SYSTEMS ENGINEERING RESEARCH CENTER | AIRC ACQUISITION INNOVATION RESEARCH CENTER | SERC RESEARCH REVIEW 2026

Updates To Systems Engineering Guide For System Of Systems

OUSW (R&E)

Dr. Ali Raz
Assistant Professor Systems Engineering and Operations Research
Assistant Director of C5I Center
George Mason University

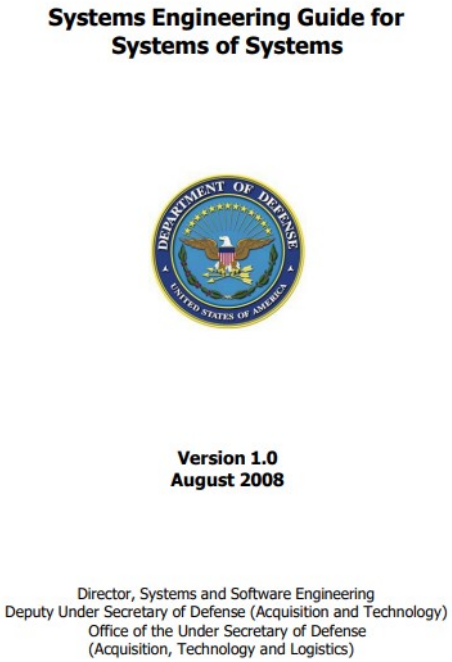
C5I CENTER

GEORGE MASON UNIVERSITY

Torkjazi, Mohammadreza, Thomas A. McDermott, and Ali K. Raz. "Guidance for System of Systems Engineering Teams: How Core Elements Address Challenges." *2026 21st Annual System of Systems Engineering Conference (SoSE)*. IEEE, 2026.

Purpose

- **DoD Systems Engineering Guide for System of Systems set initial guidance on SoS**
  - Published in 2008
  - Played a critical role in establishing the foundation of an emerging field
  - Set the foundations for SoS definitions and defining characteristics (managerial and operational independence of systems, evolutionary development, etc.)
  - Types of SoS (Directed, Acknowledged, Collaborative, Virtual)
  - Focus on adapting 16 SE technical and technical management principles for SoSE (with limited changes)



- **Major Challenges with the SoSE Guide**
  - SoSE guidebook is largely out of sync with SoSE research
  - Many SE processes have been revised since 2008
  - Particularly, no practical guidance exists in the SoSE guide for technical and management techniques for:
    - SoS engineering roles
    - SoS architecting and design
    - SoS integration and evaluation
    - SoS acquisition and evolutionary development

RECENT RESEARCH AND UPDATES OVERVIEW

- **Motivation**
  - There are major Systems Engineering (SE) challenges to successful System of Systems (SoS) realization.
  - The SoS Engineering (SoSE) guidebook characterizes seven core elements to ensure successful SoS realization.
  - Core elements comprise activities that augment current SE practices to account for the SoS challenges.
  - **Which core element should a SoS engineer implement to address a particular challenge at a certain lifecycle stage?**

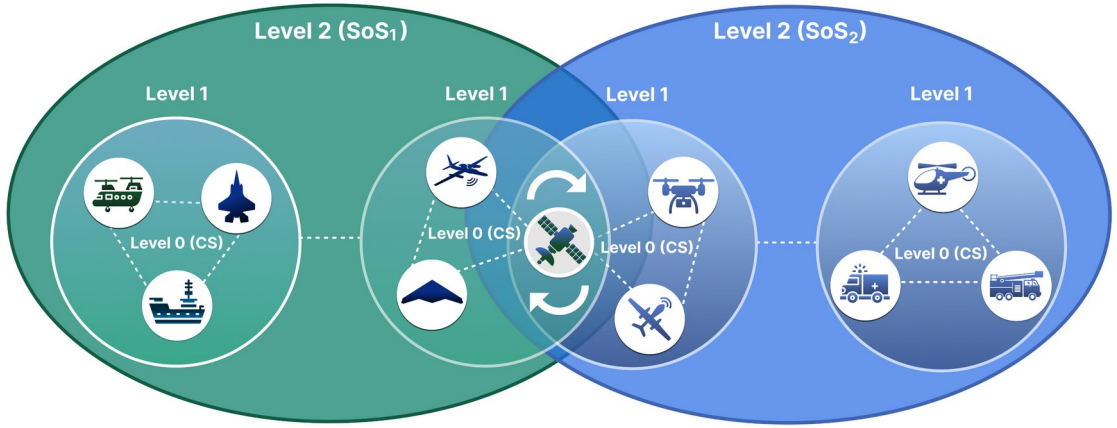


Image generated by AI (Gemini)

- **Recent Contributions**
  - Clarified SoS definitions
  - Defined new roles for SoS Engineer, SoS Team, SoS Manager
  - Developed a mapping between SoSE core elements and SoS challenges that serves as a decision-support framework to:
    - Assist SoS engineers when encountering a SoS challenges corresponding to the life-cycle, and
    - Enhance the SoSE effectiveness by tailoring SE process to address SoS challenges

BRIEF INTRO TO SYSTEM OF SYSTEMS

- SoS is a collection of multiple independent systems that interact to provide capabilities that none of the constituent systems can accomplish on their own
- Multiple SoS network together to provide SoS capabilities and may simultaneously participate in one or more other SoS



Legend : Increasing levels of SoS - **{Level 1 - Level 2}** | Constituent Systems (CS) - **Level 0** | Comm Link - - - - - - -

SoS Type	Central Authority	SoS Manager	Systems Independence	Objectives	Coordination Style	Example
Directed	Yes	Yes	Low; subordinate to SoS	Clearly defined and enforced	Top-down directed operations	Integrated air defense system
Acknowledged	No	Yes	Medium; retain ownership and operational independence	Recognized objectives, while systems may pursue additional goals	Limited interaction; Information exchange and acknowledgment between systems and the SoS	Link 16 combat communication system
Collaborative	No	No	High; act autonomously and cooperate voluntarily	Agreed-upon shared purposes	Higher interaction; Agreement-based cooperative decision-making	Internet
Virtual	No	No	Very High; act independently	No agreed-upon objective; SoS capabilities emerge as large-scale behaviors	Loose, independent coordination	Global Positioning System (GPS)

SoS do not have control over all constituent systems, as they are managerially and operationally independent

KEY ASPECTS OF SOS CHALLENGES



Collaboration pattern between constituent systems to address high-level concerns, such as management and funding.

SEVEN SOSE CORE ELEMENTS



Lays the foundation for SoS development by translating the desired SoS capabilities into high-level requirements and necessary functions.

SE PROCESSES IN EACH CORE ELEMENT

- Core elements are implemented throughout the SoS lifecycle stages.
- Each core element comprises a set of SE processes.
- Each process also corresponds to a set of detailed activities for the SoSE team.
- Activities are implemented in collaboration with systems engineers of constituent systems.

Core Element	Technical processes								Technical management processes							
	Stakeholder Requirements Definition	Requirements Analysis	Architecture Design	Implement	Integration	Verify	Validate	Transition	Technical Planning	Decision Analysis	Technical Assessment	Requirements Management	Risk Management	Configuration Management	Technical Data Management	Interface Management
Translating capability objectives	P								P			P	P	P	P	
Understanding systems and relationships		P											P	P	P	P
Assessing performance against capability objectives							P			P	P	P	P		P	
Developing and evolving an SoS architecture	P	P	P						P	P		P	P	P	P	P
Monitoring and assessing changes	P	P	P				P			P	P	P	P	P	P	P
Addressing requirements and solution options	P		P						P	P		P	P	P	P	P
Orchestrating upgrades to SoS				P	P	P	P	P		P	P	P	P	P	P	P

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PROPOSED MAPPING

- On one side, there is a list of key aspects for each identified SoS challenge
- On the other side, there is a set of detailed activities for core elements
- We examined how activities in each core element address which key aspects of SoS challenges

	SOS CHALLENGES							
SOSE CORE ELEMENT	*Authorities*	*Leadership*	*Caps&Reqs.*	*Integration*	*Arch.&Desg.*	*Evol. Bhv.*	*Emergence*	*T&E*
Translating capability objectives						✓		
Understanding systems and relationships	✓	✓	✓	✓	✓	✓	✓	
Assessing performance against capability objectives						✓	✓	✓
Developing and evolving an SoS architecture			✓	✓	✓	✓	✓	✓
Monitoring and assessing changes			✓	✓	✓	✓	✓	✓
Addressing requirements and solution options	✓	✓	✓	✓	✓	✓		
Orchestrating upgrades to SoS		✓						✓

A clear mapping assists in understanding the necessary SoSE activities to address a particular challenge

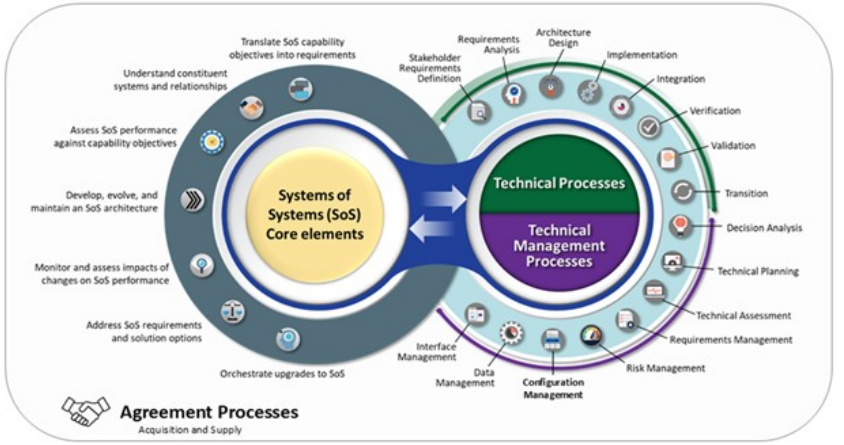
ON-GOING DEVELOPMENTS AND UPDATES

- **Completing a detailed literature review of major SoSE Publications**
  - Revising SoS definitions and types with examples
  - Introducing analytical methods for SoS analysis

- **Identifying updates to the SE processes to address SoS Challenges**
  - Updating guidance for SoS engineers in adapting SE processes for SoS challenges

- **Creating workforce development webinars based on revised SoSE Guidebook**
  - Short modules for introducing key SoS concepts

	Type	Authors	Year	Title	
1	Journal	Agarwal et al.	2015	Flexible and Intelligent Learning Architectures for SoS (FILA-SoS): Architectural Evolution in Systems-of-Systems	The proposed the DoD to de
2	Journal	Marvin and Garret	2014	Quantitative SoS Architecture Modeling	The proposed architectures
3	Journal	Manzano et al.	2020	Dynamic-SoS: An Approach for the Simulation of Systems-of-Systems Dynamic Architectures	Prediction of t
4	Conference	Hause	2014	SOS for SoS: A new paradigm for system of systems modeling	Proposes a mo Specification (
5	Journal	Mohsin and Janjua	2018	A review and future directions of SOA-based software architecture modeling approaches for System of Systems	Service-Orient
6	Conference	Borth et al.	2019	Digital Twin Strategies for SoS 4 Challenges and 4 Architecture Setups for Digital Twins of SoS	Challenges an
7	Journal	Ricci et al.	2014	Architecting Systems of Systems with Ilities: an Overview of the SAI Method	Proposes an a identifying des such propertie
				When architecture meets AI: A deep reinforcement	Proposes a de



M1: Introduction to SoS	M2: SoS Foundations	M3: SoS Engineering
• Introduction to SoSE • SoS and SoSE Examples in DoW Today • Roles and Responsibilities with SoS • Knowledge Review Quiz	• Historical Evolution • Systems vs SoS • SoS Types • SoS Characteristics • SEP vs EEMP • Knowledge Review Quiz	• SoSE Principles • SoS Management • SoSE Core Elements • SoS Challenges • Knowledge Review Quiz
M4: SoSE Processes	**M5: SoSE Intersections**	**M6: SoSE Case Study**
• SE Processes in SoS Environment • SoSE Processes • SoSE Core Elements Implementation • Knowledge Review Quiz	• MOSA • M&S • Digital Engineering • Mission Engineering • Software Engineering • Cybersecurity • Knowledge Review Quiz	• Role based SoSE Case Study • SoS Manager OR • SoS Systems Engineer • Challenge questions on M1-M5 in Case Study Context

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Thank you!

Email the presenter

✉ Ali Raz, araz@gmu.edu

Email the research team

✉ Ali K. Raz, araz@gmu.edu
Thomas A. McDermott, tmcdermo@stevens.edu
Ben Torkjazi, mtorkjaz@gmu.edu

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