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Mission Engineering: Systems of Systems Engineering in Context
What do we mean by ‘mission’?

- Any important task or duty that is assigned, allotted, or self-imposed
- An important goal or purpose that is accompanied by strong conviction
- A set of tasks that fulfills a purpose or duty
- Purpose, aim, objective
- Military mission - operation assigned by a higher headquarters
Systems of systems and systems engineering

System of Systems

A set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities

Systems of Systems Engineering

The process of planning, analyzing, organizing, and integrating the capabilities of a mix of existing and new systems into a system-of-systems capability that is greater than the sum of the capabilities of the constituent parts
What do we mean by ‘mission engineering’?

• Mission engineering treats the end-to-end mission as the “system”
• Individual systems, including organizations and other non-material elements, are components of the larger mission ‘system’ or system of systems
• Systems engineering is applied to the systems-of-systems supporting operational mission outcomes
• Mission engineering goes beyond data exchange among systems to address cross cutting functions, end to end control and trades across systems
• Technical trades exist at multiple levels; not just within individual systems or components
• Well-engineered composable mission architectures foster resilience, adaptability and rapid insertion of new technologies

Mission Engineering is the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired operational mission effects
Scale and scope of SoS

Example: A/V & Home Automation

Bang & Olufsen: Can we show consistent “user experience” as devices, content, DRM, etc., change?

Concept Alignment Example: Emergency Response System

Technical ----- Socio -Technical ----- Enterprise
Operational Mission Outcomes

Mission Threads

System of Systems

System

Systems of Systems in a mission context

Mission thread links technical performance to operational outcomes
Mission Engineering benefits from executable digital engineering model-based approaches.
Why ‘mission engineering’?

**Proactive: ME ...**

- Is initiated based on the recognition of the primary importance of mission or enterprise outcome
- Addresses the ‘health’ of the ‘end-to-end mission’ to identify gaps, issues or opportunities to maintain or enhance mission outcomes
- May lead to the identification of gaps or issues which may be affecting the mission outcomes or may do so in the future (risks)
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Reactive: ME ...

- Is triggered by issues or gaps identified in the mission performance or an element supporting the mission
- Identifies the sources of mission gaps or the effects of problems with systems or other elements on mission outcomes
- Assesses the impact of possible changes to address issues or gaps on other elements or systems supporting the mission

Why ‘mission engineering’?
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Opportunistic: ME...
- Responds to a potential new technology or other change which offers potential mission advantage technology
- Addresses the question of the impact on mission outcomes by introducing new technology, systems or processes
What are the steps in ‘mission engineering’?

1. Establish the context and motivation for ME
2. Form ME team
3. Describe the plan for data, models & analyses
4. Assess current situation
5. Delineate mission context
6. Identify options and conduct trades
7. Prototype and experiment

Recommendations
Establish the context and motivation for ME

• Recognize that the issue, gap or opportunity needs to be addressed in terms of the larger enterprise or mission outcomes

• What is potential impact on mission?

- Questions to be addressed
  - What is motivation for the ME effort – what is driving the need to conduct engineering and analysis in terms of the mission outcomes?
  - What is the mission context – what are the types of activities and expected outcomes for the mission?
  - What part of the enterprise is affected? Which organizations or systems? Who are the key stakeholders?
Establish the context and motivation for ME

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-- Example --

Opportunity: Biometrics Technology

Mission: Airport safety through passenger screening

- How can insertion of technology impact mission outcome?

To assess value requires understanding how they could be integrated into the current system of systems and the passenger screening sequence of actions (‘mission thread’) and the impact on the outcomes
Form ME Team

- **Broad range of perspectives – both technical and operational**
  - ME team lead supporting systems engineers
  - Operational and requirements SMEs
  - External environment SMEs
  - Component team members for the key systems and organizations
  - Management and resourcing
Form ME Team

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Develop ME plan

- Data, models, & analysis
  - Key activities, mission threads, scenarios, mission context
  - Systems, behavior, performance
  - Outcomes, measures

- Technical & operational analyses
  - Baseline analysis of SoS & mission operations
  - Identification of options
  - Approach to analyzing options and tradeoffs
Delineate mission context

- Collection of the mission-related data to provide the context for assessing current technical capabilities and assessing options

**Mission Related Data**

- Mission Thread(s)
  - Descriptions of activities and dependencies
- Scenarios
  - Descriptions of the scenario context(s) for executing mission
- External Environment factors
  - Current and projected external environment (e.g. threat, legal, social) actions and behaviors
- Measures of **SoS performance** and **mission effectiveness**
Delineate mission context

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**Example**

- ‘Passenger screening mission thread”
- Operational outcome measures, e.g.
  - Time through queue
  - Average wait time at checkpoints
  - Screening ‘success rate’

Source: GAO Analysis of TSA Information GAO -17-794
Assess current mission capabilities

• Analyze current capability to establish baseline state of the mission

• **Technical Assessment**: Characterize performance of current SoS - systems/nodes/organizations supporting the mission thread

• **Operational Assessment**: Assess performance of current systems/nodes/organizations operating together to evaluate/measure mission outcomes

- **Behavior and performance of the SoS** which supports the steps in the mission activity sequence (e.g. threads)
  - Organizations and human decision-making and supporting systems including communications
  - Capture the data for use in this and future analyses

- Analyze the performance of the systems in the **execution of the mission thread** against the expected mission outcomes and other **constraints** – e.g. cost, personnel
  - End to end mission execution in terms of both **technical performance** and **operational impact**
Assess current mission capabilities

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Identify options and analyze trades

• Identify alternatives and analyze their technical feasibility & mission impacts

• Identify options
  • Stakeholders and extended technical community to identify a range of options
  • Define needs/opportunities for prototyping and experimentation

• Analyze Options and Trades
  • Using analyses of current capabilities as baseline, make changes to reflect options
  • Assess impact of options on technical performance & on mission outcomes

• Conduct review of alternatives & trades to recommend approach
Identify options and analyze trades

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  - Define needs/opportunities for prototyping and experimentation
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- Conduct review of alternatives & trades to recommend approach

Example

Compare set of alternatives
- Base Case (Current security process)
- Limited opt-in and capabilities (ranges and combinations of values for parameters)
- Full Capability (more extreme rates for parameters)

Generate a full design space across all valid combinations of parameters – experimentation to support design space exploration
Prototype and experiment

- Implement a physical prototype or conduct a technical or man-in-the-loop experiment to address uncertainties

- Develop a prototype or conduct an experiment to generate data to assess viability of an option

**Approach**
- May include a range of options – models, prototype systems, operational experiment, man in the loop SIMEX, insertion of surrogate into operational context, ...
- Allows for exploration of new, innovative approaches

**Incorporate results into analysis**
- Value is based on the data and insights supporting the analysis of alternative capabilities to support the analysis of options and trades
Prototype and experiment

- Implement a physical prototype or conduct a technical or man-in-the-loop experiment to address uncertainties.

- Develop a prototype or conduct an experiment to generate data to assess viability of an option.

- Approach
  - May include a range of options – models, prototype systems, operational experiment, man in the loop SIMEX, insertion of surrogate into operational context, ...
  - Allows for exploration of new, innovative approaches.

- Incorporate results into analysis
  - Value is based on the data and insights supporting the analysis of alternative capabilities to support the analysis of options and trades.
Recommendations

• Present a recommended actions, often in terms of changes with supporting evidence to address issue

• Supports decisions on systems and systems of systems SoS in terms of implications on mission outcomes
In sum.....

Establish the context and motivation for ME

Form ME team

Describe the key elements of the mission and drivers

Delineate mission context

Assess current situation

Identify options and conduct trades

Prototype and experiment

Recommendations

A WORLD IN MOTION
Systems Engineering Vision - 2025
SERC Research Review 2020: Save-the-Date

For more information, contact Monica Brito: mbrito@stevens.edu
Visit our website for more information: https://sercuarc.org/research-reviews/
UPCOMING TALKS:
“Mission Engineering” Series

Tentative Dates:
Wednesday, October 7, 2020
Wednesday, December 2, 2020

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