SoSECIE Webinar

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



We will start at 11:30 AM Eastern Time You can download today's presentation from the SoSECIE Website: <u>https://mitre.tahoe.appsembler.com/blog</u>

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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

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

June 1, 2021 Applying an MBSE Approach for Evaluating Shipyard Operations David Jurkiewicz

June 15, 2021 Implementing a Digital Engineering Environment for Mission Engineering Jason Anderson and Jeffrey Boulware

> June 29, 2021 Digital Engineering: From Toolchain to Platform Dr. Aleksandra Markina-Khusid

July 13, 2021 Developing Meta Systems Architectures for Leading Innovation with Complex Societal and Technical Challenges Dr. Cihan Dagli

> July 27, 2021 Advancements Towards a Digital Approach for Mission Engineering Todd Shayler and Daniel Browne

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

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Application of Probabilistic Graph Models to Kill Chain and Multi-Domain Kill Web Analysis Problems

18 May 2021

Jason Baker Valerie Sitterle

Objectives of Digital Tools

- Provide leadership methods and tool to clearly show:
- When/where there are capability gaps
- What will move the needle
- How to balance existing threats with future threats
- Drill downs to various levels

Enabling leadership to strategically design for the future



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The Core Components to Digital Mission Engineering

Data/Models

- Not just curating data, also generating the right data in a time of relevance
- Models that structure intelligence, SME judgement, and analysis/studies

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Tools

- Leverage concepts from tooling designed to support engineering design problems
- Not only offer assessments, but intelligently explore trade spaces and recommend a varied set of solutions



Visualizations

- Transform data into knowledge
- Expose nth-order dependencies and trends to facilitate decision maker exploring trade space
- Simultaneously show how things are (baseline) vs. how things could be



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Overview – Kill Chain Analysis Needs

- Traditional capability and kill chain analyses
 - Largely document-centric with static result artifacts
 - Lack traceability and ability to support "what if" types of analyses
- Leveraging MBSE formalisms can provide foundations for advanced decision analysis and enable reuse of concepts
- Work seeks to evolve traditional approaches and move beyond best-of-breed, sequentially linear assumptions
 - Efficient development of model and underlying data
 - Reduction of SME cognitive burden and correctness evaluation
 - Enable analysis of effectiveness, which derives from how components and capabilities are employed



Background: What are Probabilistic Graphical Models

- Acyclic, Directed Graph
 - Bayesian Networks
- Statistical Principles
 - Conditional dependence / independence
 - Probability distributions
 - Probabilistic inference





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Bayesian Networks for Mission Engineering

Capability Assessment (PowerPoint/Notes)



- Graph approach directly enables integration across warfighting assessments. Common components are not duplicated but integrated.
- Authoritative data sources (i.e., studies, models, etc.) are identified, as well as the nature and extent of SME knowledge applied to the assessment.
- Ability to auto-generate a comparable capability assessment visualization and other integrated visualizations.



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Probabilistic Graph Model

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OSD Kill Chain Analysis



- OSD Approach
 - Relative capabilities and vulnerabilities from an S&T gap perspective, not tactical kill chain execution effectiveness
- Organized by:
 - Red \rightarrow Blue or Blue \rightarrow Red
 - Types of Targets
 - Kill Chains available for a given target type

- Similar implementation as capability assessment modeling
- User Interface for dynamic assessment and what-if analysis



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Challenges to PGM Approach

- SME / Engineer effort to construct each model
 - WCCAs: ~30 models, 100+ nodes each
 - OSD KCA: 100s of models, 30-60 nodes each
 - Model templating
- SME cognitive burden to populate CPTs consistently and accurately
 - CPT sizes grow with model complexity
 - Challenging to provide consistent answers within and across tables
 - Alternative CPT population technique

Addressing Challenges: Model Templating

What

• "Center" framework of relationships defined by general platform, domain, capability type (not platform specific)

Why

· Templates facilitate up-front understanding of model structure and influences for each KC swim lane for SMEs

And with that understanding -

- Increased speed of developing new PGMs for new KC target sets
- Flexibility to modify structure to include more or fewer model components as relevant



Addressing Challenges: Easing SME Burden

- Allow SME to enter tunable continuous distributions
 - 1 distribution per parent-child state pair
- Aggregate distributions and discretize into CPT
- Results in fewer questions and more consistent results

Number of parents	States per parent	Number of distributions in table	Number of inputs required	%		
2	2	4	4	100.000%		
2	3	9	6	66.667%		
2	4	16	8	50.000%		
3	2	8	6	75.000%		
3	3	27	9	33.333%		
3	4	64	12	18.750%		
4	2	16	8	50.000%		
4	3	81	12	14.815%		
4	4	256	16	6.250%		
5	2	32	10	31.250%		
5	3	243	15	6.173%		
5	4	1024	20	1.953%		



	shooter_rf_jamming_employed	helo_range_to_rf_sensor	no	yes
0	none	not_in_range	1.000	0.000
1	on_board	not_in_range	1.000	0.000
2	stand_off	not_in_range	1.000	0.000
3	none	in_range	0.050	0.950
4	on_board	in_range	0.500	0.500
5	stand_off	in_range	0.750	0.250
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Addressing Challenges: Consistency Checking

CPTs for nodes with several parents a challenge

• Entries = $\prod_{i=1}^{k} n_i$

k = # of parents + self, n = # states each k

How to evaluate internal consistency of CPT?

- Comparative assessment of SME first-cut vs distribution approach
- Logic holds for cases when node states are levels of a thing

Mathematical methods to aid SME CPT development promotes internal consistency Observability as a function of Engagement Range to Red ISR [Holding 3 other parent states constant for given CPT excerpt]



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Kill Chain Gap vs Effectiveness Analysis and Relation to Webs



- Presence of asset/ capability at given time
- Outcomes of contests determine effectiveness of next "phase" of battle
- Relationship of capability contests within and across time slices
- Relationship of outcomes on non-temporal technological states (tie in with traditional KCA)

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Kill Chain Capability Analysis using PGMs

Full dynamic Bayesian network structure

- Temporal order explicit in each graph, structure repeats in time
- Boolean nodes control propagation within each time slice



Sequence manageable.

Synergy harder.

Family of PGMs with definable relationships

 Temporal order implicit, controlled thru composition of PGMs



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Composable Modules for More Complex Analyses

Compositional creation of more complex capability spaces

- Decompose full scale mission models into compartmentalized, sequential functional modules that capture a subsets or steps of the mission
- Apply interface specification that allows flow of information between sequential modules
- Interact via visualization to study complex relationships across modules
- Traceable, scalable development of analyses to support mission engineering and capability assessment challenges



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Composable Modules – Feasibility Study



Parting Thoughts: Power of the Approach

Direct tie-in to the vision for Digital Engineering

 Not simply replicating document content digitally, but providing new capabilities

Model basis creates living analytical tool

- Supports integration across assessments as well as flexible, query-able analyses
- Promotes a better understanding of relational dependencies - the "why" - for senior DoD decision makers
- Modular approach allows integration of more challenging modeling concepts of the mission such as comms

Modular approach enables use of any model for input / output as long as it matches interface





Thank you!

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