SoSECIE Webinar

Welcome to the 2021 System of Systems Engineering Collaborators Information Exchange (SoSECIE)



We will start at 11AM Eastern Time You can download today's presentation from the SoSECIE Website: <u>https://mitre.tahoe.appsembler.com/blog</u> To add/remove yourself from the email list or suggest a future topic or speaker, send an email to <u>sosecie@mitre.orq</u>

NDIA System of Systems SE Committee

Mission

- To provide a forum where government, industry, and academia can share lessons learned, promote best practices, address issues, and advocate systems engineering for Systems of Systems (SoS)
- To identify successful strategies for applying systems engineering principles to systems engineering of SoS

• Operating Practices

 Face to face and virtual SoS Committee meetings are held in conjunction with NDIA SE Division meetings that occur in February, April, June, and August

NDIA SE Division SoS Committee Industry Chairs:

Mr. Rick Poel, Boeing Ms. Jennie Horne, Raytheon

OSD Liaison:

Dr. Judith Dahmann, MITRE

Join us for the NDIA's Virtual Systems and Mission Engineering Conference

Dates: Monday, December 6th through Wednesday, December 8th

• Why Attend?

- Gain insight on improving acquisition and performance of defense programs and systems.
- Hear from Program Managers, Systems Engineers, Chief Scientists, and Engineers and Managers.
- Participate in Q&As with session speakers; getting your most pressing systems engineering questions answered.
- View handouts to supplement and enhance your virtual experience.
- Network and build relationships with like-minded professionals during virtual networking opportunities.

• Topics

- Engineering and Manufacturing
- Human Systems Integration
- Systems Architecture
- Systems Security Engineering
- Systems of Systems Engineering

Register online at

https://www.ndia.org/events/2021/12/6/24th-sme-conferencevirtual/registration

Simple Rules of Engagement

- I have muted all participant lines for this introduction and the briefing.
- If you need to contact me during the briefing, send me an e-mail at sosecie@mitre.org.
- Download the presentation so you can follow along on your own
- We will hold all questions until the end:
 - I will start with questions submitted online via the CHAT window in Teams.
 - I will then take questions via telephone; State your name, organization, and question clearly.
- If a question requires more discussion, the speaker(s) contact info is in the brief.

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2021-2022 System of Systems Engineering Collaborators Information Exchange Webinars Sponsored by MITRE and NDIA SE Division

November 30, 2021 Should I Stay or Should I Go? How Constituent Systems Decide to Join or Leave Constellations in Collaborative SoS Pontus Svenson and Jakob Axelsson

December 14, 2021 A Heterogeneous Autonomous Collaborative System for Powerline Inspection Using Human-Robotic Teaming Srikanth Vemula, Jovany Avila, and Michael Frye

> January 11, 2022 Approach for Complex Deterministic and Nondeterministic Systems (ACDANS) Dr. Paul C. Hershey

January 25, 2022 Applying SoSE in Healthcare: the case for a soft systems methodology approach to Digital-first Primary Care Igra Shahzad, Melanie King, and Michael Henshaw

https://www.mitre.org/capabilities/systems-engineering/collaborations/system-of-systems-engineering-collaborators

2021-2022 System of Systems Engineering Collaborators Information Exchange Webinars Sponsored by MITRE and NDIA SE Division

February 8, 2022 Empowering Adaptive Human Autonomy Collaboration (DUAL) with Artificial Intelligence Dr. Mark Chattington

February 22, 2022 System of Systems Engineering Conference (SoSE) and Industry Perspectives and the Role of SoSE: INCOSE and IEEE Collaborations Paul Hershey, Garry Roedler, and Mo Jamshidi

March 8, 2022 An Event-based Microservice Platform for Autonomous Cyber-Physical Systems: the case of Smart Farming Mara Nikolaidou

May 3, 2022 Cross-Domain Stakeholder-Alignment in Collaborative SoS – Lego Serious Play as a Boundary Object Johann Shuetz, Julia Koehlke, and Sebastian Hanna

https://www.mitre.org/capabilities/systems-engineering/collaborations/system-of-systems-engineering-collaborators

A design method for collaborative systems of systems applied to Metropolitan Multi-Mode Transport System

SoSECIE webinar 2021-11-16 See also SoSE 2021 paper

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Systems of systems

- Systems of systems (SoS) are independently operated and managed systems that are geographically distributed, undergo evolutionary development and display emergent behavior
- The individual systems are named the constituent systems (CS)
 - Mediators SoS elements that help CS collaboratore
- A set of constituent systems that operate together is a *constellation* in the overall SoS
- Focus: collaborative SoS, no central controller that can enforce collaboration; settings where the SoS is intended to solve many problem instances



Designing collaborative SoS

- Determine what capabilities are needed to solve the problem
 - Can they be provided by an integrated system? Or a directed SoS? If not:
- Determine how to get these capabilities to work together
 - Are additional CS needed? What mediators are needed? What value flows are needed to ensure cooperation?
- Our focus is on collaborative SoS where there will be many active constellations



Problem domains and instances



The SoS must be able to solve several problems simultaneously (cf "missions")

Each instance is solved by a constellation of CS

A CS can participate in multiple constellations – Britney and John share ride, air surveillance craft Argus supports both Skåne and Bornholm missions



A system is intended to intervene in a problem domain by solving a problem instance



RI. Se The systems of systems we study are intended to intervene in a problem domain by solving multiple problem instances



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- CS have their own purpose intended intervention in (another) problem domain
- SoS has a purpose is intended to do an intervention in some problem domain
- Constellation: set of CS that act as an instantiation of the SoS to do an intervention



Example: vehicle platooning

- Vehicles solve transportation needs
- Vehicles in platoons save fuel
- Trucks are CS
- Platoons are constellations
- Need coordination and synchronization



Who are involved in designing the SoS?

- The beneficiaries of the SoS?
- The developers of CS and mediators?
- The operators of CS and mediators?
- ...
- But new operators can join the SoS, new CS from new developers can be bought by new or existing CS owners, ...

Role types involved in SoS design

- SoS initiator sees a possibility for a SoS
 - Stakeholder who wants some benefits
 - Public authorities who want some benefit
 - Company that sees a business opportunity, as a mediator or CS operator or CS developer or CS owner

- ...



Role types involved in SoS design

- SoS developer tasked by the SoS initiator to
 - Choose standards used for communication (or develop/extend)
 - Choose business rules used in SoS (or develop/extend)
 - Determine what capabilities are needed
 - Determine how to design interaction mechanisms to ensure the emergent behaviour solves the problems and the the unintended consequences are not critical

- ...

Role types involved in SoS design

- SoS supporter somebody who does not benefit directly but who wants to encourage growth of the SoS
 - Ensure that the SoS survives establishment and growth phases
 - Ensure that accessibility in urban areas meets some minimal requiremens
 - ...
- See next year's paper for more on structure and organization...



Design method – general

- Determine the problem domain. Who are the beneficiaries/stakeholders, what are the needs?
- What is the desired value that the intervention should create? What are the values that beneficiaries/stakeholders are willing to give the intervention?
- What capabilities are needed in order to solve the problem/execute the intervention? What are the values that their owners and operators want in order to participate?



Design method – what should we build?

- What capabilities are needed in order to solve the problem?
 - If the set of capabilities can be provided by a single system, build this instead of designing a system of systems.
 - If the set of capabilities can be used to solve the problem under the direction of one party, construct a directed system of systems.
- Otherwise, find a set of constituent systems combinations of which can solve the problem.



SoS specific design

- For each constituent system from the previous step, determine
 - what values (ie, capabilities) it creates?
 - what values would the CS owner and operator require in order to participate?

Value flow analysis -- iteratively

- What are the value flows so far?
- Do they fit together? Or are additional capabilities needed to make them fit?
- Can these new capabilities be filled by additional constituent systems, infrastructure, or mediators? Describe the capabilities needed.
- What value do these new elements create and what values do they need in order to participate?



Example: Mobility SoS in Harestad

- Autonomous vehicles ("pods") with different capacities combined with existing public transport system
- Travels to
 - Work
 - School
 - Shopping
 - Non-critical medical



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What is the problem and who are the beneficiaries?

- Travellers and inhabitants of Harestad will benefit from being able to have more accessible, flexible, sustainable transportation
- Values created by the SoS
 - safe, secure, sustainable and flexible transports
- The beneficiaries are willing to pay money for this
- Public authorities are willing to pay for school, elderly and medical travel



What capabilities are needed?

- Transporting people and goods from point A to point B.
- To accommodate the varying needs, there is a need for autonomous vehicles of different sizes small, medium and large.
- The vehicles should also be able to transport small cargo items
- The transport constituent systems create the value of performing a transport. They will require to get paid for this.

Value flow so far – value flows from row to column

	User	Society	Transport operator	Intervention
User				Money for transport
Society				Subsidy for some transports
Transport operator				Flexible transportation
Intervention	Flexible transportation	Transports that society subsidies have been performed		



Missing value flows

- There is a need for additional elements that ensure that
 - The transports provided by the transport operator match the flexible transportation needs of the users.
 - The money paid by the user and society is transferred to the transport operators.



To fix this, we need mediators

- There is a need for three mediators in order to fulfill these:
 - A constellation formation mediator that takes the transport needs of several users and creates constellations of transport CS that can fulfill these.
 - A payment distribution mediator, that ensures that each user only has to pay once and that each transport operator is paid according to its effort and agreements.
 - A user interface mediator that provides a simple way for users to input their transportation needs.



What values do these mediators create and require?

- The constellation formation mediator creates the optimized solution that solves the transport needs. It needs to collect a fee for this.
- The payment distribution mediator ensures that everyone gets paid. It will require a fee for this.
- The user interface mediator ensures that the users can easily input their needs. It will collect the payment from the user and take a fee.



Value flows now

	User	Society	Transport operator	Formation mediator	Payment distributor	User interface
User			Data		Ticket payment	Travel needs; Data
Society			Road infrastructure		Subsidy for some transports	
Transport operator	Transport	Transports that society subsidies have been performed		Flexible transportation options	Fee	The value to provide multiple travel options
Formation mediator	Optimized travel solution	Optimized travel solution			Fee	The value to provide optimized travel options
Payment distributor			Fair payment for work done	Fair payment for work done		Fair payment for work done
User interface	Single way of accessing multiple optimized travel options			Trvel need	Fee	

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Summary

- Determine the problem domain. Who are the beneficiaries/stakeholders, what are the needs?
- What is the desired value that the intervention should create? What are the values that beneficiaries/stakeholders are willing to give the intervention?
- What capabilities are needed in order to solve the problem/execute the intervention? What are the values that their owners and operators want in order to participate?
- Iterative value flow analysis until everything matches



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