

Department of Defense System of Systems Challenges

NASA Johnson Space Flight Center
Systems Engineering Seminar
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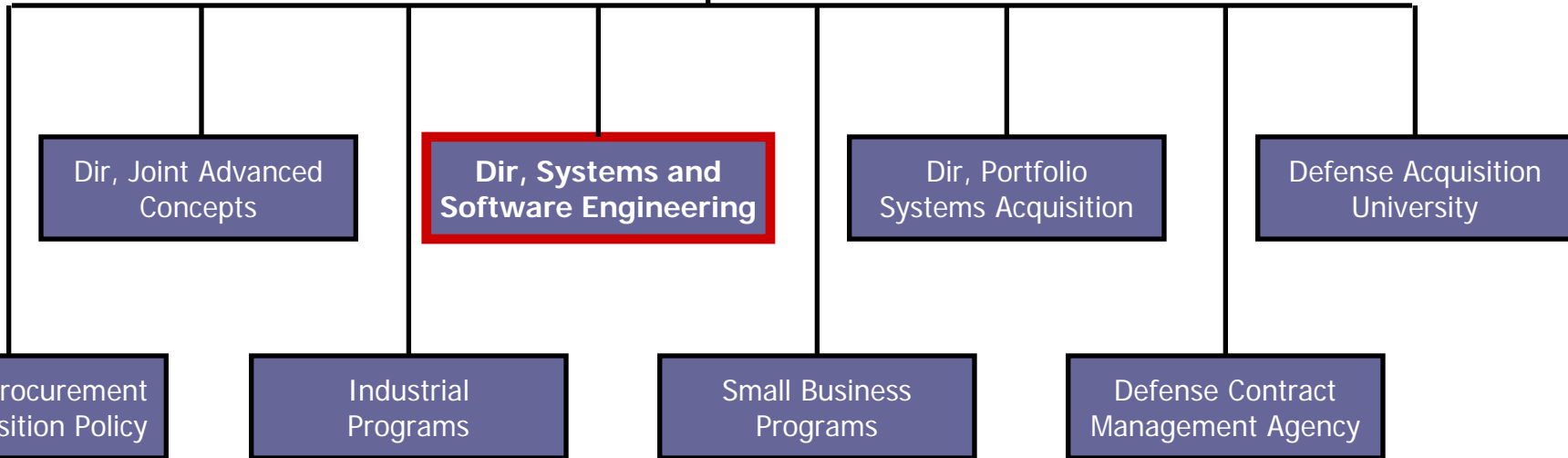
Software and Systems Engineering
DoD Acquisition, Technology and Logistics



Office of Under Secretary of Defense (USD) for Acquisition, Technology and Logistics

USD, Acquisition
Technology & Logistics

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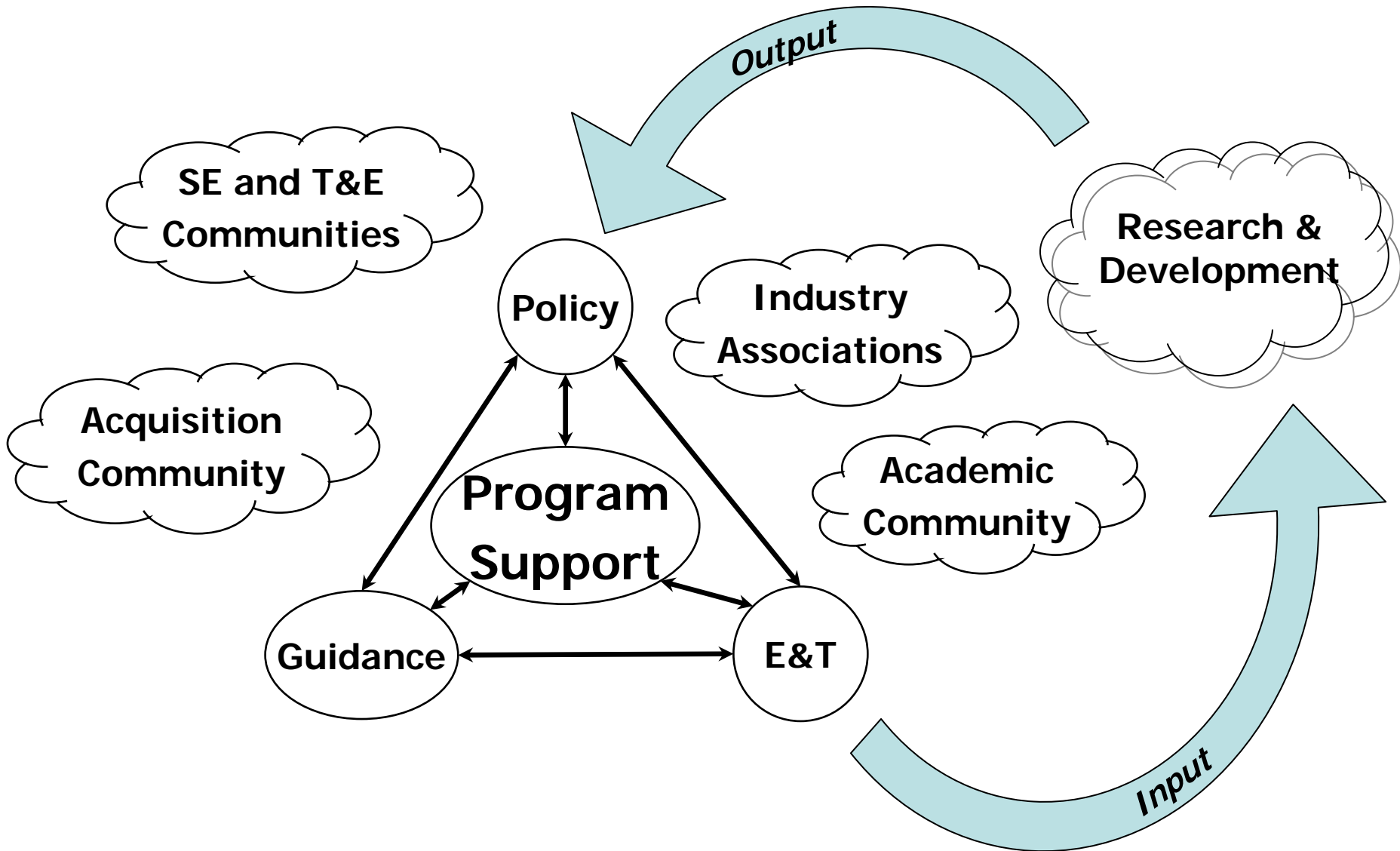
Systems and Software Engineering Mission Statement

- Shape acquisition solutions and promote early technical planning
- Promote the application of sound systems and software engineering, developmental test and evaluation, and related technical disciplines across the **Department's acquisition community and programs**
- Raise awareness of the importance of effective systems engineering and **drive the state-of-the-practice into program planning and execution**
- Establish policy, guidance, best practices, education, and training in collaboration with academia, industry, and government communities
- Provide **technical insight to program managers and leadership** to support decision making

Evolving System Engineering Challenges

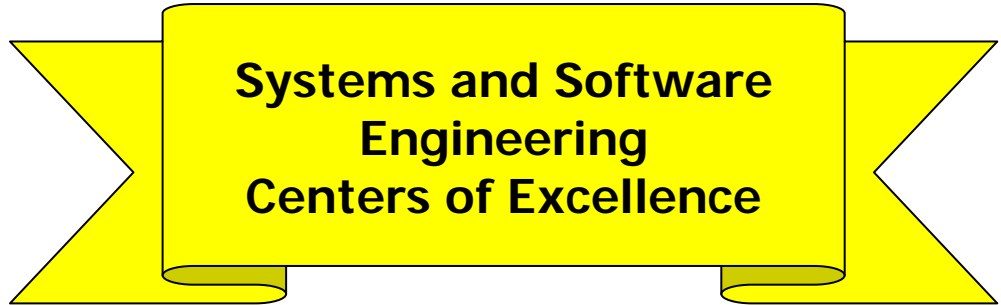
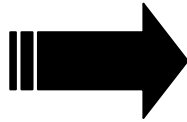


Systems Engineering Revitalization Cycle





Vision for DoD Systems Engineering and Software



- Competencies Improved
- Delivered Product Suite
 - Policy/Guidance
 - Courseware
 - Program Support methods
- Elevated Stature
- Raised Awareness
- Positive Influence

- World class leadership
- Broaden to Software Engineering, System Assurance, Test & Evaluation
- Responsive and agile, technical discipline to shape acquisition solutions
- **Complex Systems-of-Systems**

. . . the Technical Foundation that Enables Acquisition Excellence



INCOSE System of Systems Panel July 2006

- One of a number of events addressing **issues of SoS**
- Quotable quotes
 - “There is no nice line between Systems and SoS”
 - “There is no difference between SE for systems and SoS”
 - “There is simply a need for better requirements management for SoS”
 - “Thinking that traditional SE methods/techniques are sufficient for SoS is dangerous”
 - “Standard SE applies but requires extensions”
 - “Only difference is no one in control in a SoS”
 - “Nothing is new. Any system that has sub-systems is a SoS. We have been doing this forever.”



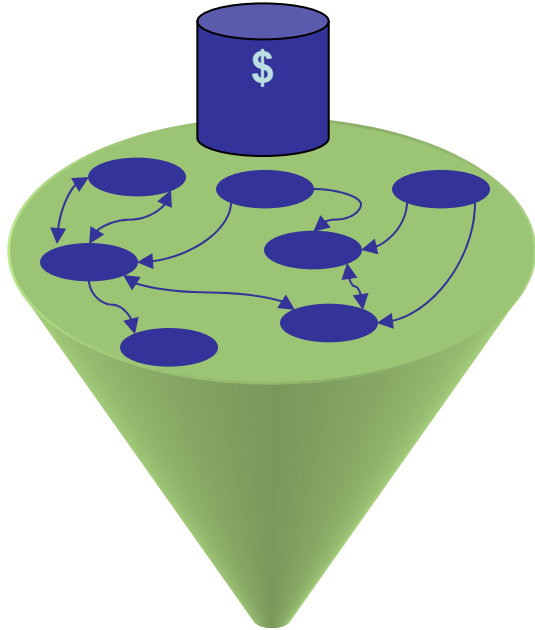
Acquiring Defense Capabilities SoS SE Considerations

- **Ownership/Management** Individual systems are owned by the military services or agencies
- **Legacy** Current systems will be part of the defense inventory for the long-term and need to be factored into any approach to SoS
- **Changing Operations** Changing threats and concepts mean that new (ad hoc) SoS configurations will be needed to address changing, unpredictable operational demands
- **Criticality of Software** SoS are constructed through cooperative or distributed software across systems
- **Enterprise Integration** SoS must integrate with other related capabilities and enterprise architectures
- **Portfolios** SE will provide the technical base for selecting components of the systems needed to support portfolio objectives

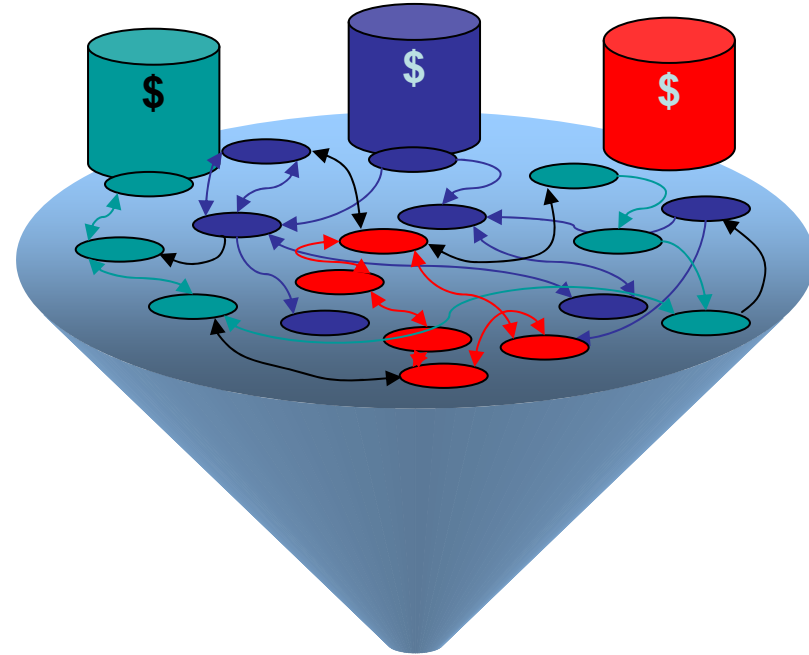
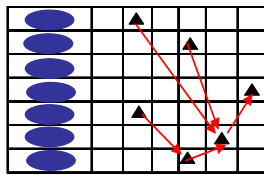
Capability needs will be satisfied by groupings of legacy systems, new programs, and technology insertion – Systems of Systems (SoS)



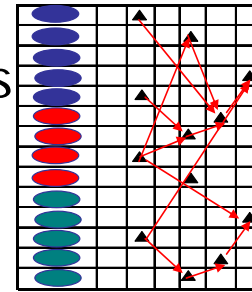
System of Systems – The Management Challenge



SoS:
Within
Single
Organization



Joint SoS:
Interdependencies
Across
Multiple
Organizations



Political and Cost Considerations Impact on Technical Issues



DoD System of Systems SE Guide

SoS Guide Version 0.9

- ❖ Initiative of the Office of the Secretary of Defense
- ❖ Collaborative approach with DoD, Industry, Academia
- ❖ Purpose:
 - Conduct six month effort to address areas of agreement across the SE community – completed December, 2006
 - Focus on technical aspects of SE applicable to SoS
 - Provide means to capture and debate current SoS experiences
- ❖ Audience: PMs and Lead/Chief Systems Engineers

Pilot

- ❖ 6 month pilot phase: “Beta test” the SoS SE Guide
 - Based on structured walkthroughs with practitioners
 - Refine guide content, identify areas for future study
- ❖ Update findings and release Version 1.0 (Fall 2007)

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



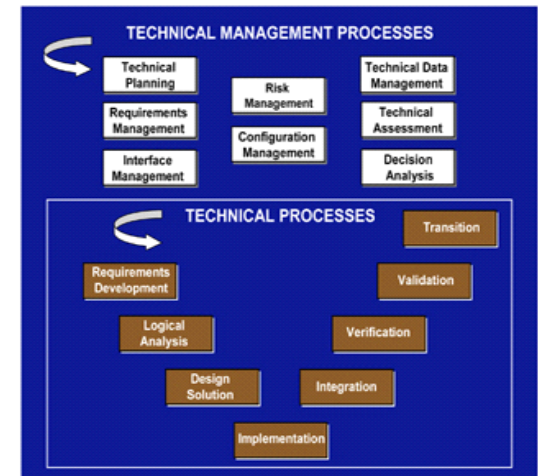
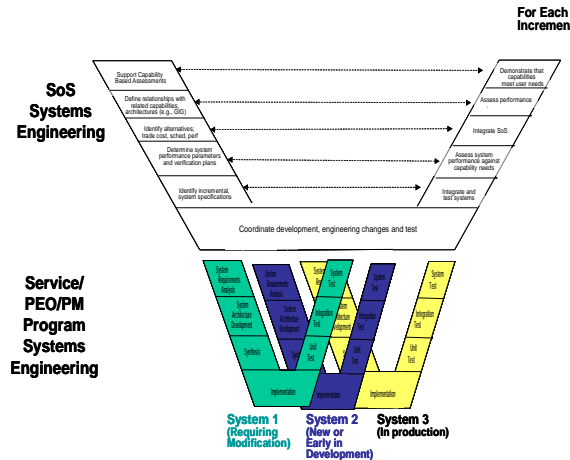
SoS SE Guide Pilot Process

❖ SoS SE Guide draft addresses

- Definitions and depictions of SoS and SoS SE
- SE process challenges and suggestions for SE in SoS

❖ Pilot reviews designed to

- Gain understanding of pilot SoS context and approach
- Assess how well different depictions of SoS and SoS SE reflect pilots' experience
- Elicit feedback on the content for each of the 16 SE processes





Pilot Participants

- Participants are asked to
 - Review the depictions of SoS and SoS SE
 - Assess how well they reflect their experiences and perspectives
 - Suggest other ways to depict SOS and SOS SE
 - Review each process
 - Assess from the perspective of their experience
 - Provide alternatives and examples

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

SE Practitioners

MILSATCOM: Military Satellite and Communications
TMIP: Theater Medical Information Systems – Joint
CAC2S: Common Aviation Command & Control System
PEO GCS: Ground Combat Systems
NIFCA-CA: Naval Integrated Fire Control – Counter Air
Navy Surf WC: Navy Surface Warfare Center Dahlgren
AOC: Air Operations Center
SMC: Space and Missile System Center
NSA: National Security Administration
FCS: Future Combat Systems
ABCS: Army Battlefield Command System
CARTS: Commissary Advanced Resale Transaction System
SIAP: Single Integrated Air Picture
BCT: Brigade Combat Team

Research Community

MIT: Massachusetts Institute of Technology
USC: University of Southern California
UCSD: University of California San Diego
SEI: Software Engineering Institute



Characterizing the SoS Environment*

Community Involvement: Stakeholders, Governance

- **System:** stakeholders generally committed only to one system
- **SoS:** stakeholders at both the systems and SoS levels with different objectives and priorities

Employment Environment: Mission Environment, Operational Focus

System: mission environment is relatively stable with clear operational focus through inevitable change

SoS: SoS mission objectives need to be met in context of systems addressing their own mission objectives

Implementation: Acquisition/Test And Validation, Engineering

System: aligned to ACAT Milestones, specified requirements, a single DoD PM, SE with a Systems Engineering Plan (SEP), T&E plan

SoS: ongoing efforts to satisfy user capability needs through systems with their own lifecycles; no clear 'completion'; involve mix of legacy & new systems, and technology insertion with multiple DoD PMs and operational and support communities; testing is more difficult

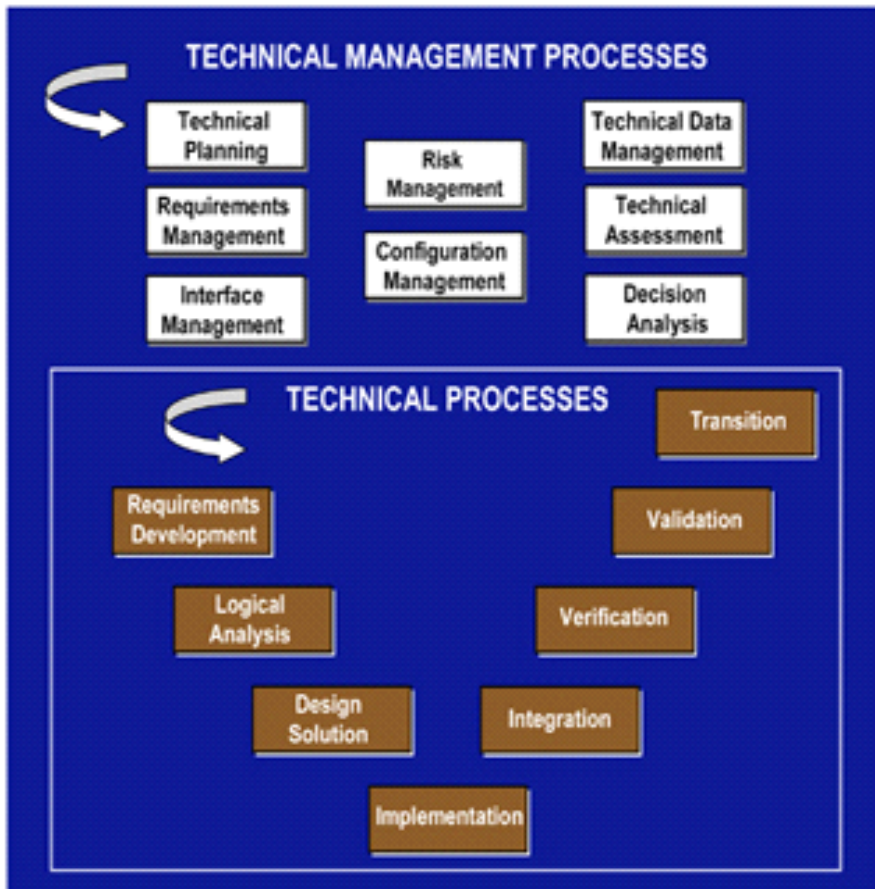


General agreement on distinctions but diverse views on depicting SoS dynamics

* Updated based on pilot results



Challenges of SoS for SE Processes*



From Chapter 4 Defense Acquisition Guide

- **Examine SE processes for SoS**
 - Identify implications of SoS
 - Challenges these pose for the SE
 - Approaches to address challenges
- **SE processes apply but the SoS environment affects approaches, methods and tools needed by SE**
 - More collaboration, less top down
 - More complexity to accommodate requirements, approaches and tools used by constituent systems
 - Balance between roles of SoS SE and the system SE
 - More need to determine ways to employ existing systems and to discover effects of combined systems

Need to address SoS SE context for SE processes

*Updated based on pilot results



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**



Emerging Insights from SoS Pilots Distinguishing Characteristics Of SoS in the DoD Today

- Tend to be ongoing efforts to satisfy user capability needs through an ensemble of systems
- Are not new acquisitions per se
 - Cases like FCS are extremely rare and, in practice, still must integrate with legacy systems
 - Typically SoS is an overlay, evolving or enveloping individual systems
- SoS 'manager' typically 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

These characteristics of SoS impact the way SE is conducted



Emerging Insights from SoS Pilots

Emerging SoS SE Principles

- Must address **organizational** as well as technical perspectives
- SoS SE focuses on areas critical to the SoS
 - Leaves the rest (**as much as possible**) to the SEs of the systems
- SoS technical management approach reflects need for **transparency and trust** with focused active participation
- SoS designs are best when **open and loosely coupled**
 - Impinge on the existing systems as little as possible
 - Are extensible, flexible, and persistent overtime
- **Continuous** ('up front') analysis which anticipates change
 - Design strategy and trades performed upfront and throughout
 - Based on robust understanding of internal and external sources of change



Emerging Insights from SoS Pilots

Core Elements of SoS SE

- Translating SoS capability objectives into high level requirements over time
- Understanding the boundary and scope of the SoS over time
- Assessing extent to which the SoS meets capability objectives over time
- Developing, evolving and maintaining a design for the SoS
- Monitoring and assessing potential impacts of changes on SoS performance
- Addressing ongoing new requirements on SoS and options for addressing these
- Orchestrating upgrades to SoS

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



Emerging Insights SE Processes Applied to SoS

- 16 SE processes apply across the SoS SE elements
 - Offer a 'toolbox' to apply to SoS SE needs

SoS SE Core Elements	Technical Management Processes								Technical Processes							
	Decision Analysis	Tech Planning	Tech Assess	Rqts Mgt	Risk Mgt	Config Mgt	Data Mgt	Interface Mgt	Rqts Devel	Logical Analysis	Design Solution	Implement	Integrate	Verify	Validate	Transition
Translating Capability Objectives				X			X		X							
Understanding Boundary and Scope	X				X	X	X	X		X						
Assessing Performance to Capability Objectives	X		X		X		X			X					X	
Developing, Evolving and Maintaining SoS Design	X	X		X	X	X	X	X	X	X	X					
Monitoring and Assessing Changes	X				X	X	X									
Addressing New Requirements and Options for Implementation	X	X		X	X		X	X	X		X					
Orchestrating Upgrades to SoS	X	X	X	X	X	X	X	X				X	X	X	X	X

Reflect the SoS SE role of technical coordination and direction across systems

Reflect the fact that technical processes are primarily implemented by systems



Next Steps

- Continue pilots and analysis of results
- Evolve understanding and share emerging insights
 - DoD Senior SE Forum and Supporting IPT
 - External Professional Conferences and Organizations
 - Software and Technology Conference (SSTC)
 - International Council on Systems Engineering (INCOSE)
 - National Defense Industry Association (NDIA)
- Update guide for review and publication in fall
- Develop plans for AT&L SE ongoing SoS SE program

Welcome input from community as we continue to capture experiences and lessons learned