## **SoSECIE Webinar**

Welcome to the 2018 System of Systems Engineering Collaborators Information Exchange (SoSECIE)



We will start at 11 am Eastern Time Skype Meeting +1 (703) 983-2020, 46013573# You can download today's presentation from the DASD(SE) Website: <u>https://www.acq.osd.mil/se/outreach/sosecollab.html</u> To add/remove yourself from the email list or suggest a future topic or speaker, send an email to <u>knharrington@mitre.org</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
- SoS Track at NDIA 21th Annual Systems Engineering Conference, Grand Hyatt Tampa Bay, Tampa, FL, October 22-25, 2018
  - Conference Info: http://www.ndia.org/events/2018/10/22/9870---21st-systems-engineering-conference
  - Call For Papers Extended to July 3, 2018: http://www.ndia.org/events/2018/10/22/9870---21st-systems-engineeringconference/call-for-papers

NDIA SE Division SoS Committee Industry Chairs:

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**OSD** Liaison:

Dr. Judith Dahmann, MITRE

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- 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 <u>knharrington@mitre.org</u>.
- 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 Skype.
  - 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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#### 2018 System of Systems Engineering Collaborators Information Exchange Webinars Sponsored by DASD(SE) and NDIA SE Division

October 16, 2018

System of Systems Architecture Feasibility Analysis to Support Tradespace Exploration MAJ Stephen Gillespie, PhD, U.S. Military Academy

October 30, 2018

Scaling Model-Based System Engineering Practices for System of Systems Applications Dr. Aleksandra Markina-Khusid and Ms. Janna Kamenetsky, The MITRE Corporation

> November 6, 2018 Model Based Systems of Systems Engineering Mr. Francis McCafferty, Vitech Corporation

November 27, 2018 Emergence as a Subject of Research, Research Methods, and Engineering Knowledge and Practice Dr. Timothy L.J. Ferris, Centre for Systems Engineering, Cranfield University, Defence Academy of the

United Kingdom







The exploration of a system of systems (SoS) tradespace is made much more efficient and effective with a method to first automatically screen a large number of SoS designs for feasibility. This is because not every combination of constituent systems is capable of forming a viable SoS, much less form a SoS that exhibits the desired emergent behavior(s). The SoS Architecture Feasibility Assessment Model (SoS-AFAM) assesses the feasibility of the physical communications, process, and organizational architectures of a SoS. The model applies algorithms based on the minimum requirements for viability relevant to all SoS such as connectivity and completeness. We present a case study to demonstrate how the algorithm can greatly prune the SoS tradespace of infeasible SoS design points, which can increase the efficiency of design exploration.





## System of Systems Architecture Feasibility Analysis to Support Tradespace Exploration

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16 October 2018

Office of the Deputy Assistant Secretary of Defense: Systems Engineering System of Systems Engineering Collaborators Information Exchange







- Tradespace Exploration (TSE) is a growing area of systems engineering
- One can use TSE for SoS Engineering
- TSE requires modeling system performance & attributes
  - In particular, one significant attribute to model is feasibility
  - SoS share properties that may be used to generally assess for feasibility
  - The SoS Architecture Feasibility Assessment Model to support this



## SoS Engineering









- Defining a tradespace
  - Combinations of <u>design</u> <u>parameters</u> produce large numbers of potential alternatives
  - Consider the attributes of those alternatives
  - Consider how those alternatives perform
  - Explore the "illuminated" tradespace





#### **SoS Tradespace**



- SoS Design Parameters
  - Defining characteristics for the (high-level) SoS Architecture
- Operational Measures (MOPs, MOEs, TPMs, etc...)
  - Chosen during problem definition
- Relate Design Parameters to Operational Measures
  - Models / simulation
- SoS Feasibility
  - Can a given SoS alternative (a set of design parameters that define an SoS (high-level) Architecture) be successfully realized?





- SoS Operational Performance Space
  - Not one single decision maker
  - Competing priorities
- SoS Design Space
  - Large
  - Categorical variables
  - More than just physical design considerations...
- Emergent Properties
  - Always a challenge...
  - Typically (not always) need to use an agent based model
  - Typically (not always) non-linear response
- This challenges brute force methods and DOE methods for developing a SoS tradespace







- Typically, tradespace exploration relies on combinatorics:
  - Look at all possible combinations of various design points
  - No regard to feasibility until after the fact
- Alternatively, screen infeasible design points out first
  - Highly unlikely (though not provably so) that all random combinations of design choices will be feasible
  - Doing this allows you to focus efforts on potentially realizable solutions
- Raises the question what is feasibility?
  - More precisely what is SoS feasibility?





- SoS have a fundamental, network structure.
  - Multiple types / views of connections / relationships
  - We can assess feasibility with this in mind for any, generic SoS
- Physical View
  - Can all of the systems in the SoS "talk" to each other?
  - Is the communications network connected?
- Process View
  - Is there sufficient functionality to elicit the desired emergent behavior?
  - Do the rules governing the SoS support this emergent behavior?
- Organization View
  - Are the relationships between the systems "acceptable"?
  - Is the organization connected?
- We can screen combinations based on these views to "winnow" our design space.





- Input is set of all physical parameters
- The central question is, can we achieve connectivity?
  - Network science algorithms exist for connectivity analysis
  - Simply need to define the adjacency matrix, where the i-j entry is a 1 if the i<sup>th</sup> and j<sup>th</sup> systems share a common communications means, and a 0 otherwise
- Higher fidelity analysis, consider:
  - Range
    Error Rate
  - Bandwidth
- System Availability
- Latency







- Process
  - Functions
  - Rules
- Three tests for Process Feasibility
  - Sufficient Functionality
    - Do the constituent systems provide the necessary functions (type & quantity)?
  - Rule Acceptance
    - Will the constituent systems abide by the given rules of the SoS?
  - System Interference
    - Can the constituent systems provide their functionality while other systems are operating?

Process 1 (P1)	$Observe \rightarrow Deconflict \rightarrow Shoot$
Process 2 (P2)	Observe (x2) $\rightarrow$ Deconflict $\rightarrow$ Shoot
Process 3 (P3)	Observe $\rightarrow$ Shoot
Process 4 (P4)	Observe (x2) $\rightarrow$ Shoot

	Afghan Artillery	U.S. 155mm Artillery	Afghan TOC	American TOC	Conventional PLT	SF Team	Afghan Platoon 1	Afghan Platoon 2	UAV
Observe					Х	х	Х	Х	Х
Deconflict			Х	Х					
Shoot	Х	X							







## **Organization Feasibility**



- Definition
  - The set of relationships between any two constituent systems
- Two Tests for Feasibility
  - Organizational Acceptance
    - Do all systems agree to their defined relationships?
  - Organizational Connectivity
    - Does the organization form a connected network?
    - Note a system may be organizationally connected but not physically or vice-versa









# **Integrating Feasibility**



- Physical Support of Organization
  - Do any two systems in the SoS that have an organizational relationship have a means of communication?
- Physical and Organizational Support of Process
  - Do the organizational and physical architectures support the processes?
  - Timely / Appropriate Form?







## Support of TSE



- Hypothetical military indirect fire SoS
- Nine potential constituent systems, one re-factorization, eight processes, eleven organizations
- 90,112 SoS alternatives
- 7,980 feasible design points
- Assess only feasible design points for operational measures









- SoS-AFAM provides a general framework / methodology for assessing the feasibility of any SoS
  - 9 Algorithms (currently coded in MATLAB)
  - Extendable to unique situations
  - Ideal
    - Exists in tradespace tool
    - Automatically pull relevant data from existing system architecture(s)
- This supports SoS tradespace development
- Further research
  - Greater levels of detailed architecting & analysis
  - Conducting SoS-AFAM over multiple points of SoS evolutionary lifecycle
  - Assess for false-positives (i.e. SoS alternatives identified as infeasible, but possibly feasible)





- "System of Systems Architecture Feasibility Analysis to Support Tradespace Exploration" Proceedings of the 12<sup>th</sup> System of Systems Engineering Conference, 2017. <u>https://ieeexplore.ieee.org/document/7994944</u>
- The System of Systems Architecture Feasibility Assessment Model. PhD Thesis, Naval Postgraduate School, 2016. <u>https://calhoun.nps.edu/handle/10945/49467</u>
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