Mission Engineering Competencies Workshop: Foundation for the Future

Abstract
This report summarizes a foundational two-day ODU Center for Mission Engineering, Mission Engineering Competencies Workshop held in March 2025 involving the U.S. Navy, Marine Corps, Air Force, and NASA, the University of New South Wales, HII-Newport News Shipyard, and Old Dominion University (ODU). The workshop focused on defining the roles, competencies, and skills essential to Mission Engineering. It presents a structured competency framework and recommendations to guide workforce development, training, and cross-agency collaboration in support of complex, mission-driven systems. ODU's Center for Mission Engineering is planning subsequent workshops in conjunction with Naval Surface Warfare Centers. With Mission Engineering (ME) playing an increasingly prominent role in defense and related industries. Workshop Finial Report can be found in full at https://digitalcommons.odu.edu/cme_pubs/1/

1. *Workshop Demand Signals*

- Clarify ME's definition, baselining core competencies, architectures, roles, and knowledge areas.
- Document proceedings to support improved future ME precepts and practices.
- Provide an ME framework for planning, professional development and recruitment.
- Promote ME alignment among government, academic, and industry stakeholders.

By articulating ME competencies and mapping them to relevant skills and roles this Report – and its robust complement of Appendices for professional readers -- contributes to a shared understanding of ME's role in delivering optimal mission-driven, risk-informed and interoperable capabilities for operational users.

1.1. Workshop Context, Goals and Objectives, and Structure

Context

ME is increasingly recognized as a critical discipline that upscales Systems Engineering (SE) practices, delivering ability to meet mission objectives with system-level capabilities[1], through mission-focused analysis and decision support[2]. As missions grow more complex and multi-domain in nature, there is increased need to define the unique interdisciplinary ME competencies that distinguish it from traditional SE, whose precepts are necessary but not sufficient to handle today's complex environment. The *SERC-2018-TR-109* report on ME laid the foundation for understanding enterprise transformation through Digital Engineering (DE), System-of-Systems (SoS) modeling, and competency development.[3]

Workshop Goals and Objectives

The ME Competency Workshop goal was to address the need for a clear, shared understanding of the roles, skills, and competencies essential to the practice of ME across the DoD, NASA, Academia, other industrial sectors, and allied partners. With increasing emphasis on delivering integrated, mission-focused and interdisciplinary capabilities, this workshop was planned to support workforce development efforts aligned with both the *OSD(R&E) Mission Engineering Guide v2.0* and broader transformation initiatives in SE and acquisition:

- Develop a draft interdisciplinary ME Competency Framework (see *Figure I)*, structured to support workforce development, education, and training at novice/practitioner/expert levels of proficiency.
- Define and clarify the roles involved in ME practice as they differ from or complement those in traditional SE, operational analysis, and acquisition.

[1] "Capability" enables task completion under specified conditions – a function of materiel/non-materiel solutions.
[2] Defense ME authorities responding to Congressional mandate in NDAA 2017 Sec. 855 include DoDI 5000.88 Mission Engineering and Concept Development, November 2020; OUSD (R&E) Mission Engineering Guide 2.0, October 2023 and Mission Architecture Style Guide, January 2025.
[3] For a detailed ME background and SERC 2018 - TR – 109 Report Capability Framework discussion, see Appendix A.

- Identify technical/non-technical competencies required for ME tasks, including mission analysis, capability decomposition, architecting, integration across domains, and mission outcome assessment.
- Capture organizational intelligence from the Navy, Marine Corps, Air Force, NASA and academia on ME implementation, gaps, and needed institutional support.
- Encourage cross-agency dialogue and knowledge sharing to build a foundation for future collaboration and refinement of ME best practices and professional development pathways.
- Align emerging competency needs with DoD strategic ME guidance and service-specific operational priorities.

1.2. ME Definition for Workshop Purposes

ME Definition and Scope

ME has evolved into a SoS-based application to mission planning and analysis that integrates technical, operational, and strategic components to ensure that system capabilities support mission objectives. ME practice emphasizes **the end-to-end interdisciplinary integration and analysis of capabilities across multiple systems, domains, and organizations** to achieve a specific mission outcome.

As defined in the *OSD(R&E) Mission Engineering Guide v2.0*, ME is "… an interdisciplinary process encompassing the entire technical effort to analyze, design and integrate current and emerging operational needs and capabilities to achieve desired mission outcomes." Mission engineers' competencies evolved during intensive workshop discussion, and are summarized in the following ME Competencies Framework graphic:

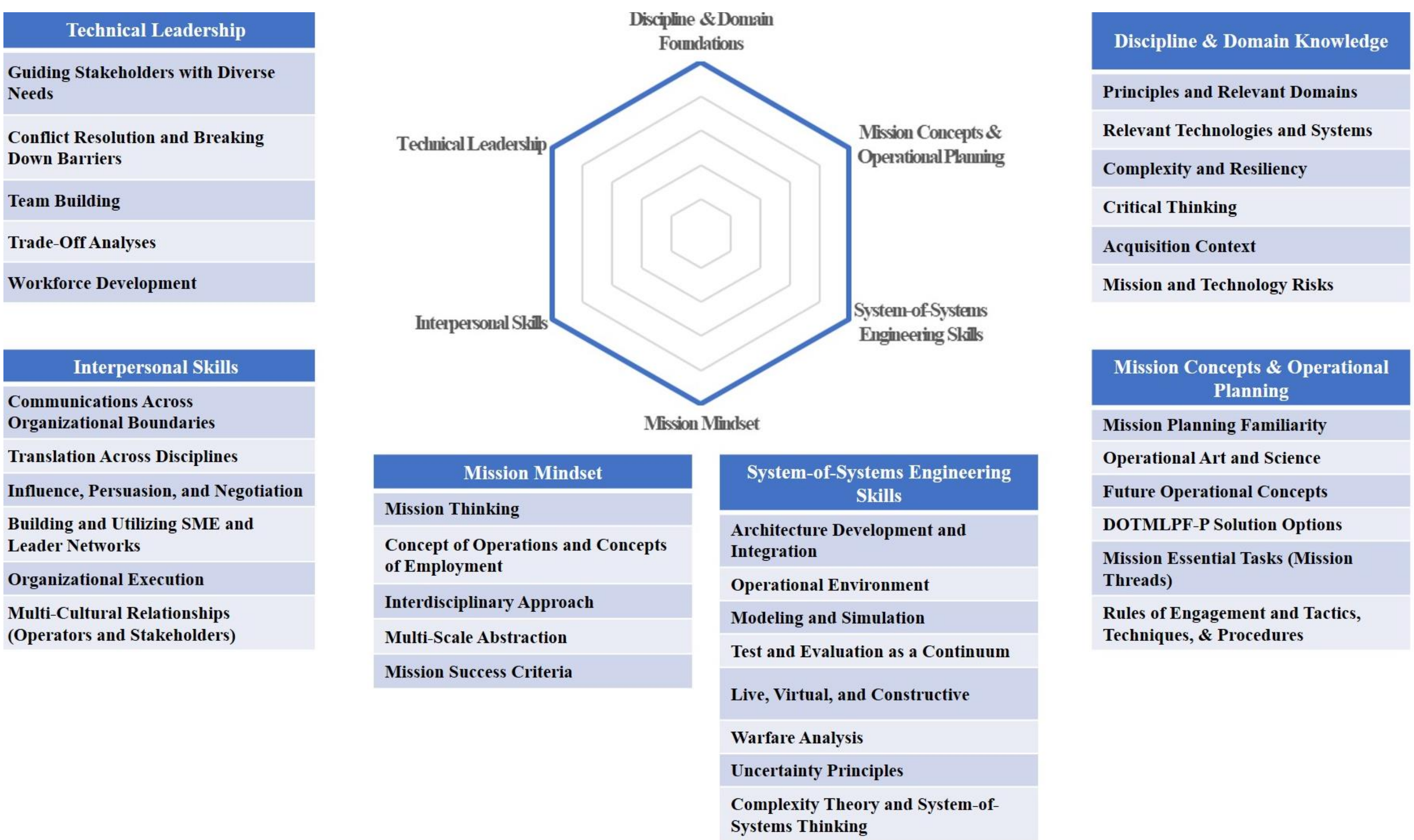

Figure 1. Workshop Results: Mission Engineering Competency Framework[4]

[4] Human Systems Integration is an additional competency common to all six Framework categories.

Interdisciplinary is defined by CME[5] as "… integrating knowledge and methods from different disciplines, using a real synthesis of approaches." Taken together, these definitions position ME as both a process and a mindset—focused on enabling mission success through scaled SE processes that inform engineering decisions, in operational environments.[6] (Note: professional readers are encouraged to consult the referenced Appendices.) *ME is essential for modern defense and aerospace organizations facing increasing complexity, multi-domain operations, and rapid innovation cycles.*

Core ME Characteristics

- **Mission-Focused**: Achieving mission success requires that all engineering decisions be made cognizant of defined mission objectives and operational constraints.
- **System-of-Systems Context**: ME inherently considers complex interdependencies across systems, platforms, and domains—including joint, interagency, and coalition environments.
- **Capability-Centric**: ME focuses on delivering integrated capabilities, assessing both current and future contributions to mission performance, and identifying capability gaps and trade-offs.
- **Risk-Informed**: Decisions are made with a deep understanding of technical, operational, and mission risk, leveraging modeling, simulation, wargaming, and analysis to explore alternatives.
- **Iterative and Adaptive**: ME supports continuous feedback and refinement throughout the capability lifecycle, from concept exploration through operations and sustainment.
- **Interdisciplinary**: ME requires integration across technical domains (e.g., cyber, space, autonomy), human systems, operations, and acquisition processes.

Scope of ME Lifecycle Activities

- **Mission Analysis and Decomposition**
  Understanding mission objectives, operational context, and desired effects; identifying mission threads, key performance drivers, and mission success criteria.
- **Capability and Gap Assessment**
  Mapping current and future capabilities against mission needs; identifying limitations, gaps, and areas for improvement or innovation.
- **Integration of Systems and Effects**
  Aligning SoS and individual systems to support coherent mission outcomes; modeling interactions, interdependencies, and interoperability.
- **Trade Space Exploration and Decision Support**
  Conducting informed trade studies to evaluate architecture alternatives, investment strategies, and operational approaches.
- **Operational Validation and Transition**
  Supporting test, evaluation, and transition of capabilities to the operational environment through mission-informed scenarios and metrics.

1.3. Key Workshop Findings and Recommendations

Key Findings

1. **ME Has Evolved as Distinct from Systems Engineering (SE)**
   ME scales SE processes to include operational context, mission-level objectives, and capability trade space exploration: ME requires broader domain awareness and decision-making agility.

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[5] Usher Institute, University of Edinburgh, 24 September 2024.

[6] For a discussion of ME's relationship to SE and System-of-Systems Engineering, see Appendix D.

2. **Current Education and Training Programs Do Not Prepare Practitioners for ME Roles**
   Existing programs focus on SE without sufficient emphasis on mission-level trade-offs, stakeholder dynamics, or operational context: ME embraces cross-disciplinary domains.
3. **A Unified Competency Model for ME is Needed to Achieve User Consensus**
   Despite key theme agreement (integration, risk-informed decision-making, etc.) there is no management protocol to guide ME development, hiring, or performance assessment[7].
4. **ME Undervalues Human Systems Integration (HSI) and Operational Context**
   Effective ME requires comprehension of human performance, cognitive load, user interfaces, and operator intent: areas often underrepresented in technical training and mission planning.
5. **Cross-Agency Collaboration Accelerates ME Competency Development**
   Collaboration across agencies and disciplines promotes consensus, accelerates learning, and improves mission outcomes: collaboration with industry and academia expands opportunities.[8]
6. **Value Engineering (VE) Precepts Will Improve ME Outcomes**
   Post-Workshop, VE was identified as vital in achieving required functions with constrained resources: VE has statutory and regulatory authority, and deserves consideration for further ME evolution planning.

Key Recommendations

1. **Establish a Common, Consensus ME Competency Framework[9]**
   Formalize ME competencies – core, enabling, and contextual – across defense and space domains and other industrial sectors, cognizant of diverse mission profiles.
2. **Develop ME Career Paths and Role Definitions**
   Clarify distinct mission-level roles (engineer, integrator, analyst, architect, T&E), define relevant skills and experience, and cite warfare analyst's holistic competencies and KSAs purview.
3. **Invest in Interdisciplinary and Experiential Training Programs**
   Design courses and exercises that blend engineering, operations, and decision-making under uncertainty – leveraging wargames, digital mission threads, and cross-agency projects.
4. **Ensure HSI Integration and Operational Context Early in ME Practice**
   Prioritize HSI and mission context, soliciting end-user input during early design and evaluation phases, and expand M&S tools to capture operator behavior and intent. *Note: HSI is common to all six of the Figure I ME Competency Framework elements.*
5. **Establish an ME Community of Practice Inclusive of Applied Research**
   Nurture continuous knowledge sharing and professional development through interagency events and shared platforms, partnering with academia on research and curriculum development.[10]
6. **Integrate Value Engineering (VE) into ME Policies and Practices**

   Post-workshop, VE was recommended for achieving required mission functions with limited resources – VE's unique, holistic data analytic contribution – to be performed by a multidisciplinary team.

Note: Report Appendices, with substantive content from Workshop preparations and proceedings, include ME Relationship to Systems and System-of-Systems Engineering, Capability Assessments, ME Competency Development, Future Workshop and ME Research Guidance, and other topics.

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[7] Navy, Marine Corps and Air Force commonly use "ME is the application of SE to the planning, designing and analysis of missions, where the mission is a system of interest." For formal DoD language, see Report Background and Context,
[8] For a discussion of organizational diversity as it impacts integration of ME into policies and practices, see Appendix E.
[9] For a competency-level discussion of Mission Analysis and Capability Assessment, see Appendix F.
[10] For Workshop session suggestions of desirable future Workshops and research, see Appendix H.

2. ME Competency Framework

2.1 Overview

The ME Competency Framework (see *Figure I)* presented in this report offers a structured view of the knowledge, skills, and attributes required for practitioners to effectively execute interdisciplinary mission-focused engineering activities across organizational, technological, and operational boundaries. The framework is built upon workshop discussions, participant input, and existing foundations in SE, integrating perspectives from workshop participants. *This competency framework provides a basis for assessing individual readiness, designing targeted workforce development programs, and aligning institutional strategies with evolving ME demands.* As noted above, *SERC – 2018 – TR-109* provided a legacy Competency Framework foundation, which workshop participants translated into interconnected domains for discussion purposes:

1. **Foundational Competencies**

These competencies represent the baseline knowledge and cognitive capabilities required for all ME practitioners, regardless of role or organization. They include: Mission Thinking and Critical Thinking, Understanding of Operational Contexts, Creative Problem Solving and Innovation, Interdisciplinary Communication and Collaboration

2. **Core Technical Competencies**

These are the mission-specific technical abilities that differentiate ME from traditional SE. They include: Mission Definition and Decomposition, Capability and Gap Analysis, Integration of Multi-Domain Systems and SoS, Modeling, Simulation, and Analysis, Risk-Informed Decision Making, Integration of Human Systems Consideration

3. **Human Systems Integration and Operational Context**

Human Systems Integration (HSI) and operational context cognition are pivotal competencies in ME. These competencies ensure that mission systems are designed and implemented with the human operator in mind, accounting for human capabilities, limitations, and the broader operational environment in which these systems are deployed. *By focusing on human capabilities and operational realities, ME strives to create systems that are not only technically advanced but also intuitive, efficient, and resilient in the face of human challenges.*

Competency Overview: HSI is the multidisciplinary approach to designing, developing, and evaluating systems that are compatible with the cognitive, physical, and social aspects of human operators. This competency emphasizes the importance of considering human factors and ergonomics in the mission system design, ensuring that operators can interact with systems safely, efficiently, and effectively in mission-critical environments. HSI is not limited to human-computer interaction; it extends to the broader interaction of humans with complex systems, including machines, technologies, and other humans.

3 Competencies for Mission Engineering

Expertise in the fundamental concepts below will ensure successful outcomes across the full lifecycle of a mission, from concept development to post-mission analysis. From SE principles to human factors integration and operational context, *these knowledge areas form the backbone of effective ME practice, ensuring that systems are designed for success, optimized for performance, and capable of adapting to evolving mission needs.*

1. **Systems Engineering Principles**

Knowledge Overview: Systems Engineering (SE) is the cornerstone of ME, providing the systematic approach to designing, integrating, and managing complex systems over their life cycles. A strong grasp of SE principles ensures that Mission Engineers can address the technical complexity, operational requirements, and constraints inherent in mission systems. This foundational knowledge involves understanding how systems interact, how requirements are gathered and analyzed, and how risks are managed to meet mission objectives.

Key Concepts:

- **Requirements Engineering:** The process of capturing, analyzing, and validating mission requirements to ensure that the systems developed meet operational goals.
- **Architecting:** The process of planning a comprehensive, interdisciplinary initiative designed to achieve a desired mission outcome.
- **System Lifecycle Management:** Knowledge of the stages of system development, from conception and design to operation and decommissioning, and understanding how decisions in one phase impact others.
- **Trade Studies and Decision Analysis:** The application of methods to evaluate design alternatives, ensuring that the best solution is selected based on mission objectives, constraints, and risks.

2. **Risk Management and Assessment**

4 Core ME Roles and Responsibilities

Mission Engineering (ME) requires diverse roles and expertise to effectively plan, design, integrate, test, and execute complex missions. These roles each carry distinct responsibilities that contribute to the overall mission success, ensuring that various systems, technologies, and operational capabilities are synchronized to achieve mission objectives. *Collaboration of Mission Engineers, Mission Integrators, Mission Analysts, Mission Architects, and Mission Test & Evaluators is crucial to mission success.*

1. Mission Engineer

Responsibilities: The Mission Engineer is responsible for the overall technical leadership and integration of all systems and capabilities that contribute to mission execution. This role focuses on understanding mission requirements, translating them into engineering specifications, and ensuring that the systems are designed and integrated to meet the defined operational goals. Mission Engineers serve as the primary point of contact between stakeholders, including operational personnel, system engineers, and mission planners.
Key responsibilities include:

- Defining mission objectives and performance criteria based on operational needs.
- Developing and managing the technical architecture of the mission, ensuring all systems work together cohesively.
- Leading risk management activities, *etc.*

2. Mission Integrator

Responsibilities: The Mission Integrator plays a critical role in ensuring that all systems, subsystems, and operational elements are effectively integrated and aligned to achieve mission success. This role focuses on bridging the gap between individual system engineers and the larger operational mission framework. The Mission Integrator ensures that interoperability, data flow, and communication channels between systems are optimized and that all operational requirements are met through system collaboration.
Key responsibilities include:

- Ensuring that all systems and subsystems meet mission interoperability standards and are capable of seamless integration into the operational environment.
- Facilitating communication and coordination among the various system and subsystem engineers to address integration challenges.
- Identifying and resolving any integration gaps, system conflicts, *etc.*

3. Mission Analyst

Responsibilities: The Mission Analyst is responsible for providing analytical support to the ME process. This role involves assessing the mission environment, evaluating system capabilities, and analyzing operational data to inform decision-making. Mission Analysts use quantitative and qualitative methods to evaluate mission outcomes, identify optimization opportunities, and assess the performance of systems within the mission context.

Key responsibilities include:

- Conducting mission analysis to define operational requirements, system performance parameters, and mission success criteria.
- Analyzing mission data to identify performance trends, potential risks, and areas for system improvements.
- Supporting the development of mission scenarios, operational models, and simulations *etc.*

4. **Mission Architect**

Responsibilities: The Mission Architect is responsible for developing the overall conceptual framework and design for the mission. This role entails translating mission objectives into a structured, cohesive architecture that includes all systems, technologies, and operational components required for mission success. The Mission Architect ensures that the mission design accounts for system interoperability, scalability, and flexibility, allowing for dynamic adjustments as mission needs evolve.

Key responsibilities include:

- Designing the mission architecture, ensuring alignment with mission goals and operational requirements.
- Identifying key technologies, systems, and platforms that need to be integrated into the mission framework.
- Developing architecture models and ensuring they support scalability, flexibility, *etc.*

5. **Mission Test & Evaluator**

Responsibilities: The Mission Test & Evaluator is responsible for planning and executing tests to validate the performance and effectiveness of mission systems and the overall mission design. This role ensures that all systems meet the defined mission requirements and that they perform as expected under operational conditions. The Mission Test & Evaluator works closely with engineers, integrators, and analysts to design, execute, and assess testing activities throughout the mission lifecycle.

Key responsibilities include:

- Developing test plans and protocols to evaluate system performance, integration, and operational readiness.
- Conducting system tests, including simulations, laboratory tests, and field trials, to validate the mission architecture and individual system components.
- Assessing system performance against mission success criteria *etc.*

5 Emerging ME Roles and Responsibilities

As ME continues to evolve in response to increasingly complex, multi-domain operational environments, new roles and responsibilities are emerging to address the challenges posed by advanced technologies, diverse mission requirements, and rapidly changing operational contexts. *These emerging roles reflect the growing need for specialized expertise that integrates advanced technologies, interdisciplinary collaboration, and novel mission requirements.*

1. **Artificial Intelligence (AI) and Machine Learning (ML) Engineer**

Role Overview: AI and ML are transforming ME by enabling systems to adapt autonomously, improve decision-making, and optimize performance. The AI/ML Engineer in ME focuses on incorporating AI/ML techniques to enhance mission planning, system operations, and decision-making processes.

Responsibilities:

- Developing and deploying AI/ML algorithms that can assist with mission planning, predictive analytics, and real-time decision support.

- Designing AI-based systems for autonomous operation, threat detection, and operational adaptation in complex mission environments.
- Integrating AI/ML models into the mission architecture, *etc.*

Emerging Importance: AI and ML have the potential to revolutionize mission execution by providing real-time decision support, optimizing system performance, and improving the adaptability of complex mission systems. As these technologies advance, the role of the AI/ML Engineer will become central to the development of next generation ME capabilities.

2. **Data Scientist for Mission Engineering**

Role Overview: The Data Scientist for ME focuses on the collection, analysis, and interpretation of large volumes of data generated by mission systems. This role ensures that data is effectively leveraged to optimize mission planning, system performance, and operational outcomes.

Responsibilities:

- Designing data collection and analysis frameworks that capture relevant mission data across all systems and operational domains.
- Applying advanced statistical, analytical, and machine learning techniques to analyze mission data and provide actionable insights.
- Developing predictive models to forecast mission outcomes, *etc.*

Emerging Importance: With the increasing reliance on big data and analytics in mission-critical environments, the role of the Data Scientist has become indispensable. This role ensures that mission teams can make informed decisions based on accurate and timely data, enhancing mission success through data-driven insights and predictive modeling.

3. **Human Systems Integration (HSI) Engineer**

Role Overview: The Human Systems Integration (HSI) Engineer focuses on ensuring that human operators, decision-makers, and end-users are effectively integrated into the mission systems. This role is becoming more critical as missions grow in complexity and human/machine tnteraction becomes more intricate.

Responsibilities:

- Designing systems and mission architectures that optimize human performance, safety, and usability.
- Ensuring that human operators can effectively interact with automated systems, AI, and decision support tools.
- Conducting human performance assessments and simulations *etc.*

Emerging Importance: As systems become more automated and integrated with AI, the role of human operators in mission success remains critical. The HSI Engineer ensures that human capabilities and limitations are effectively accounted for in system design, improving overall mission performance, safety, and operational success.

4. **Mission Resilience Engineer**

Role Overview: The Mission Resilience Engineer is responsible for ensuring that mission systems are capable of adapting to and recovering from disruptions, whether due to technical failures, cyberattacks, environmental changes, or other unforeseen events. This role is increasingly important as operational environments become more uncertain and the need for systems to remain functional under stress grows.

Responsibilities:

- Designing mission architectures with built-in resilience and redundancy to ensure continuity of operations during disruptions.
- Developing and testing systems for fault tolerance, self-healing, and rapid recovery in case of failures.
- Conducting risk assessments and developing mitigation strategies *etc.*

Emerging Importance: As missions become more complex and operate in increasingly uncertain environments, the need for systems that can quickly adapt to failures and recover seamlessly is paramount. The Mission Resilience Engineer plays a crucial role in ensuring that mission objectives can still be achieved even in the face of unforeseen challenges, enhancing operational continuity and mission success.

6 Workshop Reflections: ME in Contested, Opportune Environments

These themes highlight shared challenges, practices, and opportunities that transcend individual organizational boundaries, offering valuable insights into how different sectors are approaching ME and the skills, tools, and methods they rely on. *Commonalities will facilitate cross-organizational collaboration, drive innovation, and provide a foundation for the development of best practices in ME.*

1. **Interdisciplinary Collaboration is Essential**

A consistent theme across the organizations represented—ranging from military branches to space agencies, universities, and defense research institutions—was the critical importance of interdisciplinary collaboration. Successful ME requires contributions from a broad spectrum of technical and operational disciplines, including SE, operations research, human factors engineering, logistics, and more. This convergence of expertise helps ensure that all aspects of a mission, from concept to execution, are addressed comprehensively.

2. **Integration and Interoperability Across Systems**

A recurring theme was the challenge and necessity of ensuring integration and interoperability of systems across multiple domains, especially when working with SoS. Mission Engineers are tasked with designing systems that can not only perform individually but also work seamlessly together, often across diverse platforms, technologies, and environments.

3. **Focus on Human Systems Integration (HSI)**

Another prominent theme is the increasing emphasis on Human Systems Integration (HSI). As missions grow more complex and technology-heavy, ensuring that human operators can interact effectively with systems is a central concern. This encompasses not only designing systems that are user-friendly and intuitive but also ensuring that human decision-makers are equipped with the right tools, training, and context to make informed choices.

4. **Risk Management as a Core Competency**

Across all organizations, risk management emerged as a core competency in ME. Whether designing a new spacecraft, deploying a military asset, or conducting a research experiment, every aspect of ME must account for potential risks. These risks could be technical, operational, environmental, or even human-related, and managing them effectively is critical to mission success.

5. **Emphasis on Agility and Adaptability**

The need for agility and adaptability in ME was another key theme across the organizations. With the increasing complexity and dynamic nature of modern missions, organizations are seeking ways to adapt quickly to unforeseen challenges, new opportunities, and evolving mission requirements. Traditional, rigid approaches to mission planning and system design are replaced by more flexible processes.

6. **Data-Driven Decision Making**

The role of data-driven decision-making has become increasingly important across all organizations involved in ME. With the growth of big data, sensors, and real-time analytics, Mission Engineers are empowered to make better-informed decisions based on objective data rather than relying solely on intuition or historical trends.

7. **Cross-Organizational Knowledge Sharing and Collaboration**

Finally, the importance of cross-organizational knowledge sharing was frequently highlighted in the workshops. Organizations recognize the value of learning from each other, particularly when dealing with complex, high-stakes missions. Sharing lessons learned, best practices, and common pitfalls can accelerate the development of ME capabilities and improve outcomes.