SoSECIE Webinar

Welcome to the
2022 System of Systems Engineering Collaborators Information Exchange (SoSECIE)

We will start at 9:30 AM Eastern Time

You can download today's presentation from the SoSECIE Website:

https://mitre.tahoe.appsembler.com/blog

To add/remove yourself from the email list or suggest a future topic or speaker, send an email to sosecie@mitre.org

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.**

Disclaimer

- **MITRE and the NDIA makes no claims, promises or guarantees about the accuracy, completeness or adequacy of the contents of this presentation and expressly disclaims liability for errors and omissions in its contents.**
- **No warranty of any kind, implied, expressed or statutory, including but not limited to the warranties of non-infringement of third-party rights, title, merchantability, fitness for a particular purpose and freedom from computer virus, is given with respect to the contents of this presentation or its hyperlinks to other Internet resources.**
- **Reference in any presentation to any specific commercial products, processes, or services, or the use of any trade, firm or corporation name is for the information and convenience of the participants and subscribers, and does not constitute endorsement, recommendation, or favoring of any individual company, agency, or organizational entity.**

2022 System of Systems Engineering Collaborators Information Exchange Webinars

Sponsored by MITRE and NDIA SE Division

October 11, 2022

What Systems Engineers would Know about Emergence

Jakob Axelsson

October 18, 2022

Framework for Complex SoS Emergent Behavior Evolution Using Deep Reinforcement Learning

Ramakrishnan Raman and Anitha Murugesan

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

Australian Government
Defence

THE UNIVERSITY of ADELAIDE

SHOAL

Measurement & Assessment for SoS

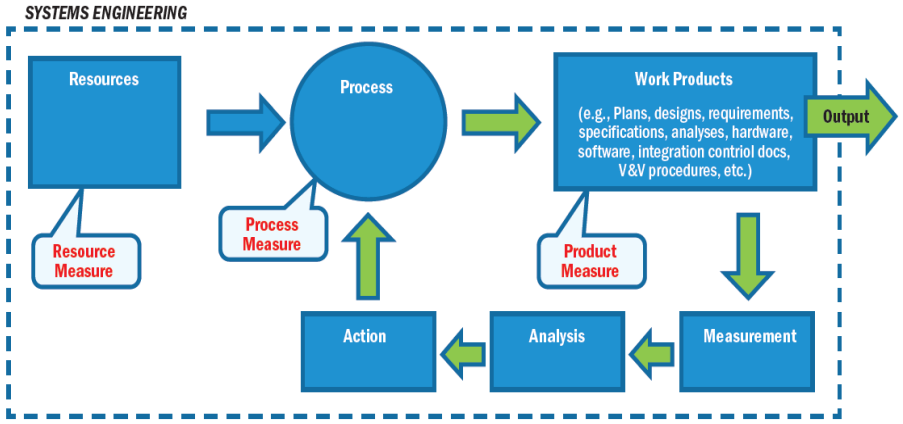


Ms Jaci Pratt & Prof Stephen Cook

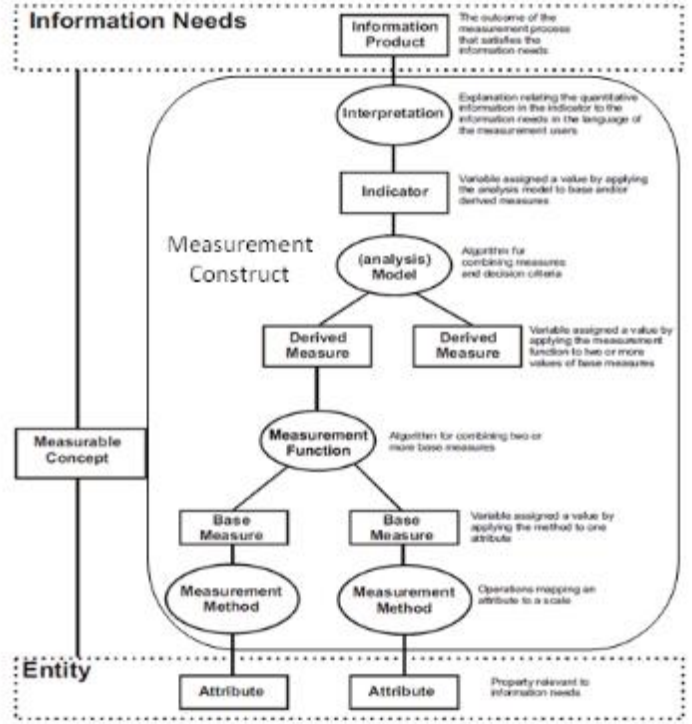
The University of Adelaide
DST Group & Shoal Group

Measurement – Some Definitions

- "Measurement quantifies processes or work products with respect to the needs and objectives of the project or enterprise" – SE Measurement Primer
- "Metric is two or more measures or attributes; defined measurement method; and measurement scale" (ISO-IEEE 24756:2010) => Hierarchy of Measures
- Measurement Information Model: base measures, derived measures and indicators



- Common measure types:
  - MoP: focus on the technical performance, or task actions, and are typically direct quantitative measurements of physical or functional attributes
  - MoE: focus on how well the solution achieves mission or operational objectives. They are usually more subjective (quantitative & qualitative) and may be difficult to measure directly, requiring the use of indicators or proxies
  - Others: Measures of Outcome (MoO), Measures of Success (MoS), and Measures of Capability (MoC)



Measurement

- Why Measure?
  - Track, influence and shape evolution objectives
  - Identify and correct problems early
  - Communicate effectively
  - Allocate priority and focus on risk
  - Inform and justify key decisions
  - Assess quality

- Measurement classes (Classical)
  - Product: System performance and behaviour including evolution rate, quality, technology effectiveness; Integration assurance; Customer satisfaction
  - Process: Process performance; Schedule & Progress
  - Resource: Resource usage and monitoring (pers / cost)

SoS Assessment & Evaluation

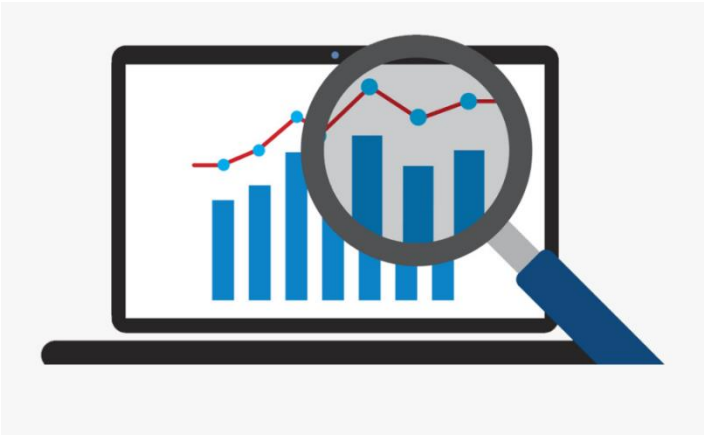
- SoSE needs assessment & measures – limited literature specific to SoS

- Assessment and evaluation are terms applied across many disciplines. Each has a different view:
  - Systems Engineering: Test & Evaluation of equipment against specs / needs
  - Social System Assessment: relationships and networks of human systems
  - Joint Force Assessment: training and certification for pers or systems at individual, team up to whole-of-force
  - Project Management and Program Evaluation: focus on performance measurement for organizations, social programs and projects
  - Enterprise and System of Systems Engineering: focuses on uncertainty and evolution of broader-scale systems

- Take lessons from all to apply to higher order assessment and evaluation such as Defence SoS

Method

- Constructive research methodology was conducted via
  - Multi-disciplinary literature review to identify:
    - Measurement concepts
    - Challenges and Best Practice
    - Measure generation processes
  - Comparison against the fundamental characteristics of SoS
  - Synthesise best practice insights
  - Identify key and SoS-relevant metric production processes
  - Conduct case studies to determine applicability to SoS
  - Harnessing these lessons, synthesise and refine a metrics generation process for SoSE
  - Develop an aligned elicitation instrument and use the process



Disciplinary Review – Key Aspects

Test & Evaluation (incl V&V)

- Objectively assess capability against requirements and mission objectives
  => effective, suitable, survivable, and safe
  - Repeatable, structured activities
  - Typically quantitative; focus on technical detail
  - Conducted in the final phases of the project

Project Eval – PuMP

- Project & Organisation performance
- Identified 8 Bad KPI Habits
  - measures that judge people; ambiguous goals
  - brainstorming measures; not involving stakeholders
  - rushing to tools, visualizations, and reports
  - making conclusions on limited data
  - using complex reports / too many measures
  - treating symptoms not problems

Social Systems

- Difficult due to inherent complexity, variability, & open to contextual interpretation/perception
- Qualitative and quantitative measures: push to quantitative; beware quantification artifacts
- Measurement process: conceptualization, nominal definition, operational definition, real-world measures
- Key measurement issues:
  - variables with multiple & ambiguous meanings
  - impact of language choice on responses/data
  - reification of constructs
  - measurement impact on the system itself
  - variability in classification, comparison inability, and traceability/causality

Disciplinary Review – Key Aspects

Joint Force Assessment

- Training & Certification focus
- Individual, team to coalition force
- Usually qualitative
- Performed by trained and independent evaluators
- Issues:
  - Weak and disconnected concepts / frameworks
  - Inconsistent, convoluted, not comprehensive & under-resourced processes
  - Poorly crafted, difficult to collect, ambiguous, yet often abundant measures
  - Lack of rigour/evidence for analysis & decision making

Program Eval

- Ethnographic & observational focus well-suited to socio-technical systems
- Stakeholder driven
- Bespoke evaluation process & measures

Enterprise SE

- Inherently qualitative approach
- Multi-methodological break point analysis
- Continuous, iterative M&S at multiple scales

SoSE

- Processes drawn from SE / software evaluation and Defence
- Initial good practices proposed

Best Practice Principles for Developing Measures

1. **Metrics are evidence and must be driven by purpose:** traceable to agreed goals and strategies
2. **Context guides selection:** Metrics need to be tailored to the context
3. **Measures must be agreed by stakeholders and have identified owners**
4. **Clarity is all:** Measures need to be clear, understood, unambiguous, well-defined, and specific. This includes both what is being measuring and how it is measured
5. **Measures must be mixed**: acknowledge the value of qualitative & subjective data. Beware of artifacts of quantification
6. **Metric Parsimony:** A minimum practical set of measures should be selected and connected in a hierarchy (<=10)
7. **Automate and reuse** where possible (noting principles 1 and 6)

Characteristics of Good Measures / Set

MEASURE:

- Relevance / Strength
- Simplicity and Feasibility
- Cost effectiveness
- Accuracy and Precision
- Validity
- Repeatability
- Predictability and boundedness
- Timeliness

SET:

- Saliency
- Completeness and cohesiveness
- Cost effectiveness
- Balance across quality and speed
- Minimal disturbance

Best Practice Principles for Assessment & Evaluation

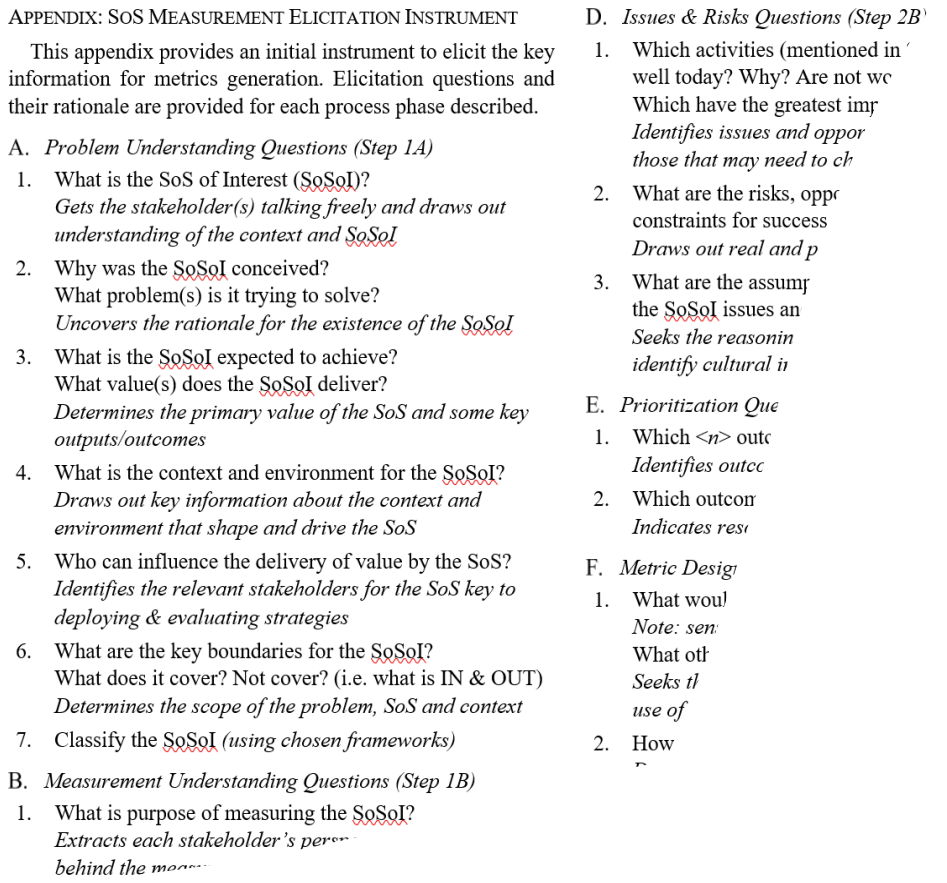
- ***Goals are the primary focus***: agreed up-front expecting them to change over time
- ***Incremental and iterative process***: it is a continuous, incremental, and iterative process edging toward improvement
- ***Evolution and emergence impact assessment scope and focus***: assessment must adapt throughout evolution based on risk / priority areas with regular milestone review
- ***Stakeholders must be involved throughout***: across the complete breadth of stakeholders for identifying and agreeing objectives, priorities, risks, and metrics
- ***SoS assessment is socio-technical***: technical assessment is insufficient; include non-functional and human aspects
- ***Metrics and Measures Hierarchy:*** an agile framework of interdependent measures and indicators (proxies) to incentivise behaviour (leading and lagging)
- ***Evidence is needed from multiple sources and methods***
- ***SoS metrics require interpretation***

Process Review – Case Study

- Shortlisted processes and applied across two case-study areas:
  1. Power Generation & Management
     - Goal-Question-Metric family (incl GQIM & GQM+Strategies)
     - Business-Mission Analysis
     - Measurement Info Model
  2. Defence Capability Integration
     - CUEMOST (Client, Utility/Understanding, Environment, Model/Method, Owner, Study, Transformation)
     - US Army Decisive Future Soldier MoE/MoP methodology
     - Performance Measurement Process (PuMP)
- Identified strengths-weaknesses-insights relevant to application to SoS
- Synthesised these into a generic process and developed an instrument
- Applied to a Defence SoS via workshop

SoS Metrics Generation Process

- Four Stage process
  1. Understand the Problem
     - A. SoSoI and its context
     - B. Measurement
  2. Design and develop Metrics
     - A. Identify Goal-Strategies-Outcomes
     - B. Discover Issues-Hypotheses/Assumptions-Risks
     - C. Conduct Prioritization
     - D. Design Indicators/Metrics
  3. Confirm Metrics and derive CS Incentives
     - A. Owner assignment
     - B. Consequences and behaviours => incentives
     - C. Reduce metrics set
  4. Document the Metrics



APPENDIX: SOS MEASUREMENT ELICITATION INSTRUMENT

This appendix provides an initial instrument to elicit the key information for metrics generation. Elicitation questions and their rationale are provided for each process phase described.

A. *Problem Understanding Questions (Step 1A)*

1. What is the SoS of Interest (SoSoI)?
   Gets the stakeholder(s) talking freely and draws out understanding of the context and SoSoI
2. Why was the SoSoI conceived?
   What problem(s) is it trying to solve?
   Uncovers the rationale for the existence of the SoSoI
3. What is the SoSoI expected to achieve?
   What value(s) does the SoSoI deliver?
   Determines the primary value of the SoS and some key outputs/outcomes
4. What is the context and environment for the SoSoI?
   Draws out key information about the context and environment that shape and drive the SoS
5. Who can influence the delivery of value by the SoS?
   Identifies the relevant stakeholders for the SoS key to deploying & evaluating strategies
6. What are the key boundaries for the SoSoI?
   What does it cover? Not cover? (i.e. what is IN & OUT)
   Determines the scope of the problem, SoS and context
7. Classify the SoSoI *(using chosen frameworks)*

B. *Measurement Understanding Questions (Step 1B)*

1. What is purpose of measuring the SoSoI?
   Extracts each stakeholder's perc
   behind the mea

D. *Issues & Risks Questions (Step 2B*

1. Which activities (mentioned in
   well today? Why? Are not wo
   Which have the greatest imp
   Identifies issues and oppor
   those that may need to ch
2. What are the risks, oppo
   constraints for success
   Draws out real and p
3. What are the assump
   the SoSoI issues an
   Seeks the reasonin
   identify cultural in

E. *Prioritization Que*

1. Which <*n*> outc
   Identifies outco
2. Which outcon
   Indicates resi

F. *Metric Desig*

1. What woul
   Note: sen
   What oth
   Seeks th
   use of
2. How

Conclusion …

- In Summary
  - Measurement is essential for development and evolution of SoS and therefore the success of SoSE
  - Conducted a cross-disciplinary review of measurement concepts and methods
  - Identified their strengths, weaknesses and applicability to SoS
  - Synthesised best practice elements for SoS in:
    - Development of measures
    - Evaluation of measures
    - Conduct of assessment
  - Conducted case studies to determine applicability to SoS
  - Synthesised metrics generation process / elicitation instrument
  - Tested the process

- Provides core direction for SEs and SoSE teams in the development and application of measurement for SoS

Thank you …

ANY QUESTIONS?

jaci.pratt@gmail.com