Systems of Systems: Perspectives, Pain Points and Prospects

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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

Systems of Systems Engineering

The process of planning, analyzing, organizing, and integrating the capabilities of a mix of existing and new systems into a system-of-systems capability that is greater than the sum of the capabilities of the constituent parts
Evolving US DoD Perspectives on SoS & SE

Roadmaps & Capability Area Reviews → Tri-Chair Concept Decision Exploration
SoS SE in US DoD
... And Beyond
…. And Beyond
Perspectives

• Scale and scope
• Complexity
• Systems
Scale and Scope

Technical ----- Socio -Technical ----- Enterprise
Complexity

Technical Complexity Across Systems
Diversity in system concept, design, control structures, data syntax, semantics.....

User Stakeholder Complexity
Independent system owners and stakeholders with their own goals, objectives, motivations......

SoS Development Complexity
Dynamics of asynchronous development

Complex Operational Dynamics
Dynamics of independent operations
SoS Considerations in System Development and Engineering

- Exploratory Stage
- Conceptual Stage
- Development Stage
- Production Stage
- Utilization Stage
- Support Stage

- Initial Review
- Requirements Review
- Design Review
- Test Readiness Review
- Physical Configuration Review

SoS Considerations in System Development and Engineering

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Software Engineering Institute
SoS Pain Points

SoS Authority
What are effective collaboration patterns in SoS?

Leadership
What are the roles and characteristics of effective SoS leaders?

Capabilities & Requirements
How can SE address SoS capabilities and requirements?

Constituent Systems
What are effective approaches to integrating constituent systems?

Testing, Validation & Learning
How can SE approach SoS validation, testing, and continuous learning in SoS?

Autonomy, Interdependencies & Emergence
How can SE address the complexities of interdependencies and emergent behaviors?

SoS Principles
What are the key SoS thinking principles?
Prospects?

SEBoK: SE For Systems Vs SoS

<table>
<thead>
<tr>
<th>Management and Oversight</th>
<th>Systems Engineering</th>
<th>Systems of Systems Engineering</th>
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<tbody>
<tr>
<td>System</td>
<td>Physical engineering</td>
<td>Socio-technical management and engineering</td>
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<tr>
<td>Stakeholder Involvement</td>
<td>Clear set of stakeholders</td>
<td>Multiple levels of stakeholders with mixed and possibly competing interests</td>
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<tr>
<td>Governance</td>
<td>Aligned management and funding</td>
<td>Added levels of complexity due to management and funding for both SoS and systems; SoS does not have control over all constituent systems</td>
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<tr>
<td>Operational Focus (Goals)</td>
<td>Designed and developed to meet common objectives</td>
<td>Called upon to meet new SoS objectives using systems whose objectives may or may not align with the SoS objectives</td>
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<tr>
<td>Implementation</td>
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<tr>
<td>Acquisition/Development</td>
<td>Aligned to established acquisition and development processes</td>
<td>Cross multiple system lifecycles across asynchronous acquisition and development efforts; involving legacy systems, developmental systems, and technology insertion</td>
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<tr>
<td>Process</td>
<td>Well-established</td>
<td>Learning and Adaptation</td>
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<tr>
<td>Test and Evaluation</td>
<td>Test and evaluation of the system is possible</td>
<td>Testing is more challenging due to systems' asynchronous life cycles and given the complexity of all the parts</td>
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<tr>
<td>Engineering and Design Considerations</td>
<td></td>
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<tr>
<td>Boundaries and Interfaces</td>
<td>Focuses on boundaries and interfaces</td>
<td>Focus on identifying systems contributing to SoS objectives and enabling flow of data, control and functionality across the SoS while balancing needs of the systems OR focus on interactions between systems. Difficult to define system of interest</td>
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<tr>
<td>Performance and Behavior</td>
<td>Performance of the system to meet performance objectives</td>
<td>Performance across the SoS that satisfies SoS use capability needs while balancing needs of the systems</td>
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<tr>
<td>Metrics</td>
<td>Well defined (e.g. INCOSE handbook)</td>
<td>Difficult to define, agree, and quantify</td>
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- What systems today are not affected by SoS?
- What systems today don’t cope with multiple diverse stakeholders?
- What systems don’t incorporate elements from other systems?
- What systems don’t face challenges of asynchronous deliveries?
- ...
Questions?

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