Systems of Systems
and
Test & Evaluation

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Overview

- SoS and T&E was identified as a topic of interest for the NDIA SoS SE Committee

- White paper on SoS and T&E used as basis for discussion

  - http://www.ndia.org/Divisions/Divisions/SystemsEngineering/Pages/SystemsofSystemsCommittee.aspx

- This presentation provides a summary of the key elements of the paper and the discussions

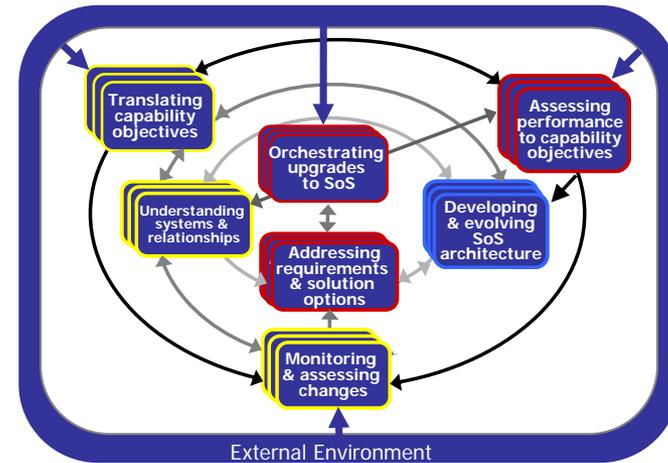- Identified as a potential 2010 focus area for NDIA SoS SE Committee

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Starting Point
System of Systems (SoS) SE Guide

❖ **DoD SoS SE Guide**

- Focus on technical aspects of SE applicable to SoS
- Characterize SoS in DoD Today
- Describe Core Elements of SoS SE
- Translate application of basic SE processes for SoS SE

❖ **SoS types and examples**

- Directed - DoD Information System Network (DISN), National System for Geospatial Analysis
- → Acknowledged – Ballistic Missile Defense System, Air Operations Center
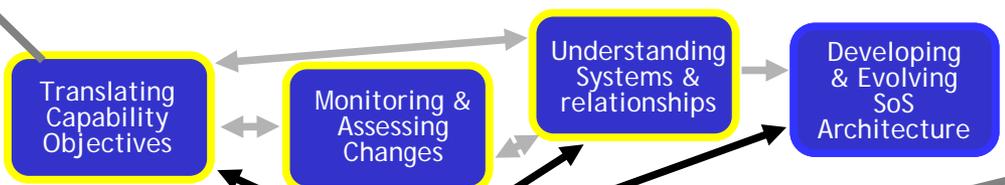- Collaborative – Communities of interest
- Virtual - Internet

System of Systems: (ref: Defense Acquisition Guide)
A set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities.
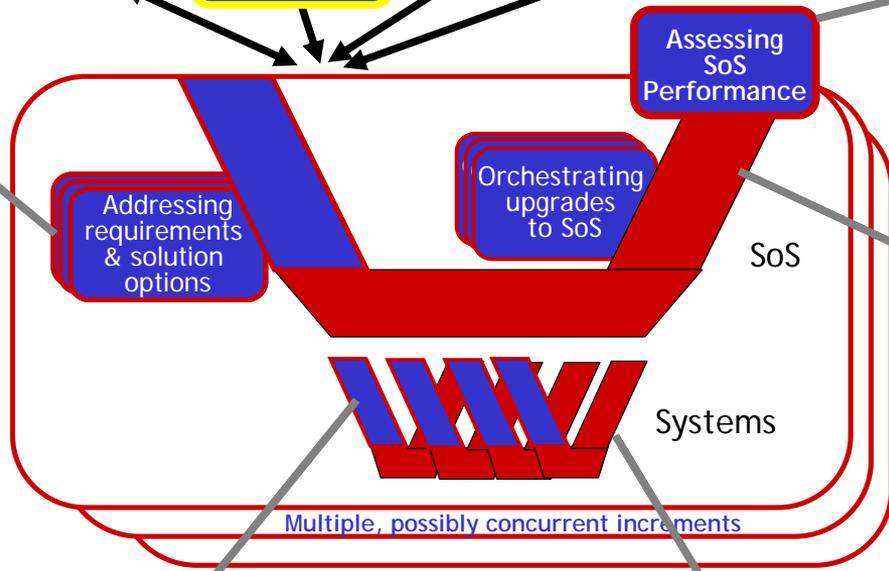
View of T&E In a SoS

Capability objectives are often stated at a higher level

Translating Capability Objectives

Monitoring & Assessing Changes

Understanding Systems & relationships

Developing & Evolving SoS Architecture

SoS performance is assessed in various settings (exercise, operations, other)

Assessing SoS Performance

Requirements are specified at the level of the system for each upgrade cycle (multiple, possibly concurrent)

Addressing requirements & solution options

Orchestrating upgrades to SoS

SoS

To varying degrees sets of systems may be integrated and tested

Systems

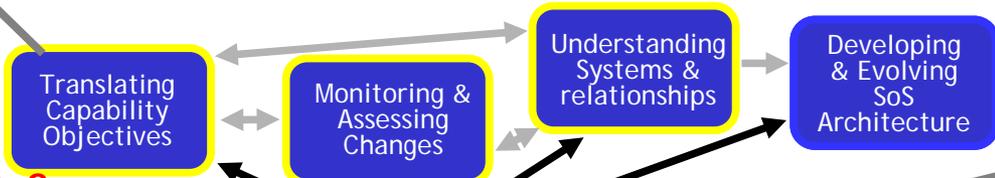**Multiple, possibly concurrent increments**

Systems implement changes as part of their own development processes
These system development processes are typically asynchronous

Systems level T&E validates implementation according to system requirements

Capability objectives are often stated at a higher level

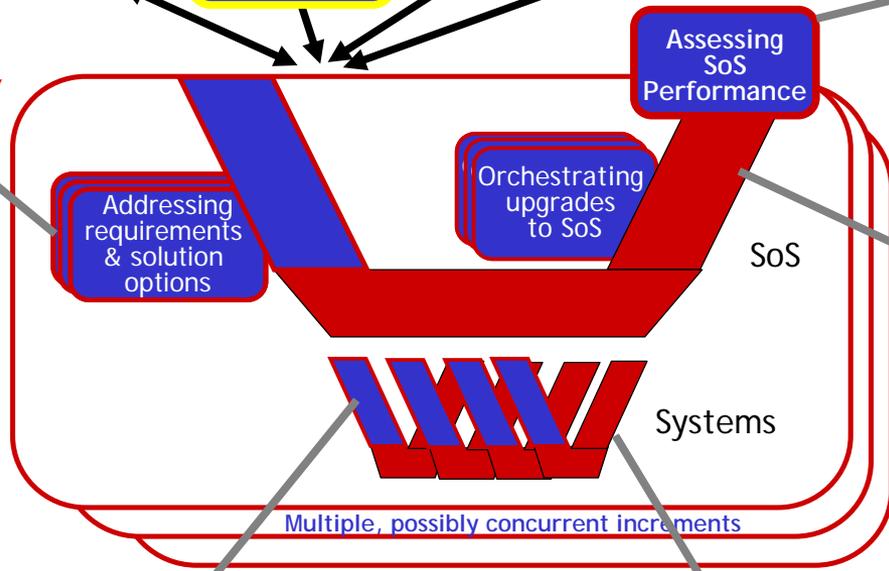**Basis for assessing SoS performance, not the same as 'test objectives'**

Requirements are specified at the level of the system for each upgrade cycle (multiple, possibly concurrent)

Basis for assessing system performance

Translating Capability Objectives

Monitoring & Assessing Changes

Understanding Systems & relationships

Developing & Evolving SoS Architecture

Assessing SoS Performance

Addressing requirements & solution options

Orchestrating upgrades to SoS

SoS

Systems

Multiple, possibly concurrent increments

SoS performance is assessed in various settings (exercise, operations, other)

SoS performance assessment may not be possible before fielding

To varying degrees sets of systems may be integrated and tested

Systems may not be available; may need surrogates

Systems implement changes as part of their own development processes

These system development processes are typically asynchronous

Systems level T&E validates implementation according to system requirements

SoS may have little impact on when systems are tested and deployed

Implications and Recommendations

- Approach SoS T&E as an evidence based approach to addressing risk

- Encourage use of analytic methods to support planning and assessment

- Develop approach to evaluation of networks which can apply across SoS

- Employ a range of venues to assess SoS performance over time

- Establish a robust process for feedback once fielded

- Respond to SoS T&E constraints
  - Full conventional T&E before fielding may be impractical for incremental changes in SoS based on systems with asynchronous development paths
  - Live testing at the SoS level can be infeasible due to difficulty in bringing all constituent systems together and set up meaningful test conditions

- Focus on areas of risk
  - Identify areas critical to success and places where changes could have adverse impacts on the user missions
  - Focus pre-deployment T&E on these risks areas
  - 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 roll-ups of activity at the level of the constituent systems

  - Activity 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

  - Feedback to end users in the form of 'capabilities and limitations' rather than as test criteria for SoS 'deployment'

    - This is done by the Navy Battle Group assessment process

Analytic methods to support SoS planning and assessment

- Analytical models of the SoS behavior can serve as effective tools to

  - Assess system level performance values against SoS operational scenarios

  - Validate the allocations to systems

  - Provide the analytical framework for SoS level verification

- Develop reasonable analytically based expectations for SoS performance

  - Relevant operational conditions should be developed with end user input

  - Guided by design of experiments discipline, so as to expose a broad a range of conditions

Develop approach to evaluation of networks which can apply across SoS

- The network is a unique constituent of almost all SoS
  - Often a major determinate of SoS effectiveness
    - Needs to be assessed as part of the SoS planning, integration, testing and evaluation
  - Realistic assessment of SoS performance demands evaluation of the network performance and it's degradation under the vagaries of operational conditions
    - Typically network is shared and performance is not predictable
- Consider an approach to network assessment which is independent of particular SoS applications, as an input to SoS planning and T&E
  - DoD is developing a set of network capabilities which are applied in a wide range of applications
  - Common way to address network performance could support multiple SoS

Employ a range of venues to assess SoS performance over time

- Evaluation criteria are conventionally established based on quantified performance requirements

  - SoS end-user metrics used to assess the results of SoS capabilities

- Recommend using a range of available opportunities to collect data on SoS performance

  - Assessment opportunities will be both planned and opportunistic

  - These may not be expressly timed to the development and fielding of system changes to address SoS capability objectives

- Performance data can serve a range of needs

  - Support periodic assessments of evolving capability

  - Provide valuable insight to developers and users including the opportunity to identify unexpected behavior

Establish a robust process for feedback once fielded

- Once deployed, continuing "T&E" of the SoS capability of the fielded operations can be used to identify operational problems and make improvements
  - Continual evaluation can be facilitated through system instrumentation and data collection to provide feed-back on
    - Constraints
    - Incipient failures warnings
    - Unique operational conditions
- Can provide a vital link to the ongoing operational needs for the SoS
- Includes technical and organizational dimensions
  - An example of the former is instrumenting systems for feedback post-fielding
  - An example of the latter is posting a member of the SoS SE and management team with the SoS operational organization
- Continually exercised feedback mechanisms between operational and acquisition/development communities

In Sum

- Characteristics of SoS pose challenges for conduct of T&E
  - Independence, synchronous development cycles, limited availability of fielded systems

- **Recommended approaches for providing assurance of SoS in light of these constraints**
  - Approach SoS T&E as an evidence based approach to addressing risk
  - Encourage use of analytic methods to support planning and assessment
  - Develop approach to evaluation of networks which can apply across SoS
  - Employ a range of venues to assess SoS performance over time
  - Establish a robust process for feedback once fielded

- Continued attention is needed in this area as DoD has increased dependence on SoS to support user capabilities