SoS Systems Engineering (SE) and Test & Evaluation (T&E)

A Report of the NDIA SE Division
SoS SE and T&E Committees

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Task

• NDIA Strategic Initiative: Best Practices Model for SoS T&E
  – Product of one-day facilitated SoS and T&E Workshop sponsored by NDIA SoS SE and DTE committees, held August 17, 2010, MITRE, McLean VA
  – Adopted by NDIA SoS SE Committee to work with T&E Committee to address this as a 2011 action
  – Purpose: Outline the fundamentals of the model of SoS T&E as a:

  “Continuous improvement process supporting capabilities and limitations information for end users and feedback to the SoS and system SE teams toward evolution of the SoS”

2010 IEEE SoSE Conference
SoS Definition, Types and Domains

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

Types of SoS

- **Directed**: SoS objectives, management, funding and authority; systems are subordinated to SoS.
- **Acknowledged**: SoS objectives, management, funding and authority; however systems retain their own management, funding and authority in parallel with the SoS.
- **Collaborative**: No top down objectives, management, authority, responsibility, or funding at the SoS level; Systems voluntarily work together to address shared or common interest.
- **Virtual**: Like collaborative, but systems don’t know about each other.

SoS Domains

Sets of systems working together to provide a broader capability or mission.

- Mission SoS
- Platform SoS
- IT-Based SoS
- Networked Information Systems to support operations within or across platforms or systems to meet mission or platform objectives.

Model focuses on Acknowledged Mission Level SoS.
Comparing Systems and SoS

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**T&E Implications**

Validation criteria more difficult to establish

Cannot explicitly impose SoS conditions on system T&E

System level operational objectives may not have clear analog in SoS conditions that need T&E

Depends on constituent system test of SoS requirements as well as SoS level

Difficult to bring multiple systems together for T&E in synchrony with capability evolution

Additional test points needed to confirm behavior

Increased subjectivity in assessing behavior, given challenges of system alignment

SoS SE as the Framework for SoS T&E

• Effective application of SE at the SoS level provides a structured framework to address SoS T&E challenges
  – Approaches to managing asynchronous system development and test
  – Architecture approaches which shelter the SoS from changes in systems

• Effective T&E is grounded in a clear understanding of objectives and requirements of the ‘test item’
  – The value of an SoS is accrued from the collective behavior of the SoS toward user capabilities
  – Systems engineering conducted at the SoS level provides the basis for T&E
  – DoD SoS SE Guide, SoS SE artifacts and wave model provide fundamentals of SoS SE for DoD

SoS SE and SoS T&E share key common elements
It can be difficult to tell where SoS SE stops and SoS T&E begins
Wave Model: Framework for Model

An implementer’s view of SoS SE
More familiar and intuitive time-sequenced “wave” model representation
Information is thus rendered in a form more readily usable by SoS SE practitioners in the field
Representation that corresponds with incremental development approaches that are the norm for SoS capability evolution

Presented at
IEEE Systems Conference
April 2011 [1]

[1] “An Implementers View of Systems of Systems” Dahmann, Baldwin, Rebovich, Lane and Lowry

Concept of Wave Planning was developed by Dr. David Dombkins
SoS SE and T&E
Evolution at Each Step

• **Recognize SoS T&E constraints**
  – Full SoS T&E to address changes in constituent systems is not feasible given the size and complexity of many SoS and the dynamic nature of constituent systems
    • Includes conventional live testing and approaches using various forms of virtual and constructive simulation

• **Focus T&E specifically on areas of risk**
  – Begin with the changes which have been made in the SoS
  – Identify where changes could have adverse impacts on the user missions
  – Assess the risk using evidence from a range of sources including live test
    – Evidence can be based on activity at the SoS level, as well as roll-ups of system level activity and can be explicit verification testing, results of models and simulations, use of linked integration facilities, and results of system level operational test and evaluation

• **Results ‘Continuous improvement’ feedback to**
  – End users in the form of ‘capabilities and limitations’ rather than as test criteria for SoS ‘deployment’
  – SE teams of both the SoS and systems on progress and issues
Approach Assumes “Initiation” of an Acknowledged SoS

• Decision has been made to establish an SoS SE organization
  • An entity is responsible for the SoS with SE support to the SoS
  • As an acknowledged SoS, the systems which constitute the SoS maintain operational and management independence

• At the initiation of an SoS, the information typically available includes initial or first order
  • Statement of top-level objectives for the SoS (SoS capability objectives)
  • Description of how systems in the SoS will be employed in an operational setting (SoS CONOPS) and
  • Programmatic and technical information about systems that affect SoS capability objectives (systems information)
  • Risks are identified when an SoS is launched and mitigation actions are tracked and updated throughout each cycle, along with new risks (Risks and Mitigations)
SoS SE: Conduct SoS Analysis

Provides analysis of the ‘as is’ and basis for SoS evolution

CONOPs
Understand operational context and developing a CONOPs -- Includes key steps in process and constraints on those steps; may be a set of mission threads, conditions, players and performance objectives

Functional Baseline
Layout the specific tasks for each component of the activity sequence to further delineate the functionality supporting the E2E capability objective

Current System Baseline
Identify systems supporting the capability objectives and align them to the components and functionality needs, with data on current performance

SoS SE Artifacts
Characterize SoS
- Capability objectives
- SoS CONOPs
- Constituent system info
- SoS Technical Baselines
- SoS Performance Measures & Methods
- SoS Performance Data
- SoS Requirement Space
- SoS Risks & Mitigations

Plan for SoS SE
- SE Planning Elements
- SoS Master Plan
- Agreements

SoS Analysis

Requirements Space
Develop an ‘functional architecture’ for the SoS by looking at the key functions to be supported across the ‘thread’ or activity sequence, including performance objectives

Results provide basis for architecture development and planning for SoS updates
T&E Component of SoS Analysis

CONOPs, mission threads and tasks are all needed elements for structuring test

Capability and performance objectives provide a foundation for T&E

- Systematic development and analysis of this data is core to SoS analysis and supports the development of the architecture, planning of updates
- Cases where more data is needed (and testing may be required) are identified

T&E foundations are established in SoS analysis which draws on T&E of fielded systems

Understanding current system performance draws on available evidence from various sources, including systems T&E
SoS SE: Develop SoS Architecture

Develops and evolves the persistent technical framework for addressing SoS evolution

**Delineate E2E SoS Capabilities**
- Each mission plan / CONOPS / COA describes a path through the various steps in the mission

**Identify Systems Contributing to Capability Objectives**
- Specify how current systems support the capability objectives

**SoS SE Artifact**
- **SoS Architecture**
  Defines the way in which the constituent systems work together
  Includes systems, SoS functions, relationships and dependencies, as well as end-to-end functionality, data flow & communications

**Identify and evaluate alternative approaches to organizing and augmenting systems to meet SoS needs**

**Align Systems (Current Capabilities) with SoS Functional Needs**
T&E Component of SoS Architecture

Identify Systems Contributing to Capability Objectives

- Each mission plan / CONOP / COA describes a path through the various steps in the mission
- Identify and evaluate alternative approaches to organizing and augmenting systems to meet SoS needs

SoS Architecture

- Specify how current systems support the capability objectives
- Identify specific systems supporting the capability objectives and align them to functionality needs

Data on attributes and performance of systems (typically drawn from system T&E) is key to identification and analysis of architecture approaches

T&E contributes to the assessment of alternative architectures through application of various approaches including LVC environments to assess alternatives against desired architecture objectives
SoS SE: Plan SoS Update

Evaluates the SoS priorities, options and backlogs to define the plan for the next SoS upgrade cycle.

Identify Needs to be Addressed in this Wave

- Areas with shortfalls in performance and feasibility of change

Evaluate Options for Addressing Needs

- Assess alternative ways to address the need and identify the selected approach

Plans for System and SoS Development, Integration and Test

SoS
- Integrated Master Schedule (Key sync points, not aggregation of plans)
- Risks and Mitigation Plans
- SoS changes and dependencies which drive testing
- Systems
- Additions to system plans for development and test

Artifacts

- An allocated baseline
- Risks and mitigations
- Agreements
- Implementation, integration & test plans
- An integrated master schedule (IMS)
- Updated
  - Master Plan,
  - Technical baselines
  - Requirements space
A critical part of planning an SoS update is the analysis of changes and risks to identify the areas to be addressed by T&E.

**Changes in the SoS are identified (both planned by the SoS and planned independently by the constituents)**
- What are the potential impacts of these changes? What are the risks?
- What evidence is there that these changes will not adversely impact other systems and mission objectives?

**What data is needed and how can this data be obtained?**
- Can this be done as part of the system tests?
- Are added test events needed?
- How are these incorporated into the overall plan and IMS?

**What testing tools and environments are needed to address the specific challenges?**
- Test drivers to address asynchronous development?
- LVC environments to address specific risks?
SoS SE: Implement SoS Update

Monitors implementations at the system level and plans and conducts SoS level testing, resulting in a new SoS product baseline.

Monitor System and SoS Development, Integration and Test

SoS
- Integrated Master Schedule (Key sync points, not aggregation of plans)
- Risks and Mitigation Plans
- SoS changes and dependencies which drive testing

Systems
- Additions to system plans for development and test

Review Progress And Inform Users and SE Process

- Collect and assess data from system and SoS development technical reviews and tests
- Update product baseline, architecture, performance assessments, and requirements space
- Provide input into ‘Continue SoS Analysis’

SoS Artifacts
- SoS Test Report
- SoS Technical Plans, Requirements Space, Performance Data
- System Test Reports
- SoS IMS
- SoS Technical Baselines
Monitor System and SoS Development, Integration and Test

**SoS**
- Integrated Master Schedule (Key sync points (not aggregation of plans))
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**T&E is a key part of implementation for both the SoS and the systems**

**Systems making updates conduct T&E at the system level**

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**SoS level T&E activities include**
- Monitoring implementation of system testing, conducting added testing to address SoS risks, and evaluating the results, recommending changes in plans as needed
- Results of the SoS capability are identified (both planned and unplanned)
  - Does performance meet expectations for this increment? What are the potential impacts on the next increment? What are the risks?
  - What evidence is there that these changes will need to be regression tested in the next increment?
Summary and Next Steps

• Key elements of the approach to SoS SE and T&E
  – Addresses the key challenges facing T&E in an SoS environment – complexity, system independence and asynchronous development
  – Integrates T&E with SE throughout the evolution of an SoS based on the SoS ‘wave model’ – T&E contributes to all steps in the evolution
  – Focuses T&E on risks to systems and SoS – recognizing full end to end testing with each system change is intractable
  – Emphasizes use range of information types to address these risks

• Presentation is the product of the 2011 joint task of the NDIA SoS SE and T&E committees
  – Represents initial product in this area
  – Open areas and considerations for next steps