Digital Engineering

- Lunch n Learn: 23 MAY 2018
- Session will start at 1230 EDT (1130 CDT).
- Audio will be through DCS – there will be a sound check 30 minutes prior to the session. Everyone but the presenter is muted.
- Audio will also available via Dial-In starting at approximately Noon EDT
  - Call (712) 770-4700, Access Code: 329063#
- Download the Presentation:
  - Click on the Bold Arrow pointing downward just below the lower left hand corner of the presentation
- Questions are welcome during the session, please type them into the DCS Chat Window

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Digital Engineering

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Director, Engineering Enterprise

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May 2018
Topics

• Need for an Evolution in Engineering Practice
• Digital Engineering
• Digital Engineering in Use
• Digital Engineering Strategy
• Developing Artifacts for Digital Engineering
• Summary
Evolve the Practice
National Defense Strategy Anchor

“To keep pace with our times, the Department will transition to a culture of performance and affordability that operates at the speed of relevance. Success does not go to the country that develops a new technology first, but rather, to the one that better integrates it and more swiftly adapts its way of fighting. Our current bureaucratic processes are insufficiently responsive to the Department's needs for new equipment. We will prioritize speed of delivery, continuous adaptation, and frequent modular upgrades.”

— Gen Mattis, SECDEF
Continuation…

We will expand the competitive space while pursuing three distinct lines of effort:

• First, rebuilding military readiness as we build a more lethal Joint Force;

• Second, strengthening alliances as we attract new partners; and

• Third, reforming the Department’s business practices for greater performance and affordability.

— Gen Mattis, SECDEF
Systems Are Changing

**From:**
- Systems built to last
- Heuristic-based decisions
- Deeply integrated architectures
- Hierarchical development organizations
- Satisfying requirements
- Automated systems
- Static certification
- Standalone systems

**To:**
- Systems built to evolve
- Data-driven decisions
- Layered, modular architectures
- Ecosystems of partners, agile teams of teams
- Constant experimentation and innovation
- Learning systems
- Dynamic, continuous certification
- Composable sets of mission focused systems

**Systems Engineering Needs to Change**

Credit: Derived from David Long, Former INCOSE President
Today’s military operations are dynamic, crossing multiple threats and mission areas. We must modernize our defense systems, prioritizing speed of delivery through continuous adaptation and frequent modular upgrades. To meet these goals, DoD engineering and acquisition practice must transform, and one way in which we will do this is by incorporating use of digital computing and analytics capabilities. Digital engineering will enable rapid iteration and response in developing, delivering, and sustaining U.S. defense systems. Our military departments are already adopting digital engineering tools and practices, and demonstrating feasibility and benefits. We are committed to working with our partners in the Services, as well as our allies, industrial base, federal agency and academic partners to institutionalize the digital engineering vision and practices across the broad engineering community.

Ms. Kristen Baldwin, Acting Deputy Assistant Secretary of Defense, R&E/Systems Engineering
INCOSE and NDIA

SE Vision 2025: Systems Engineering practices will continue to evolve from current practice to meet the demands of complex systems and work environments of the 21st century. Leveraging information technology and establishing the theoretical foundations for value driven systems engineering practices will pave the way for meeting those demands to enhance competitiveness, manage complexity, and satisfy continuously evolving stakeholder needs.

Systems Engineering Division: The division’s goals include:
- Effecting good technical and business practices within the aerospace and defense industry.
- Improving delivered system performance, including supportability, sustainability, and affordability.
- Emphasizing excellence in systems engineering throughout the program lifecycle and across all engineering disciplines and support functions.
Industrial Revolutions

1st Industrial Revolution
MECHANICAL
Use of mechanical production powered by water and steam

2nd Industrial Revolution
ELECTRICAL
Use of mass production powered by electrical energy

3rd Industrial Revolution
INFORMATION TECHNOLOGY
Use of electronics and IT to further automation

4th Industrial Revolution
DIGITAL
Use of a digitally connected end-to-end enterprise

Traditional Models and Simulations (M&S)
Simulation Based Acquisition (SBA)

Model-Based Systems Engineering (MBSE)

TODAY
Digital Engineering (DE)
Industrial Age Acquisition and Engineering Processes

- **Taylor’s scientific management**
  - Empirical methods to synthesize workflows to improve economic efficiency
  - Inspires industrial and systems engineering, business process management, lean six sigma, and operations research

- **Optimizing engineering & production** drives the need for stable requirements and well-defined processes

- **Optimizing methods to change** engineering & production requires increasing the cycles of learning:
  - Identify necessary changes
  - Incorporate those changes into systems
Digital Business Gains Executive Mindshare!

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<td>Property and facilities</td>
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<td>50%</td>
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“Compared to fiscal year 2016, how will your organization’s investments in the following business areas change in fiscal year 2017?”

n = 387 CEOs and senior business executives; total answering

© 2017 Gartner, Inc.
“In a business context, the term ‘digital’ does not have an agreed upon definition. In your own words, what do you mean when you think about ‘digital business’ in the context of your business and industry?” (Open-style responses)

2017 Gartner CEO and Senior Business Executive Survey
Large companies, worldwide, 4Q 2016, n = 388
5% “Not applicable” responses

Industry Disruptions Shape the Future of Model-based Systems Engineering, Marc Halpern, Gartner
The Digital Business Transformation Challenge

Digital Business Progress

- Harvesting/Refining: 2%
- Scaling: 12%
- Delivering: 28%
- Designing: 35%
- Desire/Ambition: 15%
- Do not have digital: 8%

Barriers to Progress

- Culture: 44%
- Resources: 18%
- Talent: 19%
- Other 7%
  - CEO Commitment: 6%
  - Board Commitment: 4%
  - IT Organization: 0.4%

Industry Disruptions Shape the Future of Model-based Systems Engineering, Marc Halpern, Gartner
Digital Business Demands Systems and Systems-of-systems Thinking to Design Products

Industry Disruptions Shape the Future of Model-based Systems Engineering, Marc Halpern, Gartner
Digital Engineering Overview

• **Background**
  – Dynamic operational and threat environments
  – Growth in system complexity and risks
  – Linear acquisition process that lacks agility
  – Cost overruns and delayed delivery of capabilities to the warfighter
  – Current practices cannot keep pace with innovation and technology advancements

• **Need**
  – Outpace rapidly changing threats and technological advancements
  – Deliver advanced capabilities more quickly and affordably with improved sustainability to the warfighter
  – Foster a culture of innovation

**Digital Engineering** transforms the way the DoD innovates and operates.

**Digital Engineering: An integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines to support lifecycle activities from concept through disposal.**
Digital Engineering: MBSE approach for DoD

Current State
- Our workforce uses stove-piped data sources and models in isolation to support various activities throughout the lifecycle
- Current practice relies on standalone (discipline-specific) models
- Communication is through static disconnected documents and subject to interpretation

Future State
- Digital Engineering moves the engineering discipline towards an integrated model-based approach
  - Through the use of digital environments, processes, methods, tools, and digital artifacts
  - To support planning, requirements, design, analysis, verification, validation, operation, and/or sustainment of a system
- Digital Engineering ecosystem links our data sources and models across the lifecycle
  - Provides the authoritative source of truth

Current: Stove-piped models and data sources  Future: Digital Engineering Ecosystem
Recognizing Digital Engineering

- A model is a representation of reality
- If you constrain the model building blocks to Data, Algorithms, and/or Processes; **AND**
- If you accept that Digital Engineering uses computers to perform as much of the lifecycle activities as practical **THEN:**
  - Digital Engineering uses computers to develop, warehouse, evolve, curate, and execute our models (SEE ABOVE) in support of system lifecycle activities, to include activities supporting ESOH concerns and decisions
    - Provides for cohesion, concordance, and continuum of information usable by all stakeholders in the system, regardless of the system form

Minimizing the risk caused by unnecessary human intervention
Infusion in Policy & Guidance

http://www.acq.osd.mil/se/pg/guidance.html

DoDI 5000.02, Enclosure 3, Section 9: Modeling and Simulation

Defense Acquisition Guidebook, Chapter 3

DoD Digital Engineering Fundamentals

Defense Acquisition University

ODASD(SE) Initiatives

DoD Digital Engineering Working Group

Digital Engineering Strategy

Digital System Model (DSM) Taxonomy: Defining categories of data across acquisition

Engineered Resilient Systems: Adapting to changing requirements

High Performance Computing Modernization Program (HPCMP)
Computational Research and Engineering Acquisition Tools and Environments (CREATE): Physics Based Modeling

Partnerships

Armed Services

DoD Components

Interagency

Industry/OEMs/Industrial Orgs

Academic

Advancing the state of practice for Digital Engineering

NASA – National Aeronautics and Space Administration
NNSA – National Nuclear Security Administration
NDIA – National Defense Industrial Association
INCOSE – International Council on Systems Engineering
AIA – Aerospace Industries Association
AIAA – American Institute of Aeronautics and Astronautics
OEMs – Original Equipment Manufacturers
• Lesson 0 Module Introduction
• Lesson 1 Digital Engineering Concepts
• Lesson 2 Preparing for a Digital Engineering Ecosystem
• Lesson 3 Acquisition Considerations
• Lesson 4 Community Acceptance and Understanding Risks
• Lesson 5 Examples of Using Digital Artifacts
• Lesson 6 Summary
DSM Data Taxonomy Overview

• **Purpose**
  
  – Provides a model to aid programs in defining an authoritative source of truth
  
  – Builds an integrated taxonomy providing stakeholders an organized structure for the types of technical data to be considered across the lifecycle
  
  – Establishes a Common Vocabulary that can be used by all programs

Use as a basis to drive the community towards Digital Engineering across disciplines, systems, and enterprises to support lifecycle activities from concept to disposal.
Digital Engineering Relationships

Digital Engineering Strategy

User selected and integrated based on desired outcome

Traditional Mod/Sim Solutions

Physics-based & Engineering Design Tools

Large Tradespace Analytics & Virtual

World-class High Performance Computing (HPC)

Infrastructure that scales to complex conditions

Other Initiatives

(DoD) Modeling and Simulation Coordination Office (DMSCO)

Computational Research and Engineering Acquisition Tools and Environments (CREATE)

Computational Environment for Digital Engineering Activities

DAU Lunch n Learn
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DISTRIBUTION STATEMENT A: UNLIMITED DISTRIBUTION.
HPCMP High-Level Operational Concept

A technology-led, innovation-focused program committed to extending HPC to address the DoD’s most significant challenges.
Digital Engineering

- Digital Engineering vision moves the engineering discipline towards an integrated model-based approach through the use of digital environments, processes, methods, tools, and digital artifacts
- Model is a representation of reality
  - Model is ‘composed of’ data, algorithms, and/or processes
  - Computable or used in a computation

CREATE

- CREATE program develops and deploys validated physics-based High Performance Computing (HPC) applications to enable DoD engineers to implement and execute the digital engineering paradigm for major DoD platforms (naval, air and ground vehicles, and RF antennas)
- Includes ability to construct and improve digital product models for weapon platforms
  - Tools address all stages of the acquisition process
CREATE is a multi-phase program that began in 2008, to develop and deploy four (now five) computational engineering tool sets for acquisition engineers:

- **Aircraft (AV) Design Tools**: Fixed-wing aircraft, rotorcraft, conceptual design, trade-space exploration and operational testing and transition

- **Ship Design Tools**: Shock/damage, hydrodynamics, early-stage design & trade-space exploration, and operational testing and transition

- **Radio Frequency (RF) Antenna Design and Integration Tools**: Conceptual design and detailed analysis tools relevant to virtually all DOD platforms

- **Ground Vehicles (GV) Tools**: End-to-end mobility solver, provide rapid, physics-based data for design and trade-space analysis

- **Meshing and Geometry (MG) Support**: The geometry and meshing project improves the ease, speed, flexibility, and quality of geometry and mesh generation, and enables the generation of CAD-neutral digital representations and product models of weapons systems & platforms and operational terrains and environments
**ERS Products in Digital Engineering Context**

**Digital Engineering**

- Digital Engineering vision moves the engineering discipline towards an integrated model-based approach through the use of digital environments, processes, methods, tools, and digital artifacts

- Model is a representation of reality
  - Model is ‘composed of’ data, algorithms and/or processes
  - Computable or used in a computation

**ERS**

- Engineered Resilient Systems (ERS) combines advanced engineering techniques with high-performance computing to develop concepts and tools that significantly amplify design options examined

- Develop/Integrate advanced engineering tools for efficient, integrated design, and development across the full range of the product lifecycle
ERS Vision

Provide an Integrated, Trusted, Computational Environment Supporting; Design, Engineering, Acquisition, and Operation

Examples:
- Virtual Proving Grounds and Computational Testbeds
- Workflow technologies that support digital engineering
- High-fidelity modeling and simulation to support Acquisition

Design/Model

Trade/Decide

Analyze
DRAFT Vision for ERS, CREATE, et al (crossing the Valley of Death)

Current Domains: Air (Fixed & Rotary), Surface, Subsurface, Ground, RF, Meshing, Geometry
Future Domains: Space, Hypersonics, Improved Turbine Engine, EW, Directed Energy, Others?

MDD
- JCIDS – ICD, CDD, CPD
- AoA – Guidance/Plan

Current ERS Uses
- Materiel Solution Analysis
- Technology Maturation & Risk Reduction
- Engineering & Manufacturing Development

Future ERS Uses
- Production and Deployment
- Operations and Support

Current CREATE Uses
- Proof of Principle Prototypes
- Pre-EMD Prototypes

Future CREATE Uses
- EC&P use of ERS, CREATE and other tools and environments
- Fieldable Prototypes

Current = [ ] Future = [ ] [ ] [ ]

Other
- Force Effectiveness/Mission models
- System CONOPS

Future ERS Use: Industry
- Force Eff / Msn Models
- Engineering Models
- System CONOPS
- Digital System Model / Digital Thread
- Digital Twin
- CAD / CAM / Add Mfg
Digital Engineering in Use
• An integrated business and technical strategy that:
  – (A) Employs a modular design that uses major system interfaces between a major system platform and a major system component, between major system components, or between major system platforms;
  – (B) Is subjected to verification to ensure major system interfaces comply with, if available, and suitable, widely supported and consensus-based standards;
  – (C) Uses a system architecture that allows severable major system components at the appropriate level to be incrementally added, removed, or replaced throughout the life cycle of a major system platform to afford opportunities for enhanced competition and innovation while yielding-
    o (i) Significant cost savings or avoidance; (ii) schedule reduction; (iii) opportunities for technical upgrades; (iv) increased interoperability, including system of systems interoperability and mission integration; or (v) other benefits during the sustainment phase of a major system;
  – (D) complies with the technical data rights set forth in Sec 2320, title 10.
Design Choices

- **Begin with the End in Mind**
  - There is no single, magic bullet for implementing MOSA
    - There are multiple pathways for MOSA
  - Determine expected outcomes up front

Implementing MOSA is about trades
MOSA Considerations At Each Stage

Pre-MDD: What are the drivers for this system and how can MOSA support these? Are these addressed in AoA guidance?

MSA: Does the preferred solution provide opportunity to employ MOSA to achieve system objectives?

TMRR: Are the factors to achieve desired MOSA benefits included in acquisition strategy, SE Plan, and T&E strategy, lifecycle support strategy, RFP and preliminary design?

EMDD: Does the detailed design and developmental test incorporate MOSA considerations, to assure design and development will achieve expected benefits?

P&D: Does the plan include continued review, testing and evaluation to ensure the product baseline modularity and openness?

O&S: How is support of the system structured to take advantage of the MOSA characteristics expected to benefit the systems?

Planning for P&D and O&S needs to be done early
Relationships

Considerations in Design

- SoS
  - System I/F
  - Subsystem I/F
- MOSA
  - Subcomponents

DSM provides Rigor in Digital Expression for Use

Evaluation of Design Options

Needed fields can be added for capture

Updates to concepts can be captured
Acquisition of Data Rights and Intellectual Property (IP) (Sec 809)

• **Acquiring Data Rights and IP**
  – Program Acquisition Strategy assists programs to appropriately promote competition
    o Acquisition programs should create and sustain a competitive environment from program inception through sustainment
    o Strategies should consider:
      ▪ Competitive prototyping, dual sourcing, an open systems architecture that enables competition for upgrades, acquisition of complete technical data packages, and competition at the subsystem level

• **IP considerations**
  – The Strategy for managing IP across programs enables competitive and affordable acquisition & sustainment
    o PMs should identify and manage the full spectrum of IP and related issues from program inception and throughout the lifecycle
      ▪ Assess program technical data needs
      ▪ Enable the development of competitive acquisition of deliverables of IP & associated license rights
Mission Integration Management (MIM) Legislation

SEC. 855. MISSION INTEGRATION MANAGEMENT.

(a) IN GENERAL.—The Secretary of Defense shall establish mission integration management activities for each mission area specified in subsection (b).

(b) COVERED MISSION AREAS.—The mission areas specified in this subsection are mission areas that involve multiple Armed Forces and multiple programs and, at a minimum, include the following:

(1) Close air support.
(2) Air defense and offensive and defensive counter-air.
(3) Interdiction.
(4) Intelligence, surveillance, and reconnaissance.
(5) Any other overlapping mission area of significance, as jointly designated by the Deputy Secretary of Defense and the Vice Chairman of the Joint Chiefs of Staff for purposes of this subsection.

(c) QUALIFICATIONS.—Mission integration management activities shall be performed by qualified personnel from the acquisition and operational communities.

(d) RESPONSIBILITIES.—The mission integration management activities for a mission area under this section shall include—

1. development of technical infrastructure for engineering, analysis, and test, including data, modeling, analytic tools, and simulations;
2. the conduct of tests, demonstrations, exercises, and focused experiments for compelling challenges and opportunities;
3. overseeing the implementation of section 2446c of title 10, United States Code;
4. sponsoring and overseeing research on and development of (including tests and demonstrations) automated tools for composing systems of systems on demand;
5. developing mission-based inputs for the requirements process, assessment of concepts, prototypes, design options, budgeting and resource allocation, and program and portfolio management; and
6. coordinating with commanders of the combatant commands on the development of concepts of operation and operational plans.

Four recommended mission areas with options for additional areas

Six ‘Responsibility’ areas

Mission Engineering (ME)

- 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 (SoS) 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 warfighting mission effects
## T&AM Focus Areas

<table>
<thead>
<tr>
<th>Verification &amp; Validation</th>
<th>Design Assurance</th>
<th>FPGA Assurance</th>
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</thead>
<tbody>
<tr>
<td>• Improves microelectronics test and verification methodologies in support of verifying the trust and assurance of parts</td>
<td>• Assured and immediate access to domestic production of advanced microelectronics and disruptive research and development investments to surpass the impending limitations of Moore’s Law on silicon microelectronics</td>
<td>• Demonstrate innovative design, manufacturing, imaging, tagging, control and assessment approaches for protecting DoD’s microelectronics supply chain and intellectual property</td>
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<tr>
<td><strong>Enhanced Manufacturing</strong></td>
<td><strong>Radiation Hardened Microelectronics</strong></td>
<td><strong>Outreach &amp; Standards</strong></td>
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</table>
| • Development of advanced node microelectronics fabrication and packaging capabilities at existing SOTP foundries with a focus on high-mix, low-volume alternatives | • Demonstrate innovative design, manufacturing, and assessment approaches for trusted, strategic radiation-hardened electronics in advanced technology nodes for next-generation strategic systems | • Develop standards and practices to foster commercial development of secure, trusted and assured parts.  
• Document and promulgate security-enhancing design practices across government, industry, and academia |
Establishing an Effective R&M Engineering Program

5000.02 Enclosure 3 SE R&M Requirements

Engineering Activities
- R&M allocations, block diagrams, and predictions
- Failure definitions and scoring criteria
- Failure Mode, Effects and Criticality Analysis (FMECA)
- Built-in Test (BIT) and maintainability demonstrations
- Reliability Growth testing at system/subsystem level
- Failure Reporting, Analysis, and Corrective Action System

Preliminary RAM-C Report in support of Milestone (MS) A and updated for RFP Release Decision Point, MS B, & MS C
- Provides an audit trail that documents and supports JCIDS thresholds
- Ensures correct balance between the sustainment metrics (Availability-KPP, Materiel Reliability-KSA, and O&S Cost-KSA)
- Provides early risk reduction by ensuring sustainment thresholds are realistic (feasible) and correct (valid)

Reliability Growth Strategy
- Documents system-level reliability growth curves in the SEP beginning at MS A and updated in the Test & Evaluation Master Plan (TEMP) beginning at MS B
- Establishes intermediate goals for reliability growth curves that will be tracked through fully integrated system-level T&E events until the threshold is achieved
- Requires MS C PMs and Operational Test Agencies to assess reliability growth required to achieve the reliability threshold during IOT&E

Tracking and Monitoring
- Requires PMs to report status of reliability objectives and/or thresholds as part of the formal system engineering review process
- Incorporates Reliability Growth Curves into the DAES review process

Table 1. R&M Engineering Activities by Functional Area

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<tr>
<th>Functional Area</th>
<th>R&amp;M Engineering Activities</th>
<th>Milestone A</th>
<th>Milestone B</th>
<th>Milestone C</th>
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System Performance Specification

Program Execution and R&M Engineering BoK
Key Protection Activities to Improve Cyber Resiliency

**Program Protection & Cybersecurity**

**Technology**

*What:* A capability element that contributes to the warfighters’ technical advantage (Critical Program Information (CPI))

*Key Protection Activity:*
- Anti-Tamper
- Defense Exportability Features
- CPI Protection List
- Acquisition Security Database

*Goal:* Prevent the compromise and loss of CPI

**Components**

*What:* Mission-critical functions and components

*Key Protection Activity:*
- Software Assurance
- Hardware Assurance/Trusted Foundry
- Supply Chain Risk Management
- Anti-counterfeits
- Joint Federated Assurance Center (JFAC)

*Goal:* Protect key mission components from malicious activity

**Information**

*What:* Information about the program, system, designs, processes, capabilities and end-items

*Key Protection Activity:*
- Classification
- Export Controls
- Information Security
- Joint Acquisition Protection & Exploitation Cell (JAPEC)

*Goal:* Ensure key system and program data is protected from adversary collection

**Protecting Warfighting Capability Throughout the Lifecycle**

Policies, guidance, and white papers are found at our initiatives site: https://www.acq.osd.mil/se/initiatives/init_pp-sse.html
Digital Engineering Strategy: Five Goals

1. Formalize the development, integration and use of models to inform enterprise and program decision making
2. Provide an enduring authoritative source of truth
3. Incorporate technological innovation to improve the engineering practice
4. Establish supporting infrastructure and environments to perform activities, collaborate, and communicate across stakeholders
5. Transform a culture and workforce that adopts and supports Digital Engineering across the lifecycle

Drives the engineering practice towards improved agility, quality, and efficiency, which results in improvements in acquisition
Goal #1: Formalize Development, Integration & Use of Models

Models as the cohesive element across a system’s lifecycle
Goal #2: Provide an Authoritative Source of Truth

Right information, right people, right uses, right time
Goal #3: Incorporate Technological Innovation

Harness technology, new approaches, and human-machine collaboration to enable an end-to-end digital enterprise.
Goal #4: Establish Infrastructure & Environments

Foundational support for Digital Engineering environments
Goals #5: Transform Culture and Workforce

Institutionalize Digital Engineering across the acquisition enterprise
# Strategy in Action Example

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<tr>
<th>Warfighting Benefits</th>
<th>How</th>
<th>Examples</th>
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<td>More Effective &amp; Lethal Weapon Systems</td>
<td>Ability to manufacture complex shapes and otherwise impossible designs/components</td>
<td>Consolidated assemblies</td>
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<td>Embedded sensors</td>
</tr>
<tr>
<td>Tailored Solutions for the Mission and Warfighter</td>
<td>Ability for mission tailorability and mass customization at almost no additional cost</td>
<td>Armor</td>
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<td>Munitions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nutrionally Tailored Foods</td>
</tr>
<tr>
<td>Agility of Production Line - New era of supply chain independence</td>
<td>Ability to produce only what is needed, where it is needed, when it is needed</td>
<td>Improved field fabrication</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“Good enough” &amp; “Conditionally Approved” parts</td>
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<td></td>
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<td>Environment-independent printers</td>
</tr>
<tr>
<td>Reduced Sustainment Costs and Increased Responsiveness</td>
<td>Ability to make obsolescence obsolete</td>
<td>Rapid reverse-engineering</td>
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<td>Anti-corrosive</td>
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<td>Anti-degradation materials</td>
</tr>
<tr>
<td>Accelerated Capability Development</td>
<td>Ability for INNOVATION; novel designs, rapid development, faster transitions</td>
<td>Urgent needs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rapid response</td>
</tr>
</tbody>
</table>

AM is any process by which digital 3D design data is used to build up a component in layers by depositing material.
Model: A Day in the Life

Customer Requirements
- Draft CDD

System Requirements

System Architectures
- Operating Scenarios
- System Behaviors
- Physical Arch
- Dynamic Simulations

Alt Prelim Design Concepts
- CAD
- Software

Trade-off Studies
1
2
3
N

Design Analyses
- Stress
- Thermal
- Vibration
- Perf
- Reliability
- Etc.

Selected Designs
- CAD
- Specs
- Drawings
- Software

Prototype Fabrication
- Mfg Instructions

Testing
- Test Plans
- Test Results

Final Designs
- CAD
- Specs
- Drawings
- Software

Mfg Info
- Process Plans
- Work Instr
- N/C Instr

Logistics Mgmt Info
- Tech Manuals
- Provisioning Data
- Trng Matrls

Baseline
(System Spec)

Baseline
(Allocated Specs)

Baseline
(Preliminary Product Baseline)

Baseline
(Product Baseline - TDP)

Technology Development

Engineering and Manufacturing Development

Production/Deployment

This is valuable Intellectual Property that must be captured and made available for reuse

This is valuable Intellectual Property that must be captured and made available for reuse
DSM Intended Use

**DSM Data Taxonomy**

- Defines the broad categories of data
- Provides the program’s DE ecosystem
- Identifies the data and data rights

**DE Ecosystem**

- Requirements
- Architecture
- Design
- Test
- Sustainment
- Configuration Management

**Component of the DE Infrastructure**

**Document Views**

- Provides multiple views to support decisions

**Data Views**

**Acquisition Views**

**Other Views**

DSM Data Taxonomy provides the broad categories of data that should be considered across the lifecycle.
Started with the 2017 INCOSE International Workshop’s (IW)

- The International Council on Systems Engineering’s (INCOSE) International Workshop (IW) 2017 highlighted the need to establish an accepted set of Digital Artifacts to help the Systems Engineering (SE) practice transform to a more model-based discipline

- Participants made requests to the INCOSE SE Transformation Team and the Model-Based Systems Engineering (MBSE) Initiative to start a more enduring “Digital Artifacts” effort

- INCOSE recommended standing up a Digital Artifacts Challenge Team at the INCOSE 2018 IW

- As a result of the INCOSE 2018 IW’s Digital Artifacts Challenge, INCOSE agreed to long standing Working Group to resolve the challenges raised

The Working Group is a result of the INCOSE IW 2018 Digital Artifacts Challenge
The 2018 INCOSE International Workshop’s (IW) Digital Artifacts Challenge

• **Purpose**
  – The participants expressed a need for a set of Digital Artifacts to transform to a model-based discipline

• **Objective**
  – To advance the understanding and acceptance of a finite set of Digital Artifacts that government and industry can use and institutionalize

• **Method**
  – **Day 1**: Reviewed ISO/IEC/IEEE 15288 processes and artifacts to refine definition and elicit concept of operations for Digital Artifacts
  – **Day 2**: Used a specific example to identify characteristics and define digital artifacts for System Requirements Review (SRR)
  – **Result**: Three Break-out groups came to 3 different conclusions

• **Planned Outputs:**
  – **Digital Artifacts Definition**: Clarify and approve the definition of “Digital Artifact”
  – **Digital Artifacts Detailed Descriptions**: Describe the top two (2) to five (5) Digital Artifacts for each Systems Engineering Process
Digital Artifacts Workshop Outcomes

• Observations
  – The “digital artifact” definition did not communicate a consistent interpretation with the INCOSE community
  – Transitioning from documents to Digital Artifacts requires more work to achieve desired objectives
  – Insufficient details behind the future Digital Engineering concept of operations

• Tasks

  Group 1  • Define characteristics and digital items

  Group 2  • Transform documents to digital viewpoints

  Group 3  • Base Digital Artifacts WG on standards organizations from other disciplines

Exhibit 1: This widely accepted operational view of MBSE lacks detailed plans and descriptions
The Digital Engineering Information Exchange Model DEIXWG Charter
(pronounced “dex-wig”)

• **Background**
  – 20 Mar: Met and agreed to co-chair an international working group on digital artifacts
  – 25 Apr: Met and agreed to the content in the charter and technical project plan (TPP)

• **Objective**
  – To adopt & codify prevailing knowledge regarding the exchange of digital engineering information
    o Inter-organizationally
    o Intra-organizationally
    o Between engineering tools

• **Membership**
  – INCOSE Chair: Troy Peterson
  – DoD Co-Chair: Phil Zimmerman
  – NDIA Co-Chairs: David Allsop & Chris Schreiber

• **Next Steps**
  – INCOSE to coordinate and approve Charter and Technical Project Plan
  – First Working Group Meeting at INCOSE International Symposium 2018
    o Announcement & general body feedback of Charter, Products, and Milestone schedule
    o Library of Congress' Digital Curation
    o SERC Model Curation
    o JPL on taxonomies and ontologies for development of lexicon
The Technical Products

• **Product Use**
  – Products will be free to the Federal Government
  – Government will tailor the products to address specific processes and needs

• **The Products**
  – **Standard Digital Engineering Lexicon**: An alphabetical arrangement of the words and their definitions as used in practices associated with digital engineering, digitalization processes, model-based engineering (MBE), virtual engineering, and other related practices.
  
  – **Digital Artifacts Constructs & Conventions**: The systematic procedures to produce digital content for classes of stakeholders by assembling defined digital artifacts.
  
  – **Digital Artifacts List (DAL)**: The finite sets of combined digital artifacts and their descriptions that entities can contractually request as it relates to reviews and audits in the ISO/IEC/IEEE 15288 systems engineering lifecycle standards.
  
  – **DEIXM Standards Framework**: DEIXM Standards Framework is a hierarchical outline of interlinked, published, or proposed standards & conventions that enable a universal exchange of digital artifacts between buyers and suppliers in global supply chains.
Digital Engineering Way Forward

**SE EXCOM** (Pentagon)

**DEWG** (Mark Center)

**DE Workshop** (Mark Center)

**DE Summit** (NDIA SE Conf)

**Vendor Challenge** (NDIA SE Conf)

**DEIXWG** (INCOSE IS)

### Agenda:
- Services brief on current implementation initiatives
- INCOSE/NRO?
- DASD(SE) brief

**Audience:** Flag-level*

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**DE Workshop** (Mark Center)

### Agenda:
- Services brief on current implementation initiatives
- NASA briefs on metrics
- DASD(SE) briefs on metrics framework

**Audience:** AO level*

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**DE Summit** (NDIA SE Conf)

### Agenda:
- DASD(SE), INCOSE, and NDIA will kick-off the Digital Engineering Information Exchange Working Group (DEIXWG)

**Audience:** INCOSE

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**Vendor Challenge** (NDIA SE Conf)

### Agenda:
- Services demo and brief on implementation initiatives
- DASD(SE) brief

**Audience:** NDIA*

---

**SE EXCOM** (Pentagon)

### Agenda:
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**Audience:** NDIA*

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*Components, Interagency, Industrial Organizations, and Academic Partners*
Expectations & Big Rocks

**Digital Engineering Expectations**

- Informed decision making/greater insight through increased transparency
- Enhanced communication
- Increased understanding for greater flexibility/adaptability in design
- Increased confidence that the capability will perform as expected
- Increased efficiency in engineering and acquisition practices

from Inter-Agency Working Group: Model-Based System Engineering (MBSE) Infusion Task Team, "Digital Model-based Engineering: Expectations, Prerequisites, and Challenges of Infusion," 2017

**Digital Engineering Big Rocks**

- Investment
- Culture and workforce
- Policy, guidance, contracting
- Governance
- Security
- Intellectual property protection
- Tool/model portability
- Infrastructure and environments
- Model quality and assurance

synthesized from Digital Engineering Working Group; National Defense Industrial Association Model-Based Engineering Report, Aerospace Industries Association Model-based Engineering reports

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Coordinating with the Services/Agencies to implement Digital Engineering strategy elements and develop mitigation for remaining challenges
Summary

- Business processes and behaviors (culture) need to be changed to realize the benefits of Digital Engineering implementation.
- Multiple activities in government, industry, academia, and professional organizations are being leveraged to advance digital engineering concepts within DoD enterprise.
- Expected benefits of implementing digital engineering practice outweigh the monetary, time, and training needed up front.
- Basic elements of Digital Engineering are in place; we need to weave them together and instantiate with policy, guidance, and training.
Systems Engineering: Critical to Defense Acquisition

Defense Innovation Marketplace
http://www.defenseinnovationmarketplace.mil

DASD, Systems Engineering
http://www.acq.osd.mil/se
Systems Engineering

Purpose

Systems Engineering focuses on engineering excellence – the creative application of scientific principles:

- To design, develop, construct and operate complex systems
- To forecast their behavior under specific operating conditions
- To deliver their intended function while addressing economic efficiency, environmental stewardship and safety of life and property

DASD(SE) Mission: Develop and grow the Systems Engineering capability of the Department of Defense – through engineering policy, continuous engagement with component Systems Engineering organizations, and through substantive technical engagement throughout the acquisition life cycle with major and selected acquisition programs.

A Robust Systems Engineering Capability Across the Department Requires Attention to Policy, People, and Practice
Additional Resources

- Defense Acquisition Guidebook Chapter 3-2.4.2 Modeling and Simulation
- CLE 023 Modeling and Simulation in Test and Evaluation
- CLE 084 Models, Simulation, and Digital Engineering
- DASD(SE) Digital Engineering Initiative page (contains an overview video of Digital Engineering)
- Systems Engineering Digital Engineering Fundamentals
- DoD Modeling and Simulation Coordination Office
- DoD Verification, Validation, and Accreditation (VV&A) Recommended Practices Guide, 2011
- MIL-STD-3022 Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulations, 5 April 2012 w/Change 1