Australian Government
Defence

THE UNIVERSITY of ADELAIDE

SHOAL

32nd Annual INCOSE international symposium
hybrid event
Detroit, MI, USA
June 25 - 30, 2022

Multi-Disciplinary Insights into Measurement & Assessment for SoS

Paper # 126



Ms Jaci Pratt & Prof Stephen Cook

The University of Adelaide
DST Group & Shoal Group

SoS Assessment & Evaluation

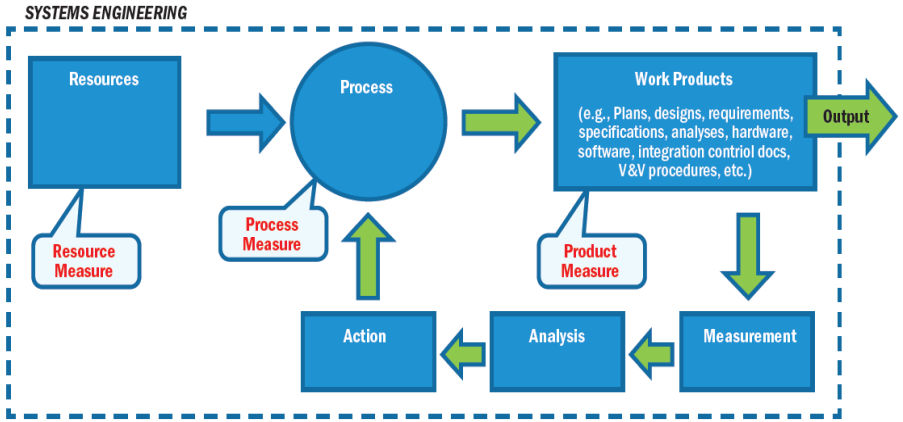
- SoSE needs assessment & measures – limited literature specific to SoS

- 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

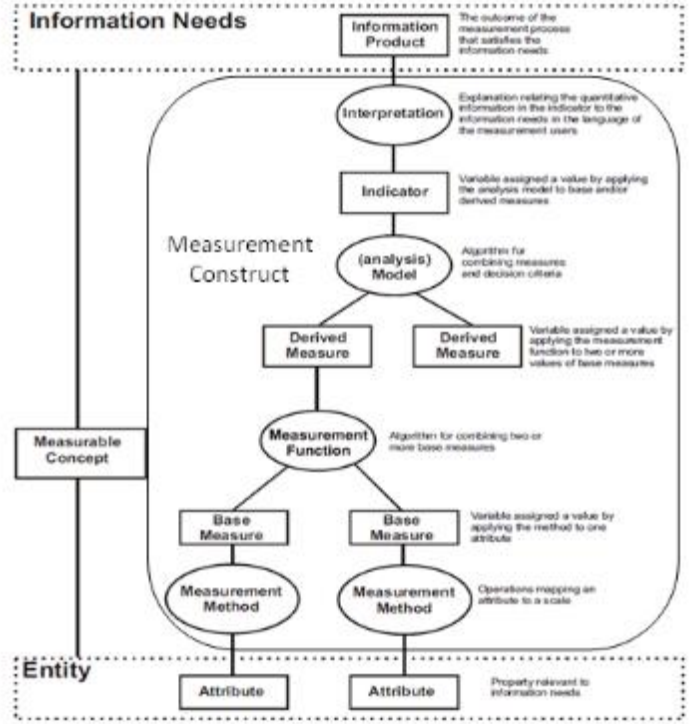
- Take lessons from all to apply to higher order assessment and evaluation such as Defence SoS

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)

Expansion of Measurement Classes for SoS

1. Schedule and progress of SoS against milestones
2. Resources and cost
3. Process performance
4. SoS performance and behaviour
5. SoS evolution rate
6. SoS quality
7. Technology effectiveness
8. SoS integration assurance
9. Customer satisfaction

Note: the SoS evolves through the action of the CS developers. While the SoS Team cannot control many of the attributes above, it can improve SoS trajectory and outcomes by anticipating issues and negotiating with CS project teams.

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***

Future Work / Next Steps

Move from principles to practical aspects of how to do it

- Review the processes for measure generation across different disciplines
- 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
- Use the process
- Write it up and share it!
  - this is mostly done! ☺

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
  - Developed SoS Measurement classes
  - Synthesised best practice elements for SoS in:
    - Development of measures
    - Evaluation of measures
    - Conduct of assessment

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

32nd Annual INCOSE international symposium

hybrid event

Detroit, MI, USA
June 25 - 30, 2022

Thank you …

ANY QUESTIONS?