Digital Twin/Digital Thread Solution Definition for Aerospace and Defense: Phase 4

Overview of A&D Industry Digital Twin/
Digital Thread Standards

Release 1.0

November 2023

Abstract

The Aerospace & Defense PLM Action Group (AD PAG) collectively sponsored a team of industry experts from AD PAG member companies to define objectives, requirements, and roadmaps for digital twin/thread solutions.

In Phase 1 the team conducted research that identified a plethora of digital twin/thread concepts and definitions. A method of describing this phenomenon was prepared to organize and understand the definitions. In support of preparing the A&D industry's digital twin/thread definitions, the team prepared constructs to describe the intended functionality and utility of the digital twin/thread. The resulting A&D industry definitions are the collaborative work of representatives from several leading A&D companies.

In Phase 2 the team published the *Digital Twin/Digital Thread Solution Definition for Aerospace and Defense: Phase 2 - Problem, Objectives, Proposed Definitions, Go Forward* position paper for the A&D industry. The purpose of this document was to facilitate an industry baseline definition and understanding of the current capabilities of the digital twin/thread in the A&D industry.

In Phase 3 the team published the *Digital Twin/Digital Thread Solution Definition for Aerospace and Defense: Phase 3 - Business Architecture Frameworks/Methodologies,* an evaluation of business architecture frameworks and methodologies to determine applicability to the digital twin/thread. The purpose of the document was to provide an understanding of the current state of architecture frameworks and the architecture methods relative to the digital twin/thread, as well as to identify the specific architecture constructs needed to support the digital twin/thread constructs.

In this Phase 4 the team reviewed popular business architecture frameworks and associated methodologies of digital twin/thread standards to determine their utility as related to the digital twin/thread definition in Phase 2.

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Revision Record

Release	Date	Description
1.0	**November 2023**	Initial release of the *Digital Twin/Digital Thread Business Architecture for Aerospace and Defense: Phase 4 - Overview of A&D Industry Digital Twin/Digital Thread Standards* paper. This paper is the Phase 4 deliverable of the AD PAG Digital Twin/Digital Thread project.

Overview of A&D Industry Digital Twin/Digital Thread Standards

Executive Summary

The Aerospace and Defense Product Lifecycle Management (PLM) Action Group (AD PAG) is an association of aerospace Original Equipment Manufacturers (OEMs) and aircraft engine manufacturers within CIMdata's globally recognized PLM Community Program, which functions as a PLM advocacy group. The AD PAG has sponsored a project team of industry experts (also known as SMEs, *subject matter experts)* from the member companies to define objectives, requirements, and roadmaps for digital twin/thread solutions for creating and managing the digital representation of a product through the various stages of the product lifecycle. As is the custom of the AD PAG, a primary objective is to present a unified voice to the software solution provider community regarding unmet needs or pain points common across the A&D industry.

This project was designed to be executed in multiple phases. Seven phases were proposed and approved, each with a specific objective and associated deliverable. Each phase builds upon the knowledge and deliverable(s) of the prior phase(s). The deliverable of Phase 1 was a literature search of documentation intended for internal use by the project team in support of the Phase 2 work. The principal deliverables of Phases 2 through 7 are publicly released position papers.

- Phase 1 – Research – Examination of existing industry digital twin/digital thread technical literature
- Phase 2 – Digital Twin/Digital Thread Solution Definition for Aerospace and Defense
- Phase 3 – Digital Twin/Digital Thread Business Architecture Frameworks/Methodologies
- Phase 4 – Overview of A&D Industry Digital Twin/Digital Thread Standards
- Phase 5 – Digital Twin/Digital Thread Value Proposition
- Phase 6 – Forward-Looking Digital Twin/Digital Thread Strategy and Roadmap
- Phase 7 – Digital Twin/Digital Thread Project Consolidation

Multiple digital twin/thread standards exist. These standards are primarily differentiated between system engineering for the digital twin and data management for the digital thread. Both the digital twin and the digital thread standards are an evolution of existing standards that were developed to address needs in other domains—digital twin standards stem from simulation, system engineering, and manufacturing practices, and digital thread standards stem from data management and data architecture practices.

In phase 4, known standards that impact digital twin and digital thread concepts have been identified and a framework[1] aligned with product lifecycle management (PLM) was utilized to categorize and align those standards, identifying overlaps for further review and reconciliation.

[1] In Phase 2 the AD PAG digital twin/thread definition framework was defined and introduced as a rational way of describing diversity in digital twin/thread definitions. The Phase 3 *Digital Twin/Digital Thread Solution Definition for Aerospace and Defense: Business Architecture Frameworks/Methodologies* paper also addresses the framework.

The team's Phase 4 work plan was to do the following:

1. Identify existing standards that apply to digital twin/thread activities.
2. Review existing standards frameworks to determine applicability to the digital twin/thread.
3. Devise and recommend an integrated digital twin/thread standards framework.
4. Align digital twin/thread standards against the proposed integrated digital twin/thread framework to identify coverage and duplication in the standards.
5. Present recommendations/observations, based on the current state of digital twin/thread standards to address duplication.

The team's findings indicate a limited availability of mature digital twin/thread standards, necessitating a greater attention by standards organizations that support the A&D industry. This includes the recognition and willingness to address the continuity of the digital twin across the product lifecycle. The following should be considered in the maturation of digital twin/thread standards

- Revised definition and alignment of the digital twin/thread construct will continue as technology aligns with the functional and operational digital twin requirements.
- Interoperability between and composition of digital twins will require new standards types to be defined within the digital thread.
- Digital Product Authoritative Source is an emergent attribute of the digital thread. The digital thread will be required to support non-persistent and long-term data storage requirements.

The concept of digital twin/thread standards introduces the need for broad standardization of complex and rapidly changing business processes, system definition, and information technology. This standardization will be needed to ensure that digital twin/thread data interoperability and data utilization complexities are minimized.

Introduction

In March 2021, executives from the AD PAG member companies–Airbus, Boeing, Embraer, GE Aerospace, Gulfstream, Pratt & Whitney Canada (P&WC), Rolls-Royce, and SAFRAN–met to review and approve a proposed special project. They agreed to sponsor a project team of industry experts from the AD PAG member companies. The AD PAG Digital Twin/Digital Thread team's task was to define objectives, requirements, and roadmaps for digital twin/thread solutions needed to create and manage a product's digital representation through the various stages of the product lifecycle.

The AD PAG Digital Twin/Digital Thread team's first workshop was held at the beginning of Q3 2021. The project team's charter defines seven phases to define and produce a series of sub-projects and associated deliverables to be executed over the course of two years.

The principal deliverables of Phases 2 through 7 are, when completed, publicly released position papers.

- Phase 1 – Research – Examination of existing industry digital twin/digital thread technical literature
- Phase 2 – Digital Twin/Digital Thread Solution Definition for Aerospace and Defense
- Phase 3 – Digital Twin/Digital Thread Business Architecture Frameworks/Methodologies
- Phase 4 – Overview of A&D Industry Digital Twin/Digital Thread Standards

- Phase 5 – Digital Twin/Digital Thread Value Proposition
- Phase 6 – Forward-Looking Digital Twin/Digital Thread Strategy and Roadmap
- Phase 7 – Digital Twin/Digital Thread Project Consolidation

Phase Four

The team's Phase 4 goal was to research and identify existing digital twin/thread standards and review the standards for applicability and utilization against the defined digital twin/thread requirements and definitions.

The team conducted an initial search of existing digital twin/thread standards. This search focused on A&D industry standards organizations and on the team's familiarity with and knowledge of those standards. Research was also conducted to determine if any existing or emergent organizations are proposing the need for new standards to either replace existing or define new digital twin/thread standards.

Problem Statement

Several industry standards organizations, such as Object Management Group (OMG), International Organization for Standardization (ISO), Society of Automotive Engineers (SAE International), and National Institute of Standards and Technology (NIST), are defining digital twin/thread standards. It is likely that these new standards may be overlooking gaps in or conflicting with the existing standards. Any conflicts and oversights would need to be addressed to facilitate the data portability and interoperability required for a successful digital twin/thread system implementation and trusted utilization.

Specific areas of consideration defined by the team for assessment of digital twin/thread standards include the following:

- Concurrency of digital twin/thread design, implementation, and utilization
- Granular/atomic levels – fundamental artifact definition
- Product lifecycle approach – toolbox approach/diagram, extensibility assessment for value stream definition
- Definition and alignment of data architecture, knowledge graphs similar to the digital thread, and complex digital thread utilization constructs (fabric)
- Digital thread security throughout product lifecycle management
- Enterprise data alignment with the ecosystem, such that the data is accurate, current, and secure
- Alignment of the digital thread to the digital twin
- Definition and modeling of monitoring, including analytics to represent organizational utility of the digital twin/thread
- Use of digital threads in the definition, construction, and analysis of digital twins (digital thread analytics)
- Capability of incorporating analytics with the digital twins/threads design
- Methodology of modeling digital twin analytical aggregation across the product lifecycle

- Modeling of
  - Digital thread interoperability
  - Digital thread utilization across the product lifecycle—how this is done currently and how it will be done with digital threads in the future
  - Digital thread data retention and long-term data preservation
  - Contextual digital twin parameters to enable consistency in representing digital twin responsiveness

Purpose and Objective

The purpose of this *Digital Twin/Digital Thread Business Architecture for Aerospace and Defense: Phase 4 - Overview of A&D Industry Digital Twin/Digital Thread Standards* paper is to provide an understanding and assessment of the current state of A&D industry digital twin/thread standards.

Standards Acceptance and Value

The importance of standards and the value derived from incorporating standards into systems and methods is represented by A&D companies' participation and financial contributions to standards organizations. Another key metric of the industry valuing standards is the incorporation of A&D industry standards into a company's typical operations. In addition, industry solution providers demonstrate their interest in A&D standards by incorporating them into their respective software offerings and solutions.

A&D Industry Standards Bodies

Standards bodies resourced in the search for digital twin/thread standards consisted of known industry standards organizations, such as the American Institute of Aeronautics and Astronautics (AIAA), Aerospace Industries Association (AIA), American National Standards Institute (ANSI), Air Transportation Association (ATA) e-Business Program, International Airline Transportation Association (IATA), International Electrotechnical Commission (IEC), Institute of Electrical and Electronics Engineers (IEEE), ISO, NIST, Nuclear Quality Assurance Certification Program (NQA), SAE International, as well as other lesser-known standards bodies.

The following table presents industry organizations that have defined and published A&D industry standards and have communicated interest in evaluating their respective standards and revising them to reflect the opportunity presented by the digital twin/thread. The *ISO Data Architecture of the Digital Twin* paper provided by the ISO TC 184 defines the alignment of ISO industry standards with the digital twin/thread data, information, and interoperability requirements (refer to the *Appendix: ISO Digital Twin Standards).*

Table 1 - List of Standards Bodies with an Interest in Digital Twin/Thread Standards

Standards Body Acronym	Organization Title	Standards Type [Artifacts, Models/Data, Tools/Methods]	Organization URL
AIAA	American Institute of Aeronautics and Astronautics	Artifacts	https://www.aiaa.org/
AIA	Aerospace Industries Association	Artifacts	https://www.aia-aerospace.org/about/
AFNeT	Association of Internet users and networked Society	Models/Data, Tools/Methods	https://www.afnet.fr/en/
AFNOR	Association Française de Normalisation	Artifacts, Tools/Methods	https://www.afnor.org/en/
ANSI	American National Standards Institute	Models/Data	https://www.ansi.org/
ASD-STAN	AeroSpace and Defence Industries Association – Standards	Artifacts, Models/Data	https://asd-stan.org/
ASME	American Association of Mechanical Engineers	Tools/Methods	https://www.asme.org
ATA	ATA e-Business Program	Models/Data	https://ataebiz.org/
CIMdata A&D PLM AG	A&D PLM Action Group	Artifacts	https://www.cimdata.com/en/aerospace-and-defense
IATA	Air Transportation Association	Artifacts, Models/Data	https://www.iata.org/
IEC	International Electrotechnical Commission	Models/Data	https://www.iec.ch/homepage
IEEE	Institute of Electrical and Electronics Engineers	Artifacts, Models/Data, Tools/Methods	https://www.ieee.org/

INCOSE	International Council on Systems Engineering	Tools/Methods	https://www.incose.org/
ISO	International Organization for Standardization	Models/Data	https://www.iso.org/home.html
LOTAR	Long Term Archiving and Retrieval	Models/Data	https://lotar-international.org
Modelica	The Modelica Association	Models/Data, Tools/Methods	https://modelica.org/
NAFEMS	National Agency for Finite Element Methods and Standards	Models/Data, Tools/Methods	https://www.nafems.org/
NIST	National Institute of Standards and Technology	Artifacts, Models/Data	https://www.nist.gov/
NQA-1	Nuclear Quality Assurance Certification Program		https://www.nqa.com/en-us
OAGi	Open Applications Group Integration	Artifacts	https://www.oagi.org
OMG	Object Management Group	Artifacts, Models/Data	https://www.omg.org/index.htm
PDES	Product Data Exchange using STEP	Models/Data, Tools/Methods	https://pdesinc.org/
Prostep ivip	ProSTEP Association for the Promotion of Product Data Standards	Models/Data, Tools/Methods	https://www.prostep.org/en/
SAE International	https://www.sae.org/	Artifacts, Models/Data, Tools/Methods	https://www.sae.org/

Digital Twin/Thread Standards Perspectives

Regarding the numerous standards bodies, several approaches exist to organize the standards into frameworks. Three reviewed examples are followed by the approach adopted by the project team.

Digital Twin Standards Organized by Use Types

Wang et al. (2022) introduced a framework of digital twin standards that collectively organizes standards by their use types: physical entities, virtual entities, data, connection, and services. Figure 1 provides a visual representation of these digital twin standards use types. The predominant industry standards included are from IEC, IEEE, and ISO. The figure should be interpreted as a unique view presented by the author. This framework is included here as an alternative perspective of how digital twin/thread standards may be organized.

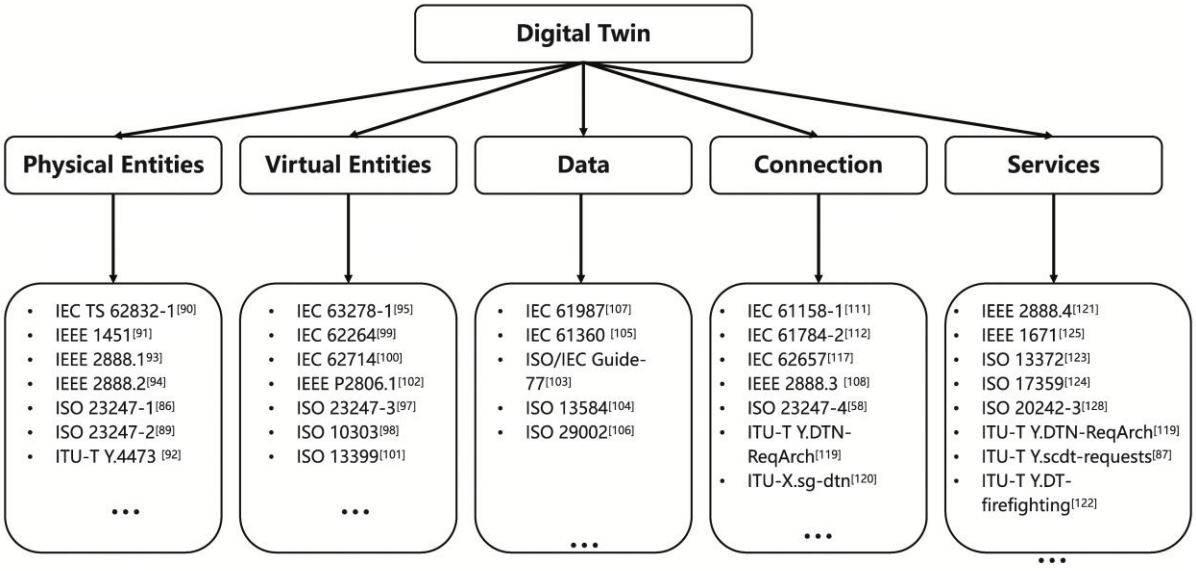

Figure 1 - Digital Twin Standards by Type (Wang et al. (2022)

Digital Twin/Thread Standards in a Product Lifecycle Context

In contrast to the framework presented by Wang et al. (2022) in Figure 1, Standard for the Exchange of Product Model Data (STEP) represents standards in context of the product lifecycle from concept to disposal, as shown in Figure 2.

The STEP digital twin/thread standards reflect an evolution from existing STEP standards. These digital twin/thread standards continue to develop in conjunction with the evolving digital twin/thread concepts. Evolving digital twin/thread standards are addressed in the project's Phase 2 position paper available at https://www.cimdata.com/en/aerospace-and-defense/publications/digtaltwin-digitalthread. This framework is referred to as *an evolutionary approach* to establishing digital twin/thread standards.

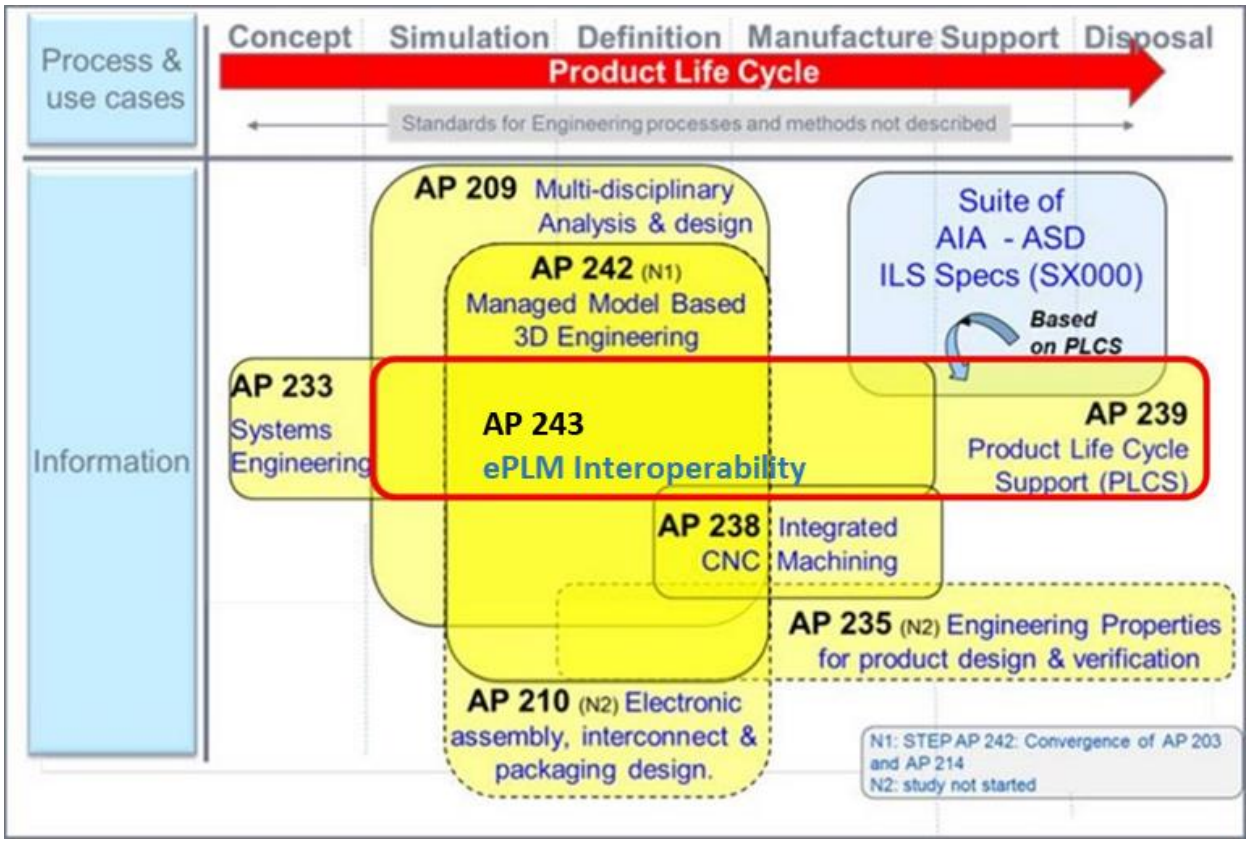

Figure 2 - STEP Application Protocol (AP) Standards

The Relationship Complexity of Defining and Using Standards

Another perspective for understanding digital twin-/thread-related standards is to illustrate the complexity of the relationship between digital standard organizations, product lifecycle solution providers, and product lifecycle solution consumers. The following figure represents an OEM and PLM solution providers' participation in several industry standards organizations. The purpose of this ecosystem view is to communicate the complex relationship and challenge of reconciling and achieving consensus in the definition and use of standards.

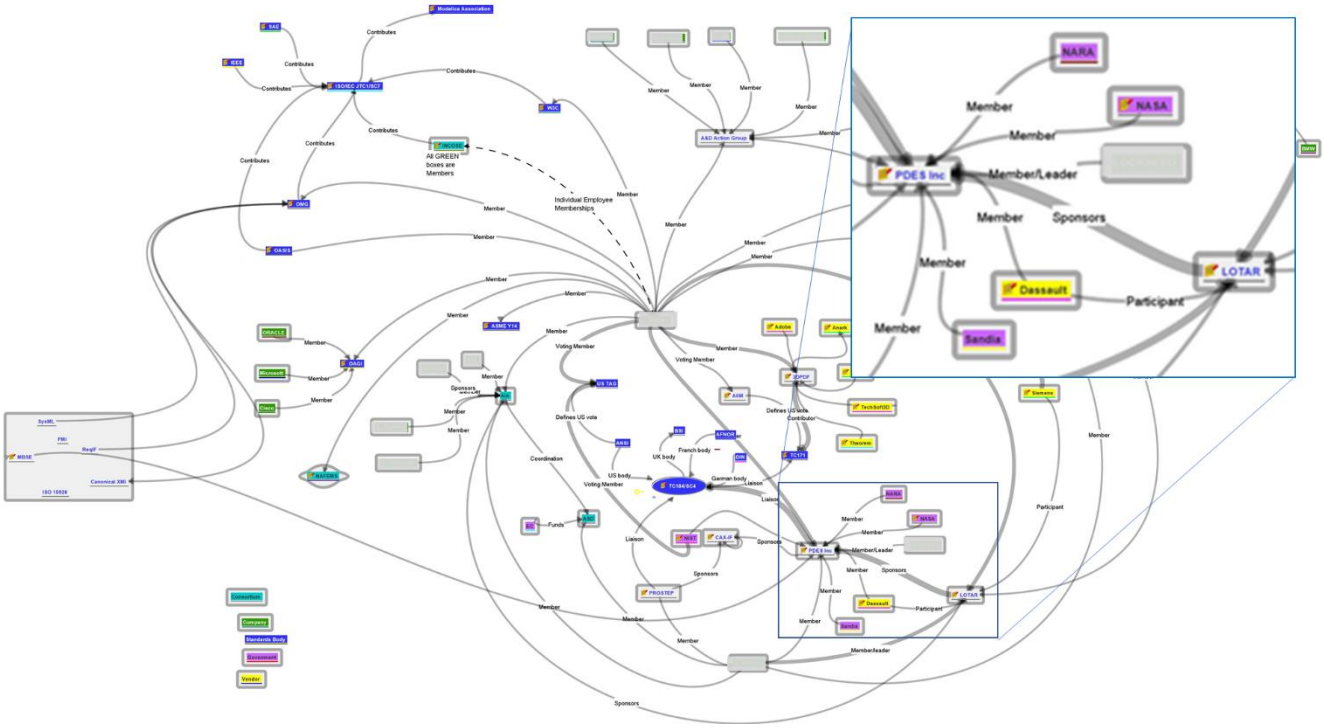

Figure 3 - Complex Relationship between OEM, Solution Provider, and Standards Bodies

AD PAG Digital Twin/Thread Definition Framework

Through research and discussions, the project team identified and categorized the differences in the description and utilization of the digital twin/thread within a three-dimensional space. First, those differences reflected the value received and terminology used by a particular organization. Second, a distinct difference in representations is observed across the business, system, and technical views. Third, the project team recognized that each product lifecycle phase presents variations in terminology and value.

In Phase 2 the digital twin/thread definition framework shown in Figure 4 was created and adopted by the project team as a rational way of organizing and describing diversity in digital twin/thread definitions. The framework consists of three rows and eight columns. The rows represent views from a business, system, and technical perspective. Each column represents a phase of the product lifecycle. And a third dimension, the organizational perspective, is overlaid on the phases of the product lifecycle.

Digital Twin/Thread Definition Framework

		Supplier	OEM				Customer/User/Owner/Operator		
		Part/ Component/ Material	Requirements	Design	Engineer	Manufacture	Operation	Maintenance	Disposition
Business	Artifacts								
System	Models and Data								
Technical	Tools and Methods								

Figure 4 - AD PAG Digital Twin/Thread Definition Framework

The Supplier column represents an OEM's perspective relative to the part or component produced by a supplier and integrated into the manufactured product. The inclusion of this Supplier column elevates the importance of the supplier and the supply chain's digital twin/thread contribution to the OEM and to the customer/user/owner/operator within the A&D ecosystem. Each cell represents a unique business perspective.

Digital Twin/Thread Standards Mapping to the AD PAG Framework

As part of Phase 4, the AD PAG framework is now being used as the preferred approach to organizing digital twin/thread standards. Iterations of the framework's use include the following:

1. Populating (mapping) it with known digital twin and digital thread standards
2. Defining the overlap of standards within a specific product lifecycle phase
3. Identifying the areas where industry standards are needed to enable interoperability of the digital twin/thread

Two examples—one digital twin (Figure 5), one digital thread (Figure 6)—of how the AD PAG Digital Twin/Thread Definition (DT/TD) Framework can be utilized to assess and contrast digital twin/thread standards are provided in the following sections.

Example of Mapped Digital Twin Standards

Figure 5 provides a representative example of how **digital twin standards** can be mapped to the AD PAG DT/TD framework. In this example STEP AP standards and ISO digital twin standards are mapped to the corresponding product lifecycle phases. While this diagram shows specific boundaries for the STEP standards, there is acknowledged overlap with product lifecycle phases.

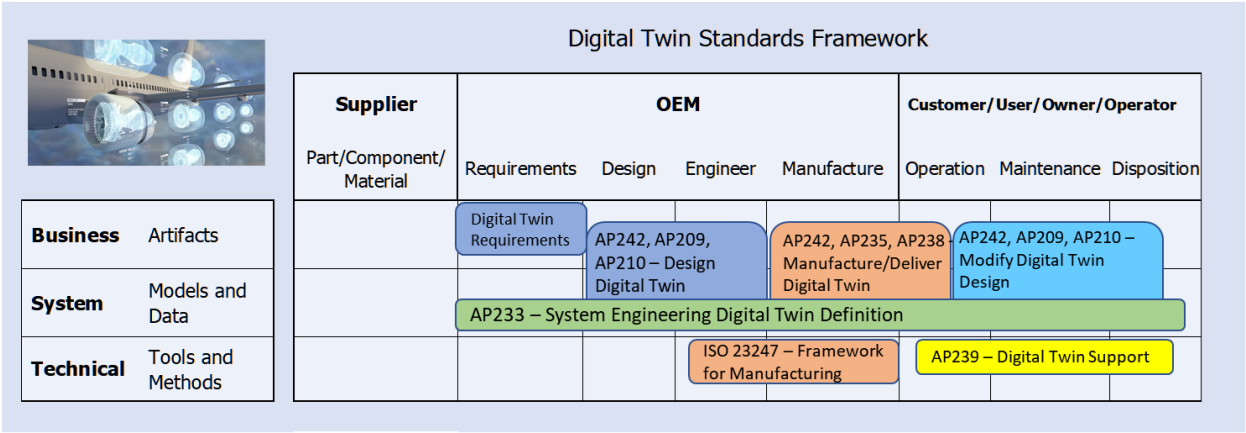

Figure 5 - Example of Digital Twin Standards Mapping to the AD PAG DT/TD Framework

Example of Mapped Digital Thread Standards

In contrast to the increasing number of digital twin standards, a significantly lesser number of digital thread standards exist. The following figure provides a representative example of how **digital thread standards**, though currently minimal, can be mapped to the AD PAG DT/TD framework of product lifecycle phases.

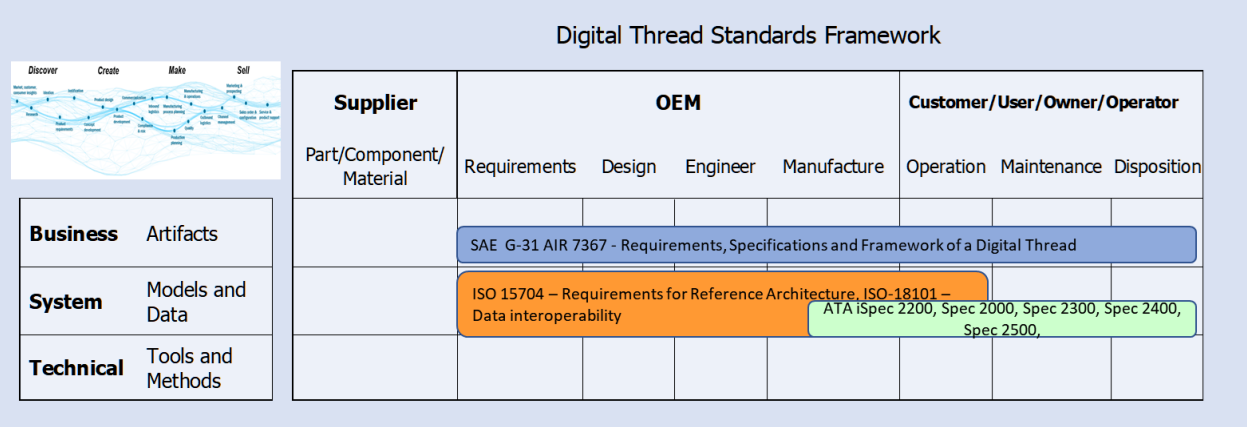

Figure 6 - Example of Digital Thread Standards Mapping to the AD PAG DT/TD Framework

The seeming disinterest in digital thread standards is surprising from an A&D industry perspective and within the respective data standards community. Consequently, it is worth noting that two publications—one from CIMdata titled *A&D PLM Action Group Digital Thread Collaborative Research Report* and another by the American Institute of Aeronautics and Astronautics (AIAA) titled *Implementing the Digital Thread - A Proof-of-Concept*—are available to provide definition of and guidance about the capabilities of the digital thread. Though not designed specifically as a digital thread standard, the ATA e-business standards (iSpec2200, Spec 2000, Spec 2300, Spec

2400, and Spec 2500) are in wide use in the civil aviation industry for in-service data exchange and could support a digital thread for the post-delivery portion of the framework. Those standards provide data exchange formats for information exchange to support engineering, maintenance, materiel management, and flight operations.

Still, the lack of digital thread standards was acknowledged by Oroz et al. (2023) stating, "the general lack of standards regarding formats, files, or data exchanges impedes collaboration and represents yet another challenge to the implementation of the Digital Thread. Indeed data, knowledge, and models exist in a wide range of formats, not all compatible with the tools and platforms that need to ingest them. The development of industry-wide, open standards is needed to ensure data and model interoperability within the Digital Thread."

Overlaps in Digital Twin/Thread Standards

The digital twin standards represented in Figure 5 indicate overlaps in digital twin standards. This is most likely a function of standards bodies representing their respective standards as an ongoing development of standards from a historical perspective. ISO and STEP are interrelated standards. They provide a good example of how standards evolve based on changes in technology and how technology influences the way in which the industry uses data and information.

Additional Viewpoints/Perspectives

The research of both digital twin and digital thread standards identified additional viewpoints and perspectives in support of the standards. For example, the AIAA Digital Engineering Integration Committee published in January 2023 *Digital Twin: Reference Model, Realizations and Recommendations*. This publication is a widely accepted perspective of the purpose, objective, and opportunity for digital twin in the A&D industry.

The AIA's *The Future of Aerospace Standardization* report, first published in 2004, referred to the role of standards as digital data and a necessary support for the digital enterprise. The recent March 2022 update addresses the use of business standards, new models, and new tools to define the digital twin/thread.

In addition to the AIA and AIAA, more standards developing organizations, national and international standards bodies, technology developers, OEMs, technology consumers, and various membership groups are trying to make something meaningful and actionable happen in the A&D industry.

Generalized Observations

The limited availability of mature digital twin/thread standards is an area needing greater attention by standards organizations that support the A&D industry. In addition to recognizing and addressing the continuity of the digital twin across the product lifecycle, the following should be considered in the maturation of digital twin/thread standards:

- The concept of the digital twin continues to evolve.

- The digital twin and the digital thread are distinct aspects of digital transformation. The corresponding digital twin and digital thread standards will be distinctly different.
- The digital twin is dependent upon the digital thread for data to facilitate the simulation and analysis of the physical twin.
- Coordinating the development of the respective standards between the digital twin/thread is needed.
- Organization, definition, and enablement of the digital twin is dependent upon data and information provided by the digital thread.

The relationship between the digital twin/thread is defined in earlier AD PAG Digital Twin/Digital Thread project team publications, which can be retrieved at www.ad-pag.com. Refer to the team's Phase 2 paper for a more complete definition and description of the interdependencies of the digital twin/thread. The Phase 3 paper provides additional digital twin/thread architecture insight.

Go Forward Plan

This *Digital Twin/Digital Thread Solution Definition for Aerospace and Defense: Phase 4 - Overview of A&D Industry Digital Twin/Digital Thread Standards* position paper has provided a review of digital twin/thread standards within the A&D industry. The team identified and presented generalized observations that could serve as recommendations for consideration in the selection and use of digital twin/thread standards in association with digital twin/thread initiatives.

While ample information regarding digital twin standards is available, there is an increasing need for the A&D industry to facilitate the maturity of the digital thread and to establish a framework of standards that enable digital thread operational capability across the heterogeneous data and information solutions.

Concepts to Consider

In summary, primary concepts to consider now and going forward include the following:

- The Why?
  - The digital twin/thread standards concept introduces the need for broad standardization of complex and rapidly changing business processes, system definition, and information technology. That standardization will need to ensure that digital twin/thread data interoperability and data utilization complexities are minimized.
- The What?
  - Revised definition and alignment of the digital twin/thread construct will continue as technology aligns with the functional and operational digital twin requirements.
  - Interoperability between and composition of digital twins will require new standards types to be defined within the digital thread.
  - Digital Product Authoritative Source of Truth is an emergent attribute of the digital thread. The digital thread will be required to support non-persistent and long-term data storage requirements.
  - Methods of modeling digital twin/thread functions within both the enterprise and the A&D ecosystem will require common industry interoperability standards.

  - Which enterprise and ecosystem organizations and partners to collaboratively participate in the definition and use of industry standards will need to be determined.
- The How?
  - Establish an authoritative matrix of organizations defining or purporting to define digital twin/thread standards. (The AD PAG is not a standards-defining body.)
  - Establish an authoritative list of required PLM digital twin/thread standards.
  - Define the information technology (IT) system requirements supporting implementation and operational sustainment of the digital twin/thread solution.
  - Define digital twin/thread standards in support of product development and the product lifecycle.

Digital Twin/Thread Value Proposition (Phase 5)

Phase 5 of the Digital Twin/Digital Thread project is to establish the digital twin/thread value proposition, which will identify, define, and demonstrate five A&D industry digital twin/thread use cases. The use cases will be aligned with the PLM lifecycle phases.

The knowledge from the use cases will then be extrapolated and used to validate digital twin/thread value propositions, as well as to evaluate solution providers' ability to enable digital twin/thread solutions. The AD PAG Digital Twin and Digital Thread project team will also identify industry software and technology vendors who have demonstrated capabilities aligned with the defined value propositions.

About A&D PLM Action Group

The Aerospace & Defense PLM Action Group (www.ad-pag.com) is an association of aerospace and defense companies within CIMdata's globally recognized PLM Community Program, which functions as a ***PLM advocacy group*** to:

- Set the direction for the aerospace & defense industry on PLM-related topics that matter to members (*including promoting, not duplicating, the work of standards bodies*)
- Promote common industry PLM processes and practices
- Define requirements for common interest PLM-related capabilities
- Communicate with a unified voice to PLM solution providers
- Sponsor collaborative PLM research on prioritized industry and technology topics

CIMdata administers Group operations, coordinates research, and manages the progression of policy formulation.

Note: This project is one of two current projects sponsored by the AD PAG focused on the digital thread. Concurrent with the effort to broadly define a vendor-neutral solution encompassing the digital twin/thread requirements, the AD PAG is conducting a survey in sponsorship with multiple software solution providers focused on the current state and anticipated future trends of digital thread implementation designed to maximize the benefits that can be received from any Product Lifecycle Management investments.

To learn more, visit https://www.cimdata.com/en/news/item/21976-cimdata-announces-ebook-on-digital-thread-in-aerospace-defense.

About CIMdata

CIMdata, a leading independent worldwide firm, provides strategic management consulting to maximize an enterprise's ability to design and deliver innovative products and services through the application of Product Lifecycle Management (PLM) solutions. Since its founding over thirty years ago, CIMdata has delivered world-class knowledge, expertise, and best-practice methods on PLM solutions. These solutions incorporate both business processes and a wide-ranging set of PLM-enabling technologies.

CIMdata works with both industrial organizations and providers of technologies and services seeking competitive advantage in the global economy. CIMdata helps industrial organizations establish effective PLM strategies, assists in the identification of requirements and selection of PLM technologies, helps organizations optimize their operational structure and processes to implement solutions, and assists in the deployment of these solutions. For PLM solution providers, CIMdata helps define business and market strategies, delivers worldwide market information and analyses, provides education and support for internal sales and marketing teams, as well as overall support at all stages of business and product programs to make them optimally effective in their markets.

In addition to consulting, CIMdata conducts research, provides PLM-focused subscription services, and produces several commercial publications. The company also provides industry education through PLM certification programs, seminars, and conferences worldwide. CIMdata serves clients around the world from offices in North America, Europe, and Asia-Pacific.

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References

Oroz, J., Roohi, Z. A., Abelezele, S., Fronk, G., Fawares, R. A., Pinon-Fischer, O. J., Gharbi, A., Mavris, D. N., Petersen, M., Karl, A., Matlik, J. F., & Schwering, B. (2023). Implementing the Digital Thread - A Proof-of-Concept. In AIAA SCITECH 2023 Forum. https://doi.org/10.2514/6.2023-1405

Wang K, Wang Y, Li Y, Fan X, Xiao S, &Hu, L. (2022) A review of the technology standards for enabling digital twin [version 2; peer review: 2 approved]. Digital Twin 2022, 2:4 (https://doi.org/10.12688/digitaltwin.17549.2)

Swope. K, ISO/TC 184. (2019) Data Architecture of the Digital Twin. https://www.ththry.org/activities/2020/AdHocGroup_DigitalTwin_V1R8.pdf

Appendix: ISO Digital Twin Standards

The following table[2] is an example of how an industry standards organization has aligned exiting standards to the digital twin (Swope, 2019). The table is an extract of base standards from each SC in TC 184. Note that many standards contain multiple parts. For the purpose of brevity, only the base standard title and number is identified.

Committee	Standard number	Standard title
ISO/TC 184	ISO/TS 18101-1	Oil and gas interoperability -- Part 1: Overview and fundamental principles
ISO/TC 184	ISO/TR 23087	The Big Picture of standards
ISO/TC 184/SC 1	ISO 14649	Industrial automation systems and integration -- Physical device control -- Data model for computerized numerical controllers
ISO/TC 184/SC 1	ISO 22093	Industrial automation systems and integration -- Physical device control -- Dimensional Measuring Interface Standard (DMIS)
ISO/TC 184/SC 1	ISO 23570	Industrial automation systems and integration - Distributed installation in industrial applications
ISO/TC 184/SC 1	ISO 2806	Industrial automation systems - Numerical control of machines - Vocabulary
ISO/TC 184/SC 1	ISO 2972	Numerical control of machines -- Symbols
ISO/TC 184/SC 1	ISO 3592	Industrial automation systems -- Numerical control of machines -- NC processor output -- File structure and language format
ISO/TC 184/SC 1	ISO 4342	Numerical control of machines -- NC processor input -- Basic part program reference language
ISO/TC 184/SC 1	ISO 4343	Industrial automation systems -- Numerical control of machines -- NC processor output -- Post processor commands
ISO/TC 184/SC 1	ISO 6983	Automation systems and integration -- Numerical control of machines -- Program format and definitions of address words
ISO/TC 184/SC 1	ISO 841	Industrial automation systems and integration -- Numerical control of machines -- Coordinate system and motion nomenclature
ISO/TC 184/SC 1	ISO/TR 6132	Industrial automation systems -- Numerical control of machines -- Operational command and data format
ISO/TC 184/SC 4	ISO 10303	Industrial automation systems and integration -- Product data representation and exchange
ISO/TC 184/SC 4	ISO 13584	Industrial automation systems and integration -- Parts library
ISO/TC 184/SC 4	ISO 14306	Industrial automation systems and integration -- JT file format specification for 3D visualization
ISO/TC 184/SC 4	ISO 15531	Industrial automation systems and integration -- Industrial manufacturing management data
ISO/TC 184/SC 4	ISO 15926	Industrial automation systems and integration -- Integration of life-cycle data for process plants including oil and gas production facilities
ISO/TC 184/SC 4	ISO 16739	Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries
ISO/TC 184/SC 4	ISO 18629	Industrial automation systems and integration -- Process specification language
ISO/TC 184/SC 4	ISO 18828	Industrial automation systems and integration -- Standardized procedures for production systems engineering
ISO/TC 184/SC 4	ISO 22745	Industrial automation systems and integration -- Open technical dictionaries and their application to master data
ISO/TC 184/SC 4	ISO 8000	ISO 8000 Data quality
ISO/TC 184/SC 4	ISO/PAS 17506	Industrial automation systems and integration -- COLLADA digital asset schema specification for 3D visualization of industrial data
ISO/TC 184/SC 4	ISO/TS 18876	Industrial automation systems and integration -- Integration of industrial data for exchange, access and sharing
ISO/TC 184/SC 4	ISO/TS 29002	Industrial automation systems and integration -- Exchange of characteristic data

[2] ISO TC 184 Ad Hoc Group on the Digital Twin; Version 1 Revision 8: 7 July 2019

Committee	Standard number	Standard title
ISO/TC 184/SC 5	ISO 11354	Advanced automation technologies and their applications -- Requirements for establishing manufacturing enterprise process interoperability
ISO/TC 184/SC 5	ISO 13281	Industrial automation systems – Manufacturing Automation Programming Environment (MAP LE) – Functional architecture
ISO/TC 184/SC 5	ISO 14258	Industrial automation systems -- Concepts and rules for enterprise models
ISO/TC 184/SC 5	ISO 15704	Industrial automation systems – Requirements for enterprise-reference architectures and methodologies
ISO/TC 184/SC 5	ISO 15745	Industrial automation systems and integration -- Open systems application integration framework
ISO/TC 184/SC 5	ISO 15746	Automation systems and integration -- Integration of advanced process control and optimization capabilities for manufacturing systems
ISO/TC 184/SC 5	ISO 16100	Industrial automation systems and integration – Manufacturing software capability profiling for interoperability
ISO/TC 184/SC 5	ISO 18435	Industrial automation systems and integration -- Diagnostics, capability assessment and maintenance applications integration
ISO/TC 184/SC 5	ISO 18436	Condition monitoring and diagnostics of machines -- Requirements for qualification and assessment of personnel
ISO/TC 184/SC 5	ISO 19439	Enterprise integration -- Framework for enterprise modelling
ISO/TC 184/SC 5	ISO 19440	Enterprise integration -- Constructs for enterprise modelling
ISO/TC 184/SC 5	ISO 20140	Automation systems and integration -- Evaluating energy efficiency and other factors of manufacturing systems that influence the environment
ISO/TC 184/SC 5	ISO 20242	Industrial automation systems and integration – Service interface for testing applications
ISO/TC 184/SC 5	ISO 22400	Automation systems and integration - Key performance indicators (KPIs) for manufacturing operations management
ISO/TC 184/SC 5	ISO 9506	Industrial automation systems -- Manufacturing Message Specification
ISO/TC 184/SC 5	ISO/PAS 19450	Automation systems and integration -- Object-Process Methodology
ISO/TC 184/SC 5	ISO/TR 10314	Industrial automation – Shop floor production
ISO/TC 184/SC 5	ISO/TR 11065	Industrial automation glossary
ISO/TC 184/SC 5	ISO/TR 13283	Industrial automation -- Time-critical communications architectures -- User requirements and network management for time-critical communications systems
ISO/TC 184/SC 5	ISO/TR 18161	Automation systems and integration – Applications integration approach using information exchange requirements modelling and software capability profiling