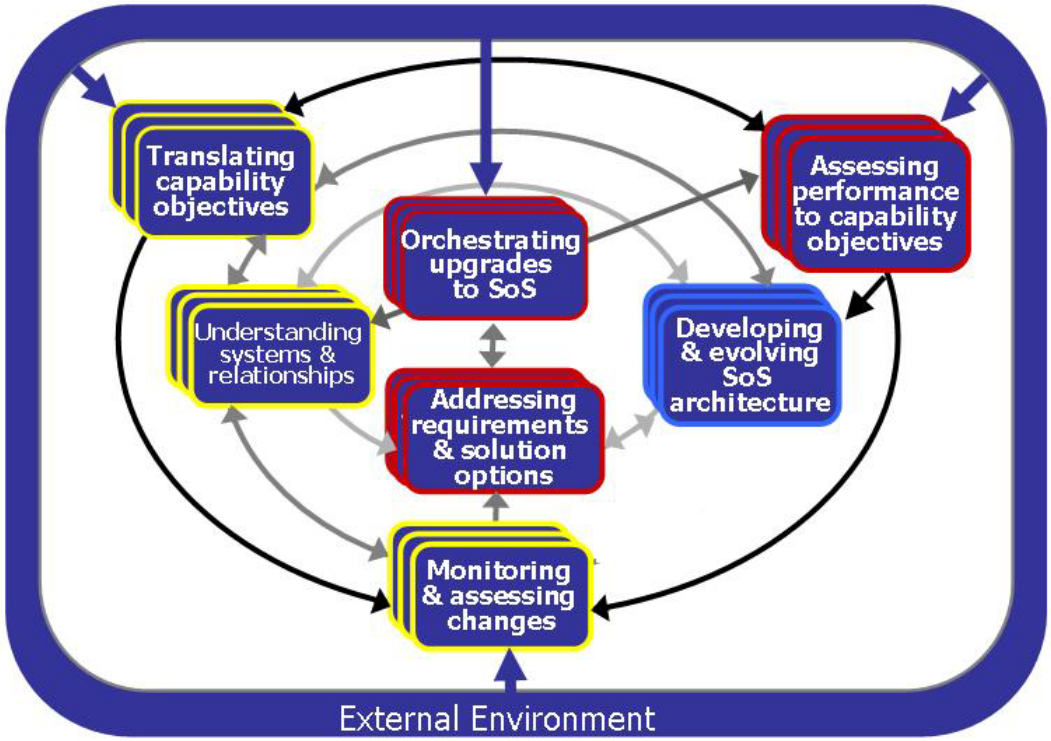
Modeling and Simulation in SoS*

- A technical toolset used regularly in systems acquisition & engineering [NDIA, 2004]
- Applied throughout system development lifecycle
  - Supports early concept analysis, through design, DT&E and OT&E
- Supports SoS SE in a number of areas
  - Understand complex & emergent behavior of systems that interact with each other
  - Provides an environment to help SoS SE team create new capability from existing systems
  - Illuminates integration issues that can have a direct effect on the operational user
  - Analysis of architecture approaches & alternatives
  - Analysis of requirements & solution options
  - Support T&E when difficult or infeasible to do in other ways, particularly end-end performance
- Challenges
  - Ensuring M&S validity
  - Include M&S considerations early in SE planning, including resources to identify, develop, evolve & validate M&S to support SE and T&E.

**** From SEG Reference Guide, section 1.7.4***

Specific Survey Request

SE Model for SoS Based on 7 Core Elements of SoS SE



New SoS SE role | Persistent SoS overlay framework | SoS upgrade process | External influences

For each of the seven core elements of SoS systems engineering (SE), please share your views on:

- The potential for applying modeling and simulation, including why M&S has potential value
- Your experience using M&S for this SoS SE element, including the context of the application, the ways M&S was applied, the products produced, how they were used, and the value added by M&S
- The enablers for use of M&S in this element, including what attributes made successful use of M&S possible (in cases where it was applied)
- and barriers that inhibited use of M&S (in cases where the potential is not being realized).

Summary of Survey Inputs

Organization	Quick Summary	Example
Raytheon	Views and specific experiences	X
AF Research Lab (AFRL/XPT)	Organizational experience	
Aegis Technologies	Perspective on issues	
Lockheed Martin	Views and specific experiences	X
Aeronautical Sys Ctr (ASC/END)	Organizational experience	
NUWC Newport	Views based on M&S for SE	
Lockheed Martin	Views and specific experiences	
Lockheed Martin	Perspective on issues	
National Science Foundation	Views based on M&S for SE	
Lockheed Martin	Views and specific experiences	X
3CE	Views and specific experiences	X
NAVAIR	Views based on M&S for SE	
MC Systems Command	Views and specific experiences	X
MITRE	Views and specific experiences	X
NSWC Dahlgren	Perspective on issues	
Aegis Technologies	Perspective on issues	
Boeing Company	Views and specific experiences	X
Aegis Technologies	Perspective on issues	
Australia	Paper	

- **19 responses from 14 organizations**
- **10 volunteers synthesized the report on survey results**
- **Responses were of several types**
  - Views and specific experiences with M&S and SoS
  - Perspective on issues of M&S and SoS
  - Views based on M&S for SE
  - Organizational experience
  - Relevant papers on topic
- **8 specific project experiences cited in survey responses or papers**

NDIA Survey Analysis: What We Did and Why We Did It

What we did …..

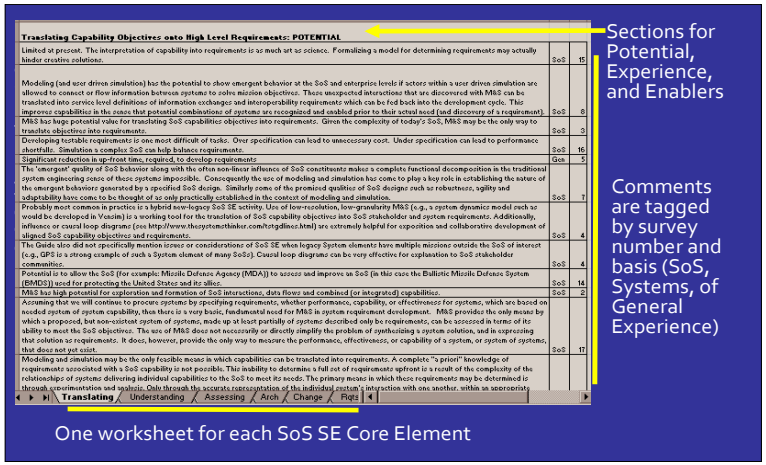
- Listed key SoS SE activities for each core element
- Mapped survey responses to each of these key activities by asking ourselves "how can M&S support this key SoS SE activity?"
- We retained the *potential-experience-enabler/inhibitor* organization of responses under each activity – it is a useful organizing principle for presenting information
- Added a "General" category for those responses that were relevant but not easy to categorize by SoS core element

Why we did it …..

- We saw the audience for this information as SoS SEs asking 2 basic questions:
  - ***What are the critical or unique SE activities in each core element?***
  - ***What are the potential, experience, & enablers/inhibitors of M&S to support me in executing each core element activity?***

Process

- Compiled inputs into master workbook
- Reviewed inputs by SoS SE core element



- Binned inputs for each element in terms of the key activities in each element

Core Element	Element Activities	M&S Responses		
		Ptnl	Exp	En/ In
Translating Capability Objectives	SoS SE translates needed capabilities into high-level requirements at the outset of the program & as the situation changes & SoS evolves	3		
	SoS SE needs to understand nature & dynamics of SoS & anticipate areas likely to vary in implementation & over time			
	SoS SE defines functions to provide capability & variability in environment that impacts different ways they are executed			
	Evaluate operational utility & derive requirements via reference missions & use cases		1	

- Summarized the inputs across elements and activities

M&S in *Assessing Performance to Capability Objectives* (1 of 2)

- **SoS SE establishes metrics and methods for assessing performance of SoS capabilities independent of implementation alternatives**
  - **Potential:** M&S can be applied to systems as they are developed and then re-applied to systems as they are combined to prove concepts at each development phase
  - **Potential:** Measurements of envisioned performance can be determined such as the amount of time it takes for an associated function of the capability to be performed (e.g., an hour to get updated information on pilot availability from an envisioned Pilot Skills System).
  - **Experience:** M&S-based interoperability HWIL testing to assess performance of the fielded SoS configuration provides key data for the accreditation authority's decisions about caveats and limitations in accreditation of the constructive simulation of the SoS
  - **Experience:** We have used hardware in place of the ship simulation and still provided the environment to the hardware through a Force-On-force or Mission level simulation. Examples of this approach include performance analysis of a C4I network connection of a SoS, missile flyout for design verification, an Asymmetric Missile Defense architecture concept, and a proof of concept for a Wide Area Surveillance of land and sea.
  - **Enabler:** Availability of appropriately high-resolution element M&S for integration into the SoS-level M&S in performance assessment
  - **Enabler:** Define and supply the data necessary to construct a valid M&S solution.

- Presented results to the M&S committee at August meeting

Results of M&S Committee Survey on M&S in SoS SE

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http://www.ndia.org/Divisions/Divisions/SystemsEngineering/Pages/Modeling_and_Simulation_Committee.aspx

Findings from Survey Responses
(1 of 3)

- **General**
  - Many feel that M&S can be value-adding for many aspects of SoS development and evolution
  - M&S is better suited to some SoS domains/aspects than others
  - However, there seems to be limited SoS-level experience with M&S and often this experience is with low-fidelity M&S tools with limited usefulness
  - Most experience appears to be with respect to testing/assessment, with results fed back to the next evolution/development cycle

- **Types of models/simulations identified in responses**
  - Static models such as DoDAF, SysML, and parametric cost models
    - Depiction of organizational relationships among the systems
    - Use cases to identify scenarios
    - Identification of SoS configurations and evolution options
    - Identification of gaps
    - Cost vs. performance analysis

Findings from Survey Responses
(2 of 3)

- **Types of models/simulations identified in responses *(continued)***
  - Dynamic interface simulators to provide data needed to drive systems, support analysis/testing, and evaluate mission scenarios
  - Dynamic simulations to probe current and future
    - Capabilities/functions
    - Relationships and dependencies
    - Architecture/design alternatives
    - CONOPS
  - Dynamic simulations to support performance evaluations
    - Background loading for mission evaluations
    - Data to facilitate accreditation authority decisions
    - Network analysis
    - Algorithm analysis
    - System interoperability assessment
    - Proof of concept
  - Dynamic simulations to support operator-in-the-loop exercises and training

Findings from Survey Responses
(3 of 3)

- **Few enablers reported with respect to experiences**
  - Most were a "need" to realize a potential
- **Considerable inhibitors/barriers to effective M&S in the SoS environment:**
  - Inexperienced staff (developers to develop needed models/sims, analysts that can interpret/make use of the results, and people with both M&S and domain experience)
  - Low-fidelity tools (when high-fidelity tools are needed)
  - Data to drive the models/sims
  - Flexible/easily-adapted tools
  - Funding
- **Some comments suggested that M&S can replace some testing**
  - Additional insights into that would be useful

Summary and Conclusions
(1 of 2)

- **All SoS SE core elements supported to some extent by M&S as indicated by the experience responses**
- **But, continue to struggle with the application of M&S in the SoS environment**
  - Lots of potential identified
  - Considerable number of enablers/inhibitors for M&S in the SoS SE environment
  - Much less experience (8 specific project experiences) with M&S in the SoS SE environment
    - Consistent with SoS SE pilot program interviews
- **Considerable overlap between actual use in experiences and potential**
  - Implication: A few have found ways to realize some of the potential

Summary and Conclusions
(2 of 2)

- **Inhibitors key to understanding lack of actual experience**
  - Models/simulations not comprehensive and tend to focus on a specific aspect or area of interest
  - Often not applicable "as is" for other opportunities
    - Needed models/simulations not at the right fidelity
    - Considerable time/resources needed to develop/modify models/simulations
    - Not worth the ROI given the needed lead time and funding
- **If M&S is to be a valuable tool for SoSs, need to overcome barriers**
- **Potential follow-on**
  - Details of experiences
  - Additional insights into using M&S instead of testing