Department of Defense System of Systems Challenges

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

USD, Acquisition Technology & Logistics

DUSD, Acquisition & Technology

Dir, Joint Advanced Concepts

Dir, Systems and Software Engineering

Dir, Portfolio Systems Acquisition

Defense Acquisition University

Defense Procurement and Acquisition Policy

Industrial Programs

Small Business Programs

Defense Contract Management Agency
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

Policy

Guidance → E&T

Program Support

Academic Community

E&T

Industry Associations

Research & Development

Acquisition Community

SE and T&E Communities

Input

Output
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
• 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

- 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
**NI FCA-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*

- 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

*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

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<td>Decision Analysis</td>
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<td>Translating Capability Objectives</td>
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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