

# Mission Engineering, Systems Engineering and Systems of Systems Engineering

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**Dr. Steven Doskey**  
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**Systems of Systems Engineering Collaborators Information  
Exchange (SoSECIE), April 21, 2020**

*as presented at the NDIA Systems and Mission Engineering Conference,  
October 24, 2019*

# Abstract

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There is increasing interest in application of systems engineering to '**missions**'.

The DoD Defense Acquisition Guidebook defines Mission Engineering as: "the **deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired operational mission effects**" (DAG Chapter 3). The term was coined by the US Navy under their Interoperability and Integration (I&I) initiative and has been adopted by OSD under their new organization as part of a push spurred by legislation to focus on 'mission integration management' to assure effective system support to priority defense missions.

OSD conducted a series of **roundtables** in FY17 to review current mission engineering practices in the DoD. Since then the Air Force and Army have undertaken initiatives to focus on cross functional integration for priority missions. As we look to better manage the systems and portfolios of capabilities which support effective mission execution, how do we address the technical considerations driving effective mission outcomes. Expansion of the application of systems engineering beyond individual systems to systems of systems, enterprises, capabilities and now missions raise the question of the relationships among these.

How does the application of systems engineering change with the focus or the engineering? This presentation addresses the definition, overlap, and individual contributions of systems engineering for systems, systems of systems, enterprises and now missions.

# Purpose and Topics

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## ■ Purpose

- There is increasing interest in application of systems engineering to 'missions', raising questions about how 'mission engineering' relates to current practices of systems engineer for systems and system of systems (SoS)
- This presentation addresses the definition, overlap, and individual contributions of systems engineering for systems, systems of systems, enterprises and now missions.

## ■ Topics

- Background on emerging concept of mission engineering
- Review of definitions and engineering focus of systems engineering applied to systems, systems of systems and now missions based on emerging perspectives
- Relationship among these applications of systems engineering

**This presentation addresses the definition, relationship, and individual contributions of systems engineering for systems, systems of systems, enterprises and now missions.**

# Background – Mission Engineering

- The DoD Defense Acquisition Guidebook defines Mission Engineering as:  
**“the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired operational mission effects”**  
(DAG Chapter 3)
- The term was coined by the US Navy under their Interoperability and Integration (I&I) initiative and has been adopted by OSD under their new organization as part of a push spurred by legislation to focus on ‘mission integration management’ to assure effective system support to priority defense missions.
- OSD conducted a series of roundtables in FY17 to review current mission engineering practices in the DoD. Since then the Air Force and Army have undertaken initiatives to focus on cross functional integration for priority missions.
- As we look to better manage the systems and portfolios of capabilities which support effective mission execution (2017 NDAA), how do we address the technical considerations driving effective mission outcomes?
- Expansion of the application of systems engineering beyond individual systems to systems of systems, enterprises, capabilities and now missions raise the question of the relationships among these.

# Objective

The collage consists of approximately 15 overlapping document thumbnails. Key titles and logos include:
 

- Mission Engineering** (Robert Gold, Office of the Deputy Assistant Secretary of Defense for Systems Engineering)
- Extending the DoD Digital Engineering Strategy to Missions, Systems and Portfolios** (Philomena Zimmerman, Dr. Judith Dahmann, Dr. Tracee Gilbert)
- LEADING EDGE** (INTEGRATION & INTEROPERABILITY MISSION ENGINEERING)
- Mission Engineering Competency Model** (Dr. Gregg Vesonder, Dr. Nicole A.C. Hutchison, Stevens Institute of Technology)
- Systems of Systems Characterization and Types** (Dr. Judith S. Dahmann, The MITRE Corporation)
- Industry Support to Mission Analysis and Mission Engineering** (Preliminary Study Report - May 2016)
- Mission Based Analysis in the Systems Engineering Process** (William Scott, Office of the Deputy Assistant Secretary of Defense for Systems Engineering)
- Systems of Systems Engineering Technical Approaches as Applied to Mission Engineering** (Dr. Judith Dahmann, et al.)
- Mission Threads: Bridging Mission and Systems Engineering** (Dr. Greg Butler, Dr. Carol Woody)
- Mission Engineering: Evolving Acquisition to Support the Warfighter** (James Thompson)
- Mission Engineering: Systems of Systems Engineering in Context** (Dr. Judith Dahmann, MITRE)
- Developing Standards for Systems of Systems (SoS) Engineering** (ISO/IEC/IEEE 21839: SoS Considerations through the Lifecycle of a System)
- Mission Engineering** (Andres Sousa-Poza, Old Dominion University)
- Systems and software engineering - System life cycle processes** (IEEE)

Despite the recent emergence of ME, there has been quite a bit of work which provides a perspective on the relationship between ME, SE and SoSE

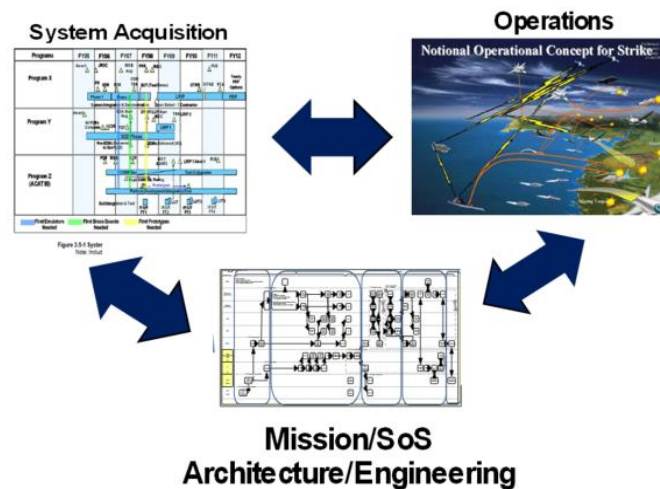
The objective of this presentation is to: **synthesize these materials to develop an emerging picture of mission engineering in the context of SE of systems and systems of systems**

# Approach

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- A working Definition of Mission Engineering
- Connecting to Systems to Missions
- Bringing it Together – Synthesizing an Emerging Picture of Mission Engineering in the Context of SE of Systems and Systems of Systems
- What Makes this Hard... → Complexity of Perspectives

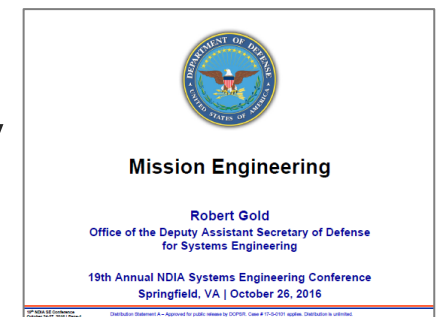
# Mission Engineering



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

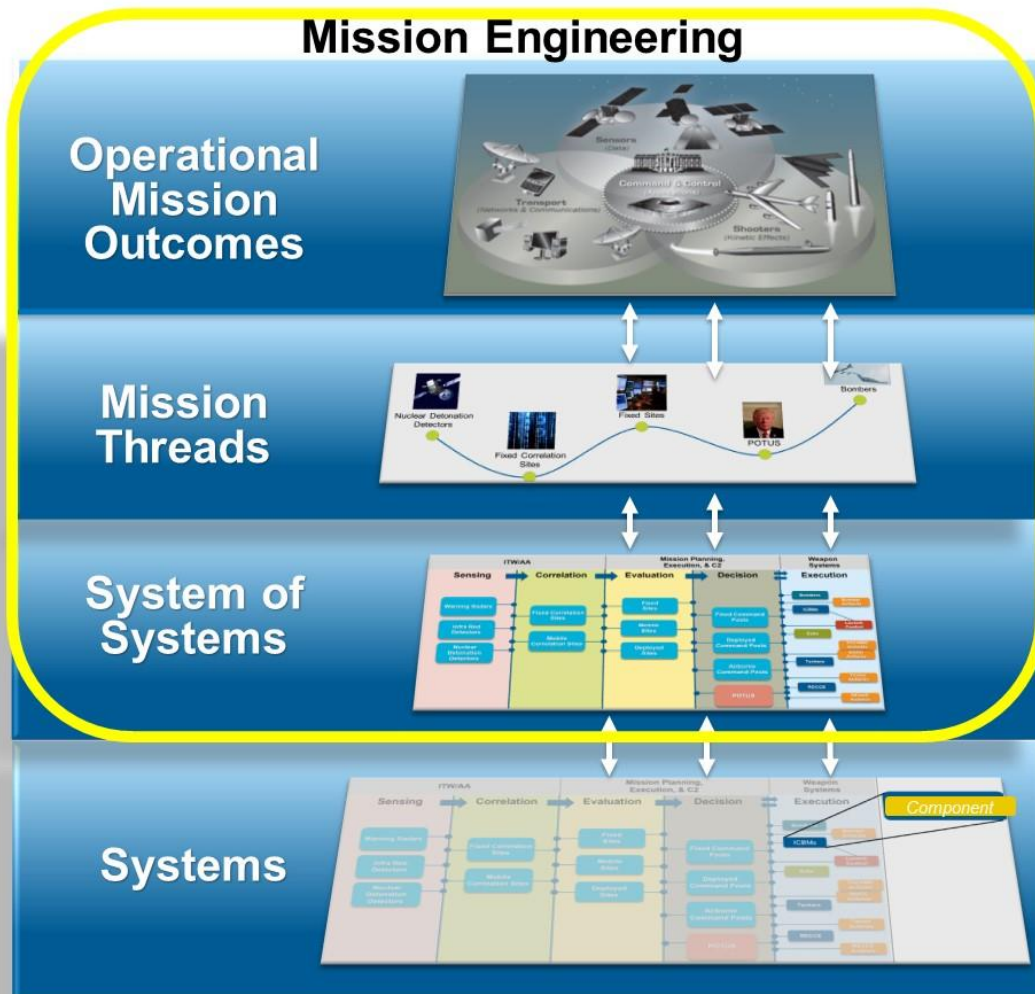
- Mission engineering treats the end-to-end mission as the “system”
- Individual systems are components of the larger mission ‘system’
- Systems engineering is applied to the systems-of-systems supporting operational mission outcomes
- Mission engineering goes beyond data exchange among systems to address 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

“The mission is the system”

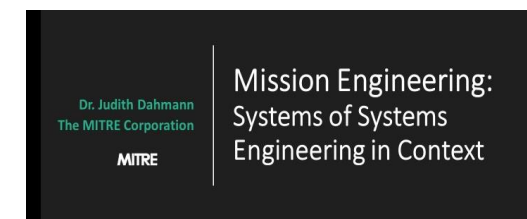




# Top level view of the relationships

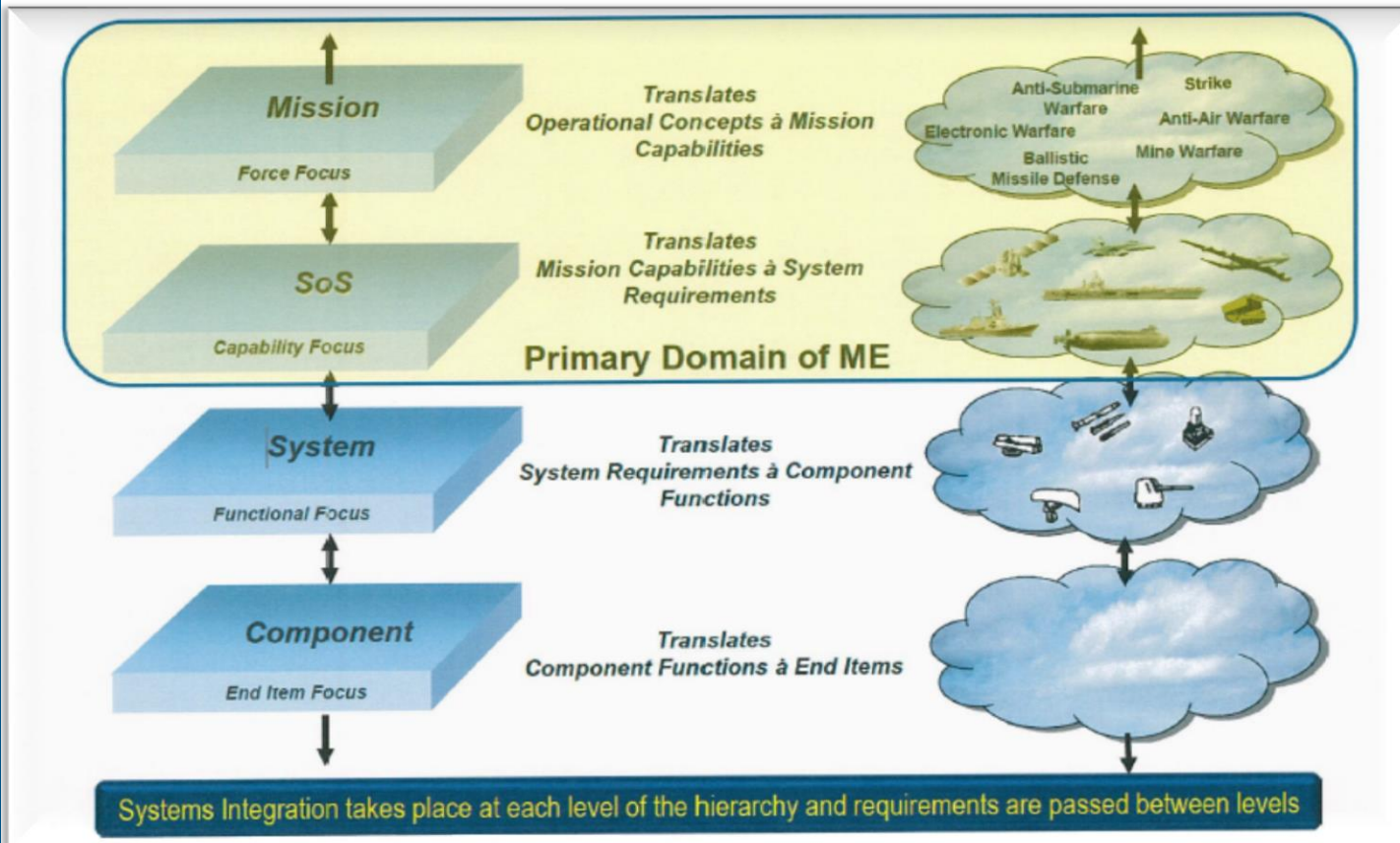


- In this view, systems engineering applies at multiple levels
  - Systems and components
  - Systems of systems
  - Operational missions
- Mission engineering is considered ‘above the system level’, addressing systems of systems in a mission context
- ‘Mission Threads’ provide linkage between SoS/ systems and operational mission

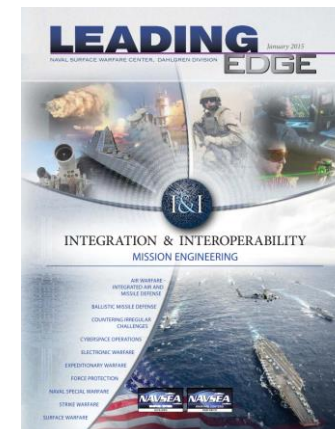




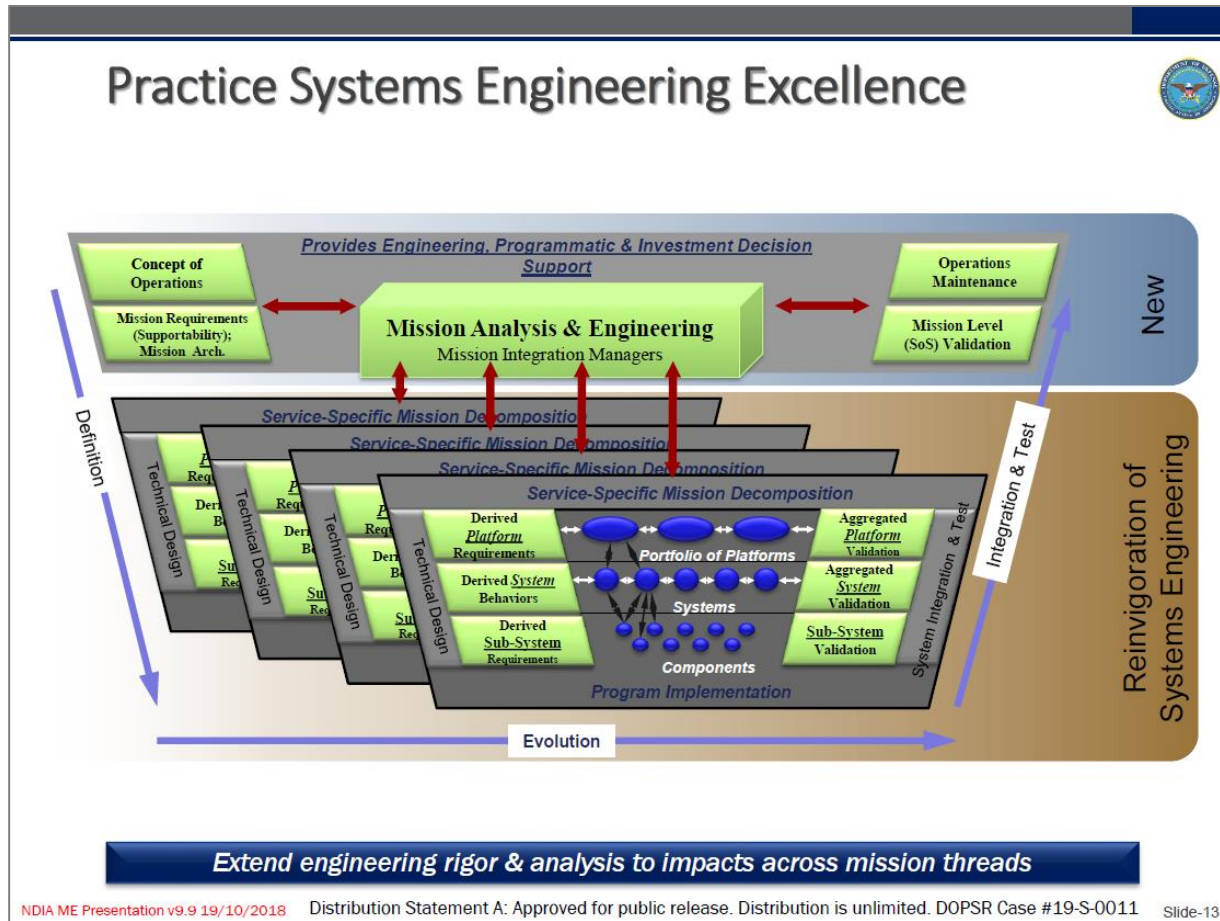
# Another very similar view



- Navy perspective is very similar
- For mission engineering
  - Operational concepts drive mission capabilities
  - Mission capabilities in turn drive systems requirements in a systems of systems
  - These translate to system requirements and component functions and end items



# Mission analysis and engineering as context for systems



- Emphasis on mission analysis and engineering as a cross-cutting engineering activity that provides the basis for
  - Defining systems
  - System evolution
  - System integration and test

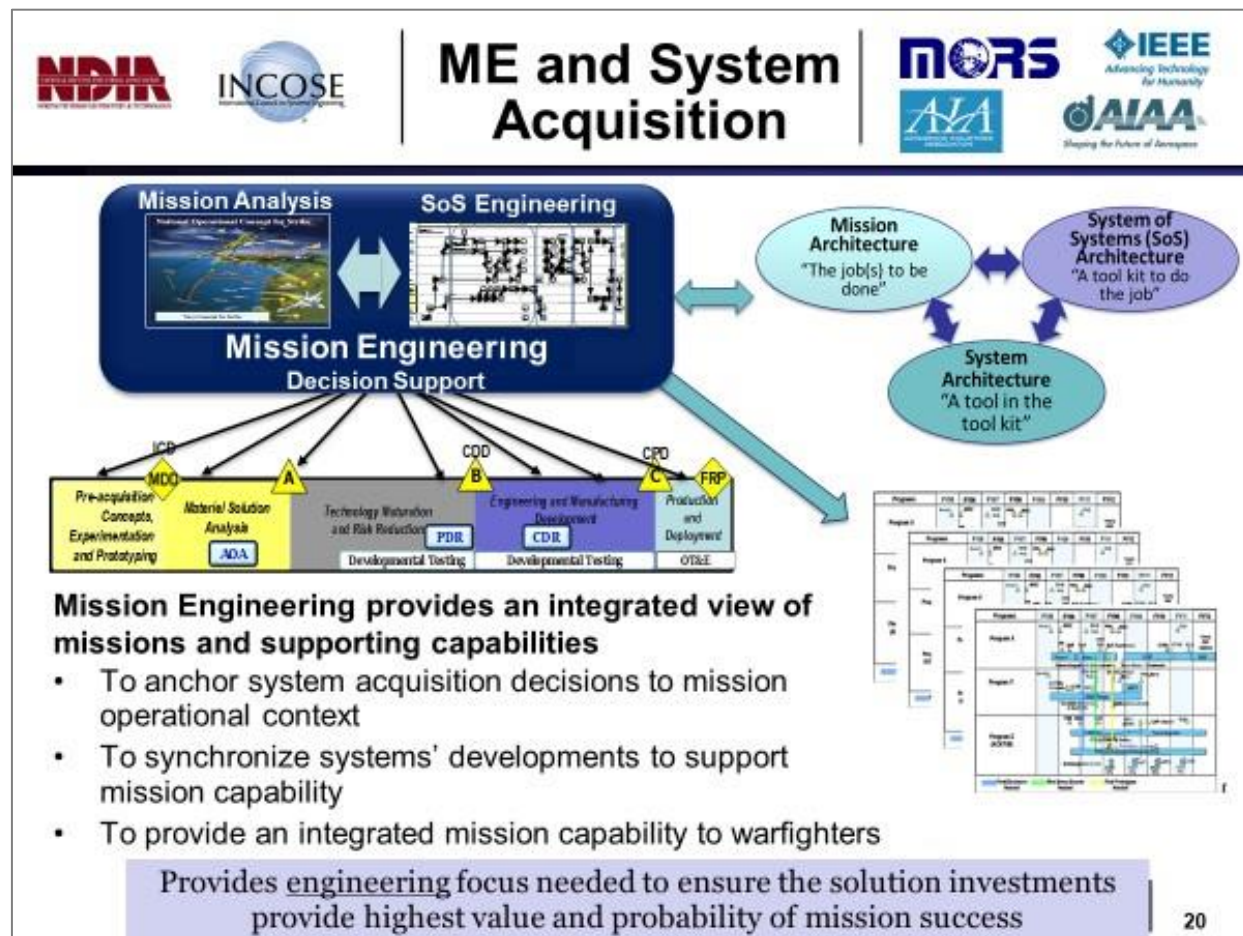
21<sup>st</sup> Annual National Defense Industrial Association Systems and Mission Engineering Conference

**Mission Engineering: Evolving Acquisition to Support the Warfighter**

James Thompson  
Office of the Under Secretary of Defense for Research and Engineering  
October 24, 2018

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# An industry perspective



- Industry perspective on mission analysis and mission engineering
- Views mission engineering as encompassing
  - Mission analysis and
  - SoS engineering
- Provides decision support for system acquisition and engineering

**Industry Support to Mission Analysis and Mission Engineering**

Preliminary Study Report – May 2016

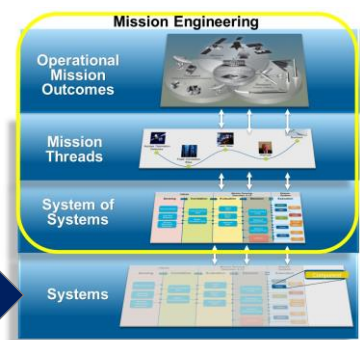
NOTE: Not an official position from these organizations, but the study was coordinated through them.

Date: 18 May 2016

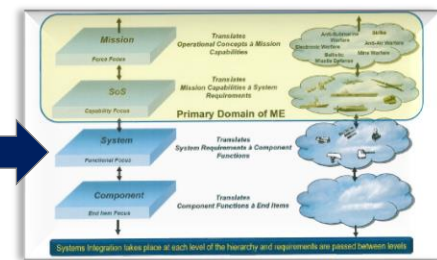
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# From a system perspective, SE standards support for mission & SoS context for systems

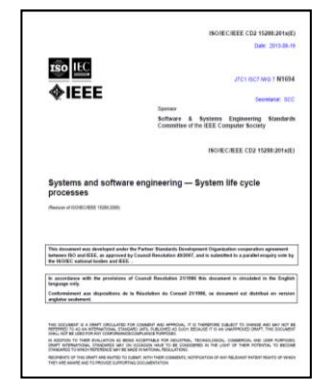
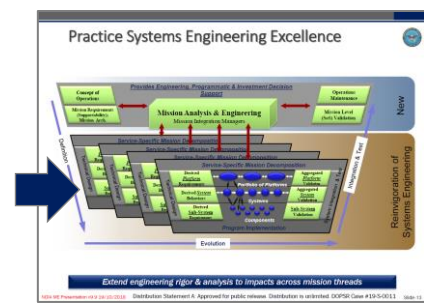


- Mission Analysis is a core process in ISO/IEC/IEEE 15288
  - **“The purpose of the Business or Mission Analysis process is to define the business and mission problem or opportunity, characterize the solution space, and determine potential solution class(es) that could address a problem or take advantage of an opportunity.”** (Section 6.4.1.1)
  - Recognizes the importance of understanding mission context in developing systems



- ISO/IEC/IEEE 21839 – SoS considerations throughout the system lifecycle

- **“Capability Considerations: In this document, capability refers to the ability to achieve overall user objectives in a mission or business context.... right from the earliest point in a system life cycle, an understanding of the role of a new system in supporting the needed user capability is a key concern, particularly understanding how the system is envisioned to function in the operational or business ...”** (Section 4.3)



Developing Standards for Systems of Systems (SoS) Engineering  
 ISO/IEC/IEEE 21839: SoS Considerations through the Lifecycle of a System

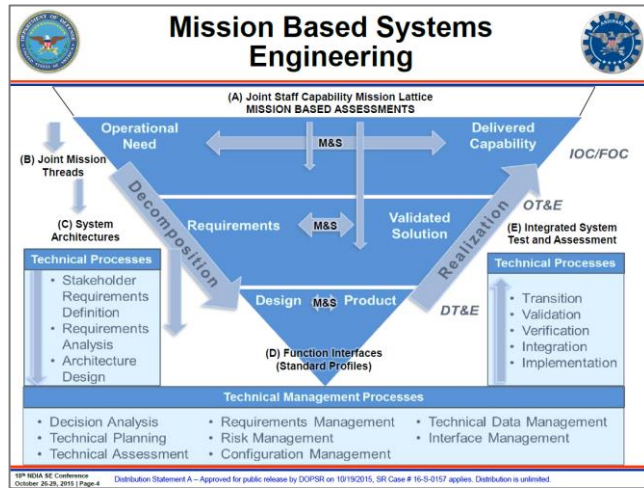
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**NDIA**

## Increasing recognition of the criticality of context in designing and engineering of systems

# Emphasis on importance of mission to drive systems



**Mission Based Analysis in the Systems Engineering Process**

William Scott  
Office of the Deputy Assistant Secretary of Defense for Systems Engineering

18th Annual NDIA Systems Engineering Conference  
Springfield, VA | October 27, 2015

OP-MAE Conference, October 2015, 2015 | Page 4 Distribution Statement A - Approved for public release by DOPSR on 10/19/2015, SR Case # 16-S-0157 applies. Distribution is unlimited.

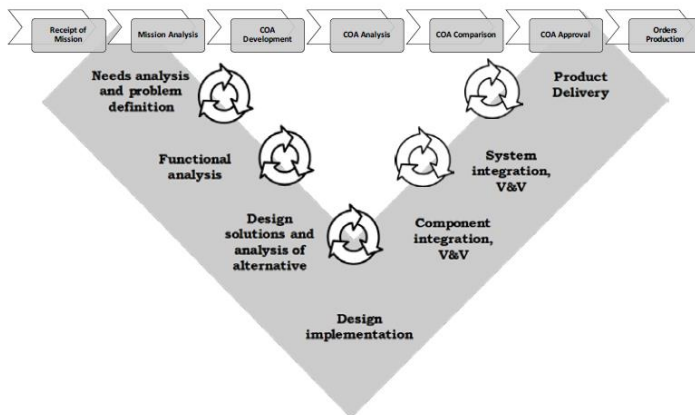
- Increased attention to the role of mission analysis and operational context in systems engineering

- DoD level in terms of systems engineering guidance

- Applying Military decision-making approaches to the engineering of systems

- Military SE education focus

- Naval Post Graduate School Systems Engineering capstone Projects



*Proceedings of the American Society for Engineering Management 2017 International Annual Conference*  
E-H. Ng, B. Nepal, and E. Schott eds.

**MISSION ENGINEERING AND ANALYSIS: INNOVATIONS IN THE MILITARY DECISION MAKING PROCESS**

Dr. Alejandro S. Hernandez\*  
Ms. Tahmina Karimova  
U.S. Naval Postgraduate School

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**systems**

Article  
**The Naval Postgraduate School's Department of Systems Engineering Approach to Mission Engineering Education through Capstone Projects**

Douglas L. Van Bossuyt\*, Paul Beery, Bryan M. O'Halloran, Alejandro Hernandez and Eugene Paulo

Department of Systems Engineering, Naval Postgraduate School, Monterey, CA 93943, USA  
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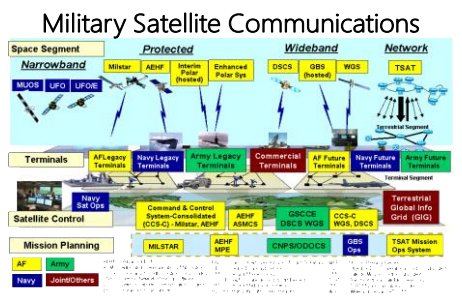
# Systems of systems for missions?



Tactical Vehicle

## Platforms

A military platform (e.g. ship, aircraft, satellite, ground vehicle) equipped with independent systems (e.g. sensor, weapons, communications) needed to meet platform objectives



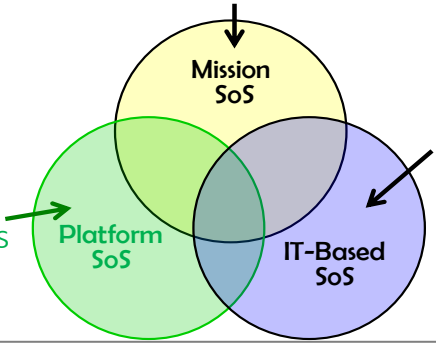
## Missions

Sets of systems working together to provide a broader capability or mission



## Information Technology

Networked information systems to support operations within or across platforms or systems to meet mission or capability objectives



- SoS in DoD have been described as covering 3 domains
  - **Platforms** – integration of multiple systems on a platform to provide ‘platform’ warfighting capability
  - **IT** – Networked information systems to support warfighting capabilities
  - **Missions** – Sets of systems working together to provide a broader capability or mission

- Engineering “**Mission-Based SoS**” aligns with “**Mission Engineering**” from a material or systems perspective

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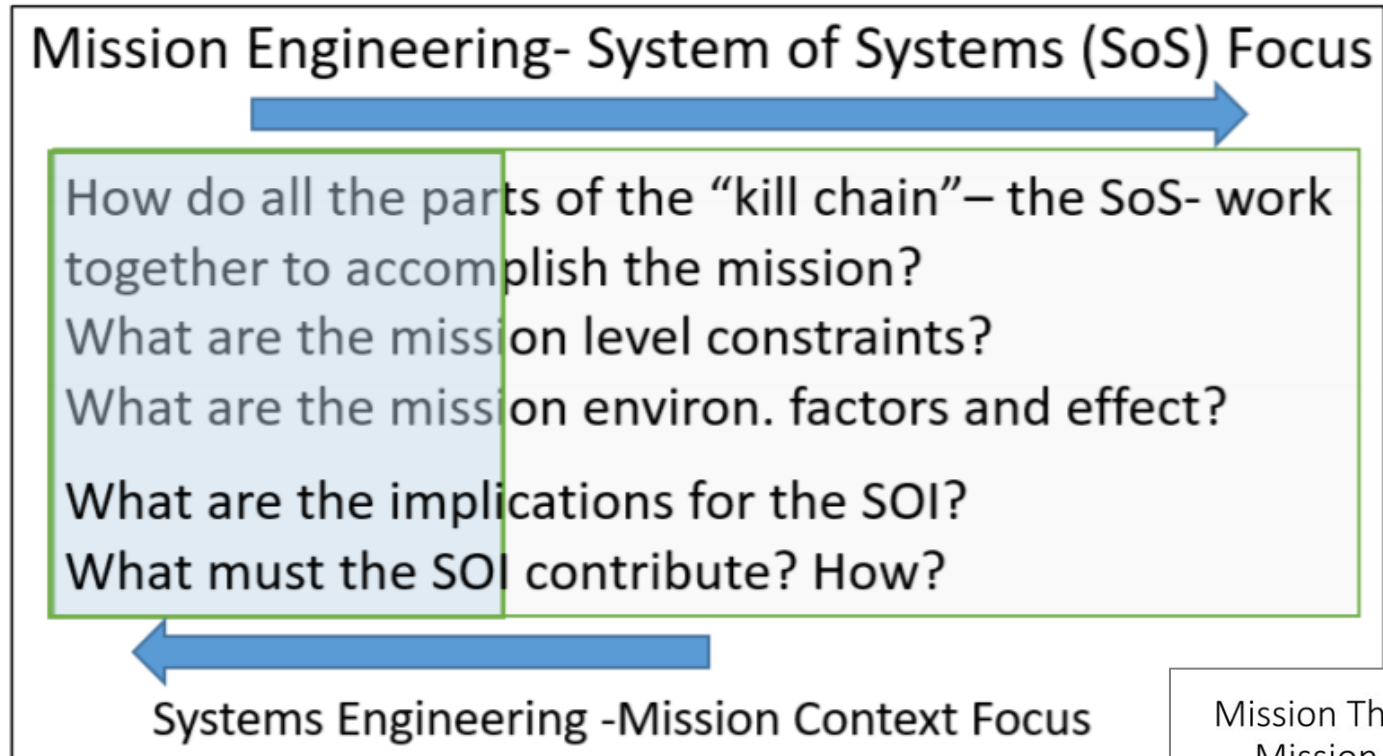
NATO OTAN S&T

**Systems of Systems  
Characterization and Types**

Dr. Judith S. Dahmann  
The MITRE Corporation  
7525 Colshire Drive  
McLean, VA 22301  
USA



# Relationship between SoSE and ME?



- Mission threads or kill chains have been presented as a **mechanism to link SoS to operational mission**
  - From one perspective they drive the SoS engineering
  - From another perspective they assess impact on operational mission

Mission Threads: Bridging  
Mission and Systems  
Engineering

Dr. Greg Butler  
Engility Corp

Dr. Carol Woody  
Software Engineering  
Institute

SoSECIE Webinar  
June 20, 2017

Release. Distribution unlimited 19-01904

# Drawing on practitioner views

**Mission Engineering Context**

- Mission engineering differs from mission analysis in that the latter only addresses current operational and system capabilities and not the engineering to assure the mission.
- Mission engineering within the Department of Defense (DoD) applies an **operational mission context to the complex systems of systems (SoS)**.
- The SoS approach has arisen in response to the DoD's needs for capabilities requiring multiple linked systems that are greater than the sum of the capabilities of the constituent parts.
- Mission engineering differs from traditional systems engineering because from the **mission engineering perspective, the individual systems that comprise the military capability are inherently flexible, functionally overlapping, multi-mission platforms** supported by a complex backbone of information communication networks.
- Several other allied nations use the term "capabilities engineering" rather than mission engineering.

**Summary**

- Based on the research findings, the team recommends a broader view:

***Mission engineering combines the structure of systems engineering and the tactical insights of operational planning to a system of systems to deliver a specific capability.***

- Research tasking and objectives identify the critical skills required to successfully accomplish and shepherd mission engineering.
- Competency model builds on grounded theory leveraging the Helix methodology on developing effective system engineers, using a combination of mission engineer interviews as informed by searching the open source literature.
- Interviews and open source literature covers 1) mission engineering definition and organizational support, 2) identification of competencies and gaps, and 3) future vision.
- Mission engineering overlaps systems engineering competencies with important differentiation in 1) governance, 2) foundational math/science/general engineering skills, 3) operational concepts, 4) interpersonal skills, 5) and leadership skills.

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- Mission engineering differs from mission analysis in that the latter only addresses current operational and system capabilities and not the engineering to assure the mission.
- Mission engineering within the Department of Defense (DoD) applies an **operational mission context to the complex systems of systems (SoS)**.
- Mission engineering differs from traditional systems engineering because from the **mission engineering perspective, the individual systems that comprise the military capability are inherently flexible, functionally overlapping, multi-mission platforms** supported by a complex backbone of information communication networks.

***Mission engineering combines the structure of systems engineering and the tactical insights of operational planning to a system of systems to deliver a specific capability.***

**Mission Engineering Competency Model**

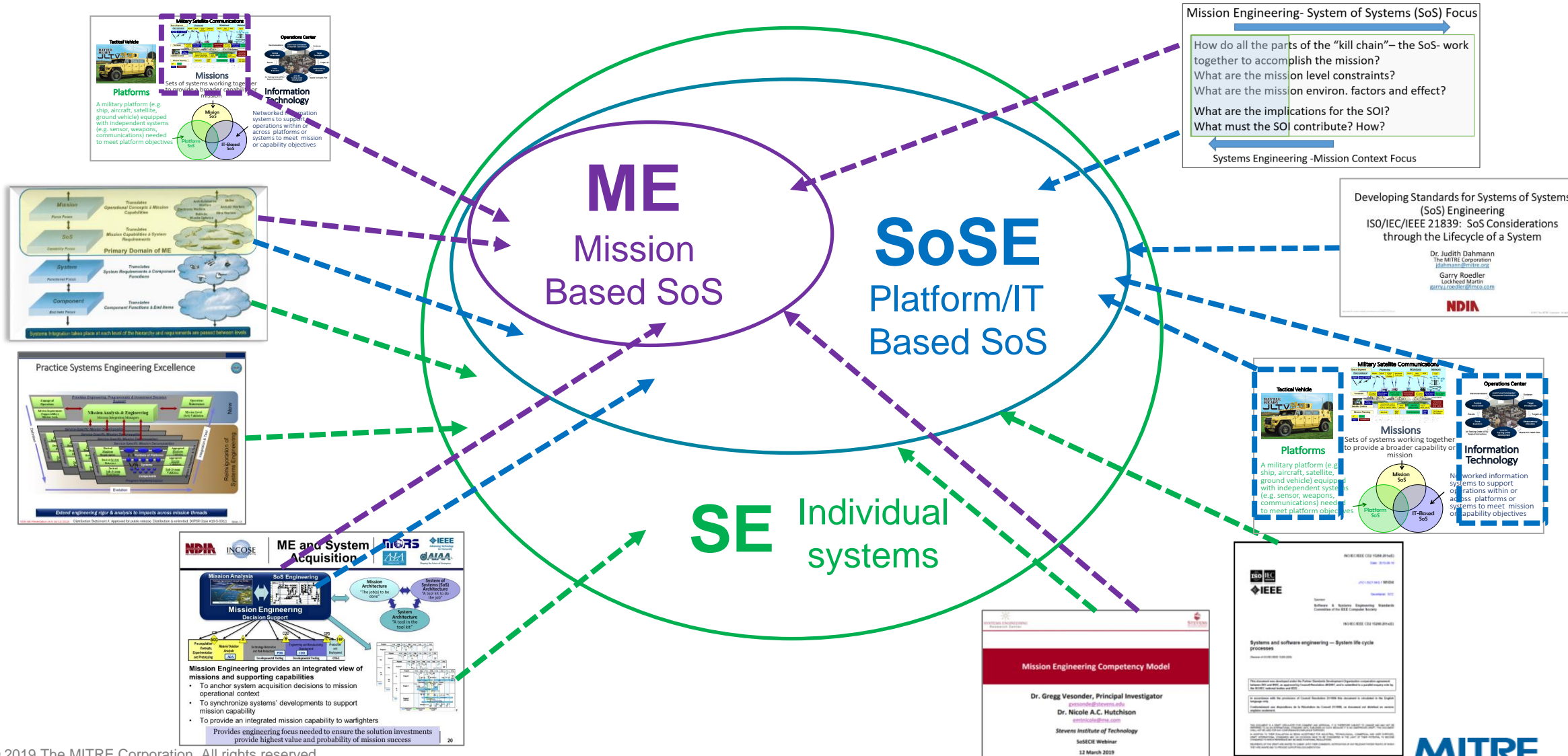
Dr. Gregg Vesonder, Principal Investigator  
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 Dr. Nicole A.C. Hutchison  
 emtnicole@me.com  
 Stevens Institute of Technology  
 SoSECIE Webinar  
 12 March 2019

**Mission Engineering Definition**

Mission engineering is the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and systems capabilities to achieve desired warfighting mission effects – Gold 2016

Or, more simply put . . .  
**The mission is the system.**

# Bringing it together - Logical View



**Mission Engineering- System of Systems (SoS) Focus**

How do all the parts of the "kill chain"—the SoS- work together to accomplish the mission?  
 What are the mission level constraints?  
 What are the mission level factors and effect?  
 What are the implications for the SOI?  
 What must the SOI contribute? How?

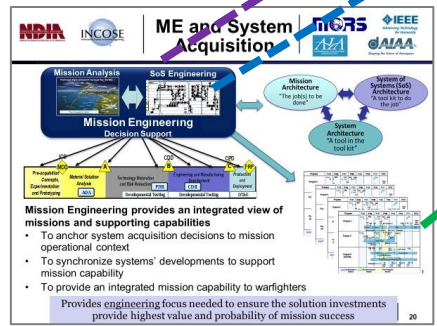
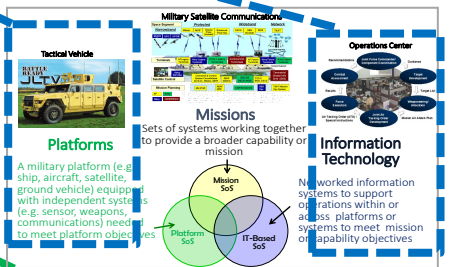
← Systems Engineering -Mission Context Focus

**Developing Standards for Systems of Systems (SoS) Engineering**  
 ISO/IEC/IEEE 21839: SoS Considerations through the Lifecycle of a System

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**NDIA**






**Mission Engineering Competency Model**

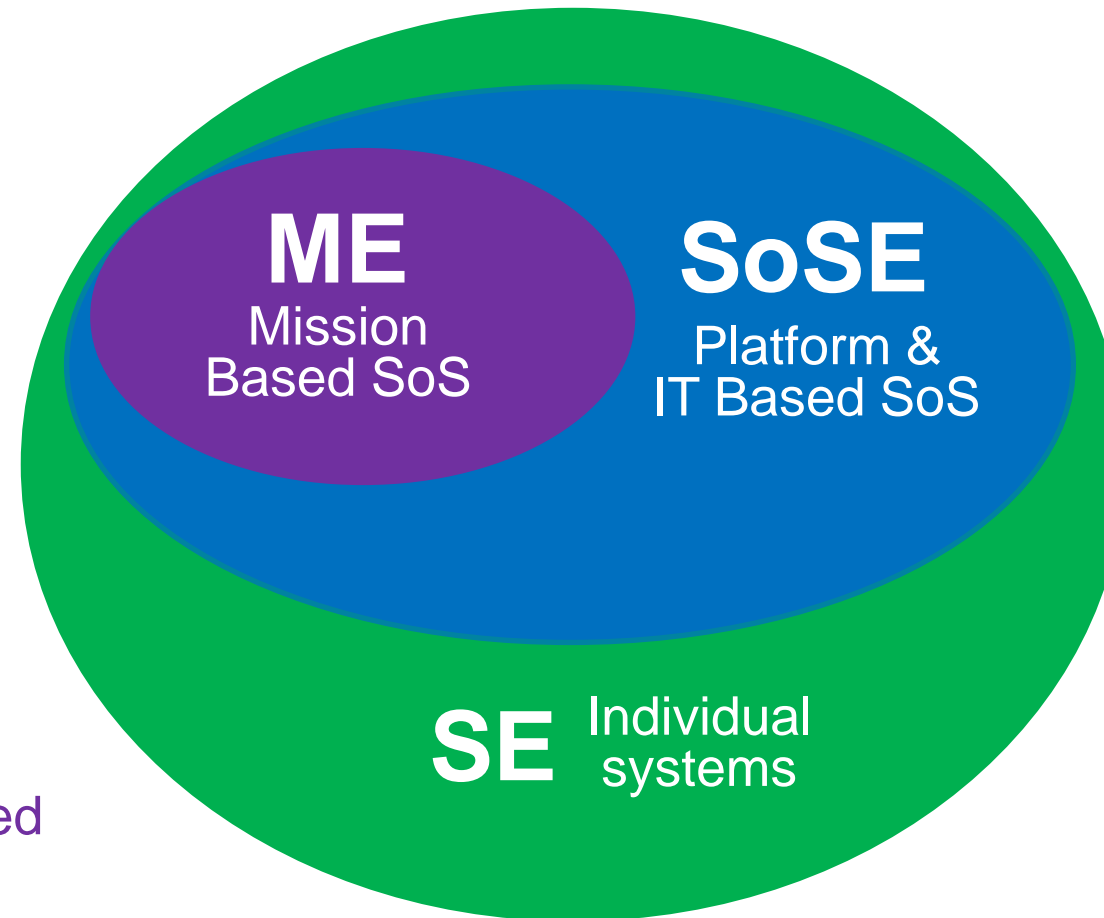
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 SoSECE Webinar  
 12 March 2019

**Systems and software engineering - System life cycle processes**

IEEE Std 1735-2015

# Logical View

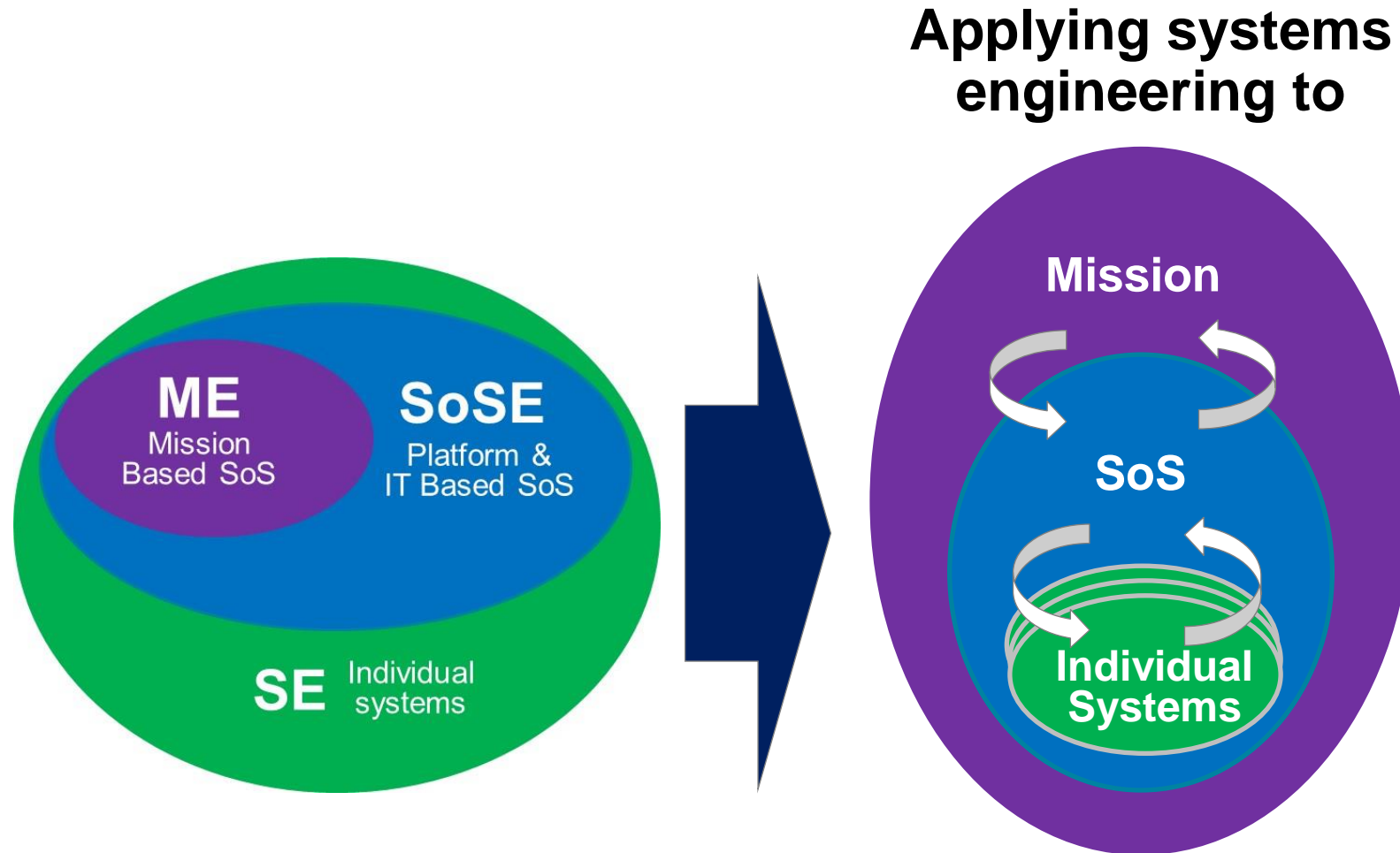
-  Systems Engineering applies across individual systems, SoS and missions
-  Systems of systems engineering applies to platform, IT-based and mission based SoS
-  Missions engineering applies to mission-based SoS



A top-level **logical** view of the relationship between SE, SoSE and ME

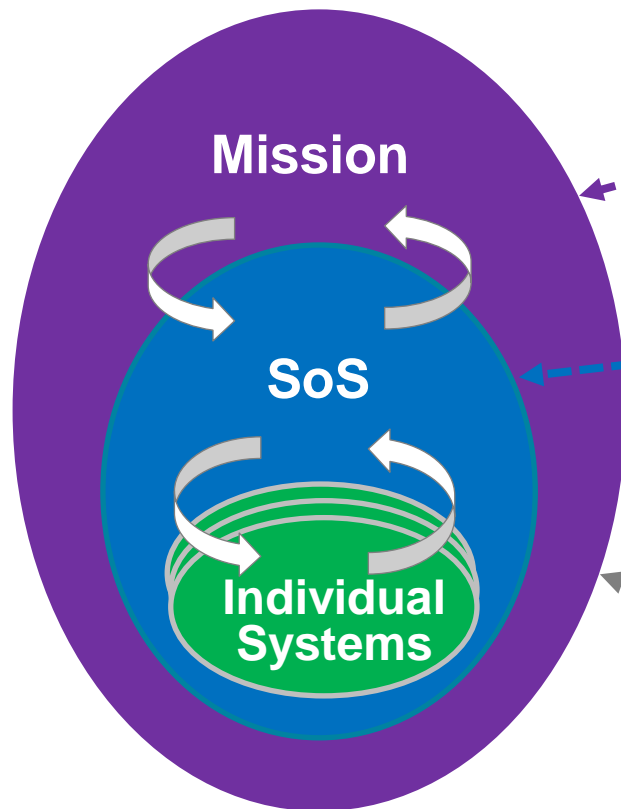


# Bringing it together – from a logical view to implementation



- From a mission perspective - drivers for SoS and systems
- From a systems of systems view – drivers for systems
- Engineering a system addresses the 'fit' to the SoS to support the mission

# What makes this hard?



## ■ Complex dynamic mission environment

- Mission context - variable physical environments, threats and non-material elements - critical in driving SoS for missions

## ■ Situation driven composition

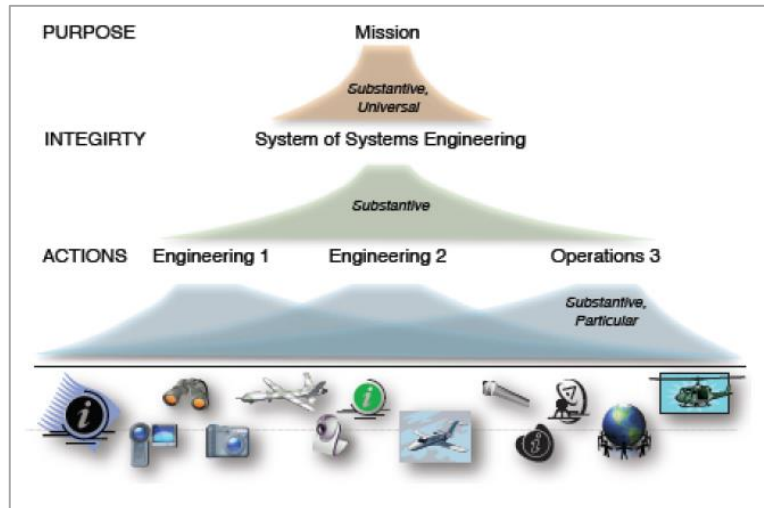
- Execution of missions is based on the employment of the set of systems available and appropriate for the mission environment
- Performance needs of a system in the Mission SoS may vary depending on the performance of other systems in the SoS ('AKA 'Float and Flow')

## ■ Mission 'webs' versus 'threads'

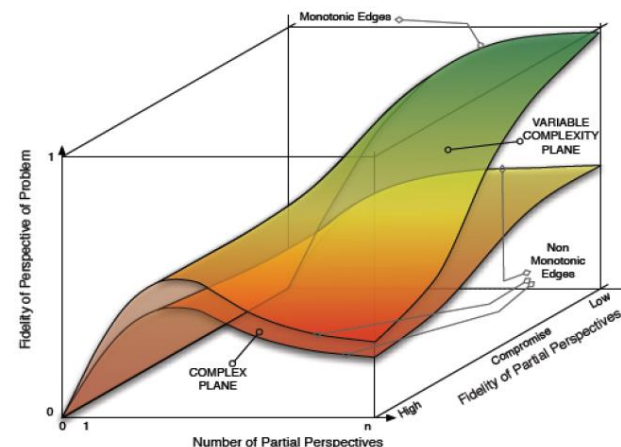
- While there may be a logical sequence of actions for a mission, in practice there are sets of systems which support missions under different situations



# Complexity of perspectives



- An added source of complexity in systems engineering across mission, SoS and systems is the diversity of perspectives across the participants
- This goes beyond the traditional SoS since a mission perspective must incorporate a wider range of operational and other non-material considerations



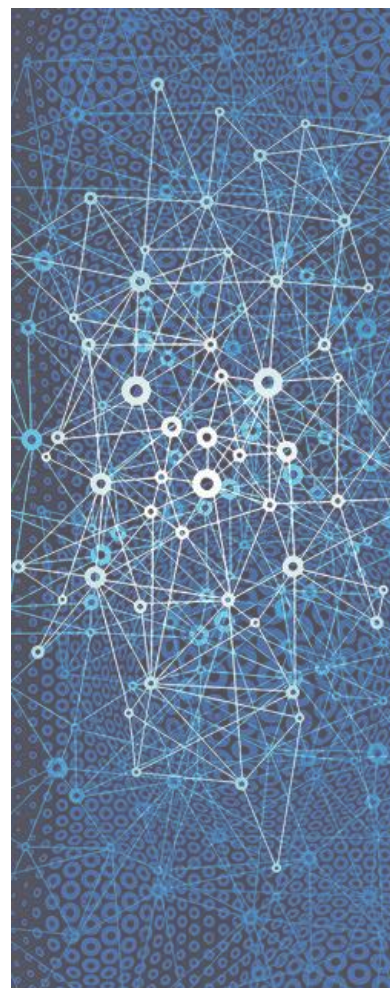
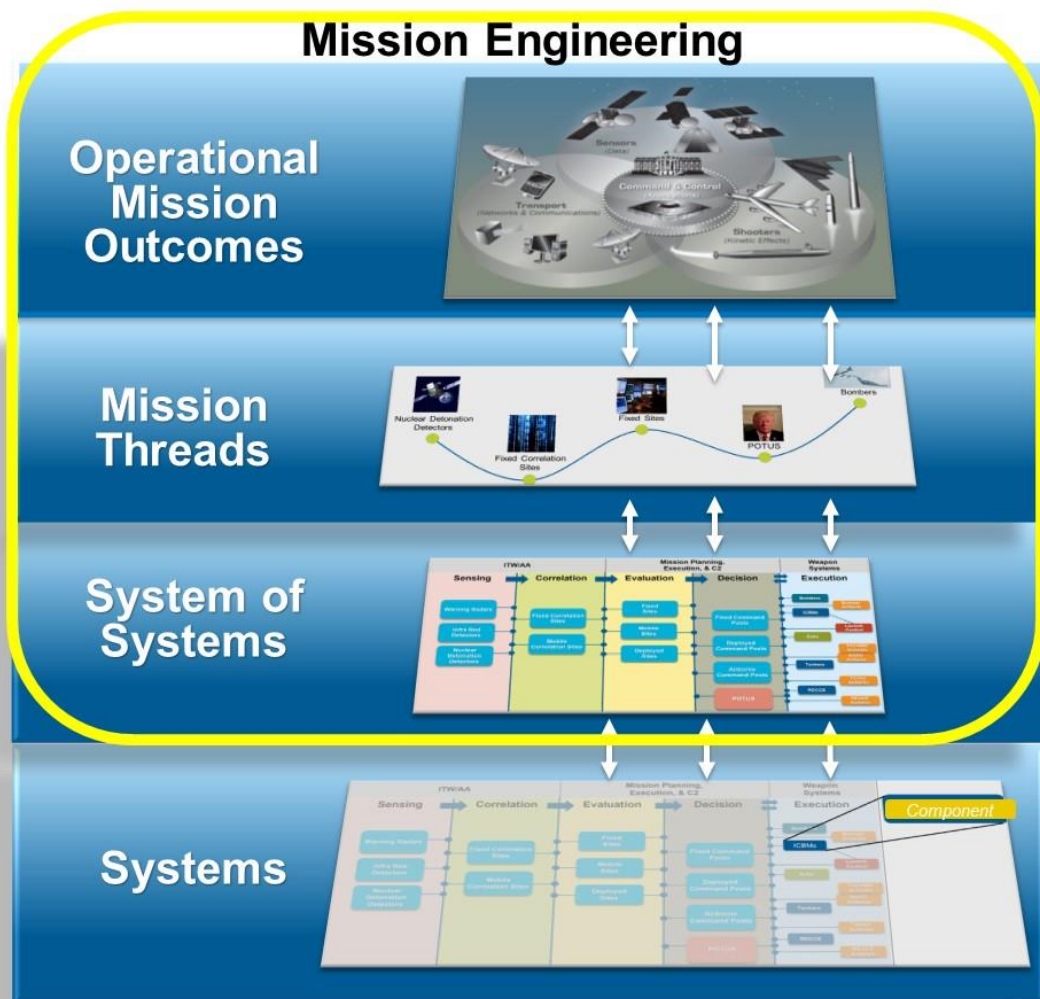
*Int. J. System of Systems Engineering, Vol. 6, No. 3, 2015*

## Mission Engineering

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# Complexity of the mission 'web'



## Mission Web

### Temporal Interdependencies

- Actions can have delayed consequences
- Actions can have repeated consequences

### Feedback loops

- Feedbacks on the different levels
- Feedbacks between the different layers
  - From upper layers to lower layers
  - From lower layers to upper layers
  - Feedback is not limited to neighbored layers

### Nonlinear relations

### Dynamic re-composition

# Summary

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- **Systems architecture focus on the development of systems that provide functionality need to contribute to tasks**
- **System of systems architectures focus on the composition of functionality of systems in orchestration to allow to conduct tasks beyond the systems perspective**
  - Ensembles are purposely designed
  - Collectives emerge within a situation and may be exploited
- **Mission engineering provides a non-system centric view on the challenges to successfully conduct military operations in complex environments**
- **All three methods provide unique features to achieve desired operational mission effects, using ensembles and collectives composed of available systems**

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# Discussion

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