Digital Engineering Primer: Practical Considerations for Implementation across the System Lifecycle

Darryl Howell

Abstract

The adoption of digital engineering processes is being accelerated by the increasing use of digital technologies, the growing demand for software-based solutions to address complex business problems, and the proliferation of internet-connected devices, platforms, and systems. The pace of development in Digital Engineering has led to an explosion of ideas and new practices in how it can support Engineering requirements, architectures, design, manufacturing, deployment, and sustainment. The rapid pace of the adoption of digital engineering has also led to a lack of agreement and understanding of purpose, outcomes, activities, and terms. This presentation will provide a discussion of key digital engineering definitions, considerations, and activities across the systems lifecycle to engineering practitioners.

Presenter Biography

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- Darryl Howell is the Chief Operating Officer at PCG. Mr. Howell is a high-energy, visionary leader with over 30 years of demonstrated achievement in systems engineering and technology development. Darryl is also a Principal Systems Engineer supporting the Office of Assistant Secretary of Defense for Research & Engineering/ Systems Engineering & Architecture as the lead contractor support for the Digital Engineering Modeling and Simulation Community of Practice. Retired US Navy CAPT with 30 years of experience as a Surface Warfare Officer.

Outline

- Purpose and Objectives
- Scope
- DE Exemplar
- Digital Engineering Defined
- System Lifecycle Stages and Processes
- DE Stakeholders
- Digital Engineering Considerations Across the System Lifecycle
- Special Topics of Interest
  - Digital Artifacts
  - Data Management and Integration
  - Digital Twin Technology
  - Measuring Digital Engineering Across Lifecycle
  - Change Management
- Timeline
- INCOSE – Journey to Digital Transformation

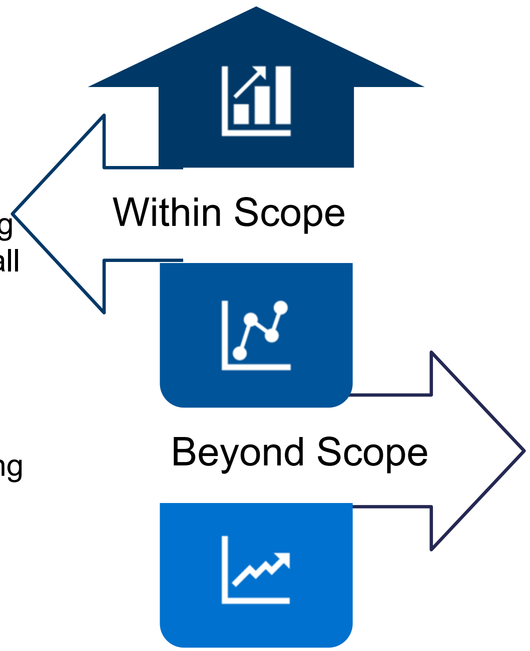
Digital Engineering Primer:
Practical Considerations for Implementation across the System Lifecycle

Purpose and Objectives

- Provide an update on "What" DE is and "Considerations" on how to apply it across the system lifecycle
- Communicate DE definitions, considerations, and activities across the systems lifecycle to engineering practitioners
- Provide knowledge and expertise on digital engineering in support of other INCOSE working groups working in their systems engineering areas
- Respond to frequently asked questions from INCOSE leadership and stakeholders
- Provide a precursor to a new INCOSE-sponsored DE Guide, which is under development

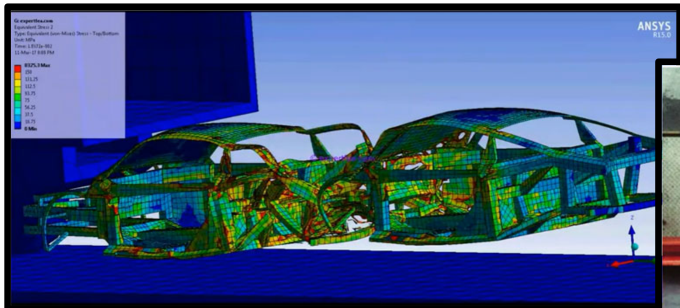
Project Scope

- ✓ Answers the question of how to apply ISO 15288 in a Digital Engineering Environment
- ✓ Addresses domain of Digital Engineering as it relates to Systems Eng applied to all levels and all types of systems.
- ✓ Focused on process models and best practices (methods and techniques) (3)
- ✓ Takes a holistic view of the system, along with its digital representation (4)
- ✓ Emphasizes use of digital engineering throughout the entire system lifecycle, evolving data as a system is developed.
- ✓ Provides general guidance. Answers the "what" and not the "how"



- ✗ Independent of the application domain (aerospace, manufacturing, medical, software development, etc.)
- ✗ Focuses on process and does not prescribe any specific views or diagrams
- ✗ Flexible. Does not require updates for new technologies or specify specialized topics (digital twin, IOT, etc.)
- ✗ Technology agnostic
- ✗ Tool agnostic

Digital Engineering Exemplar: Successes from the Automotive Industry



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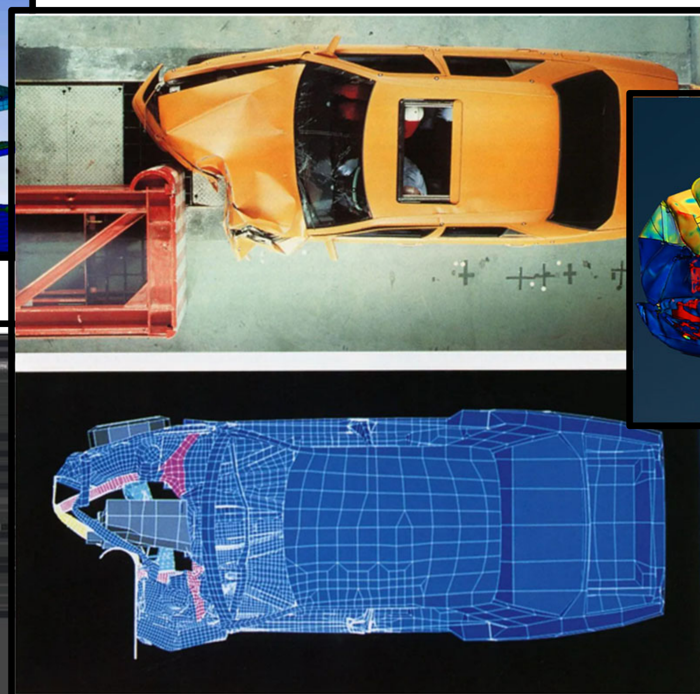
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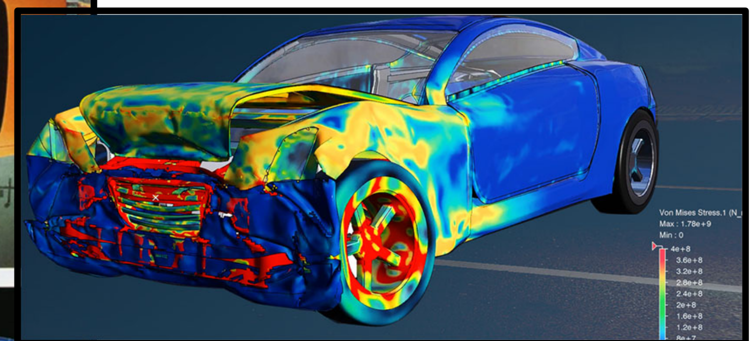
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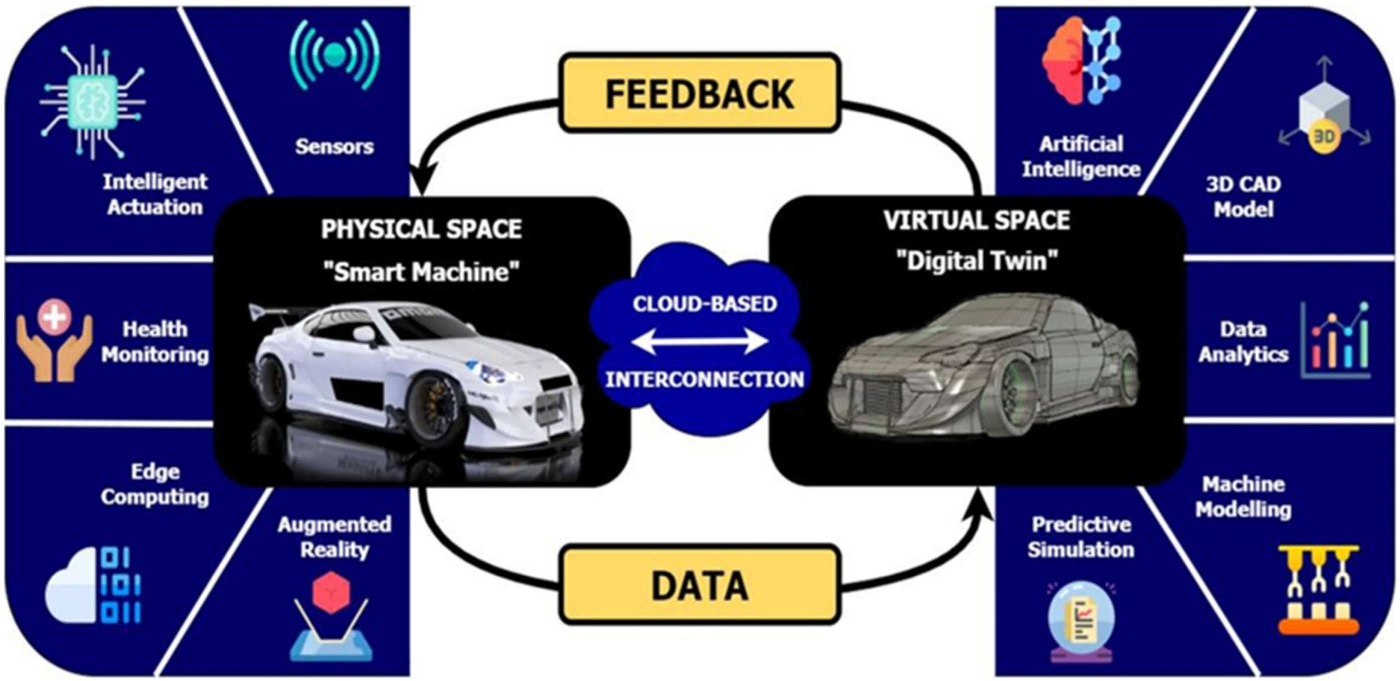
Source: BMW, NVIDIA

Digital Engineering Exemplar: Automotive Industry



What Are the Practical Considerations Across the System Lifecycle To Realize The Vision of Digital Engineering?

NDIA National Defense Industrial Association | INCOSE International Council on Systems Engineering | Department of Defense, United States of America

Digital Engineering Strategy: What, not How

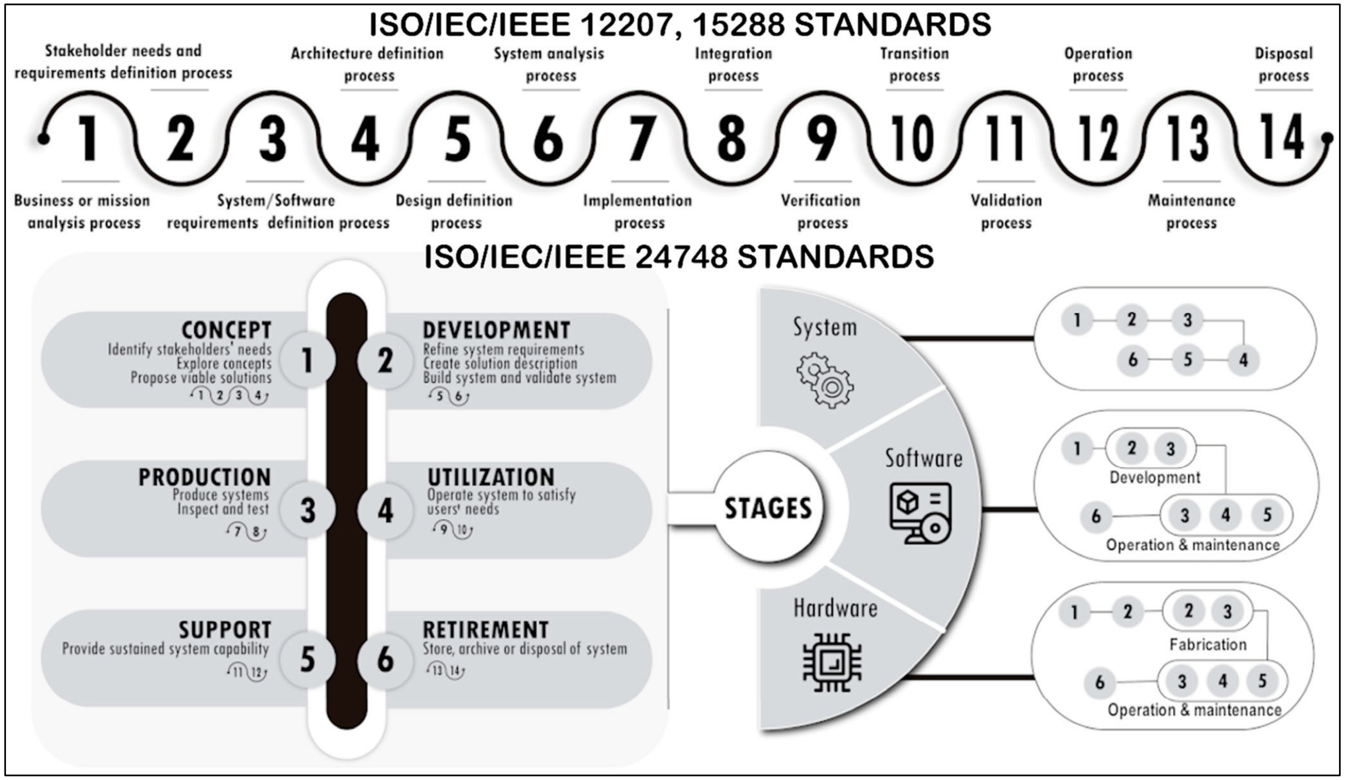
1. Formalize the **development, integration and use of models** to inform enterprise and program decision making
2. Provide an enduring **authoritative source of truth**
3. Incorporate **technological innovation** to link digital models of the actual system with the physical system in the real world
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

Describes an integrated digital approach that uses authoritative sources of systems' data and models as a continuum across disciplines <u>to support life cycle activities</u> from concept through disposal

Layman's terms: combine standard representations of 'system', with computers, additional computational techniques as a <u>continuous, complete and evolving</u> ecosystem to provide data for data-informed decisions and interactive visualizations to a continuum of questions

National Defense Industrial Association

INCOSE International Council on Systems Engineering



What are the digital engineering considerations and activities across a systems lifecycle?

Key DE Stakeholders

The success of Digital Engineering relies on stakeholder buy-in regarding the development, implementation, and maintenance of digital systems and processes.

Concept Phase: Identify stakeholder needs, explore concept and propose viable solutions

DE Considerations (Excerpts from DE Workshop at INCOSE International Symposium)
Identify the goals for incorporating digital engineering.
Understand the current state of your engineering processes and tools
Develop a strategy and plan for integrating teams, tools and platforms, facilitating seamless information sharing and management of authoritative source of truth
Identify skill gaps in your team
Define the key performance indicators (KPIs) to monitor progress
Capture, visualize, and analyze system requirements and design using MBSE tools
Ensure that the tools chosen for concept development are interoperable or integrated, allowing for seamless transitions and data flows from one phase of the development process to the next
Establish a system for managing digital data, ensuring it's organized, traceable, and accessible
Consider how digital replicas of the system (digital twins) might be used throughout the lifecycle for predictive analysis, optimization, and real-world performance matching
Ensure the workforce is trained and updated on the latest DE techniques and technologies
Use digital tools and platforms to engage stakeholders continuously

Development Phase: Refine system requirements; Create solution description Build system; Verify and validate system

DE Considerations (Excerpts from DE Workshop at INCOSE International Symposium)
Define and establish DE methods and processes (ex. Data governance…..)
Leverage virtual prototyping and simulation tools to validate and refine system designs before physical implementation
Incorporate feedback from simulations, testing, and end-users to refine designs
Utilize modeling techniques to create a digital representation of the systems
Reduce physical prototyping costs and time by testing designs in a virtual environment
Perform various analyses (e.g., structural, thermal, fluid dynamics) to ensure design robustness
Use system models to capture and manage system requirements, design decisions, and other relevant information
Establish data architectures, storage, and retrieval methods that allow for efficient data usage and sharing
Incorporate agile methodologies for rapid prototyping, feedback, and iteration
Ensure the workforce is trained and updated on the latest DE techniques and technologies
Use digital tools and platforms to engage stakeholders continuously

Practical Digital Engineering Considerations across the System Lifecycle

Production Phase: Produce systems; Inspect and Test

DE Considerations (Excerpts from DE Workshop at INCOSE International Symposium)
Develop a digital replica of your physical assets (e.g., machinery, facilities)
Ensure product operational information is digital, constantly up-to-date, and contains dynamic, interactive 3D models, how-to videos, and other multimedia presentations
Ensure key project and product information managed to ensure data visible, accessible, understandable, linked, trustworthy, interoperable, and secured (VAULTIS)
Use digital twins to monitor the system in real-time, predict failures, and assist in maintenance planning
Use simulation tools to validate how components or the entire system will function
Use digital tools to offer traceability throughout the production phase

Utilization Phase: Operate system to satisfy users' needs

DE Considerations (Excerpts from DE Workshop at INCOSE International Symposium)
Integrate real-time data from IoT sensors to monitor and optimize performance
Utilize data analytics and machine learning techniques to predict and prevent system failures, optimizing maintenance schedules and minimizing downtime.
Regularly review the KPIs and adjust your strategy as needed
Inform product improvement
Use digital tools to offer traceability throughout the utilization phase
Use digital tools to continuously monitor system performance

Support Phase: Provide sustained system capability

DE Considerations (Excerpts from DE Workshop at INCOSE International Symposium)
Use digital twins to help monitor the health of systems, forecast failures, and improve system performance
Use DE tools to analyze big data in order to monitor system performance, user behavior, and potential areas of improvement
Continually update the system models to reflect the as-operated, as-maintained state is essential for keeping digital representations current
Leveraging machine learning and digital models to automatically diagnose issues which may reduce downtime and streamline maintenance

Retirement Phase: Store, archive, or dispose of system

DE Considerations (Excerpts from DE Workshop at INCOSE International Symposium)
Develop detailed plan for how the system will be decommissioned
Ensure that all valuable and necessary data from the system is safely backed up and archived
Develop a strategy for migrating data securely and accurately to replacement system(s) as required
Ensure that knowledge about the system is documented and preserved

Practical Digital Engineering Considerations across the System Lifecycle

Data Management Considerations (1 of 2)

Data Integrity and Quality

- **Ensure data is accurate, consistent, and unaltered**
- **Deploy mechanisms for data validation and purification**

Interoperability and Standards

- **Adopt standardized data formats for seamless integration across diverse tools and platforms**
- **Embrace open standards to promote data compatibility**

Granularity and Scalability

- **Design data management strategies that fulfill specific requirements and can be scaled efficiently**

Data Access and Control

- **Introduce role-based access protocols and preserve a comprehensive audit log**

Data Management Considerations (2 of 2)

Data Security

- **Ensure data encryption both while stored (at rest) and during transfers (in motion)**
- **Adopt robust cybersecurity measures aligned with requisite standards**

Data Lifecycle Management

- **Oversee data throughout its lifecycle from creation to obsolescence**
- **Define and execute strategies for archiving old data**

Version Control

- **Uphold rigorous version tracking and control mechanisms**

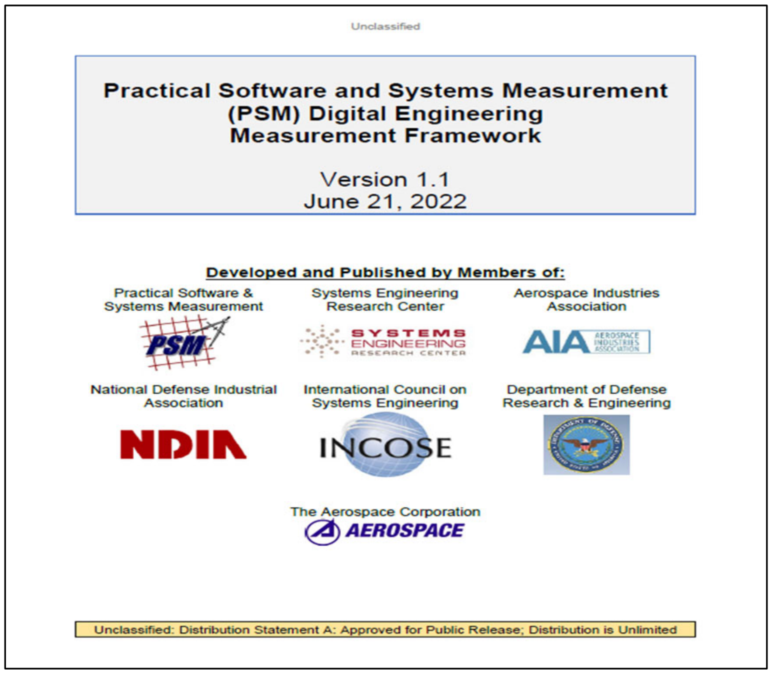
Metadata Management

- **Archive pertinent descriptive information (metadata) about the data, enhancing context**

Collaboration and Sharing

- **Initiate collaborative practices and methodologies while safeguarding data privacy and integrity**

Measuring DE across the Lifecycle



Unclassified

Practical Software and Systems Measurement (PSM) Digital Engineering Measurement Framework

Version 1.1
June 21, 2022

Developed and Published by Members of:

Practical Software & Systems Measurement
Systems Engineering Research Center
Aerospace Industries Association
National Defense Industrial Association
International Council on Systems Engineering
Department of Defense Research & Engineering
The Aerospace Corporation

Unclassified: Distribution Statement A: Approved for Public Release; Distribution is Unlimited

Takeaways

- Consensus measurement framework to 1) help enterprises transition from traditional document and artifact-based development to a digital model-based future and 2) to better assess the measurable impacts and benefits they aspire to achieve.
- Provides a reference for projects and enterprises to establish an initial path toward a measurably effective transition and implementation of digital engineering processes, tools, methods, and measures

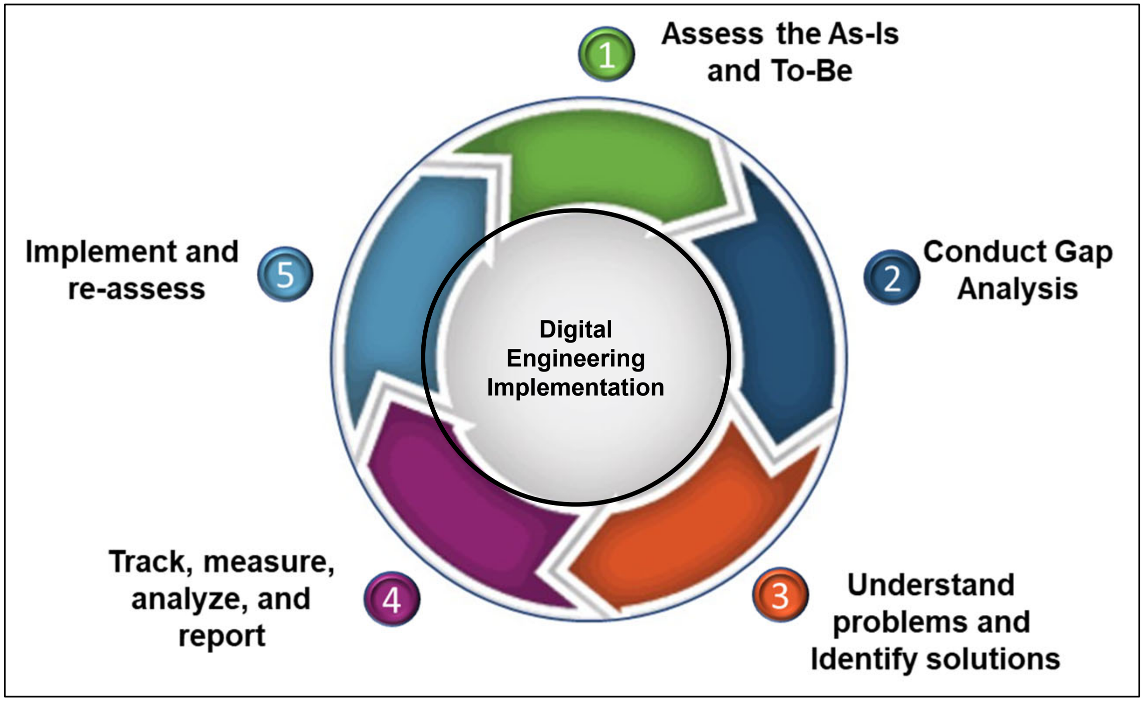
INCOSE DE Primer will provide considerations on how to measure DE across the lifecycle

Digital Twin

This white paper explores the development and implementation of Digital Twins and the identified need for tools, methods, and best practices to accelerate the understanding, adoption, and broader realization of Digital Twins.

INCOSE DE Primer will address how digital artifacts related to the digital twins

Change Management

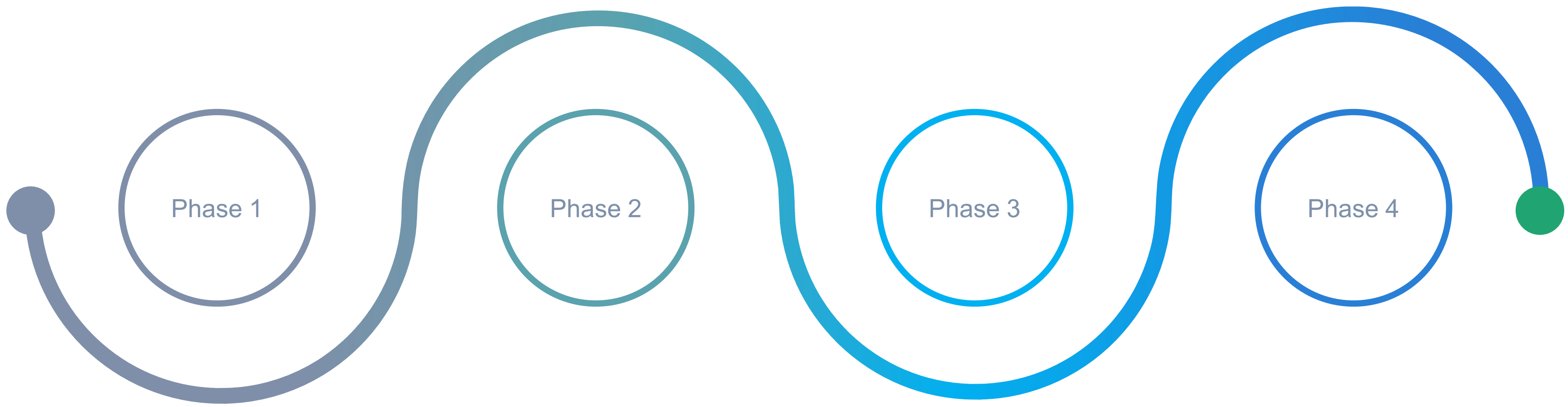


DE Change Management Steps

- Define the Vision
- Assess Readiness
- Develop a Strategy
- Build a Coalition
- Communicate and engage
- Provide Training and Support
- Implement in Phases
- Monitor and Evaluate
- Address Resistance and Barriers
- Sustain and Embed the Change
- Learn from your lessons and continuously improve

DE Primer will address change management for organizations and enterprises

INCOSE DE Primer Timeline



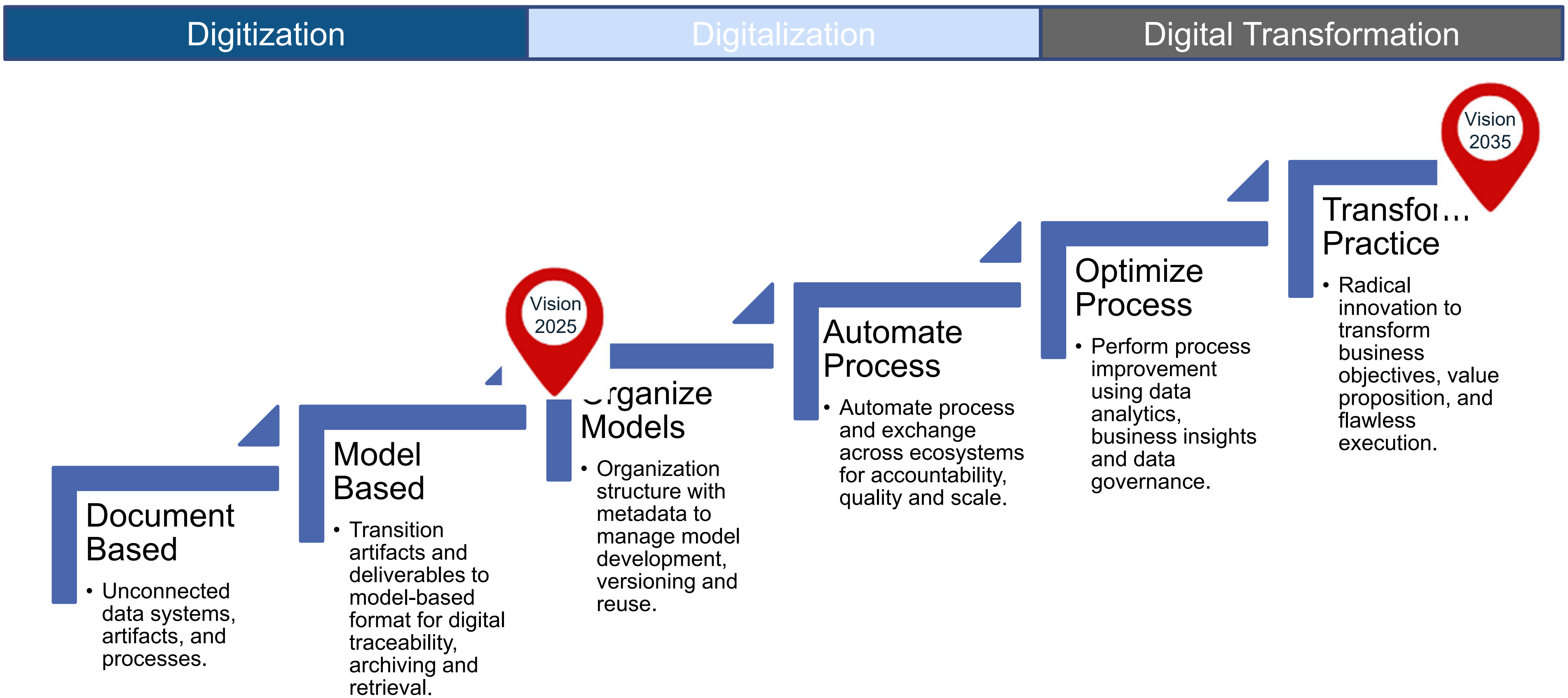
Scope (FEB – APR 23)
- Define objectives
- Identify key stakeholders and contributors
- Begin preliminary research

Research (MAR – AUG 23)
- Conduct interviews
- Obtain case studies
- Review references

Draft Guide (JUL – DEC 23)
- Conduct workshop
- Develop 1st draft
- Develop 2nd draft
- Develop 3rd draft

Review (JAN – MAR 24)
- Internal Review
- Incorporate changes
- External Review
- Incorporate changes
- Final review
- QA check

INCOSE: Journey to Digital Transformation



Summary

optimization
Speaking
empowerment
behavior
strategy
disruption
activity
agile
ecosystem
context
invention
stakeholders
connectivity
automation
industry
privacy
Digital
innovation
impact
context
Society 5.0
Transformation
forward
culture
business
experience
economic
technology
customer
marketing
supply chain
ecosystem
Success
challenge
partner
change
interdependency
improvment
Intelligent
everywhere
information

Backup

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What is the DEIXWG?

- Collaboration between the International Council of Systems Engineers (INCOSE), National Defense Industrial Association, and the Office of the Under Secretary of Defense for Research and Engineering (DoD OUSD(R&E))
- The DEIXWG supports the strategic objective of accelerating digital engineering transformation by characterizing the content and relationships involved in the exchange of digital artifacts between stakeholders of various disciplines throughout the engineering lifecycle

Use the authoritative source of truth to produce digital artifacts, support reviews, and inform decisions

As the technical baseline matures, preserving the knowledge across programs and lifecycle phases is essential. Technical reviews can be conducted from the authoritative source of truth on a continuous basis. Stakeholders will generate digital artifacts, representing multiple views and various perspectives from the authoritative source of truth. Digital artifacts provide visibility of appropriate information across functional domains, disciplines, and organizations.

--- DoD Digital Engineering Strategy, 2018