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Automation systems and integration — Digital twin framework for manufacturing —

Part 1:
Overview and general principles

Systèmes d'automatisation industrielle et intégration — Cadre technique de jumeau numérique dans un contexte de fabrication —

Partie 1: Vue d'ensemble et principes généraux

Reference number
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Contents

Page

Foreword .... **v**

Introduction .... **vi**

1 Scope **1**

2 Normative references **1**

3 Terms, definitions and abbreviated terms **1**
- 3.1 General terms 1
- 3.2 Terms related to digital twin for manufacturing 2
- 3.3 Abbreviated terms 3

4 Overview of digital twin for manufacturing **3**
- 4.1 Concept of the digital twin for manufacturing 3
- 4.2 Applications of the digital twin for manufacturing 4
  - 4.2.1 Real-time control 4
  - 4.2.2 Off-line analytics 5
  - 4.2.3 Predictive maintenance 5
  - 4.2.4 Health check 5
  - 4.2.5 Engineering design 5
  - 4.2.6 Production control 5
  - 4.2.7 Video surveillance 5
- 4.3 Benefits of the digital twin for manufacturing 5
  - 4.3.1 In-loop planning and validation 5
  - 4.3.2 Production scheduling assurance 5
  - 4.3.3 Enhanced understanding of manufacturing elements 5
  - 4.3.4 Dynamic risk management 6
  - 4.3.5 Part/assembly traceability 6
  - 4.3.6 Process traceability 6
- 4.4 Observable manufacturing elements 6
  - 4.4.1 Personnel 6
  - 4.4.2 Equipment 6
  - 4.4.3 Material 6
  - 4.4.4 Process 6
  - 4.4.5 Facility 7
  - 4.4.6 Environment 7
  - 4.4.7 Product 7
  - 4.4.8 Supporting document 7

5 General principles of the digital twin framework for manufacturing **7**
- 5.1 Overview 7
- 5.2 Limitations and boundaries of the digital twin framework for manufacturing 7
- 5.3 Requirements of the digital twin for manufacturing 8
  - 5.3.1 Accuracy 8
  - 5.3.2 Communication 8
  - 5.3.3 Data acquisition 8
  - 5.3.4 Data analysis 8
  - 5.3.5 Data integrity 8
  - 5.3.6 Extensibility 8
  - 5.3.7 Granularity 8
  - 5.3.8 Identification 8
  - 5.3.9 Management 8
  - 5.3.10 Product life-cycle 8
  - 5.3.11 Security 9
  - 5.3.12 Simulation 9
  - 5.3.13 Synchronization 9
  - 5.3.14 Viewpoint 9

5.3.15 Hierarchical modelling of digital twin for manufacturing 9
5.4 High level outline for framework implementations 9
Annex A (informative) **Digital twins and the product life-cycle** **10**
Bibliography **12**

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 4, *Industrial data*.

A list of all parts in the ISO 23247 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The ISO 23247 series defines a framework to support the creation of digital twins of observable manufacturing elements including personnel, equipment, materials, manufacturing processes, facilities, environment, products, and supporting documents.

A digital twin assists with detecting anomalies in manufacturing processes to achieve functional objectives such as real-time control, predictive maintenance, in-process adaptation, Big Data analytics, and machine learning. A digital twin monitors its observable manufacturing element by constantly updating relevant operational and environmental data. The visibility into process and execution enabled by a digital twin enhances manufacturing operation and business cooperation.

The type of manufacturing supported by an implementation of the ISO 23247 framework depends on the standards and technologies available to model the observable manufacturing elements. Different manufacturing domains can use different data standards. As a framework, this document does not prescribe specific data formats and communication protocols.

The scopes of the four parts of this series are defined below:

— ISO 23247-1: General principles and requirements for developing digital twins in manufacturing;

— ISO 23247-2: Reference architecture with functional views;

— ISO 23247-3: List of basic information attributes for the observable manufacturing elements;

— ISO 23247-4: Technical requirements for information exchange between entities within the reference architecture.

Figure 1 shows how the four parts of the series are related.

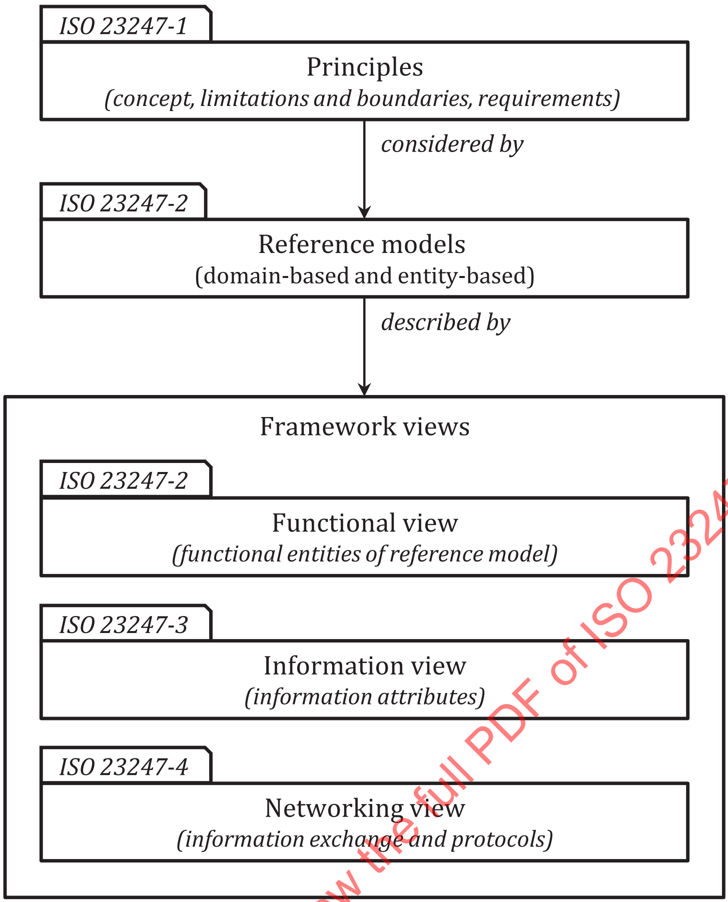

Figure 1 — ISO 23247 series structure

ISO 23247-4:2021, Annexes A to E, provide use cases that demonstrate the digital twin framework for manufacturing. The use cases are in the discrete manufacturing domain and the digital twins are modelled using the ISO 10303 series. In other domains, different standards and technologies can be used. For example, in the oil and gas industry, digital twins may be modelled using the ISO 15926 series, and for building and construction, digital twins may be modelled using the ISO 16739 series.

Automation systems and integration — Digital twin framework for manufacturing —

Part 1:
Overview and general principles

1 Scope

This document provides an overview and general principles of a digital twin framework for manufacturing including:

— terms and definitions;

— requirements of the digital twin framework for manufacturing.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 General terms

3.1.1
control
purposeful action on or in a process to meet specified objectives

[SOURCE: IEC 60050:2013, 351-42-19, modified — The Notes to entry have been removed.]

3.1.2
element
basic system part that has the characteristics of state, behaviour, and identification

[SOURCE: ISO 14258:1998, 2.2.4]

3.1.3
enterprise
one or more organizations sharing a definite mission, goals, and objectives which provides an output such as a product or service

[SOURCE: IEC 62264-1:2013]

3.1.4
entity
anything (physical or non-physical) having a distinct existence

[SOURCE: ISO/IEC 15459-3:2014, 3.1, modified — The Note to entry has been removed.]

3.1.5
Internet of Things
IoT
infrastructure of interconnected entities, people, systems and information resources together with services which processes and reacts to information from the physical and virtual world

[SOURCE: ISO/IEC 20924:2021]

3.1.6
management
direction, *control* (3.1.1), and coordination of work performed to develop a product or perform a service

[SOURCE: ISO/IEC/IEEE 24765:2017, 3.3064, modified — In the term, "process" has been removed.]

3.1.7
physical element
thing that has material existence

3.1.8
resource
any device, tool and means, except raw material and final product components, at the disposal of the *enterprise* (3.1.3) to produce goods or services

Note 1 to entry: Resources, as they are defined here, include human resources.

[SOURCE: ISO 15531-1:2004, 3.6.43, modified — Note 1 has been modified. Note 2 has been deleted.]

3.1.9
sensor
device that observes and measures a physical property of a natural phenomenon or process and converts that measurement into a signal

[SOURCE: ISO/IEC 29182-2:2013, 2.1.5, modified — "man-made" has been removed and Note 1 to entry has been deleted.]

3.1.10
universally unique identifier
UUID
computer-generated identification that, for practical purposes, is unique

3.2 Terms related to digital twin for manufacturing

3.2.1
digital identification method
<manufacturing> method selected to identify each *OME* (3.2.5) and its digital twin

Note 1 to entry: Twins can be identified using *UUIDs* (3.1.10), part numbering or some other mechanism.

3.2.2
digital representation
<manufacturing> data element representing a set of properties of an *observable manufacturing element* (3.2.5)

[SOURCE: IIC:PUB:G8V2.1:PB:20180822, modified — In the definition, "physical element" has been replaced with "observable manufacturing element".]

3.2.3
digital twin
<manufacturing> fit for purpose *digital representation* (3.2.2) of an observable manufacturing element with synchronization between the element and its digital representation

3.2.4
manufacturing process
set of processes in manufacturing involving a flow and/or transformation of material, information, energy, control, or any other element in a manufacturing area

[SOURCE: ISO 18435-1:2009, 3.16, modified — Note 1 to entry has been deleted.]

3.2.5
observable manufacturing element
OME
item that has an observable physical presence or operation in manufacturing.

Note 1 to entry: Observable manufacturing elements include personnel, equipment, material, process, facility, environment, product, and supporting document.

3.2.6
presentation
manner in which information is displayed for use by a human

Note 1 to entry: Information can be presented in any way that human can sense.

[SOURCE: ASME Y14.47-2019, modified — Note 1 to entry has been modified.]

3.2.7
representation
manner in which information is modelled for interpretation by a machine

[SOURCE: ASME Y14.47-2019, modified — In the definition, "stored" has been changed to "modelled".]

3.2.8
view
viewpoint
projection of a model, from a given perspective, which omits entities that are not relevant to this perspective

[SOURCE: ISO/IEC 19501:2005, 000_3, modified — In the definition "which is seen" has been removed before "from"; "or a vantage point and" has been removed after "perspective".]

3.3 Abbreviated terms

CAD	computer aided design
CAI	computer aided inspection
CAM	computer aided manufacturing
CNC	computerized numerical control

4 Overview of digital twin for manufacturing

4.1 Concept of the digital twin for manufacturing

A digital twin in manufacturing is a fit for purpose digital representation of an observable manufacturing element with synchronization between the element and its digital representation.

A digital twin can exist across the entire product life-cycle and leverages aspects of the virtual environment (high-fidelity, multi-physics, external data sources, etc.), computational techniques (virtual testing, optimisation, prediction, etc.), and aspects of the physical environment (historical performance, customer feedback, cost, etc.) to improve the performance of a manufacturing system.

The ISO 23247 series defines an IoT framework for digital twins in manufacturing as illustrated in Figure 2.

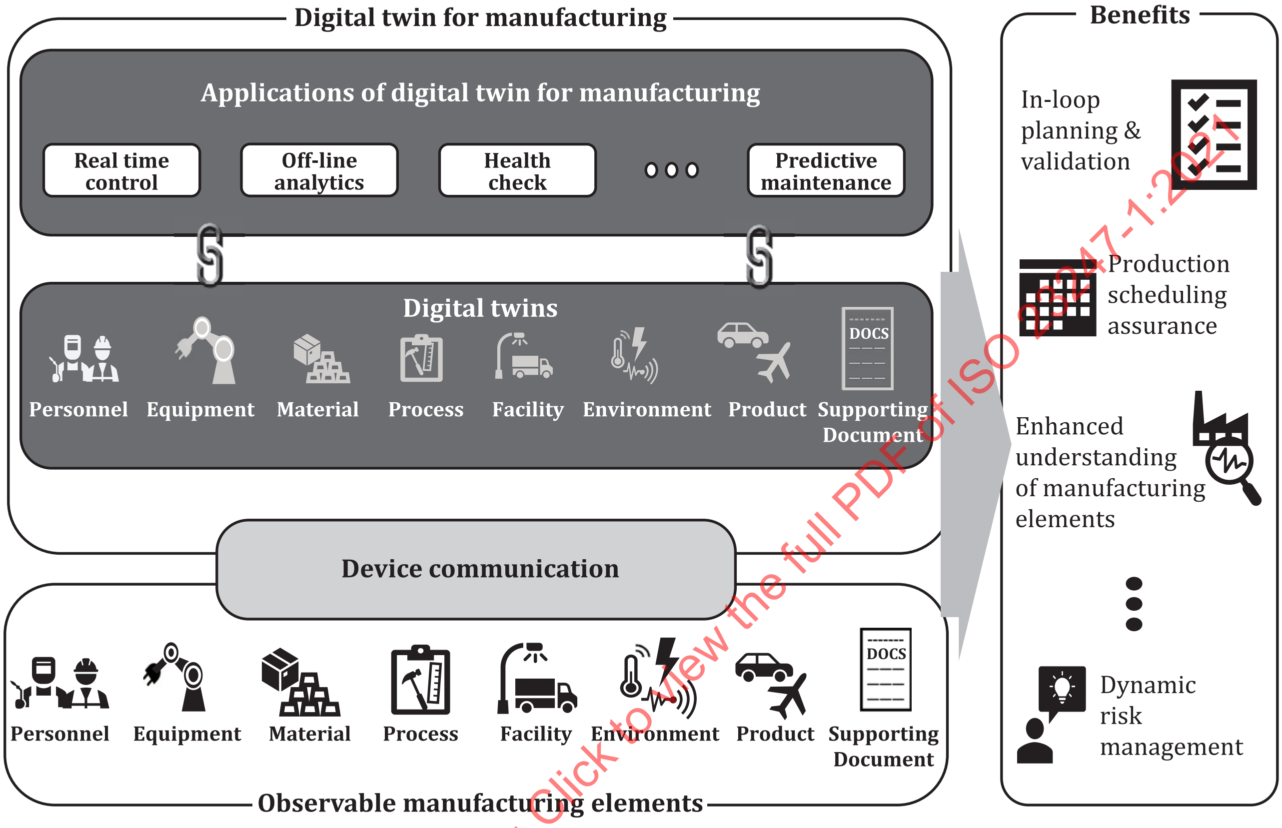

Figure 2 — IoT framework for digital twins in manufacturing

A digital twin assists with detecting anomalies in manufacturing processes and to achieve various functional objectives such as real-time control, off-line analytics, health check, predictive maintenance, synchronous monitoring/alarm, manufacturing operations management (MOM) optimization, in-process adaptation, Big Data analytics, and machine learning.

An application monitors select characteristics of OMEs by analysing digital twins. The digital twin is updated at a rate required by the application with relevant operational and environmental data such as the status, conditions, product geometries, and manufacturing resources. A digital twin may recall previous states or predict future states of its OME. The visibility into process and execution enabled by a digital twin enhances business cooperation and multiple other efficiencies such as in-loop planning and validation, production scheduling assurance, dynamic risk management, and cost reduction.

Examples of applications and benefits are given in 4.3 and 4.4, but are not limited to those provided.

4.2 Applications of the digital twin for manufacturing

4.2.1 Real-time control

A real-time control application monitors the OMEs through their digital twins and makes necessary changes to a manufacturing process in real-time.

4.2.2 Off-line analytics

An off-line analytics application compares the digital twins of multiple OMEs to determine trends and changes and make recommendations for future changes to manufacturing processes.

4.2.3 Predictive maintenance

A predictive maintenance application uses digital twins to schedule and adapt maintenance activities for OMEs that are production equipment. The application may operate in real-time or off-line.

4.2.4 Health check

A health check application uses digital twins to check conditions of OMEs and if necessary, schedule maintenance.

4.2.5 Engineering design

An engineering design application uses digital twins to learn about previously manufactured products to optimise new and existing product designs.

4.2.6 Production control

A production control application uses digital twins to make optimal scheduling decisions.

4.2.7 Video surveillance

A video surveillance or imaging application monitors an OME to validate its state and enable analysis by people and artificial intelligence systems.

4.3 Benefits of the digital twin for manufacturing

4.3.1 In-loop planning and validation

The digital twin for manufacturing facilitates in-loop planning, validation, and adjustment of manufacturing processes.

In-loop planning can be utilized to dynamically re-sequence and adjust a manufacturing process during production in response to exceptions that occur on the shop floor. In-loop validation can be used to confirm that a manufacturing process has completed successfully.

4.3.2 Production scheduling assurance

The digital twin for manufacturing facilitates real-time monitoring of production, allowing management to dynamically adjust throughput to meet a production schedule.

Sophisticated manufacturing processes adapt in real-time to variations in the manufacturing environment. These variations include changes in material characteristics and equipment. The digital twin of a manufacturing process enables prediction of the completion time of a manufacturing process. This prediction can be used to adjust scheduling at the factory level, and/or optimise the manufacturing process.

4.3.3 Enhanced understanding of manufacturing elements

The digital twin for manufacturing facilitates more accurate modelling of equipment reliability, accuracy, and productivity.

The digital twin can be used to reduce costs by predicting equipment failures earlier, improve production rates by adjusting processes more quickly, and enhance productivity by resolving scheduling issues without interrupting production.

4.3.4 Dynamic risk management

The digital twin for manufacturing facilitates real-time control, off-line analytics, predictive maintenance, and health checks.

Digital twins provide context for any anomalies that may occur during a manufacturing process, for example, collisions or equipment failures. The continuous integration enables just in time risk management so that resource allocation and process improvements can be made constantly during production.

4.3.5 Part/assembly traceability

The digital twin for manufacturing facilitates part validation and adjustment of downstream processes.

A digital twin can be used to automatically generate downstream process instructions for the completion of a part, or can be used in a final validation of the completed part/assembly.

4.3.6 Process traceability

The digital twin for manufacturing facilitates the tracking and validation of production sequences.

A digital twin for an executed process can be validated against requirements to show they have been met. The flexibility to make changes to processes allows schedules to be adjusted and material to be modified without slowing or interrupting production.

4.4 Observable manufacturing elements

4.4.1 Personnel

Personnel in manufacturing generally include those employees who are engaged directly or indirectly in manufacturing processes.

NOTE A personnel digital twin can model availability, certification level, or other key attributes relevant to manufacturing. It is not required to be a full three-dimensional model of a human.

4.4.2 Equipment

Equipment is a physical element that carries out an operation that is directly or indirectly involved in manufacturing processes. Examples of equipment include hand tools, CNC machines, conveyer belts, and robots.

4.4.3 Material

Material is physical matter that is used to produce a manufactured product such as a metal block, or that aids the manufacturing process such as coolant.

4.4.4 Process

A process is an observable sequence of physical operations in manufacturing. Processes may include fabrication processes, assembly processes, inspection processes, maintenance processes, and management processes.

4.4.5 Facility

Facility is infrastructure that is related to or affects manufacturing. Examples of facility are special purpose rooms, buildings, energy supply, water supply, environmental controllers, etc.

4.4.6 Environment

Environment is a necessary condition that is supplied by facilities for the correct execution of a manufacturing process. Examples of environmental conditions are temperature, humidity, and luminance.

4.4.7 Product

A product is an output of a manufacturing process. Depending on the manufacturing process stage, from a business perspective, a product can be classified as an intermediate product or an end product.

4.4.8 Supporting document

A supporting document is any form of artefact (requirement, plan, model, specification, and configuration) that assists manufacturing.

5 General principles of the digital twin framework for manufacturing

5.1 Overview

The digital twin framework for manufacturing provides guidance on how to construct a digital twin for manufacturing. The framework does not require the adoption of any specific implementation technology.

5.2 Limitations and boundaries of the digital twin framework for manufacturing

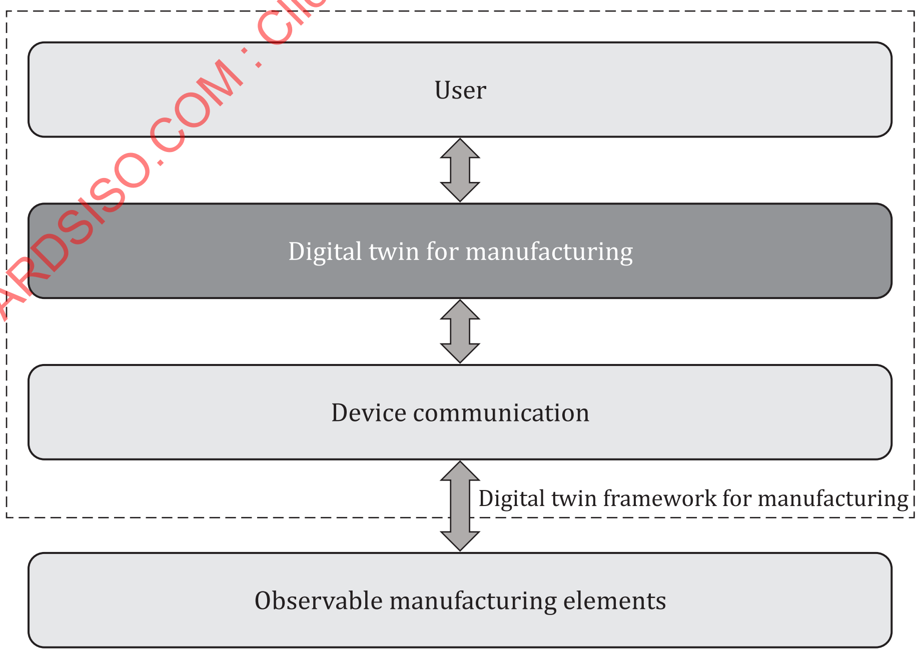

Figure 3 — Boundary of the digital twin framework for manufacturing

Figure 3 shows the boundary of the framework. A digital twin and the physical world, depicted as observable manufacturing elements, are connected and synchronized through device communication.

Synchronization between digital twins and OMEs ensures that the manufacturing systems are constantly optimised as the digital twins receives real-time performance information from the physical system.

The digital twin is implemented using appropriate methods and tools with specific objectives and scope. The integration between model components within a digital twin is enabled through application of relevant interoperability standards as described in ISO 23247-2, ISO 23247-3, and ISO 23247-4.

A digital twin is context-dependent and could be a partial representation of a physical system. It may consist only of relevant data and models that are specifically designed for their intended purpose. Different views and representations of the same OME are synchronized by using an identification method that allows the views and representations to be connected through different stages of the product life-cycle.

5.3 Requirements of the digital twin for manufacturing

5.3.1 Accuracy

A digital twin shall describe the state of its corresponding OME at an appropriate level of fidelity.

5.3.2 Communication

A digital twin shall be connected to an OME using communicate protocols that enable synchronization.

5.3.3 Data acquisition

A digital twin shall collect data from sensors installed on or around an OME. The sensors may be integral or remote to the manufacturing equipment.

5.3.4 Data analysis

A digital twin shall enable analysis of the state of its OME.

5.3.5 Data integrity

A digital twin shall correctly describe the state of its OMEs.

5.3.6 Extensibility

A digital twin shall be extensible to new applications.

5.3.7 Granularity

A digital twin shall provide insight into the state of its OME at appropriate levels of detail.

5.3.8 Identification

A digital twin shall contain data that uniquely selects its OME.

5.3.9 Management

A digital twin shall enable optimization of resources.

5.3.10 Product life-cycle

A digital twin shall support information continuity throughout the product life-cycle including design, planning, manufacturing, and maintenance. Examples of product life-cycle digital twins are given in Annex A.

5.3.11 Security

A digital twin shall only communicate with authorized resources.

5.3.12 Simulation

A digital twin shall enable simulation of an observable manufacturing element in operation.

5.3.13 Synchronization

A digital twin and its observable manufacturing element shall be updated to each other's value using an appropriate method. The method may be event-based or time-based. An event-based method updates the twin in response to an event. A time-based method updates the twin continuously by reading values from a time-stamped data stream.

5.3.14 Viewpoint

A digital twin shall support different views for different objectives.

5.3.15 Hierarchical modelling of digital twin for manufacturing

A digital twin shall model any level of the functional and role-based hierarchy defined in IEC 62264-1.

5.4 High level outline for framework implementations

The following is an outline of how the framework can be applied to a manufacturing application. Detailed examples are given in ISO 23247-4:2021, Annexes A to E.

— A digital identification method is selected for the OMEs that are to be twinned. Selection of a single, consistent identification method, such as UUID's, reduces implementation complexity.

— Standards and technologies are selected for the data collected from the OMEs.

— Standards and technologies are selected for the control of the OMEs.

— Standards and technologies are selected for the digital representations of the OMEs.

— Standards and technologies are selected for communication between the OME, device communication and digital twin levels.

— Standards and technologies are selected for communication with the user applications of the enterprise.