



Challenges for Test and Evaluation (T&E) in the Defense System of Systems Environment

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System of Systems:

A set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities. **DoD Defense Acquisition Guide**



Why Systems of Systems (SoS)?

- **SE is a critical enabler for systems acquisition**
 - ◆ Today's acquisition process focuses on the development of systems
- **Most military systems today are part of an SoS whether or not explicitly recognized**
 - ◆ Most systems are created & evolve without explicit SE at the SoS level
 - ◆ Traditionally the combination of systems to meet operations has been in context of operations
- **Given increased networking and ranges of both sensors and weapons, it is becoming important to recognize SoS in development and systems engineering**
 - ◆ SoS dependencies have an impact on development and engineering of systems
 - ◆ DoD is recognizing SoS from both a management and engineering perspective



Objective

- Ensure the DoD SE community is equipped to support war fighting capabilities at the system, system of systems, and enterprise levels by
 - ♦ **Understanding** the nature of the current and emerging development environments and the challenges they pose for SE
 - ♦ **Identifying** best practices in conduct of SE in supporting development and acquisition
 - ♦ **Providing** enabling policy, guidance, education and training



What Are We Doing with SoS and SE?

- **Completed SoS SE Guide v.1.0 in December 2007**
- **Executed six month 'pilot phase'**
 - ♦ SoS practitioners, research teams and industry
 - ♦ Structured walkthrough of the draft guide contents to capture their experience
- **Pilot results**
 - ♦ Identified key SoS SE elements and principles
 - ♦ Identified SoS SE issues which require further attention
- **Socializing results (INCOSE, IEEE, NDIA, others)**
- **Next steps**
 - ♦ Update DoD SE Guides (SEP, DAG) for SoS considerations
 - ♦ Plan for DAU Continuous Learning Module in FY08
 - ♦ Implement FY08 activities to address identified issues
 - **Testing**

A mechanism to share emerging insights on SoS and implications for SE



Pilot Participants

Objective of the pilots
was to gain a
'boots on the ground'
perspective

Researchers/FFRDCs

INCOSE: International Council on SE
MIT: Massachusetts Institute of Technology
MITRE: MITRE Corporation
Purdue: School of Engineering
SEI: Software Engineering Institute
Stevens: Institute of Technology
USC: University of Southern California
UCSD: University of California San Diego

NDIA: National Defense Industry Assoc.
Australia: Defence Materiel Organisation

SE Practitioners

ABCS: Army Battle Command System
AOC: Air Operations Center
BMDS: Ballistic Missile Defense System
CAC2S: Common Aviation Command & Control System
DCGS-AF: Distributed Common Ground Station
DoDIIS: DoD Intelligence Information System
FCS: Future Combat Systems
MILSATCOM: Military Satellite Communications
NIFC-CA: Naval Integrated Fire Control – Counter Air
SR: Space Radar
NSA: National Security Agency
NSWC: Naval Surface Warfare Center Dahlgren
PEO GCS: Ground Combat Systems
SIAP: Single Integrated Air Picture
SMC: Space and Missile Systems Center
TMIP: Theater Medical Information Systems – Joint
USGC: US Coast Guard C2 Convergence



Emerging Insights from SoS Pilots

SoS: Is It New?

- Most military systems today are part of an SoS whether or not explicitly recognized
 - ♦ Most systems are created and evolve without explicit SE at the SoS level
- A formal SoS comes into existence when something occurs to trigger recognition of SoS
- An organization is identified as 'responsible for' the SoS 'area' along with definition of the objective of the SoS
 - ♦ Typically does not include changes in ownership of the systems in the SoS
- The SoS is then structured
 - ♦ Membership is defined starting with identification of systems in the SoS
 - ♦ Processes and organizations are established for the SoS, including SE

**SoS in the DoD is not new;
Recognizing SoS in development, and recognizing SoS SE is new**



What Does SoS Look Like in the DoD Today?

Insights From Pilots

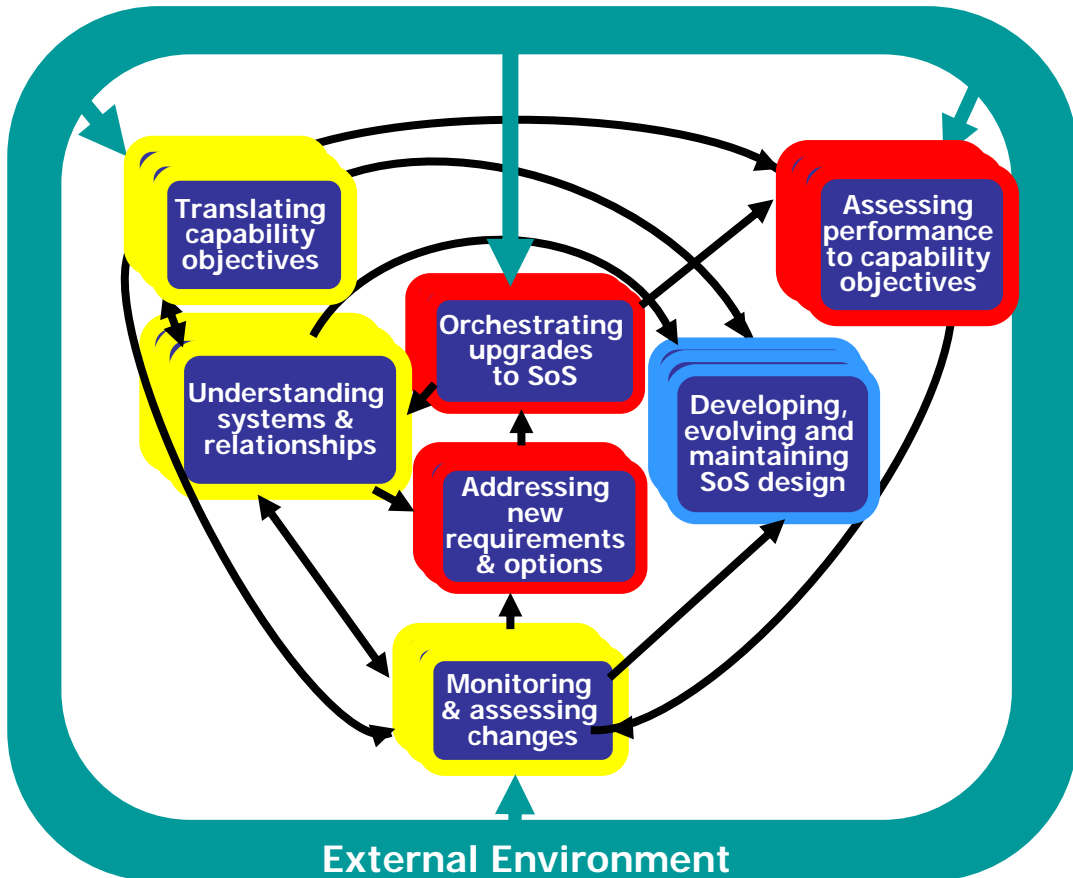
- Typically an **overlay** or ensemble of individual systems brought together to satisfy user capability needs
- **Not new acquisitions** per se
 - ◊ Cases like FCS are extremely rare and, in practice, still must integrate with legacy systems
- SoS 'manager' does not control the requirements or funding for the individual systems
 - ◊ May be in a role of **influencing** rather than directing, impacts SE approach
- Focus of SoS is on **evolution** of capability over time
- A functioning SoS takes start-up time but, in steady state, seems well-suited to routine **incremental** updates

Most military systems are part of an SoS operationally
Only by exception do we manage and engineer at SoS level



Relationship Among Core Elements of SoS SE

Insights From Pilots



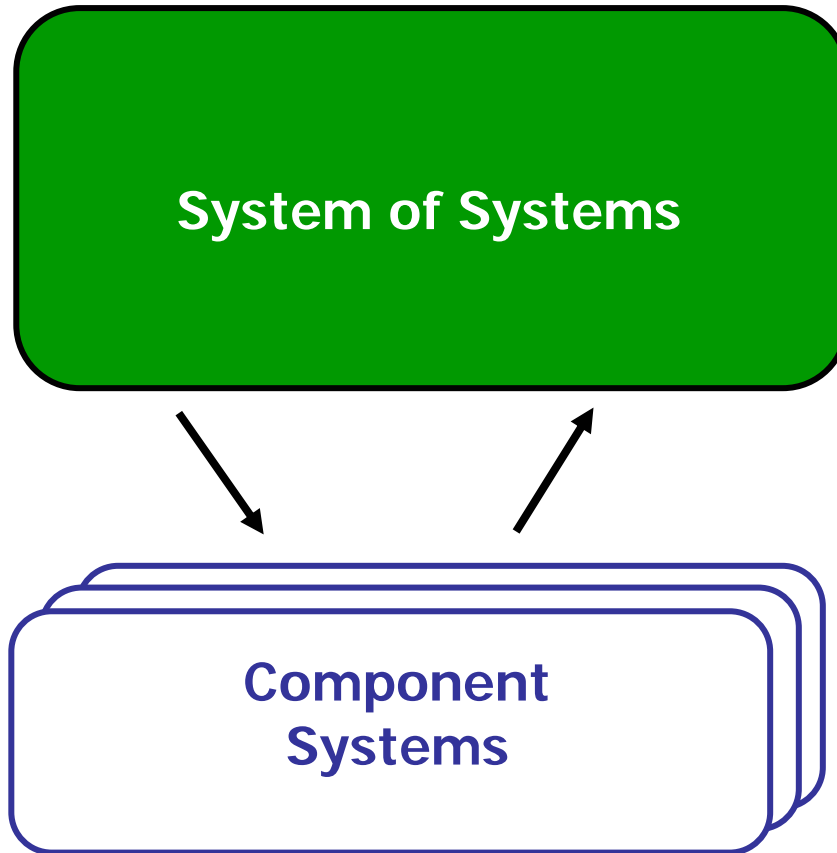
- Translating SoS capability objectives into high level requirements over time
- Understanding the systems in the SoS and their relationships
- Assessing extent to which the SoS meets capability objectives over time
- Developing, evolving and maintaining a design for the SoS
- Anticipating and assessing impacts of potential changes on SoS performance
- Evaluating new and evolving requirements on SoS and options for addressing these
- Orchestrating upgrades to SoS



SoS SE creates and continually applies approaches to accomplish these elements



Where Does T&E Fit into SoS SE?



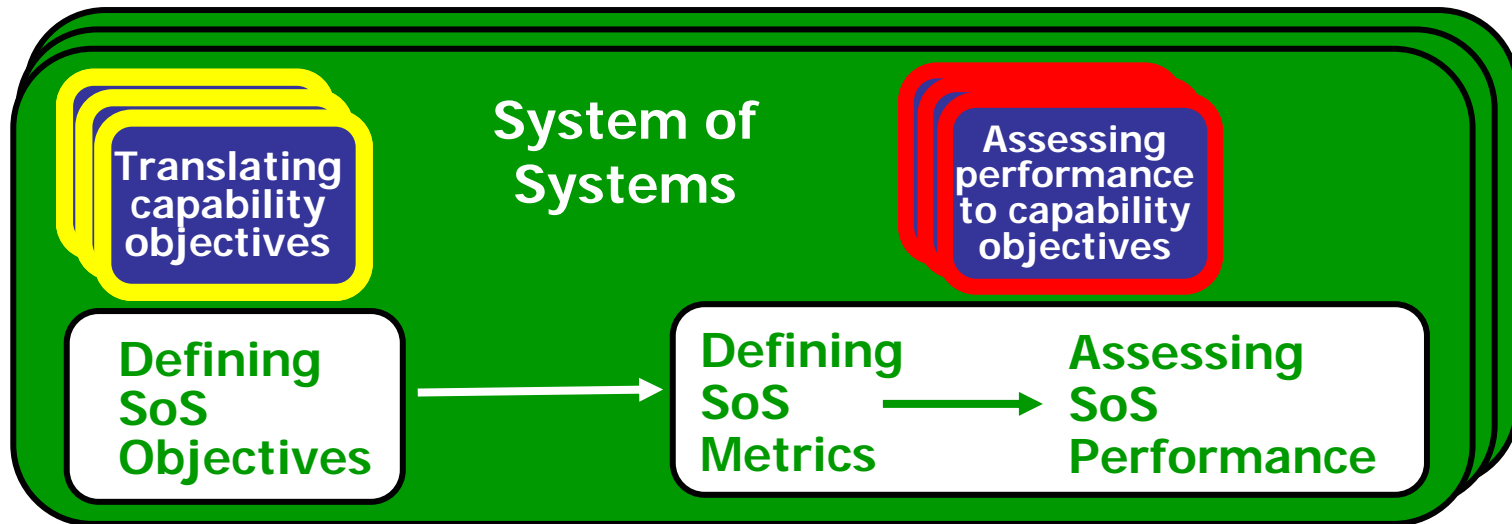
- Focus of SoS engineering on providing end-to-end performance that meets capability needs
- Within the context of the performance requirements and capability limitations of the constituent systems
- Focus in engineering in a single system environment on optimizing to meet specific performance objectives

Creates a tension and balance that must be addressed across the system and SoS levels



Where Does T&E Fit into SoS SE?

SoS

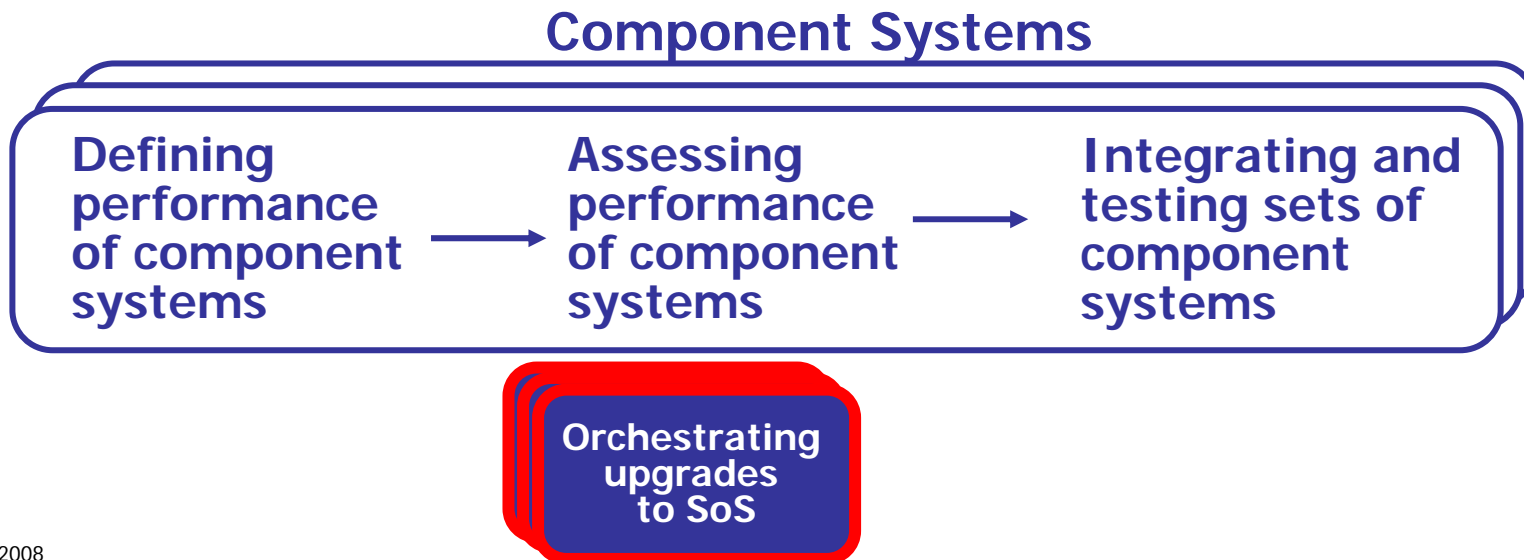


- SoS metrics and methods assess **capability performance** as differentiated from capability development
- SoS metrics need to focus on SoS performance instead of program execution metrics, and on the **intended integrated behavior and performance of the SoS** in actual operations



Where Does T&E Fit into SoS SE? Systems

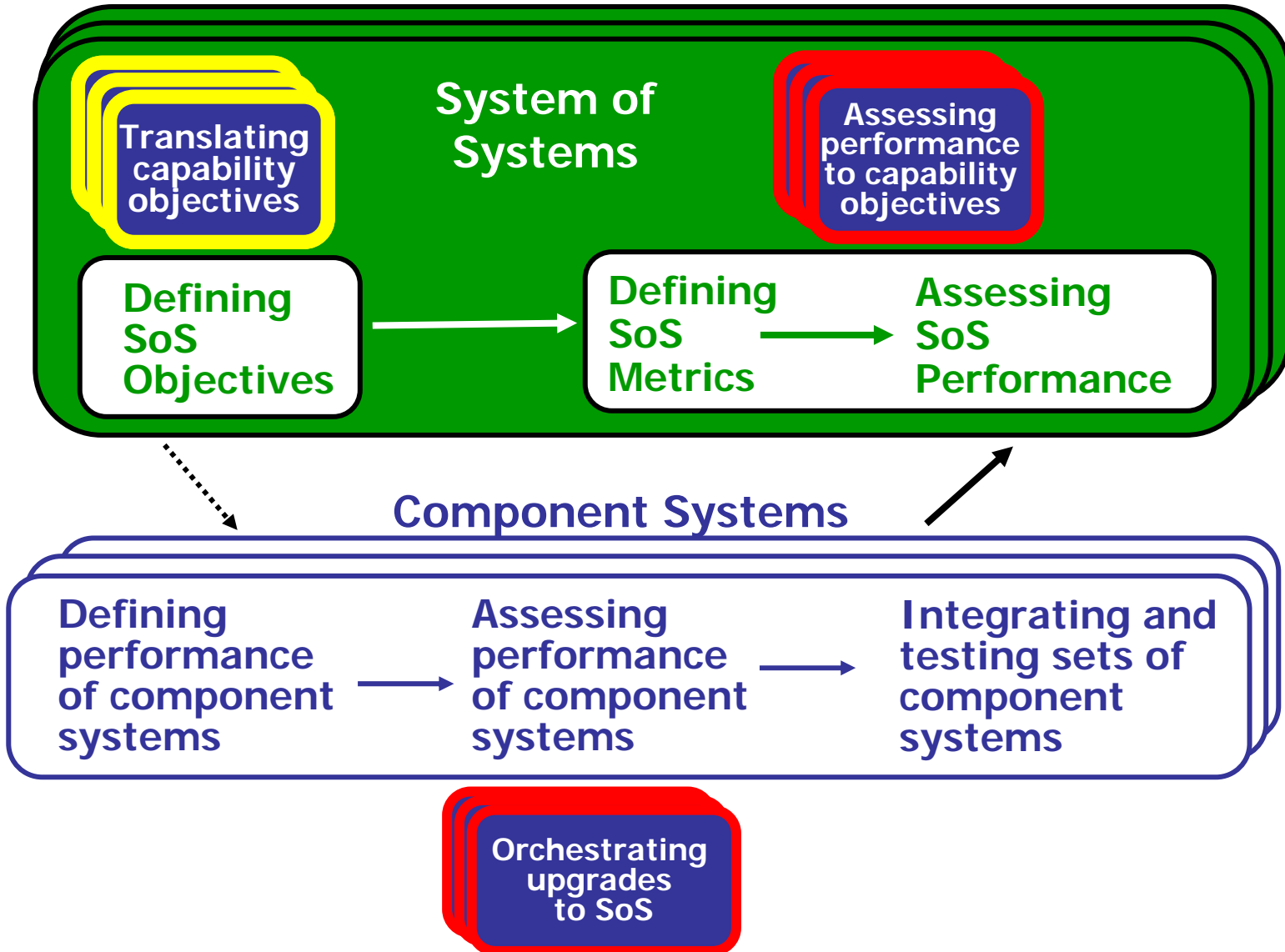
- Changes in systems are made to meet SoS objectives
 - Typically done as part of the **system development and test** process
 - Include system testing as well integration and test **across sets of system**





Where Does T&E Fit into SoS SE?

SoS and Systems





SoS T&E Assumptions

- **Operational Independence** of Systems
 - ◆ Each system has a useful purpose outside of the SoS
- **Managerial Independence** of Systems
 - ◆ Each system is acquired and sustained, independent of the other systems
- **Evolutionary** Development of Systems
 - ◆ Each system is developed in operationally useful increments, uncoordinated with the other systems
- **SoS provides synergistic capabilities**
 - ◆ Unique capabilities not available with a single system
 - ◆ **Synergy** works both ways – positive and negative



SoS T&E Thoughts

- **Traditional requirements process leads to a “point design”**
 - ◆ System designs are optimized and tested for individual system requirements
 - ◆ SoS applications are not necessarily aligned with initial system purpose
- **SoS capability relies on effective interaction between systems**
 - ◆ Increases emphasis on testing the collective behavior and sustainment of that behavior
- **Focus on system capabilities and limitations would provide better knowledge base for SoS application(s)**
 - ◆ Helps identify useful SoS capabilities
 - ◆ Helps identify harmful SoS interactions



SoS T&E Challenges

- **Clear Identification of SoS capability requirements**
- **How much SoS testing is needed?**
 - ◆ Piggy back on system test (non-interference)
 - ◆ Simulations
 - ◆ Regression of SoS capabilities and limitations
- **SoS Visibility into individual system design and capabilities**
 - ◆ “White Box” vs “Black Box” system visibility
- **Resolution of SoS capability or limitation issues**
 - ◆ Which system(s) to change? Trade space
 - ◆ Requires establishment of a value construct between individual systems
 - ◆ Timing may be driven by opportunities



SoS T&E Challenges (cont.)

- **Identification of SoS unique test risks**
 - ◆ How do you identify synergistic weaknesses?
- **Infrastructure capability to test SoS**
 - ◆ May require networked test ranges, labs, models, simulations (technical issues)
 - ◆ May require coordinated asset times (management issues)
 - ◆ Instrumentation capability including long term field data
 - ◆ Data management
 - ◆ Sharing of data – including classified and proprietary issues
- **Evaluation methodology for SoS**
 - ◆ Can we scale analysis and system evaluation methods to SoS size?



Next Steps for SoS T&E



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- Develop a robust understanding of the **challenges** and their **sources**
- Assess **current** initiatives and approaches and
- Identify emerging **principles** and **opportunities** for new initiatives
 - Remove barriers as necessary



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Contact us to provide feedback and share your experience



Backup



Core Elements of SoS SE

Insights
From
Pilots

- Translating SoS capability objectives into high level requirements over time
- Understanding the systems in the SoS and their relationships
- Assessing extent to which the SoS meets capability objectives over time
- Developing, evolving and maintaining a design for the SoS
- Anticipating and assessing impacts of potential changes on SoS performance
- Evaluating new and evolving requirements on SoS and options for addressing these
- Orchestrating upgrades to SoS

The SoS SE is responsible for creation and continual application of approaches to accomplish these elements

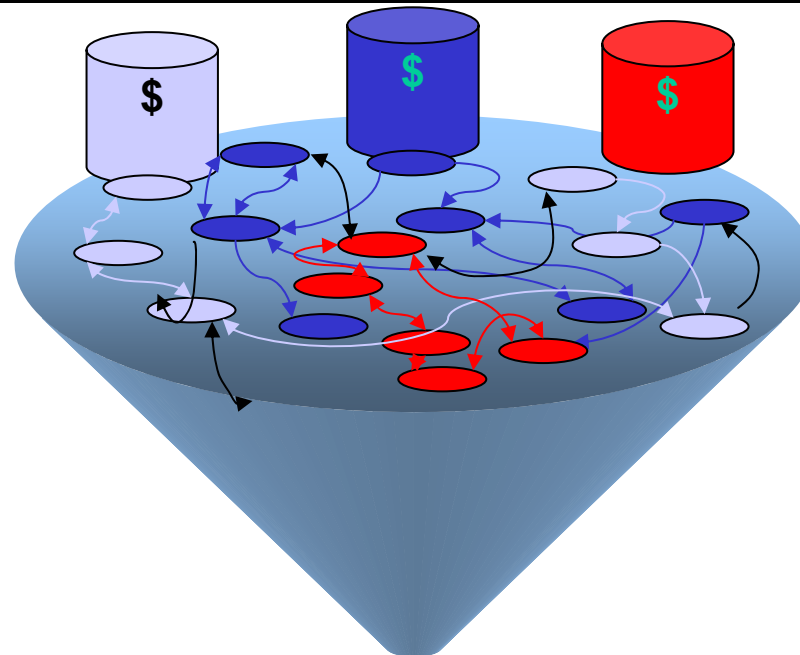
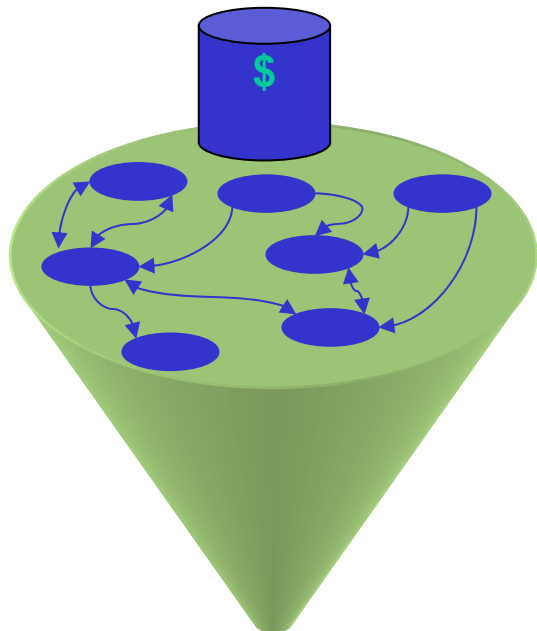


DoD SE Community

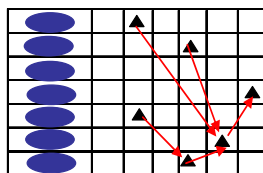
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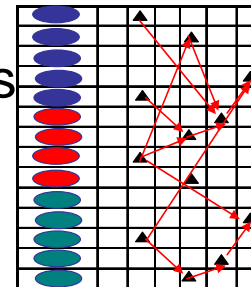
System of Systems – The Management Challenge



SoS:
Within
Single
Organization



Joint SoS:
Interdependencies
Across
Multiple
Organizations



Political and Cost Considerations Impact on Technical Issues



SoS Characteristics Which Impact Testing

- Difficulty in creating measurable **SoS objectives**
- Continued **independent** ownership of requirements and development of the component systems
- Variable component system **contexts**
- **Asynchronous** nature of the development processes across the SoS
- Size and **variability** in SoS membership and application domains
- **Scale** of the SoS
- **Emergent** behaviors