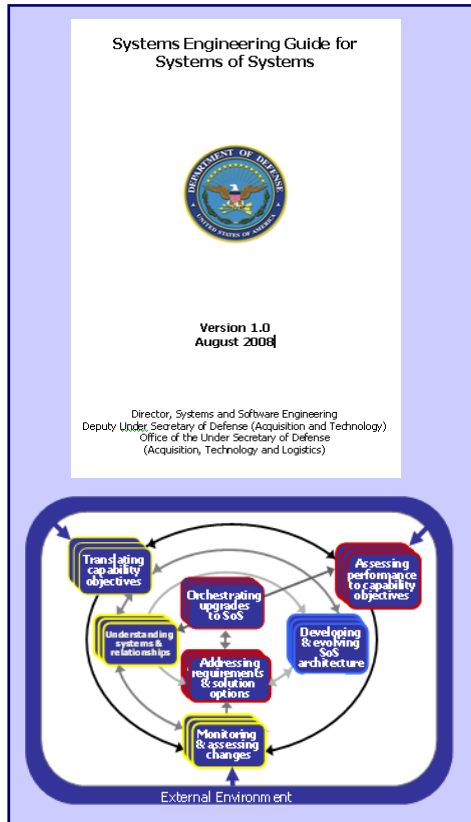


Update on
Survey on Modeling and Simulation Support
for the
Systems Engineering of Systems of Systems

February 2009

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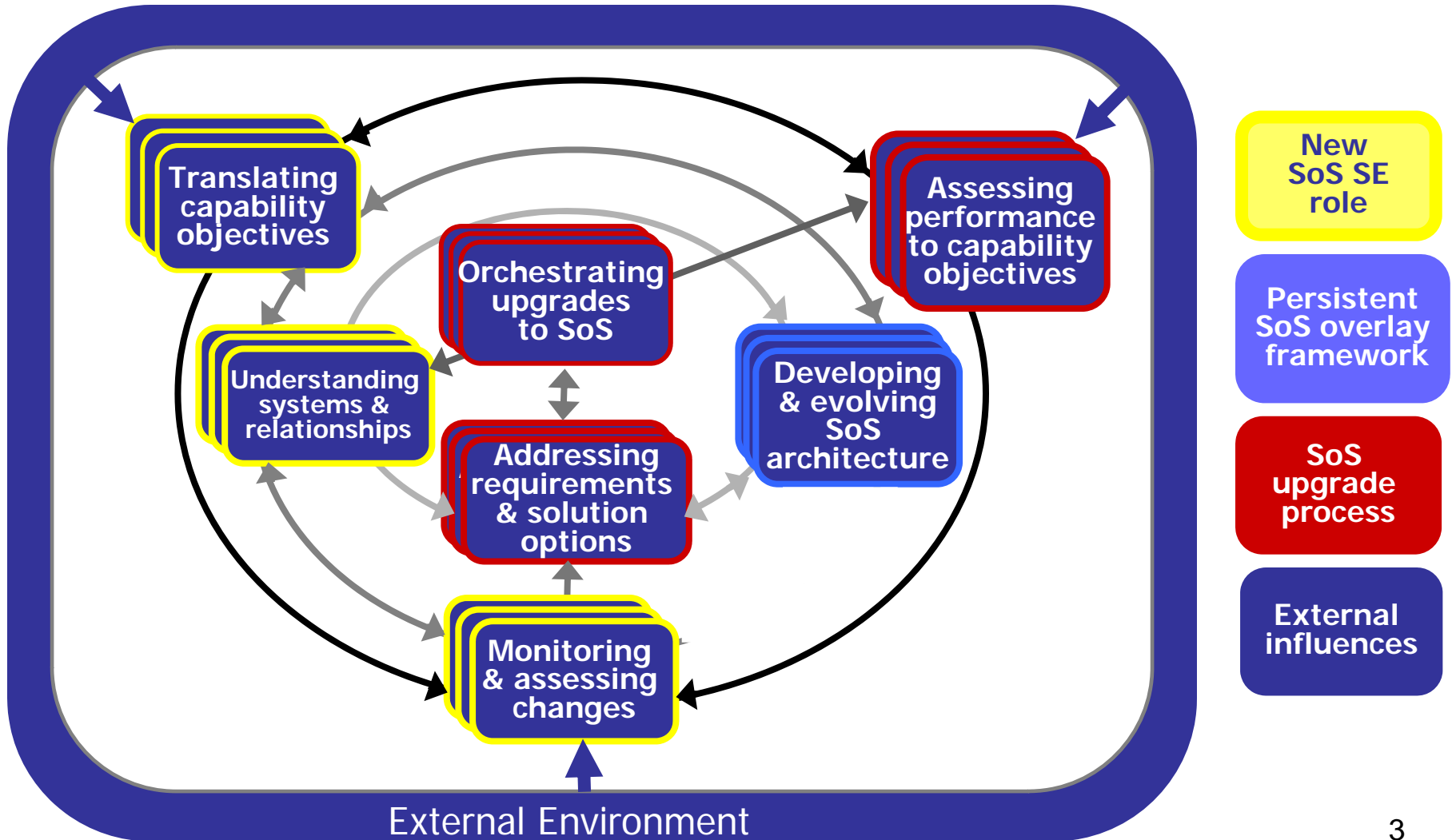
Systems Engineering for Systems of Systems



- “Systems Engineering Guide for Systems of Systems” Version 1.0
 - Characterizes SoS in the DoD Today
 - Identifies core elements of SoS SE
 - Discusses application of SE processes to SoS SE core elements
 - Highlights ‘emerging principles’
- Only briefly addresses M&S
 - Requested NDIA SE Division M&S Committee to provide input on use of M&S to support SE for SoS
- Purpose of this presentation is to provide a status update

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

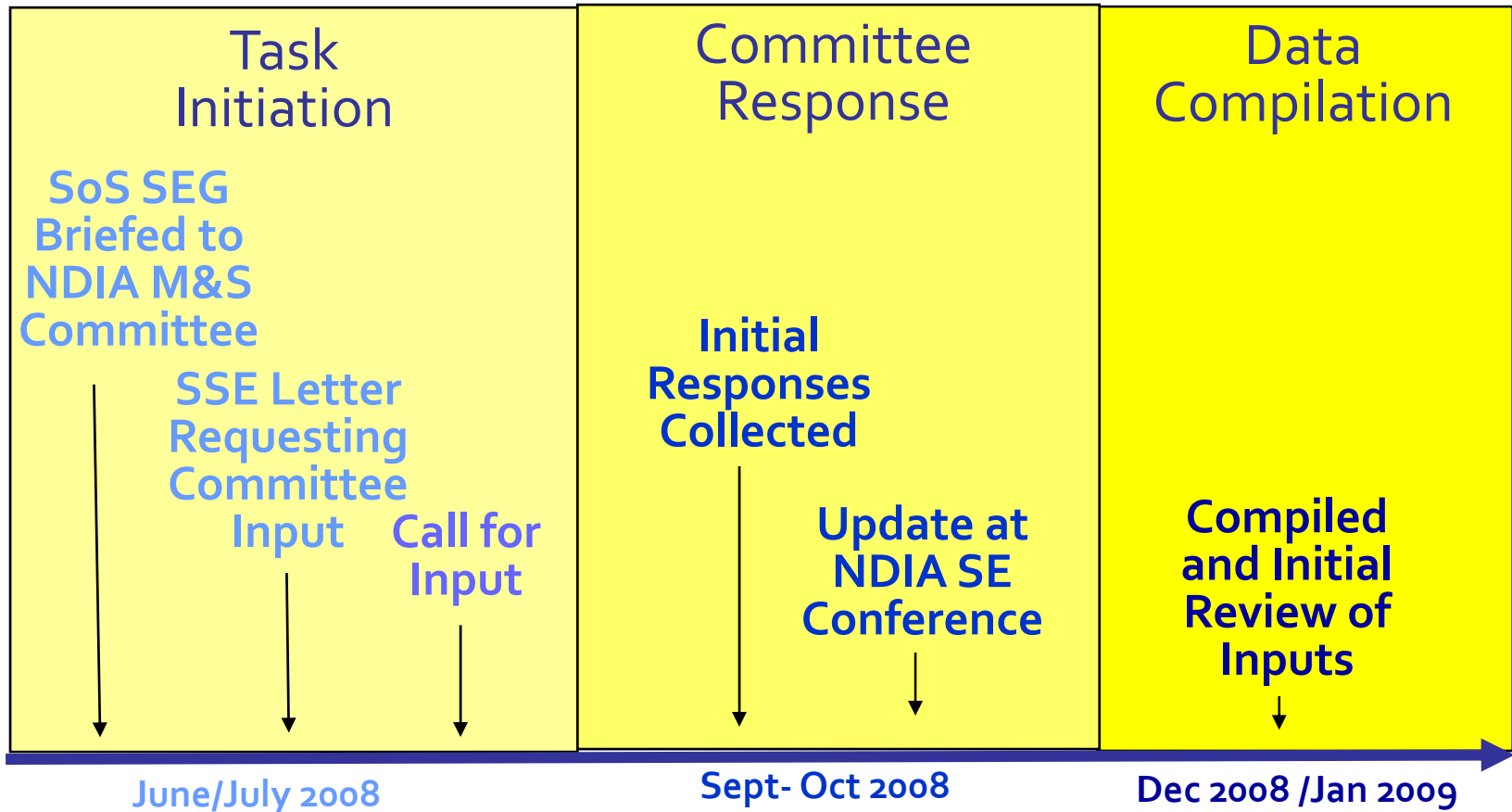
SE Model for SoS Based on 7 Core Elements of SoS SE



Specific Request

- 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).

Timeline



How did we get here?

Summary of Responses

- 19 Responses from 14 organizations
- 10 volunteers to help to synthesize 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

Summary of Survey Inputs

	Name	Organization	Quick Summary	Example
1	Andrew	Raytheon	Views and specific experiences	X
2	Christian	AF Research Lab (AFRL/XPT)	Organizational experience	
3	Dubuque	Aegis Technologies	Perspective on issues	
4	Grange	Lockheed Martin	Views and specific experiences	X
5	Griffis	Aeronautical Sys Ctr (ASC/END)	Organizational experience	
6	Haley	NUWC Newport	Views based on M&S for SE	
7	Hall	Lockheed Martin	Views and specific experiences	
8	Harris	Lockheed Martin	Perspective on issues	
9	Hazelrig	National Science Foundation	Views based on M&S for SE	
10	Koury	Lockheed Martin	Views and specific experiences	X
11	Lopez	3CE	Views and specific experiences	X
12	Lyda	NAVAIR	Views based on M&S for SE	
13	McGough	MC Systems Command	Views and specific experiences	X
14	Prochnow	MITRE	Views and specific experiences	X
15	Small	NSWC Dahlgren	Perspective on issues	
16	Thomas	Aegis Technologies	Perspective on issues	
17	Tucker	Boeing Company	Views and specific experiences	X
18	Upchurch	Aegis Technologies	Perspective on issues	
19	Chen	Australia	Paper	

Data Compilation

- Data has been extracted from surveys
- Compiled into an Excel workbook
 - Seven worksheets; one for each core SoS SE element
 - Each sheet includes 3 sections
 - Potential Opportunities
 - Experience
 - Enablers
 - Each response is tagged with
 - Number of the source survey
 - Whether the comment is explicitly an SoS comment, is based on experience with systems, or is a general comment
- Workbook plus papers provide rich source of data

Snapshot of Workbook

Translating Capability Objectives onto High Level Requirements: POTENTIAL		
Limited at present. The interpretation of capability into requirements is as much art as science. Formalizing a model for determining requirements may actually hinder creative solutions.	SoS	15
Modeling (and user driven simulation) has the potential to show emergent behavior at the SoS and enterprise levels if actors within a user driven simulation are allowed to connect or flow information between systems to solve mission objectives. These unexpected interactions that are discovered with M&S can be translated into service level definitions of information exchanges and interoperability requirements which can be fed back into the development cycle. This improves capabilities in the sense that potential combinations of systems are recognized and enabled prior to their actual need (and discovery of a requirement).	SoS	8
M&S has huge potential value for translating SoS capabilities objectives into requirements. Given the complexity of today's SoS, M&S may be the only way to translate objectives into requirements.	SoS	3
Developing testable requirements is one most difficult of tasks. Over specification can lead to unnecessary cost. Under specification can lead to performance shortfalls. Simulation a complex SoS can help balance requirements.	SoS	16
Significant reduction in up-front time, required, to develop requirements	Gen	5
The 'emergent' quality of SoS behavior along with the often non-linear influence of SoS constituents makes a complete functional decomposition in the traditional system engineering sense of these systems impossible. Consequently the use of modeling and simulation has come to play a key role in establishing the nature of the emergent behaviors generated by a specified SoS design. Similarly some of the promised qualities of SoS designs such as robustness, agility and adaptability have come to be thought of as only practically established in the context of modeling and simulation.	SoS	7
Probably most common in practice is a hybrid new-legacy SoS SE activity. Use of low-resolution, low-granularity M&S (e.g., a system dynamics model such as would be developed in Vensim) is a working tool for the translation of SoS capability objectives into SoS stakeholder and system requirements. Additionally, influence or causal loop diagrams (see http://www.thsystemsthinker.com/tstgdlines.html) are extremely helpful for exposition and collaborative development of aligned SoS capability objectives and requirements.	SoS	4
The Guide also did not specifically mention issues or considerations of SoS SE when legacy System elements have multiple missions outside the SoS of interest (e.g., GPS is a strong example of such a System element of many SoSs). Causal loop diagrams can be very effective for explanation to SoS stakeholder communities.	SoS	4
Potential is to allow the SoS (for example: Missile Defense Agency (MDA)) to assess and improve an SoS (in this case the Ballistic Missile Defense System (BMDS)) used for protecting the United States and its allies.	SoS	14
M&S has high potential for exploration and formation of SoS interactions, data flows and combined (or integrated) capabilities.	SoS	2
Assuming that we will continue to procure systems by specifying requirements, whether performance, capability, or effectiveness for systems, which are based on needed system of system capability, then there is a very basic, fundamental need for M&S in system requirement development. M&S provides the only means by which a proposed, but non-existent system of systems, made up at least partially of systems described only by requirements, can be assessed in terms of its ability to meet the SoS objectives. The use of M&S does not necessarily or directly simplify the problem of synthesizing a system solution, and in expressing that solution as requirements. It does, however, provide the only way to measure the performance, effectiveness, or capability of a system, or system of systems, that does not yet exist.	SoS	17
Modeling and simulation may be the only feasible means in which capabilities can be translated into requirements. A complete "a priori" knowledge of requirements associated with a SoS capability is not possible. This inability to determine a full set of requirements upfront is a result of the complexity of the relationships of systems delivering individual capabilities to the SoS to meet its needs. The primary means in which these requirements may be determined is through experimentation and analysis. Only through the accurate representation of the individual system's interaction with one another, within an appropriate		

Sections for Potential, Experience, and Enablers

Comments are tagged by survey number and basis (SoS, Systems, or General Experience)

One worksheet for each SoS SE Core Element

First Look at Data Suggests

- Lots of potential for M&S across all seven elements
 - Reflected in both general perspectives and specific experiences
 - Specific experiences are important because they provide more insight into how this potential may be realized
- Variable experience with SoS
 - Several respondents have had considerable SoS experience and their responses reflect their lessons learned
 - Others have had less SoS experience but suggest experience with systems provides insight into SoS applications
 - Important to differentiate among these in developing results
- Enablers/Barriers tend to be similar across elements
 - Tools and standards
 - Reusable, flexible, rigorous models
 - Available M&S technical expertise for systems as well SoS
 - A question is how these are specific to SoS
- Can be difficult to extract lessons without context of specific application

Next Steps

- Share data, review responses, and develop results
 - Meet with volunteers to develop plan
- Plan to hear more from about specific examples cited on survey responses
 - Plan for presentations?
 - Options:
 - Include in upcoming committee meetings?
 - Schedule a series of phone conference presentations?
- Target is a completed report to AT&L SSE by June

Working Group Volunteers to Help Prepare Report

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Lockheed Martin
- Griffis, Hugh
USAF ASC/END
- Haley, Tom
NUWC Newport
- Harris, Chett
Lockheed Martin
- Koury, Bob
Lockheed Martin
- Lopez, LTC Favio
3CE/FCS
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- Prochnow, Dave
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- Tucker, Bill
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