**ISO/IEC JTC1/SC7/AHG6 “Digital Engineering”**

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AHG Report – Digital Engineering

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**Description**

Report of the Ad Hoc Group on Digital Engineering Version 1.0, will be discussed during the June 2022 Plenary.

**Ad Hoc Group Report**

**Digital Engineering**

**June - 2022**

**Version 1.0**

**Background**

At the Chair presentation (SC7N8622) done at its May 2021 Virtual Plenary meeting, ISO/IEC JTC1/SC7 instructs its Secretariat to create an Ad Hoc Group for the investigation of Standards on Digital Engineering and to explore the possibility of additional standards or guidance in the area of software and systems engineering within SC7.

The terms of reference for this AHG are thus to:

* Provide an analysis of the requirements of the market and a status of current standardization activities, if any are available.
* If pertinent, make recommendations for the creation of new standards or TR or initiate a NWIP.
* Additional guidance for the AHG: The AHG is free to invite external parties to contribute to its work.

In accordance with this guidance, AHG 6 convened a meeting on 12 October 2021 with the International Council on Systems Engineering (INCOSE) Digital Engineering Information Exchange Working Group (DEIX WG) members to work on this report.

The AHG is chaired by Dr. Sundeep Oberoi (SC7 Chair).

Others who joined the AHG are:

* Cheryl Jones (Committee member)
* Anupam Agrawal (Committee member)
* Timothy M King (Committee member)
* Wanda Eyre (INCOSE liaison representative)
* Sean McGervey (INCOSE liaison representative)
* Celia Tseng (INCOSE liaison representative)
* Hélène Xu (Document monitor)
* Andrew Dryden (Technical programme manager)

Other expert contributors invited by INCOSE DEIX WG are:

* Frank Salvatore (INCOSE DEIX WG Co-chair)
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* Ken Zhang (INCOSE DEIX WG Technical Lead)
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* Ryan Noguchi
* Anthony Sill
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* John Stevens
* Amy Thompson
* Ashish Tiwari

Important Note

The contributing members of this study group have provided inputs from several cited sources and their own analyses. This report is intended to provide recommendations and guidance for future standardization efforts by the ISO/IEC JTC1/SC7 community.

Participation in development of this report has been US-centric. The study group encourages SC7 and the international community to provide information on other released or in work standards or body of knowledge artefacts on digital engineering.

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# 1. Introduction

## 1.1. Digital Transformation

The fourth industrial revolution, the digital revolution, is transforming engineering and many other disciplines across the globe. This digital transformation is affecting engineering in industry, government, and academia. Traditionally, a complex system is developed using a linear “waterfall” document-based process, leading to functional silos with systems that become increasingly difficult to change and sustain. Digital engineering has the potential to address the demands of exponential complexity growth and access to actionable information throughout the product development lifecycle.

The term digital engineering generally refers to the digital transformation of engineering to leverage digital technologies. “The crux of digital engineering is the creation of computer readable models to represent all aspects of the system and to support all the activities for the design, development, manufacture, and operation of the system throughout its lifecycle.” [1]

As a result of effective digital transformation, engineering disciplines benefit from informed and timely decisions at all levels. These decisions are enabled by appropriate information being visible and digestible across functional domains, disciplines, and organizations. Digital technologies enable this transformation through increased computer processing capabilities for rapid prototyping, experimentation, test decisions, and iterate solutions in a virtual environment.

## 1.2. Digital Engineering Information Exchange

As more organizations and disciplines move towards a holistic, integrated digital engineering approach, there is a growing need to share, cross-reference, integrate, reuse, and extend models of various kinds. This constitutes transforming engineering information exchange from traditional approaches for exchanging documents to model-based approaches for exchanging digital artefacts. Industries and governments are grappling with a currently disjointed use of those models. As such, industries now have the added challenge of exchanging engineering information in a new digital environment, while addressing issues like tool and data interoperability, model language and standards, obsolescence, workforce development, and organization cultural change.

## 1.3. Need for Standards

The digital revolution is the movement towards model-based approaches for exchanging, integrating, and referencing digital artefacts. For this transformation of engineering information exchange to be effective, standards are necessary to define associated terminology, processes, and other concepts.

The International Council on Systems Engineers (INCOSE) began initial groundwork for digital engineering concepts when two workshops were held at the 2017 INCOSE International Workshop (IW) to address the digital engineering challenge. One was the Digital System Model workshop led by the US Department of Defense (DoD) Office of the Secretary of Defense (OSD), and the second was the Digital Thread workshop led by the U.S. Air Force. These workshops led to the creation of the Digital Artefacts Challenge Team at the 2018 INCOSE IW which announced the following findings:

1. There was no majority agreement on common digital engineering terminology and concepts within the engineering community.
2. There was no formalism and conventions for a generic digital viewpoint model that stakeholders can use for digital engineering information exchange.
3. There was no industry-wide reference model for developing, maintaining, identifying, discovering, and reusing digital data and models in a model-centric engineering ecosystem.
4. There was no industry-wide consensus for standards related to digital engineering and digital engineering information exchange.

As a result of these findings, INCOSE, the National Defense Industry Association (NDIA) Modeling and Simulation (M&S) Subcommittee, and the Department of Defense, Office of the Under Secretary for Research and Engineering (DoD OUSD (R&E)) chose to collaborate to resolve these challenges by forming the Digital Engineering Information Exchange Working Group (DEIX WG).

Within the DEIX WG, four sub-teams were formed to address each finding respectively:

* The Digital Engineering Information Exchange Encyclopedia sub-team (DEIXPedia) to address common terms and definitions
* The Digital Viewpoint Model sub-team (DEIX-DVM) to create a generic digital viewpoint model
* The Digital Engineering Information Exchange Model (DEIXM) sub-team to create a reference process model for exchanging digital engineering information
* The Digital Engineering Information Exchange Standard Framework (DEIX-SF) sub-team to survey the current digital engineering standardization landscape and make recommendations

DEIX-SF conducted a preliminary standards survey in 2018 by reviewing standards owned by or compiled by the following organizations for applicability to digital engineering:

* The INCOSE-PEDS joint collaboration working group
* The INCOSE Standards Initiative group
* The International Association for the Digital Modeling, Analysis and Simulation Community (NAFEMS) standards Initiative
* The Object Management Group (OMG)
* The Open Services for Lifecycle Collaboration (OSLC) Project Group
* The CIMdata PLM Action Group
* The Prostep IVIP

More than fifty standards were evaluated for applicability to the five goals of the DoD Digital Engineering Strategy:

* Formalize modeling
* Provide authoritative source of truth
* Incorporate technological innovation
* Establish infrastructure
* Transform culture and workforce.

A summary of the findings was presented at the 2019 NDIA Systems and Mission Engineering Conference. The list of standards was also evaluated for applicability to the four digital engineering exchange use cases developed by the DEIX WG:

* Exchange digital artefact files
* Synchronize digital artefact in clone systems
* Grant remote access to source digital artefacts
* Loan and borrow digital artefacts from third party trusted agent.

The standards evaluation findings for the four digital engineering exchange use cases was presented at the 2019 INCOSE International Symposium.

Since the preliminary standards survey, other organizations have also worked on defining digital engineering standardization needs and initiated standards development.

* INCOSE published the Model-Based Capabilities Matrix and user guide in 2019, and the future release of the Model Portfolio Management guide to help organizations determine model-based capabilities and their evolution in digital transformation.
* The German Chapter of INCOSE (GfSE) began work on integrating systems specification and model transformation through Specification Integration Facility (SpecIF) and Model Transformation and Integration Facility (MoTIF).
* The American Society of Mechanical Engineers (ASME) formed the Model-Based Enterprise (MBE) Standards Committee in 2018 to investigate and develop standards that provide rules, guidance, and examples for the creation, use and reuse of model-based datasets, data models, and related topics within a model-based enterprise.
* A collaborative working group between NDIA, INCOSE, DoD OUSD (R&E), Systems Engineering Research Center (SERC), Aerospace Industry Association (AIA), and Practical Software and Systems Measurement (PSM) was formed in 2020 to define a digital engineering measurement framework with the initial framework release in 2022.
* The Department of U.S. Air Force Material Command (AFMC) launched a Digital Campaign in 2020 with the goal of creating an integrated digital ecosystem that provides enterprise access to the data individuals need to develop, test, field and maintain complex weapon systems. A memorandum was issued in 2021 to provide guidance for e-Program Designations, which defined the digital building code as a living set of standards for digital transformation. The essentials of an e-Program designations includes the implementation of the “digital trinity”: digital engineering, agile software development, and open system architecture.

In summary, there are many industry and standards organizations investigating standardization in digital engineering. Industry is struggling with achieving consensus on a set of standards organically due to diversity among industrial sectors, stakeholders, models, and its interrelationships. ISO/IEC JTC1/SC7, with its vast expertise in systems engineering and liaison with other standards organizations, is ideally placed to contribute a set of harmonizing digital engineering standards with industry consensus.

# 2. Analysis of Digital Engineering Topics in Standards

Analysis reveals that there are several standards on various digital engineering topics. Below is a list of relevant standards compiled from the DEIX-SF standard survey. [2] [3]

ISO/IEC JTC 1/SC 7 (Software and systems engineering) standards

* ISO/IEC/IEEE 15288:2015 Systems and software engineering — System life cycle processes
* ISO/IEC 19770-1:2017, Information technology — IT asset management — Part 1: IT asset management systems — Requirements
* ISO/IEC/IEEE 42010 Systems and software engineering — Architecture description
* ISO/IEC/IEEE 42020 Software, systems and enterprise — Architecture processes
* ISO/IEC/IEEE 12207 Systems and software engineering — Software life cycle processes
* ISO/IEC/IEEE DIS 24641 Systems and software engineering — Methods and tools for model-based systems and software engineering

ISO/TC 184/SC 4 (Industrial data) standards

* ISO 10303-243 Industrial automation systems and integration — Product data representation and exchange — Part 243: Application protocol: For modelling and simulation information in a collaborative systems engineering context (MoSSEC)
* ISO 10303-233 Industrial automation systems and integration — Product data representation and exchange — Part 233: Application protocol: Systems engineering
* ISO 10303-239 Industrial automation systems and integration — Product data representation and exchange — Part 239: Application protocol: Product life cycle support
* ISO 10303-242 Industrial automation systems and integration — Product data representation and exchange — Part 242: Application protocol: Managed model-based 3D engineering
* ISO 23247 (all parts) Automation systems and integration — Digital twin framework for manufacturing
* ISO/TR 24464 Automation systems and integration — Industrial data — Visualization elements of digital twins

ISO/TC 184/SC 5 (Interoperability, integration, and architectures for enterprise systems and automation applications) standards

* ISO 15704 Enterprise modelling and architecture — Requirements for enterprise-referencing architectures and methodologies

ISO/TC 184 (Automation systems and integration) standards

* IEC/TR 63319 A meta-modelling analysis approach to smart manufacturing reference models
* IEC 63339 Unified reference model for smart manufacturing

ISO/TC 171/SC 2 (Document file formats, EDMS systems and authenticity of information) standards

* ISO 12029 Document management — Machine-readable paper forms — Optimal design for user friendliness and electronic document management systems (EDMS)

ISO/TC 260 (Human resource management) standards

* ISO 30401 Knowledge management systems — Requirements

ISO/TC 59/SC 13 (Organization and digitization of information about buildings and civil engineering works, including building information modelling) standards

* ISO 19650 (all parts) Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling

ISO/IEC JTC1/SC32 (Data management and interchange) standards

* ISO/IEC 21838-1 Information technology — Top-level ontologies (TLO) — Part 1: Requirements
* ISO/IEC 21838-2 Information technology — Top-level ontologies (TLO) — Part 2: Basic Formal Ontology (BFO)
* ISO/IEC 11179-1 Information technology — Metadata registries (MDR) — Part 1: Framework
* ISO/IEC TS 11179-30 Information technology — Metadata registries (MDR) — Part 30: Basic attributes of metadata
* ISO/IEC TR 19583-1 Information technology — Concepts and usage of metadata — Part 1: Metadata concepts
* ISO/IEC 19763 (all parts) Information technology — Metamodel framework for interoperability (MFI)

LOTAR standards

* EN/NAS 9300-500, MBSE Archiving Requirements
* EN/NAS 9300-510, Archiving Requirements for Design Specifications
* EN/NAS 9300-520, How to Archive System Behavior and Simulation Models Using FMI

World Wide Web Consortium (W3C)

* Resource Description Framework (RDF)
* OWL 2 Web Ontology Language
* SPARQL Query Language

U.S. DoD standards

* DoD MIL-STD-31000B, Technical Data Package
* DoD MIL-STD-3022, Documentation of Verification, Validation, and Accreditation for Models and Simulations

OMG standards

* OMG ReqIF
* OMG SysML
* OMG United Architecture Framework (UAF)
* OMG IEPPV, v1.0, Information Exchange Packaging Policy Vocabulary

ASME standards

* ASME Y14.41, Digital Product Definition Data, Standard Industry Requirements
* ASME Y14.47, Model Organization, Standard Industry Requirements

OSLC Open Project standards

* Core 3.0 OS, OSLC 3 Specification

Modelica Association Project Functional Mockup Interface

* Functional Mockup Interface (FMI) Standard

# 3. Analysis of Digital Engineering Topics in Existing Body of Knowledge

Analysis reveals that numerous publications in the existing body of knowledge discuss various digital engineering topics. These include, but are not limited to, the following.

U.S. DoD

* DAU Glossary, Defense Acquisition Glossary
* DoD Digital Engineering Strategy
* Exchanging Digital Artefacts for the Engineering Life Cycle
* DoD Digital Engineering Fundamentals
* Digital Engineering Body of Knowledge (DEBoK)
* Guidance for e-Program Designations, Department of U.S. Air Force, 2021
* Department of Air Force, Digital Maturity Guide version 1.0, 2021
* There is No Spoon: The New Digital Acquisition Reality, Dr William Roper, Department of U.S. Air Force, 2020

INCOSE

* Systems Engineering Body of Knowledge, Digital Engineering
* Digital Engineering Information Exchange Working Group (DEIX) wiki
* INCOSE Digital Ecosystem (DECO)
* INCOSE Model-Based Capabilities Matrix
* GfSE SpecIF
* GfSE MoTIF
* INCOSE- PEDS joint collaboration working group
* INCOSE standards initiative working group

Practical Software and Systems Measurement

* PSM Digital Engineering Measurement Framework v1.0

American Institute of Aeronautics and Astronautics

* Digital Twin: Definition and Value, An AIAA and AIA Position Paper

Prostep IVIP, standardization projects

* SysML Workflow Forum
* SysML Implementor Forum

Systems Engineering Research Center (SERC), Digital Engineering

* Digital Engineering Competency Framework
* Digital Engineering Measures
* Transform Systems Engineering through Model-Based System Engineering

CIMdata Action Groups

* Aerospace and Defense PLM Action Group, Global Collaboration 2021 White Paper

NAFEMS

* NAFEMS standards Initiative, standards catalog
* NAFEMS glossary terms

# 4. Areas for Standardization

## 4.1 Standardization Summary

Existing standards and bodies of knowledge in the digital engineering space use overlapping and sometimes conflicting terminology. Due to the diversity of industries undergoing digital engineering transformation, many have developed standards specialized to their own domain areas. These standards can compete, duplicate, or be inconsistent with each other. With regards to standardization, there is a growing need to achieve consensus for organizations implementing digital engineering. In addition, input from the international community is needed.

The many existing standards, other publications, and initiatives in digital engineering suggest several candidates for digital engineering standardization.

## 4.2 Near-term Candidate for Standardization

Given the diversity of organizations and industrial sectors driving or being impacted by digital transformation, a common vocabulary is critical to minimize misunderstandings and associated re-work.

For this reason, the most immediate candidate for standardization is digital engineering taxonomy. Terms include, but are not limited to, the following:

* Digital artefact
* Digital engineering
* Digital system model
* Digital twin
* Digital thread
* Authoritative source of truth
* Model curation
* Digital engineering ecosystem
* Digital view
* Digital viewpoint
* Digital viewpoint Model
* Digital system model
* Model based engineering
* Digital transformation

## 4.3 Longer-term Candidates for Standardization

Mid- and long-term candidates for standardization include, but are not limited to, the following areas in digital engineering:

* Stakeholder concepts
* Viewpoint (perspective) concepts
* Process concepts for digital engineering information development, exchange, curation, etc.
* Information product/structure concepts
* Digital Viewpoint Model guide and how to use it
* Metrics

# 5. Recommendations

AHG 6 recommends ISO/IEC JTC 1/SC 7 extend the target date for completion of the work by AHG 6 to 2022-12-31. This extension will allow AHG 6 to achieve the following:

* Continue analysis of digital engineering terminology in existing standards and the wider body of knowledge. This activity also includes socializing this work with other ISO groups, such as wider ISO/IEC JTC 1/SC 7 and ISO/TC 184/SC 4, and with other professional organizations identified in Section 3 of this report
* Complete an ISO Form 4 for a new work item that addresses the scope of a taxonomy for digital engineering. The new item will require the creation of a new working group within ISO/IEC JTC 1/SC 7. This working group will build on the work of AHG 6 and continue to investigate the potential for one or more additional new projects to address other aspects of digital engineering.
* Submit the Form 4 and a final set of recommendations to the ISO/IEC JTC 1/SC 7 plenary meeting in December 2022.

# 6. Bibliography

[1] Giachetti, R., *Digital engineering*, Guide to the Systems Engineering Body of Knowledge (SEBoK). Online. Available from: <https://www.sebokwiki.org/wiki/Digital_Engineering> [viewed 2022-05-13]

[2] Tseng, C., *DEIX Standards Framework Updat*e, Object Management Group Meeting Charts and Notes from DEIX forums. Online. Available from: [https://www.omgwiki.org/MBSE/doku.php?id=mbse:clicWiki] (omgwiki.org)](https://www.omgwiki.org/MBSE/doku.php?id=mbse:click_here_for_meeting_charts_and_notes) [viewed 2022-05-18]

[3] Tseng, C., *DEIX standards for DE Policy*, Object Management Group Meeting Charts and Notes from DEIX forums. Online. Available from: [https://www.omgwiki.org/MBSE/doku.php?id=mbse:clicWiki] (omgwiki.org)](https://www.omgwiki.org/MBSE/doku.php?id=mbse:click_here_for_meeting_charts_and_notes) [viewed 2022-05-18]