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Automation systems and integration — Digital twin framework for manufacturing —

Part 4:
Information exchange

Systèmes d'automatisation industrielle et intégration — Cadre technique de jumeau numérique dans un contexte de fabrication — Partie 4: Échange d'informations

Reference number
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Foreword

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This document was prepared by Technical Committee ISO/TC 184, *Industrial 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.

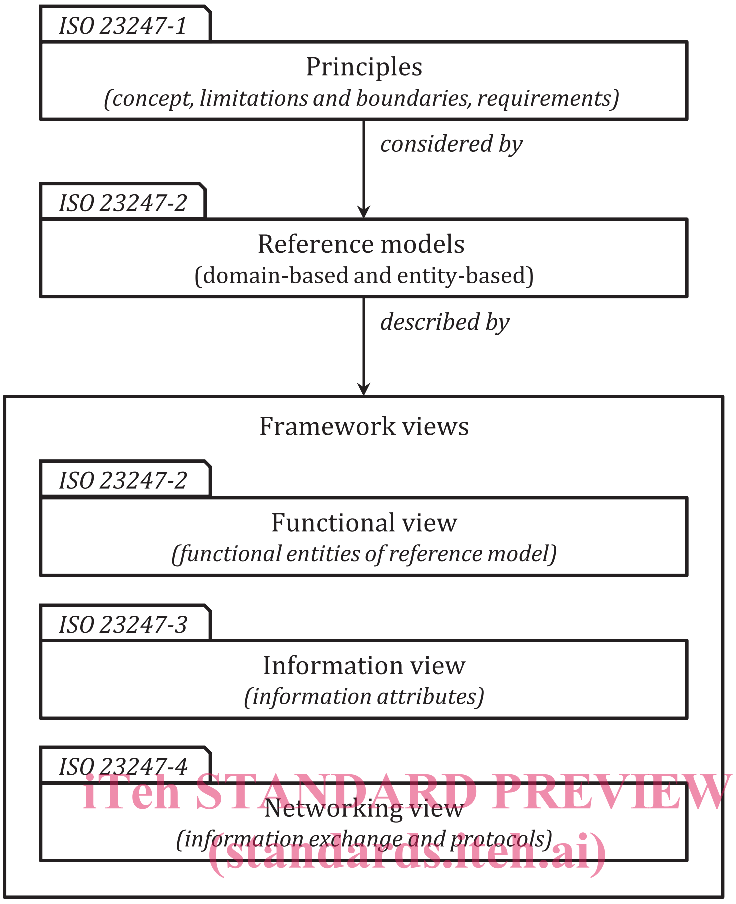


Figure 1 — ISO 23247 series structure

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 oil and gas, the digital twins may be modelled using the ISO 15926 series, and for building and construction, the digital twins may be modelled using the ISO 16739 series.

Automation systems and integration — Digital twin framework for manufacturing —

Part 4: Information exchange

1 Scope

This document identifies technical requirements for information exchange between entities within the reference architecture.

The requirements for information exchange in the following networks are within the scope of this document:

— user network that connects the user entity and the digital twin entity;

— service network that connects sub-entities within the digital twin entity;

— access network that connects the device communication entity to the digital twin entity and to the user entity;

— proximity network that connects the device communication entity to the observable manufacturing elements.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 23247-1, *Automation systems and integration — digital twin framework for manufacturing — Part 1: Overview and general principles*

ISO 23247-2, *Automation systems and integration — digital twin framework for manufacturing — Part 2: Reference architecture*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 23247-1 and the following apply.

ISO and IEC maintain terminological 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
device communication entity
(set of) system or device providing device communication

EXAMPLE A cell controller sending instructions to the devices in a manufacturing cell, and collecting results from sensors on the devices

[SOURCE: ISO 23247-2:—, 3.4]

3.2
digital twin entity
(set of) system(s) providing functionalities for the digital twins such as realisation, management, synchronization, and simulation

EXAMPLE A system providing simulation, synchronization, and data analytics for a manufacturing cell

[SOURCE: ISO 23247-2:—, 3.6]

3.3
user entity
human users, applications, and systems that use the services provided by the digital twin entity

EXAMPLE An enterprise resource planning (ERP) system that uses the application programming interfaces (APIs) provided by a digital twin application to update the current status of resources in its database

[SOURCE: ISO 23247-2:—, 3.8]

3.4
visualization
<computer graphics> use of computer graphics and image processing to present models or characteristics of processes or objects for supporting human understanding

Note 1 to entry: Example: A visual display of a computerized numerical control (CNC) machine milling an aluminium block.

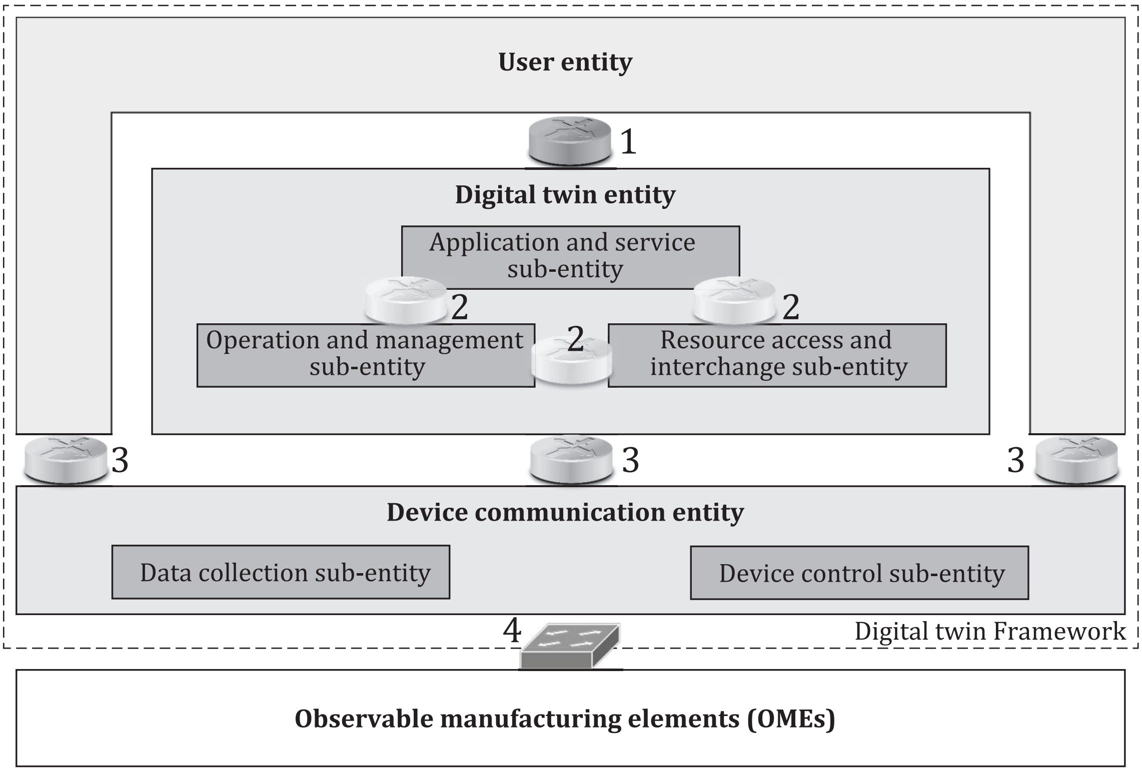
[SOURCE: ISO/IEC 2382:2015, modified — Note 1 to entry changed to address manufacturing examples. Note 2 to entry and Note 3 to entry deleted.]

4 Networking view of the digital twin reference models

4.1 Overview

ISO 23247-2 defines reference models of the digital twin framework for manufacturing, and a functional view of those reference models. This document defines a networking view. The networking view shall apply to the reference models given in ISO 23247-2.

Figure 2 shows the four types of communication networks that are used to connect the entities described in the reference models of ISO 23247-2.



Key

1 user network
2 service network
3 access network
4 proximity network

Figure 2 — Networking view of digital twin reference models

4.2 User network

The user network connects the user entity with the digital twin entity. Through this network, the user entity makes use of the digital twin instances managed by the digital twin entity.

The user network can be either public Internet or private intranet.

4.3 Service network

The service network connects the operation and management sub-entity, application and service sub-entity, and resource access and interchange sub-entity. The service network is typically a wired network running IP-based protocols.

If the digital twin entity is implemented as a single private system, then a service network is not necessary.

4.4 Access network

The access network connects the device communication entity with the digital twin entity and the user entity. The data collection sub-entity transmits data collected from the OMEs to the digital twin entity. The device control sub-entity transmits commands from the user entity or the digital twin entity to control the OMEs.

The access network can be a wired communication network such as local area network (LAN) or wireless communication network such as wireless LAN (WLAN) and mobile (cellular) network. The access network generally adopts IP-based communication protocols regardless of communication type.

4.5 Proximity network

The proximity network connects the device communication entity with the OMEs. Through this network, the device communication entity transmits commands to OMEs that are industrial devices, and receives results from OMEs that are industrial sensors.

The proximity network can be an Industrial Ethernet or a proprietary network with a specialized configuration. Some networks use protocols other than IP. However, if an OME is physically attached or integrated into the device communication entity then the proximity network is not necessary.

5 Requirements for information exchange in the user network

5.1 Overview

The user network shall enable the exchange of information between the user entity and the digital twin entity. The information shall be exchanged to enable services and applications such as visualization, process monitoring, statistical analysis, and simulation. The information is defined in ISO 23247-3.

5.2 Provisioning

The user network shall enable the delivery of information to configure a digital twin to an initial state.

EXAMPLE 1 The digital twin of a product is provisioned at the start of its life from information contained in Product lifecycle management (PLM). This information can be product requirements, 3D models, configuration, simulation models, and traceability.

EXAMPLE 2 The digital twin of a work cell is provisioned at the start of its life from information in PLM or other data sources. This information can be kinematics, capacity, capability, certification, and calibration

EXAMPLE 3 The digital twin of a process is provisioned at the start of its life from information in PLM or other data sources. This information can be high-level and low-level process plans, production schedule, and manufacturing requirements.

5.3 On-demand status acquisition

The user network shall enable the delivery of information on the current state of the OMEs as represented by its digital twin.

The user network shall enable the delivery of information on the historical state of the OMEs as represented by its digital twin.

EXAMPLE 1 A user entity queries a digital twin entity, so that it can show the current status of a machine by creating a visualization of the current geometry of a part.

EXAMPLE 2 A user entity queries a digital twin entity, so that it can dynamically predict the remaining life for a cutting tool by analysing its previous machining activities.

5.4 Standardized method for information exchange

The user network shall use standardized methods for exchanging information.

NOTE As described in A.2.1, examples for standardized protocol include REST and HTTP.

5.5 Verification of exchanged digital models

The standardized method for information exchange should include methods for verifying the syntax and semantics of the exchanged model and validating its contents.

NOTE As described in A.2.1, examples of information models with methods for checking syntax and semantics include STEP and QIF.

5.6 Security

The user network shall maintain security and privacy of the digital twin.

NOTE Standard such as IEC 62443 define a protocol for secure communication.

5.7 Synchronization

The user network shall enable applications to operate on digital models that have been appropriately synchronized. The rate of synchronization depends on the application.

5.8 Exchange of digital models

The user network shall enable exchange of information about the digital representation of the OMEs. The communication shall allow applications to operate on common models of the OMEs. Depending on the application, it is possible that the types of OMEs shown in Figure 3 need to be modelled for information exchange.

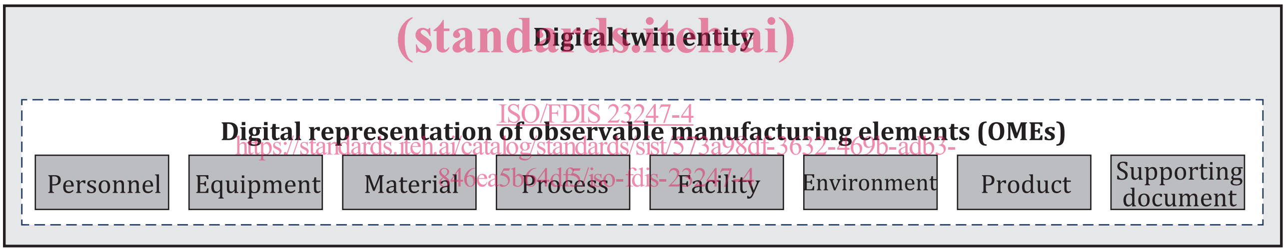


Figure 3 — Type of digital models for exchange

NOTE Several standards define information for one or more of the OME types but no single standard has been identified for all types of OME at the time of publication.

6 Requirements for information exchange in the service network

The Service network is used to transmit information between sub-entities of the digital twin entity. As such, this network can be private to a particular implementation of the digital twin entity and does not need to be defined by this document.

7 Requirements for information exchange in access network

7.1 Overview

The access network connects the device communication entity to other entities. The device communication entity collects information about the OMEs as they operate using an appropriate streaming protocol. The device communication entity controls the OMEs by sending commands in a language understood by the OMEs.

7.2 Connectivity

Depending on the circumstances, a connection to the device communication entity may be discovered dynamically using an appropriate protocol or using a fixed network address. In either case, the connection delivers data about the OMEs to the digital twin entity.

EXAMPLE 1 With a fixed network address, an MTConnect agent for a machine tool on the shop floor is published to the network as URL 192.168.0.1:5000. In this case, the digital twin for the machine tool uses this address to listen for changes to its OME.

EXAMPLE 2 With a dynamic network address, an MQTT subscriber discovers the availability of a data stream from the device communication entity responsible for the OMEs and uses the information to update its digital twin.

7.3 Standardized method for communication

The access network shall provide a standardized method for delivering data collected by the device communication entity. The method shall include information sufficient to identify the OMEs, and describe each change that has occurred to a monitored characteristic of the OME.

The access network shall provide a standardized method for delivering data to control the OMEs through the device communication entity.

7.4 Synchronization

The access network shall enable the digital twin to be connected to its OME. The bandwidth and latency shall be sufficient to support the required level of synchronization.

NOTE 1 IEC has defined standards that describe various synchronization methods for industrial enterprises.

NOTE 2 The latency requirements for servicing an urgent fault or alarm are different to those for updating a 3D model.

7.5 Transaction method

The access network shall support any of the three types of transaction methods that follow:

— PULL method: requester requests information from the provider;

NOTE 1 The digital twin entity is the requester and the device communication entity is the provider.

— PUSH method: sender sends new or changed information to the receiver;

NOTE 2 The digital twin entity is the receiver and the device communication entity is the sender.

— PUBLISH method: publisher publishes data to be received by the subscribers.

NOTE 3 The digital twin entity is the subscriber and the device communication entity is the publisher.

The PUBLISH method is recommended, when multiple digital twin entities are listening to a single device communication entity.

7.6 Support of mobility

If the network location of the device communication entity changes, then the access network shall maintain the connectivity to its digital twin.

7.7 Security

The access network shall maintain security and privacy of the digital twin.

NOTE Standards such as IEC 62443 define protocols for secure communication.

8 Requirements for information exchange in proximity network

8.1 Overview

The proximity network is an interface between the device communication entity and the OMEs. The proximity network is not necessary if the device communication entity is hosted on the OME.

8.2 Support of local connectivity

The proximity network shall connect the device communication entity to the OMEs using industrial ethernet or a proprietary network.

8.3 Support of adaptation

The proximity network shall support adaptation of data received from OMEs to data that is understood by the device communication entity.

8.4 Support of data volume, transmission efficiency, and storage

The proximity network shall support data volume, transmission efficiency, and storage necessary to transmit information between the device communication entity and OMEs.

Annex A
(informative)

Technical discussion — Implementation options for digital twin framework for manufacturing

A.1 Acronyms used in Annexes A to E

This clause lists acronyms of protocols or standards that can be considered as an implementation options of digital twin framework for manufacturing.

3D PDF	3-dimensional portable document format
AAS	asset administration shell
AES	advanced encryption standard
AMF	additive manufacturing file format
API	application program interface
ASTM	American society for testing and materials
AutomationML	automation markup language
B2MML	business to manufacturing markup language
CAD	computer aided design
CAM	computer aided manufacturing
CBC	cipher-block chaining
CCM	counter with CBC-MAC
CFX	connected factory exchange
COLLADA	collaborative design activity
EASA	European aviation safety agency
ECDHE	elliptic-curve diffie–hellman
EtherCAT	ethernet for control automation technology
FAA	federal aviation administration
FBX	filmbox
HTTP	hypertext transfer protocol
IoT	Internet of Things
IPC	inter-process communication

ISA	international society of automation
JSON	Javascript object notation
JT	Jupiter tessellation
LwM2M	lightweight machine to machine
MES	manufacturing execution system
MOM	manufacturing operations management
MQTT	message queuing telemetry transport
MTConnect	machine tool connect
OCF	open connectivity foundation
OPC-UA	open platform communications - unified architecture
OpenGL	open graphics library
PLC	programmable logic controller
PSK	phase-shift keying
QIF	quality information framework
RAPINet	real-time automation protocols for industrial ethernet
RDF	resource description framework
REST	representational state transfer
RSA	Rivest–Shamir–Adleman
SHA	secure hash algorithm
STEP	STandard for the Exchange of Product model data
STL	standard template library
TSN	time-sensitive networking
WebGL	web graphics library
XML	extensible markup language

A.2 Information exchange examples

A.2.1 General

Figure A.1 shows how information may be exchanged within a digital twin framework using currently available communication protocols.