Systems Engineering for Systems of Systems: Update

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Background

- **DoD SoS SE Guide** was published in late 2008 and is now being applied in a variety of settings across the DoD
- **Current DDR&E SoS emphasis** is on implementation, with major activities focus on
  - Outreach
    - DAU Continuous Learning Module
    - NDIA SoS SE Committee, SharePoint and Webinars
  - Collaboration - TTCP and DoD SoS Initiatives
  - Initiatives to support SoS SE Implementation
    - SoS and T&E
    - SoS and Development Planning
    - SoS Artifacts
    - SoS ‘Wave’ Model
- **Next Steps**
• Defense Acquisition University (DAU) provides education and training to US DoD workforce

• SoS SE Continuous Learning Module (CLM) is in development
  - Presents critical information from the SoS SE Guide
  - Online offering, 3-4 hour course
  - Expected to be available ~December 2010
Outreach

NDIA SoS SE Committee

- National Defense Industrial Association (NDIA) Systems Engineering Division (SED)
  - Forum for industry, government and academic collaboration
- SoS SE Committee created in Feb 2009
  - Meet every 2 months (20-50 participants)
  - Identify areas of common interest; current focus
    - SoS and T&E
    - Approaches to SoS Assessment
  - Sponsor track at Annual NDIA SE Conference
    - Webinar Series
Outreach
SoS SE Webinar Series

- Twice monthly webinar on topics of interest to SoS SE Community
- Began with selected presentations from initial NDIA SE Conference SoS SE Track with added presentations from other venues
- Presentations are available on DDR&E Website and NDIA SoS SE Share Point Site
Outreach
SoS SE Webinar Series

• An Introduction to Influence Maps: Foundations, Construction, and Use
  February 23, 2010, Jim Smith, SEI

• On Modeling and Simulation Methods for Capturing Emergent
  Behaviors for Systems of Systems

• A Distillation of Lessons Learned from Complex System of Systems
  Acquisitions

• Dynamic Modeling of Programmatic and Systematic Interdependence for System of Systems
  April 13, 2010, Dan DeLaurentis, Purdue and Brian Sauser, Stevens

• SysML Strategies to Characterize and Analyze Systems of Systems
  April 27, 2010, Dr. Jo Ann Lane, USC and Tim Bohn, IBM

• System of Systems Interoperability Challenges and Potential Approaches: Reports from the Field
  May 25, 2010, Dr. Carol Sledge, SEI

• Assurance Cases for Analysis of Complex System of Systems Software
  June 8, 2010, Stephen Blanchette, Jr., SEI

• System of Systems Artifacts
  July 13, 2010, Dr. Judith Dahmann, Mitre

• Accelerating System of Systems Engineering Understanding and Optimization through Lean Enterprise Principles
  July 27, 2010, Dr. Jo Ann Lane, USC and Dr. Ricardo Valerdi, MIT
Collaboration
US DoD and International

• The Technical Cooperation Program
  • Joint Systems Analysis Technical Panel 4: SE and Modernization SoS SE focus area with active interest by US, UK, Canada, and Australia
    • Focus on SoS SE Artifacts
    • Shared lessons learned from nations

• DoD Components and Agencies have been instituting SoS SE efforts or applying SE to SoS areas
  • DDR&E SE collaboration with these activities to
    - Share experiences
    - Identify areas of common interest
    - Understand experience with application of DoD SoS SE Guidance
    - Assist in developing component specific guidance
Initiatives
SoS and T&E

• Topic of 2009 in NDIA SoS SE Committee
• IEEE SoSE Conference 2010 Paper: SoS and T&E Challenges
  - Distinct characteristics of systems of systems that impact their test and evaluation
  - Unique challenges and strategies
  - Recommendations drawn from experiences of active SoS SE practitioners
• Foundation for August 2010 SoS and T&E Workshop
• Sponsored by NDIA SoS SE and DT Committees
• ~25+ participants from T&E and SoS Communities
• Facilitated by Martin Leek, Raytheon
• Developed insights into 5 issues identified prior to the workshop
• Identified 8 potential areas for action
• Selected 3 for follow up
Strategic Initiatives

- **Best Practices Model for SoS T&E**
  - Develop and validate T&E model for SoS as a
    - Continuous improvement process
    - Provides information on ‘capabilities and limitations’ of SoS to end users and feedback to SoS SE on areas for attention
    - Leverages various non-traditional methods for generating ‘test type’ data
  - Identify use cases and investigate as basis for assessing model
  - Objective is to publish a validated model as an SoS T&E community best practice

- ** Radical Approach to SoS T&E**
  - Investigate the concept of replacing DT, OT, NR-KPPs, etc. with an overall SoS capability test.

- **SoS Governance**
  - Minimum set of characteristics that are required to govern SoS T&E efforts
Development Planning Policy Memo (DTM 10-017) establishes new MDD Entrance Criteria

1. The candidate materiel solution approaches have the potential to effectively address the capability gap(s), operational attributes and associated dependencies.
2. There exists a range of technically feasible solutions generated from across the entire solution space, as demonstrated through early prototypes, models, or data.
3. Consideration has been given to near term opportunities to provide a more rapid interim response to the capability need.
4. The plan to staff and fund analytic, engineering, and programmatic activities supports the proposed milestone entry requirements.

MDD is the lever to provide greater technical and engineering foundation for initiating an acquisition.

Early Systems Engineering
10844 – Development Planning Update
Wednesday 8AM
Mission 1
Development planning activities span the lifecycle, including:

- Analysis of future user needs and engineering of new system concepts in a System of Systems (SoS) operational environment.
- Multiple sufficiently robust, material options to address gap.
- Defined costs and benefits of the options including technical risk.
- Preferred solution with clear evidence & understanding of risk.
- Sufficiently robust, material solution and a risk-based TD Plan.

Development Planning is the upfront technical preparation to ensure successful selection and development of a materiel solution.
Initiatives
SoS SE Artifacts

Artifacts
In the Context of the Core Elements of SoS SE

SoS SE Artifacts Developed as Part of an International SoS SE project under The Technical Cooperation Program (TTCP)

Described in 2010 IEEE Systems Conference Paper
Initiatives Implementers View of SoS SE

- **Trapeze Model**
  - Presents the core elements of SoS SE and relationships
  - Provides a good ‘conceptual’ view of SoS SE
  - Not very useful to practitioner to help chart an implementation approach

- **Wave Model**
  - ‘Unwinds’ the trapeze model
  - Provide a view of SoS SE in terms of series of major steps in implementing an SoS SE process
  - More intuitive for an implementer
Implementer View - Key Features

**Backbone of ongoing analysis**

**Architecture Evolution**

**Multiple overlapping iterations of SoS evolution**

**Forward movement with possible iterations**
SoS SE Activities At Each Step

Initiate SoS

Establish the foundation for the SoS SE including an understanding of objectives, key users, user roles and expectations, and core systems supporting capabilities.

Conduct SoS Analysis

Establish initial ‘SoS Baseline’ based on the CONOPs including
- Measures of SoS performance
- Data on current performance
- Understanding how systems currently support SoS
- Risks and mitigations

Develop initial plans for the SoS engineering including
- Key planning element (Battle rhythm, organization, decision processes, roles and responsibilities)
- Agreements with critical players (users, constituent systems)
- SoS Master Plan

Continue SoS Analysis

Update ‘SoS Baseline’ based on
- Changes in objectives, CONOPs or external factors
- Results of the last SoS update
- Data on SoS performance
- Data on unanticipated factors
- Changes in systems
- Risks and mitigations

Update plans including
- Key planning element (Battle rhythm, organization, decision processes, roles and responsibilities)
- Agreements with critical players (users, constituent systems)
- SoS Master Plan

Develop SoS Arch

Develop the persistent technical framework for addressing SoS evolution and a migration plan identifying risks and mitigations.

Plan SoS Update
- Identify the issues and evaluate options
- Create allocated baseline for update
- Identify risks and mitigations
- Develop agreements
- Create implementation, integration and test plan
- Develop IMS for update
- Update SoS Master Plan

Implement SoS Update

- Systems implement and test changes while SoS SE monitors and troubleshoots, updating IMS
- SoS SE leads SoS integration and test, developing data on SoS performance and unanticipated factors
- Result is updated SoS Product Baseline

• Understanding activities at each step provides a vehicle for implementation level guidance and support
Initiatives
SoS SE Artifacts

• Artifacts can be usefully understood from a implementer perspective in terms of the role they play in each step in the SoS SE process
• Work in progress with NDIA SoS SE Committee to address a set of SoS questions posed by DDR&E Director, SE

• Two parallel actions
  • Examine how current guidance addresses questions
  • Set of presentations to committee on SoS analysis approaches

• Review and assessment now underway

The acquisition community needs the ability to assess risk and review progress on programs where the significant capability is provided by investment in SoS, not by any one of the individual systems

- How do we capture a coherent picture of the capabilities provided by a SoS?
- How do we characterize and capture the sub-allocated requirements, risks and interfaces visible at the individual program level that contribute to SoS level capabilities?
- How do we assess progress and risk associated with building toward these SoS capabilities?
- How do we manage change in a SoS environment, etc.?
Ongoing Initiative
Key SoS Acquisition Questions (2 of 3)

- Mapped questions to current SoS SE guidance and research results
  - SoS SE Core Elements
  - SoS SE Artifacts
  - Wave Model

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<th>Original Wavy Question</th>
<th>Elements of Questions</th>
<th>Direct Core SoS SE Elements</th>
<th>SoS SE Artifacts</th>
<th>Steps in the SoS SE Wave Model</th>
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<td>How do we capture a coherent picture of the capabilities provided by a SoS?</td>
<td>Characterizing Capabilities</td>
<td>- Assessing Performance vs. Objectives</td>
<td>- Capability Objectives</td>
<td>- SoS Analysis</td>
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<td>How do we assess progress and risk associated with building toward these SoS capabilities?</td>
<td>Assessing performance</td>
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<td>How do we characterize and capture the suballocated requirements, risks and interfaces visible at the individual program level that contribute to SoS level capabilities?</td>
<td>Characterizing</td>
<td>- Developing and evolving arch</td>
<td>- Developing and Planning SoS Architecture</td>
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<td>How do we manage change in a SoS environment, etc.?</td>
<td>Planned change</td>
<td>- Addressing requirements and solution options</td>
<td>- Planning SoS Updates</td>
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<td>Uncontrolled change</td>
<td>- Monitoring and addressing change</td>
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<td>SoS SE Planning Elements</td>
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Requirements space for the SoS
- Information about systems which impact capability objectives
- Risks and Mitigations
- Performance measures and methods
- Data on performance of the SoS
- SoS Technical Baselines
- Technical Plan(s)
- Integrated Master Schedule
Ongoing Initiative
Key SoS Acquisition Questions (3 of 3)

• NDIA Architecture Task Force Report
  Joe Kuncel

• Engineering Systems of Systems: An Integration Perspective
  Emmet Maddry (NSWC Dahlgren)

• SoS Quality Attribute Specification and Architecture Evaluation
  Michael Galiardi (SEI)

• Integrated Air and Missile Defense (IAMD) Studies
  Dr. Joseph T. Buontempo (IDA)

• Enabling Engineering of Complex Systems Through Simulation-Based Experimentation
  Zach Furness (MITRE)
Next Steps

• Continuing to work with the broader community through NDIA and TTCP to address growing interest and understanding of SoS and SE

• Continued technical work
  - To support DoD acquisition initiatives which call for a SoS perspective
    - SoS Acquisition Programs
    - Development Planning
  - To apply current understanding and learn from experiences with Component initiatives
  - To build guidance which supports the SoS SE practitioner
    - Wave model
    - Artifacts
    - Relationship to DoD acquisition
  - To address Director, SE questions