21st Annual National Defense Industrial Association Systems and Mission Engineering Conference

Digital Engineering Support to Mission Engineering

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Abstract

In the U.S. Department of Defense (DoD) there is increased interested in mission engineering – the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects. The Components have implemented mission engineering in areas where there is a critical interest in achieving mission capability, such as ballistic missile defense or naval mission areas, and there is growing interest in addressing a broad set of mission areas through the implementation of mission integration management – the coordination all the programmatic elements – matching funding, schedules, technical improvements, resources (technical staff, development and test infrastructure, M&S etc.) across the relevant mission systems and supporting systems to develop, test, and field a phased set of mission capabilities.

While interest in mission engineering is growing, so is the development and use of Digital Engineering (DE). The DoD has developed a DE Strategy, and the Components are working to adopt DE to support their acquisition programs. This presentation outlines key mission engineering activities and describes opportunities for application of digital engineering to support mission engineering.

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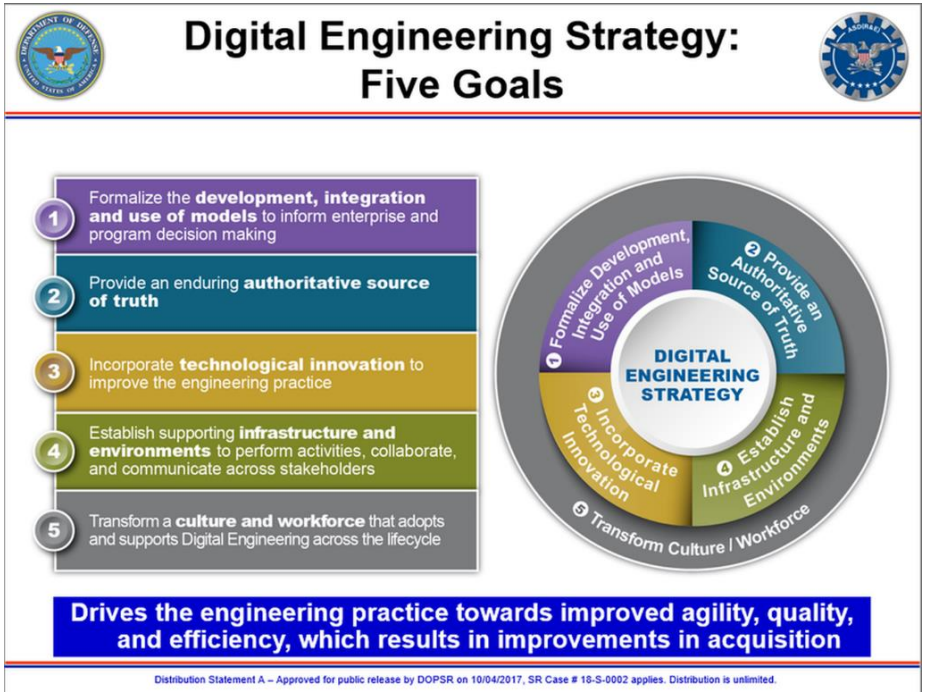
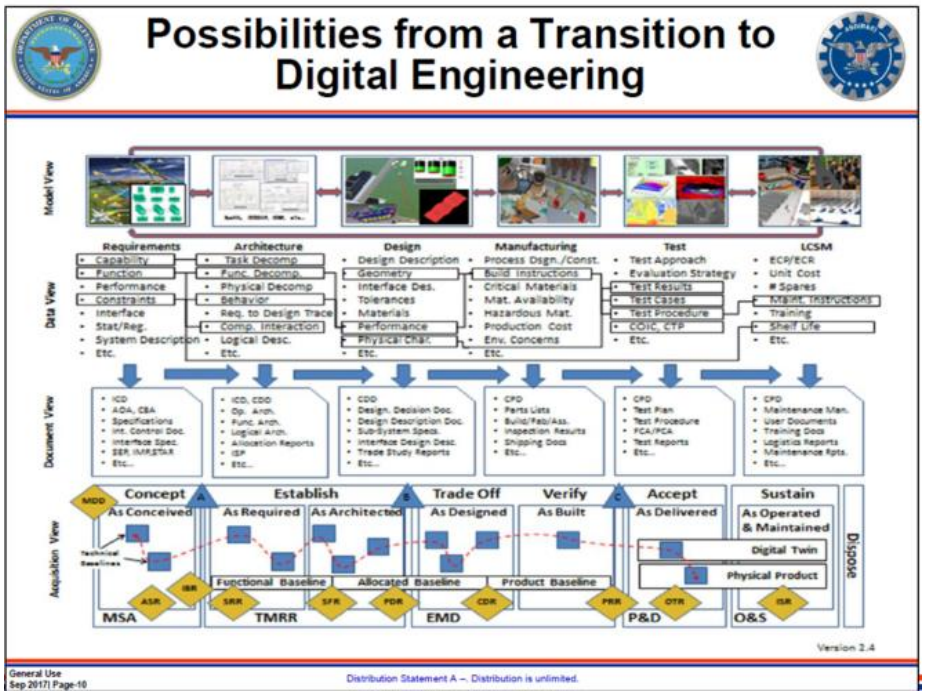
Topics

- Digital Engineering (DE) and 5 Goals of the DoD DE Strategy
- Mission Engineering (ME) and Top Level ME Activities
- Mission Engineering Challenges
- How ME can Benefit from DE

Digital Engineering

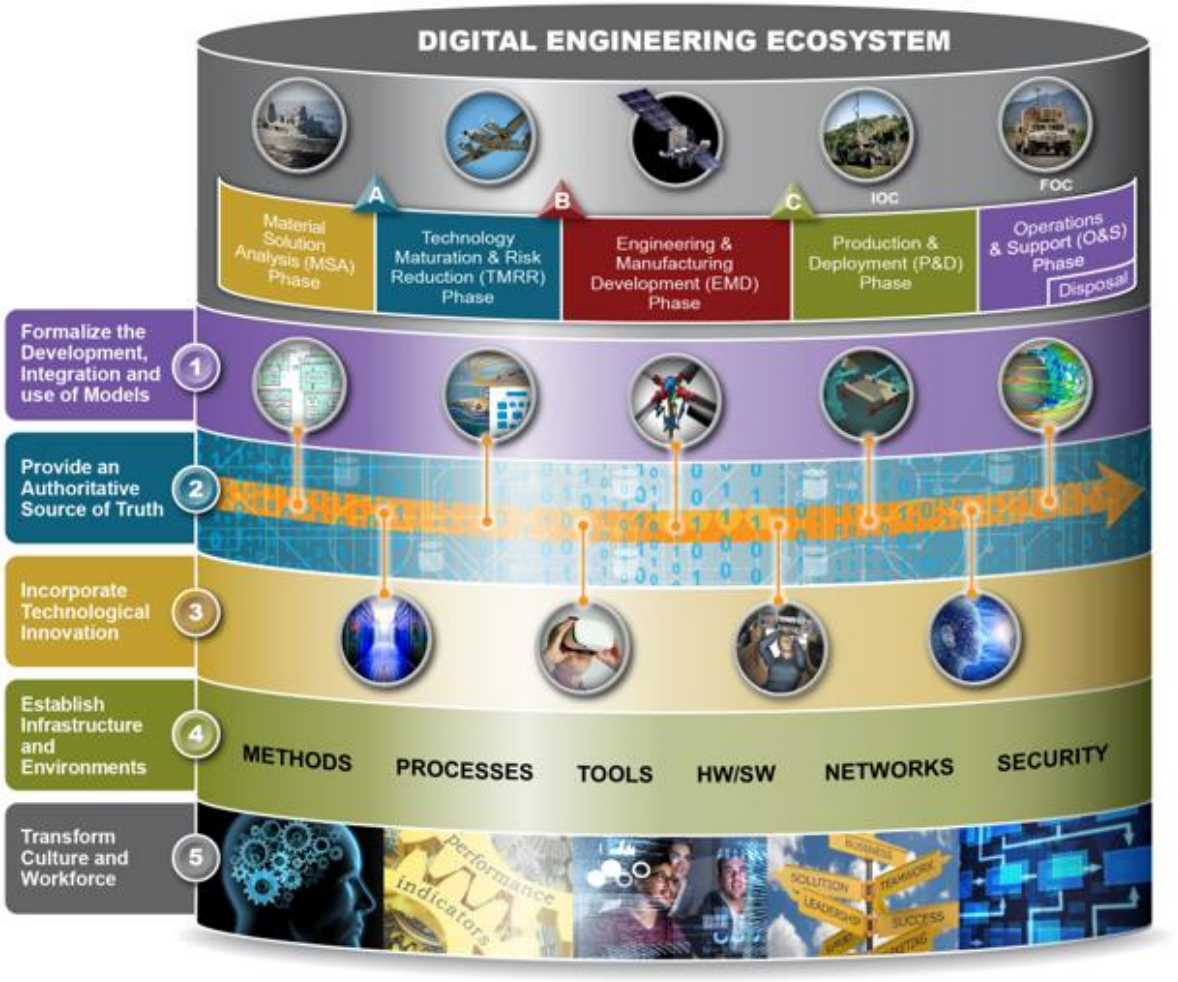
- DoD is pursuing a **digital engineering strategy**
- DE principals and implementation possibilities provide the basis for transforming systems engineering





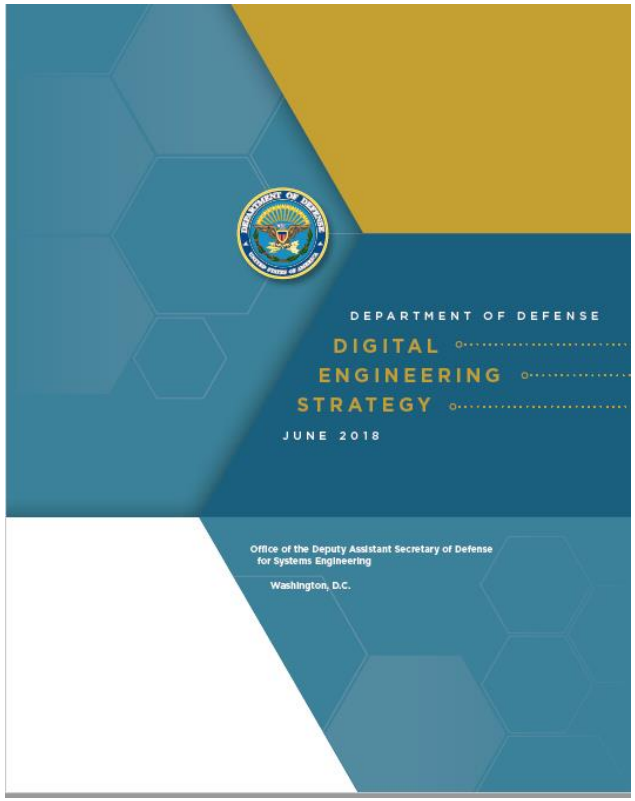
Digital Engineering Overview

- **What is Digital Engineering?**
  - Combines model-based techniques, digital practices, and computing infrastructure
  - Enables Delivery of high pay off solutions to the warfighter at the speed of relevance
- **Reforms Business Practices**
  - Digital enterprise connects people, processes, data, and capabilities
  - Improves technical, contract, and business practices through an authoritative source of truth and digital artifacts



Modernizes how we design, operate, and sustain capabilities to outpace our adversaries

DoD Digital Engineering Strategy



The strategy promotes the use of digital representations of systems and components and the use of digital artifacts to design and sustain national defense systems.

- **The Department's five strategic goals for digital engineering are**
  - Formalize the development, integration, and use of models to inform enterprise and program decision making
  - Provide an enduring, authoritative source of truth
  - Incorporate technological innovation to improve the engineering practice
  - Establish a supporting infrastructure and environment to perform activities, collaborate, and communicate across stakeholders
  - Transform the culture and workforce to adopt and support digital engineering across the life cycle

https://www.acq.osd.mil/se/initiatives/init_de.html

Digital Engineering Fundamentals

The Digital Engineering (DE) Fundamentals lay out a set of precepts for applying digital engineering to support systems engineering by Defense programs

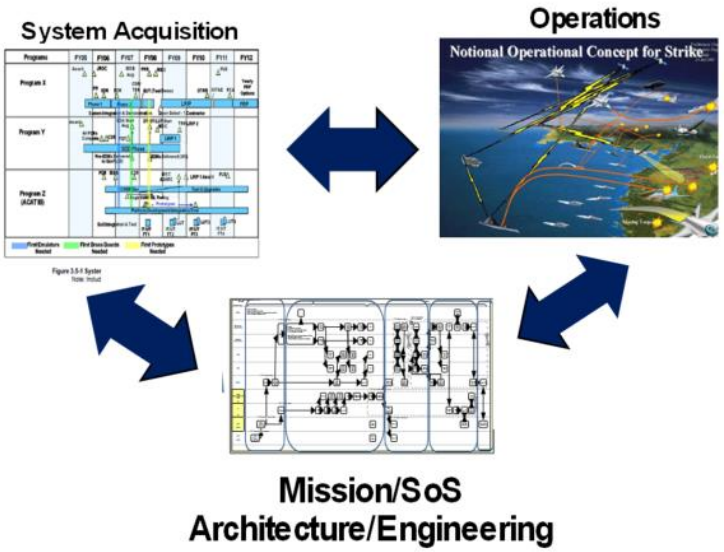
DEPARTMENT OF DEFENSE
DIGITAL ENGINEERING WORKING GROUP

Systems Engineering Digital Engineering Fundamentals (Including Models and Simulations)

1. The program should use a digital model to develop depictions of the system to support all program uses, including requirements analysis, architecture, design and cost trades; design evaluations; optimizations; system, subsystem, component, and subcomponent definition and integration; cost estimations; training aids and devices development; developmental and operational tests; sustainment and disposal. In addition, models and simulations should be used, to the greatest extent feasible, in systems engineering and program/project risk management; cost and schedule planning; and providing critical capabilities to effectively address issues in areas including but not limited to interoperability, joint operations, and systems of systems across the entire acquisition life cycle.
2. The responsibility for planning and coordinating programs' use of models, simulations, tools, data, data rights, and the engineering environment belongs to the program manager; the performance of the actual tasks may be delegated to the program systems engineer and other program staff as appropriate.
3. Programs should identify and maintain model-centric technology, methodology/approach and usage preferably in a digital format (e.g., a digital system model(s)), that integrates the authoritative technical data and associated artifacts generated by all stakeholders throughout the system life cycle. Unless impractical, the program should develop the digital system model(s) using standard model representations, methods, and underlying data structures.
4. The digital system model(s) is a collaborative product of systems engineering and design engineering efforts. The program should construct the digital system model(s) by integrating data consumed and produced by the activities across and related to the program. The digital system model(s) should include, but should not be limited to, the technical baseline, parametric descriptions, behavior definitions, internal and external interfaces, form, structure, and cost. This data should be traced at a minimum from operational capabilities through requirements, design constructs, test, training, and sustainment. The program should validate the digital system model(s) baseline at appropriate technical milestones.
5. Systems engineers should use models to define, understand, evaluate, communicate, and indicate the project scope, and to maintain an "authoritative source" about the system. When captured digitally, the system model may be used to produce technical documentation and other artifacts to support program decisions. It is expected that a properly managed, digitally based system model will be more accurate, consistent, and sharable.
6. Models, simulations, tools, methodology, and data employed in acquisition activities should have an established level of trust, and the program should use the activities with an acknowledged level of risk appropriate to the application. The development of models, construction of simulations, and/or use of these assets to perform program definition and development activities (including pre-Materiel Development Decision and pre-Milestone A) requires collaboration among all project stakeholders and is led by the systems engineer.
7. The program office should ensure sufficient training in the appropriate use of models, simulations, tools, data, and the engineering environment. The program should identify metrics that show the link between training and the appropriate use of activities that result in benefits to the program, especially in the areas of early identification of defects, cost avoidance, and risk reduction.
8. The program should update the digital system model(s) throughout the program life cycle and maintain configuration management (i.e., version controls). These updates will provide continuity among all program stakeholders, including the program model developers, simulation uses, and other engineering and program management activities.

DE Fundamentals apply at all levels and to any organizations which apply systems engineering – including Mission Engineering

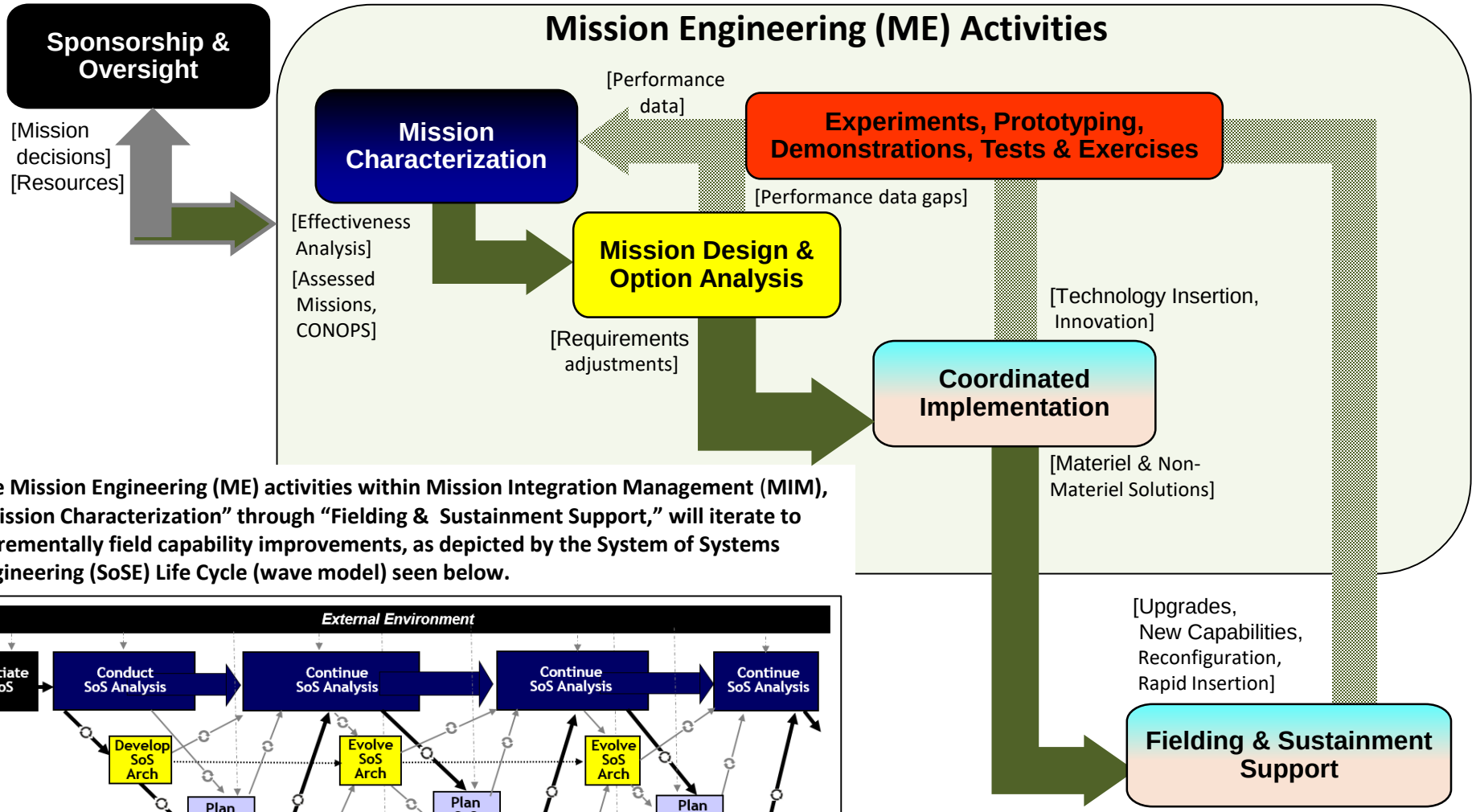
Mission Engineering



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

Top-Level Mission Engineering Activities

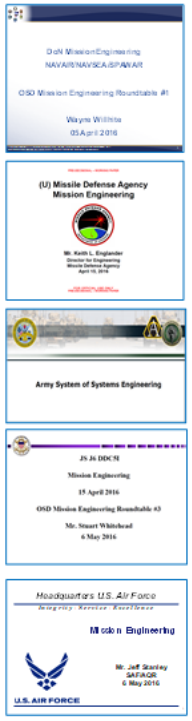


The Mission Engineering (ME) activities within Mission Integration Management (MIM), "Mission Characterization" through "Fielding & Sustainment Support," will iterate to incrementally field capability improvements, as depicted by the System of Systems Engineering (SoSE) Life Cycle (wave model) seen below.

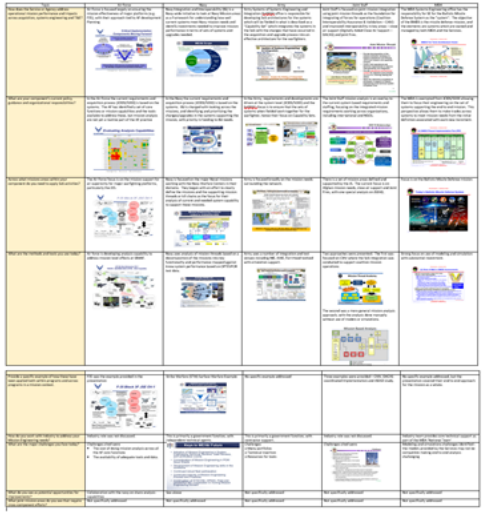
Source: Defense Acquisition Guidebook, Chapter 3 Systems Engineering, Section 3.1.2 Systems of Systems

Building on Experience

Mission Engineering is Underway By Components



Snapshot of Roundtables



Hosted Roundtables
April – May 2016

Results: Service activities are focused on unique approaches and mission perspectives.

- Assess current mission capabilities as basis for analysis of shortfalls, options and recommended programming and budgeting changes (Navy I&I)
- Address integration during development (Army NIE/AWE)
- Early development planning to derive mission gaps and capability solutions (AF)
- Comprehensive, ongoing engineering and integration towards improved mission performance (Missile Defense Agency)

SE Staff Meeting
2017 Page-19

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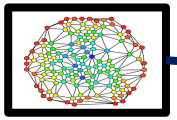
- While there is growing interest in ME in DoD, the Components have been implementing ME in various forms over the past 5 years
- Their experience provides insights into ME challenges

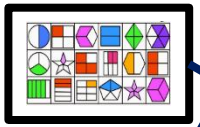
Mission Engineering Technical Challenge Areas


Scope and Complexity


Cross Organizational Engagement


Integrated Analysis Capability


Testing and Assessment


Common Mission Representations

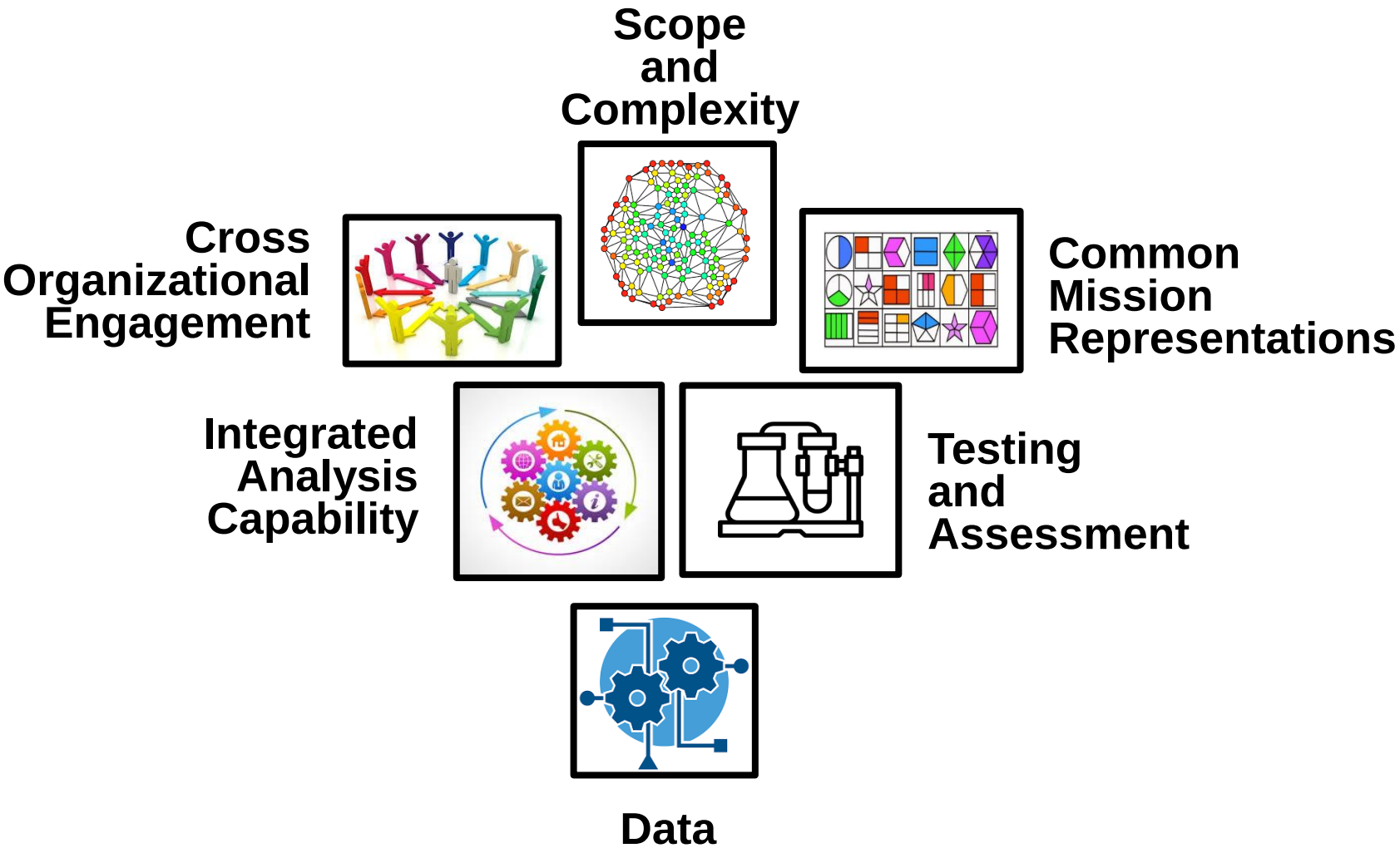

Data

- Limited corporate/leadership demand for ME [1]
- Large scope and complexity of missions; Multiple complex, system interdependencies [1]
- Cross multiple portfolios and organizations [1]
- Lack of dedicated ME resources (funding, people, tools, data); Availability and development of ME skills [1]
- Development of effective ME processes and practice
- Challenges of developing integrated analysis capabilities that bridge engineering and mission effects [1]
- Need for data on missions, systems, interfaces, interactions and interdependencies [1]
- Defining Stakeholders; Stakeholders exist at both the system and mission levels with competing interests and priorities and no directed interest in mission engineering [2]
- Testing and Assessment; How to test capability across multiple system lifecycles: legacy systems, systems under development, emerging solutions, and technology insertion [2]
- Sustainment of Mission Threads; Managing sustainment of mission effect/kill chains [2]
- Working Across Organizational Boundaries; Must assemble interdisciplinary teams to effectively execute this process across the Department [2]
- Realigning the USD(R&E) Workforce; Transition from program oversight to capability management [2]
- Tools and Models; MIM tools and models are still evolving across the Department [2]

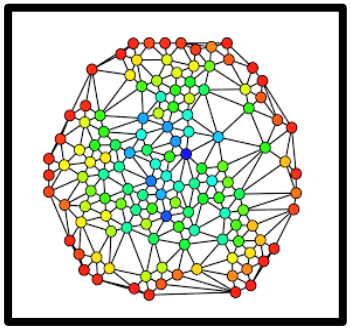
Review of current ME experience identifies challenges which can be addressed by DE Strategy

[1] 2016 ME Roundtable [2] MIM 60 Day Pilot

Mission Engineering Challenges That Digital Engineering Can Address



Scope and Complexity



- Missions span multiple systems, organizations, scenarios
- Multiple stakeholders with their own interests, motivations, and perspectives, often participate with their own models and analysis tools at the system, components, and mission function
- To address the mission in a coherent way requires methods, processes, and tools which can provide a shared view of key elements of the mission

Large scope and complexity of missions

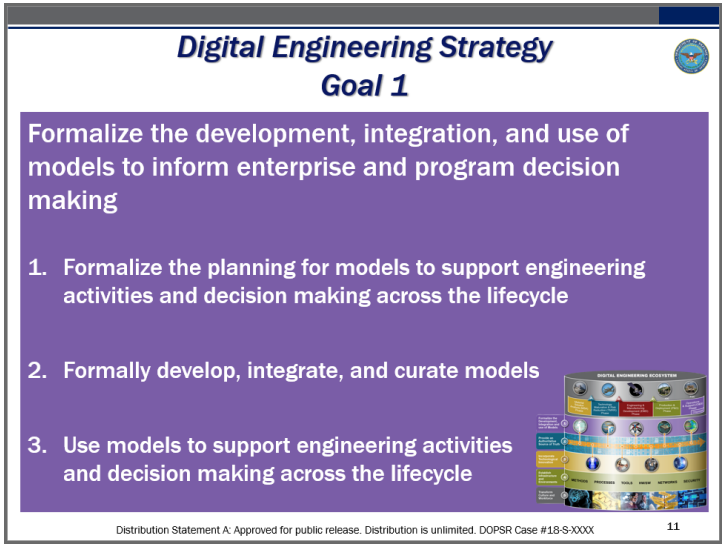
Cross multiple portfolios and organizations

Multiple complex, system interdependencies

Defining Stakeholders

Stakeholders exist at both the system and mission levels with competing interests and priorities and no directed interest in mission engineering

- Use of formalized, shared, linked models can provide the framework
  - for addressing issues at different levels of detail for different purposes
  - while maintaining integrity and coherence across the mission addressing complexity and scope through partitioning
- Enterprise-wide mission modeling strategy and framework provides the basis for cost effective ME



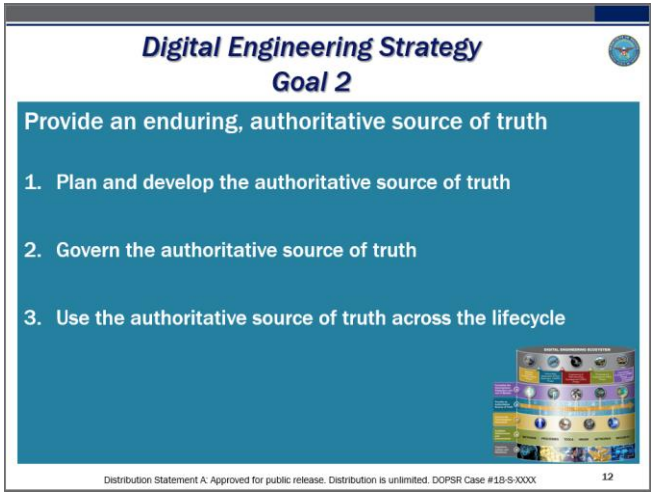
Data

Need for data on missions, systems, interfaces, interactions and interdependencies

- Very distributed, maintained in various forms by different organizations
- Focus on specific system needs and do not address interdependencies and interactions
- Even when available, can be hard to locate or access
- Current system models are developed for different purposes which can challenge their effective use in addressing mission level issues

- Data is critical to effective engineering at any level and common data shared across models and analyses is key to successful mission engineering
- In the absence of ME, typically each organization invests considerable resources to develop data which is often not known or shared across a mission

- Driving common, shared data through coordinated modeling and data management provide backbone for coherency across models and analyses
  - For ME this includes data from mission operations – often the source of gaps and opportunities
- A mission-wide distributed enterprise data strategy supporting curated linked models is key to effective ME



Cross-Organizational Engagement

- DoD missions depend on effective interaction among systems owned, development, managed and operated by different organizations
- Each organization has its own systems engineering processes and tools to support the needs of its organization
- To effective engineer across the mission requires the same type of effective interaction across engineering as is needed across systems
- Use of shared supporting digital infrastructure and DE methodologies can enable collaborative analysis and engineering across key organizations responsible for systems and functions critical to mission outcomes

Working Across Organizational Boundaries

Must assemble interdisciplinary teams to effectively execute this process across the Department

Integrated Analysis Capabilities

- Given the complexity and scope of most Defense missions, and the number of stakeholders and organization key to the mission, effective ME needs to support analysis capabilities that draw on a range of models and data to address the mission level options and impacts

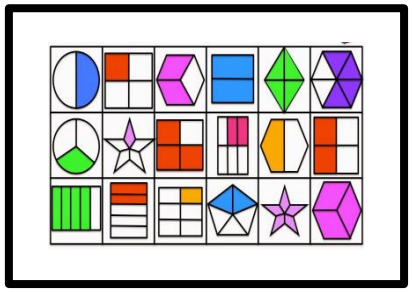
Challenges of developing integrated analysis capabilities that bridge engineering and mission effects

- Limits on the available analysis methods to address complexity and dynamics
- Difficult to link changes in systems or SoS engineering models with impacts on missions in operational or mission simulations
- Tools address only subset of issues, making complex analysis and engineering trades manpower intensive and time consuming, are difficult to use together

- The combined effects of
  - Curated linked models
  - Managed data
  - Supporting infrastructure

  provide the capabilities needed to address mission level integrated analysis challenges

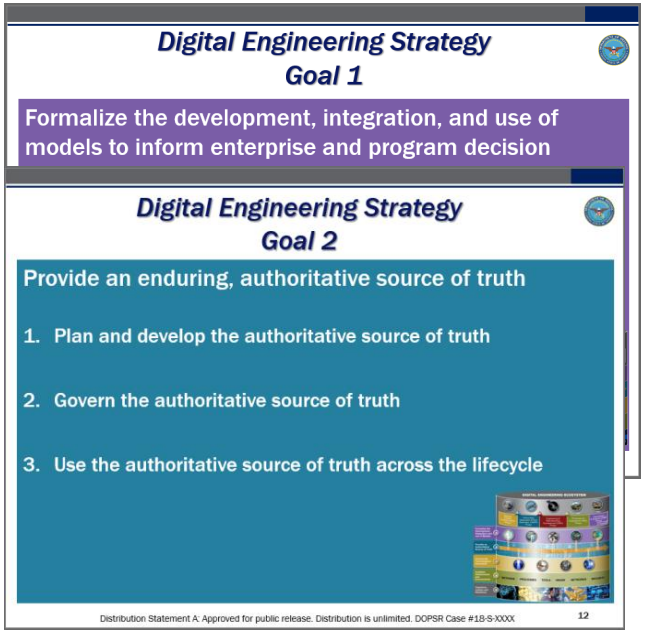
Common Mission Representations



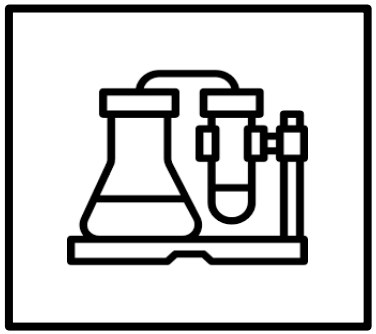
Sustainment of Mission Threads

Managing sustainment of mission effect/kill chains will require some adjustments to existing job functions and creative thinking by analysts who have heretofore focused on programs and Services individually

- Effective ME requires a common view of the mission – CONOPs, systems capabilities, threats – that are shared across the enterprise to provide a shared framework across the mission which can be used as context for more detailed views of specific issues related some elements of the mission, Component mission perspectives, and the view of the systems
- Curation of both models and data – including mission threads – for use across the mission for analysis and engineering is core to effectively applying ME ensuring that there is a common underlying understanding and assumptions driving decisions which affect the mission



Test and Assessment



- One factor that leads to the complexity of ME is that many of the systems are independent, are at different stages of their lifecycles and their development cycles are geared toward their system users, which means the mission-level engineering has a limited ability to synchronize and validate impacts of system changes on the missions

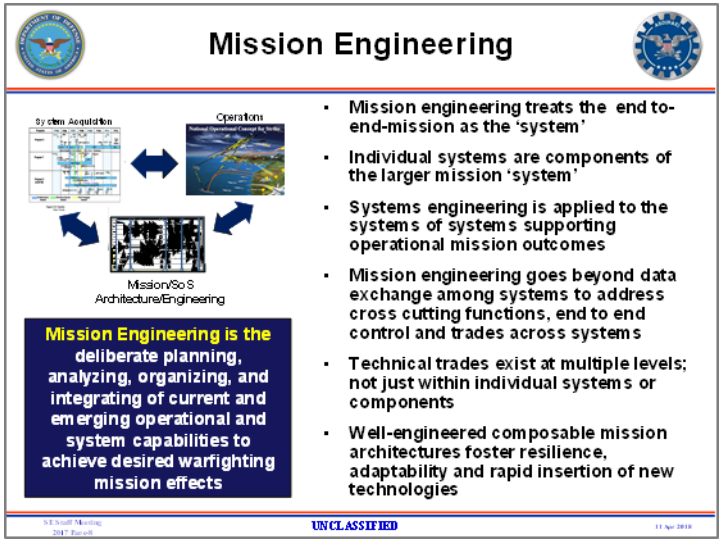
Testing and Assessment

How to test capability across multiple system lifecycles: legacy systems, systems under development, emerging solutions, and technology insertion

- The availability of linked models allows for innovative approaches to identifying and assessing impacts of changes in systems on the mission when live end-to-end testing is not feasible
- In addition regular input from mission operations is key to assess models and ensuring data reflects operational reality

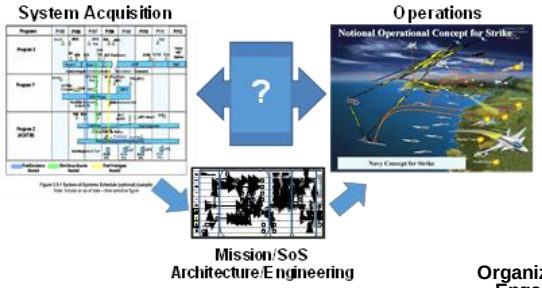
An Opportunity

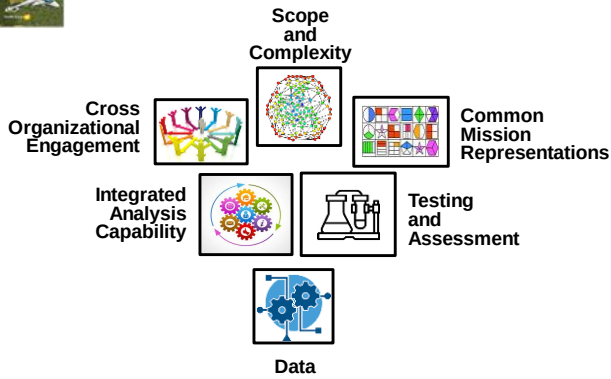
- The fifth DE goal is to transform the way we do engineering, taking advantage of the computational capability available to us today – recognizing this is a change for the culture and the workforce
- Notably, ME is also a change for the DoD – for the culture and workforce – with the shift from a program/ system focus to a focus on the 'mission' as the system, and applying systems engineering across the mission and the systems-of-systems supporting the mission outcome
- Since change is not linear – this may be the ideal time – as we address ME in earnest across the DoD – to use this opportunity to embrace DE as a means to address the ME challenges

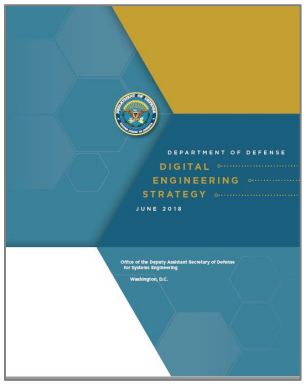


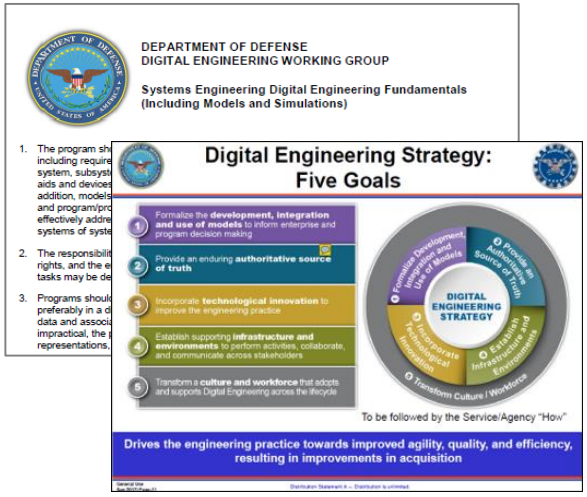
In Sum.....

- The DoD DE strategy and its driving fundamentals, when considered at the mission-level, provides a set of enablers to address some of the key challenges facing ME in the DoD today
- DE does not, in and of itself, address these challenges, but by providing an approach to shared, curated models and data supported by an collaborative infrastructure, it offers a viable, extensible set of tools and methodologies to address these ME challenges with an innovative and cross organizational approach which leverages today's computational technologies









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Digital Engineering website:

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