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Automation systems and integration – Digital Twin framework for manufacturing – Part 1: Overview and general principles

DIS stage

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Foreword

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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

ISO 23247 series defines a framework to support the creation of Digital Twins of observable manufacturing elements including personnel, equipment, materials, processes, facilities, environment, and products.

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

- Part 1: Overview and general principles

  Provides an overview of Digital Twin for manufacturing, describes general principles, and provides requirements and guidance for developing a Digital Twin framework for manufacturing;

- Part 2: Reference architecture

  Provides a reference architecture goals and objectives, reference model, and reference architectural views for a Digital Twin framework for manufacturing

- Part 3: Digital representation of manufacturing elements

  Identifies manufacturing elements of the Digital Twin framework for manufacturing that shall be represented in digital models;

- Part 4: Information exchange

  Identifies technical requirements for information synchronization and information exchange within the Digital Twin framework for manufacturing.

The types of manufacturing that can be supported by an implementation of the framework will depend on the technologies selected to implement its functional elements.

Use cases for Digital Twin framework for manufacturing will be detailed in technical reports attached to this series of standards.

Automation systems and integration – Digital Twin framework for manufacturing – Part 1: Overview and general principles

1 Scope

This part of ISO 23247 provides an overview and general principles of Digital Twin for manufacturing.

ISO 23247 series defines a framework to support the creation of Digital Twins of observable manufacturing elements including personnel, equipment, materials, processes, facilities, environment, and products.

The following are within the scope of this part of ISO 23247;

- scope statement for ISO 23247 as a whole;
- overview of ISO 23247;
- structure of ISO 23247;
- terms and definitions used throughout ISO 23247;
- overview of Digital Twin framework for manufacturing;
- requirements of Digital Twin for manufacturing.

The following are described in other parts of ISO 23247;

- reference architecture of the Digital Twin framework for manufacturing (Part 2);
- digital representation of manufacturing elements of the Digital Twin framework for manufacturing (Part 3);
- information exchange of the Digital Twin framework for manufacturing (Part 4);
- use cases of the Digital Twin framework for manufacturing to be detailed in technical reports.

The following are outside of the scope of ISO 23247;

- selection of the implementation methods and technologies for a Digital Twin for manufacturing;
- selection of the communication protocols for a Digital Twin for manufacturing;
- selection of the manufacturing devices and other resources to be represented by a Digital Twin;
- selection of the manufacturing processes to be represented by a Digital Twin;
- selection of the manufacturing products to be represented by a Digital Twin;
- design and process planning, and other non-manufacturing stages of the product lifecycle.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 http://www.electropedia.org/

3.1 General terms

3.1.1
actuator

device that provides a physical output in response to an input signal in a predetermined way

[SOURCE: ISO/IEC 29182‐2]

3.1.2
area

physical, geographical or logical grouping of resources determined by the site

[SOURCE: IEC 62264-1:2013]

3.1.3
control

purposeful action on or in a process to meet specified objectives

[SOURCE: IEV 351-42-19]

3.1.4
element

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

[SOURCE: ISO 14258:1998, 2.2.4]

3.1.5
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]

3.1.6
entity

thing (physical or non-physical) having a distinct existence

[SOURCE: ISO/IEC 15459-3:2014, 3.1]

3.1.7
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 20924:2018]

3.1.8
management

direction, control, and coordination of work performed to develop a product or perform a service

[SOURCE: ISO/IEC/IEEE 24765:2017, 3.3064]

3.1.9
physical element

thing that has material existence in physical world

3.1.10
resource

any device, tool and means, except raw material and final product components, at the disposal of the enterprise to produce goods or services

Note 1 to entry: Resources as they are defined here include human resources considered as specific means with a given capability and a given capacity. Those means are considered as being able to be involved in the manufacturing process through assigned tasks. That does not include any modelling of an individual or common behaviour of human resource except in their capability to perform a given task in the manufacturing process (e.g.: transformation of raw material or component, provision of logistic services). That means that human resources are only considered, as the other, from the point of view of their functions, their capabilities and their status (e.g.: idle, busy). That excludes any modelling or representation of any aspect of individual or common «social» behaviour.

Note 2 to entry: This definition includes ISO 10303-49 definition.

[SOURCE: ISO 15531-1:2004, 3.6.43]

3.1.11
sensor

device that observes and measures a physical property of a natural phenomenon or man-made process and converts that measurement into a signal

Note 1 to entry: Signal can be electrical, chemical, etc.

[SOURCE: ISO/IEC 29182-2]

3.1.12
task

activities required to achieve a goal

Note 1 to entry: These activities can be physical and/or cognitive.

[SOURCE: ISO 9241‑11:1998, 3.9]

3.2 Digital Twin manufacturing specific terms

3.2.1
digital entity

computational and/or data element

Note 1 to entry: A digital entity can exist as a cloud service or as a service in a data centre, or as a network element or as an IoT gateway.

[SOURCE: ISO/IEC 20924:2018, 3.1.14]

3.2.2
digital model

fit for purpose digital representation of something designed to support decisions related to it

Note 1 to entry: It is recognized that some practitioners in some industries may refer to this as a "Digital Twin." For the purpose of this document, "Digital Twin" refers to a specific subclass of digital models.

3.2.3
Digital Twin

fit for purpose digital representation of some realized thing or process with a means to enable convergence between the realised instance and digital instance at an appropriate rate of synchronisation

3.2.4
Digital Twin modelling

procedure of creating a digital model of an observable element

3.2.5
manufacturing process

structured set of activities or operations performed upon material to convert it from the raw material or a semi-finished state to a state of further completion

Note 1 to entry: Manufacturing processes may be arranged in process layout, product layout, cellular layout or fixed position layout. Manufacturing processes may be planned to support make-to-stock, make-to-order, assemble-to-order, etc., based on strategic use and placements of inventories.

[SOURCE: ISO 15531-1:2004, 3.6.25]

3.2.6
presentation

manner in which information is displayed for use by a human Note 1 to entry: Digital model can be presented audibly and visually.

[SOURCE: ASME Y14.47-2019]

3.2.7 representation

manner in which information is stored for interpretation by a machine

[SOURCE: ASME Y14.47-2019]

3.2.8
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: Examples: A display image of a CNC machine milling an aluminium block.

Note 2 to entry: scientific visualization; visualization: terms and definition standardized by ISO/IEC [ISO/IEC 2382-13:1996].

[SOURCE: ISO/IEC 2382:2015, 2125942, Note 1 to entry changed to address manufacturing examples. Note 3 to entry deleted]

3.2.9
view/viewpoint

projection of a model, seen from a given perspective or vantage point and which omits entities that are not relevant to this perspective

[SOURCE: ISO/IEC 19501:2005]

3.3 Abbreviated terms

API	Application Program Interface
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
DCDCD	Data Collecting and Device Controlling Domain
DTME	Digital Twin of Observable Manufacturing Element
ERP	Enterprise Resource Planning
IE	Information Exchange
IoT	Internet of Things
IPC	Inter-Process Communication
MES	Manufacturing Execution System
O&M	Operation and Management
OME	Observable Manufacturing Element

4 Overview of Digital Twin for manufacturing

4.1 Concept of Digital Twin

A Digital Twin is a fit for purpose digital representation of some realized thing or process with a means to enable convergence between the realised instance and the digital instance at an appropriate rate of synchronisation

Digital Twin may exist across the entire life-cycle and can leverage 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 elements of the overall system (design, behaviour, manufacturability, etc.). [15]

NOTE Definitions in this document are being harmonized with those in Ad Hoc Group Digital Twin, currently published as ISO/TC 184/SC 1 N517.

4.2 Digital Twin for manufacturing

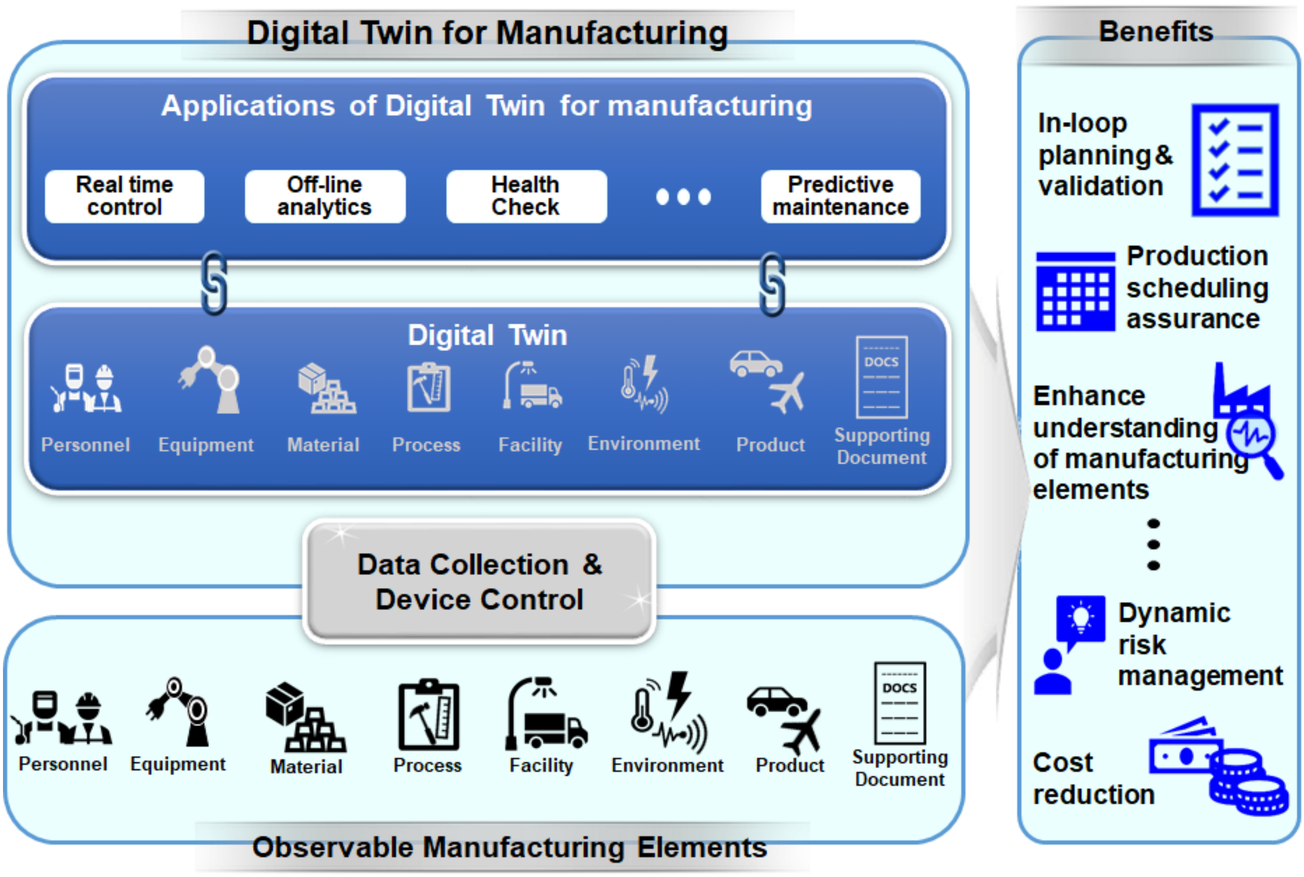

Figure 1 – Concept of Digital Twin for manufacturing

A Digital Twin for manufacturing updates as its physical counterpart changes to represent its status, conditions, product geometries, states of resources, and any other observable status and conditions.

A Digital Twin is kept current with its observable manufacturing elements at an appropriate rate of synchronization. Additionally, a Digital Twin for manufacturing may recall previous states of the observable manufacturing elements.

The Digital Twin enables functionalities to synchronize its representation with its corresponding observable manufacturing elements by constantly exchanging operational and environmental data.

A Digital Twin assists with detecting anomalies in the 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, machine learning, etc.

The visibility into process and execution enabled by Digital Twin for manufacturing enhances business cooperation and multiple other efficiencies such as in-loop planning and validation, production scheduling assurance, enhancement of understanding manufacturing elements, dynamic risk management, cost reduction, etc.

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

4.3 Applications of Digital Twin for manufacturing

4.3.1 Real time control

A real time control application uses the current state of the Digital Twins to make changes to a manufacturing process in real time.

4.3.2 Off-line analytics

An off-line analytics application uses the changed state of the Digital Twins to make recommendations about the manufacturing process.

4.3.3 Predictive maintenance

A predictive maintenance application is a real-time or off-line application that uses the Digital Twins to schedule and adapt maintenance activities for the production equipment.

4.3.4 Health check

A health check application uses the Digital Twins to check conditions of observable manufacturing elements and if necessary, schedules maintenance.

4.3.5 Engineering design

An engineering design application uses Digital Twins to learn about previously manufactured products to optimize new and existing product designs.

4.4 Benefits of Digital Twin for manufacturing

Use case technical reports will provide examples on how to achieve these benefits.

4.4.1 In-loop planning and validation

Digital Twin for manufacturing facilitates in-loop planning, validation, and adjustment of manufacturing processes through simulation.

4.4.2 Production scheduling assurance

Digital Twin for manufacturing facilitates real time monitoring of production, allowing management to dynamically adjust the manufacturing throughput to meet a production schedule.

4.4.3 Enhanced understanding of manufacturing elements

Information of observable manufacturing elements contained within Digital Twins facilitates accurate planning of manufacturing and production schedules.

4.4.4 Dynamic risk management

Applications of Digital Twin for manufacturing such as real time control, off-line analytics, predictive maintenance, health check, etc., allows management to improve prediction and control of current and future risks.

4.4.5 Cost reduction

Overall, various applications of Digital Twin for manufacturing reduce manufacturing and management cost.

4.5 Elements of Digital Twin for manufacturing

4.5.1 Observable manufacturing element

An observable manufacturing element is an item that has observable physical presence or operation in manufacturing.

4.5.1.1 Personnel

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

NOTE In Digital Twin for manufacturing, availability and certification level of personnel are examples of digital models.

4.5.1.2 Equipment

Equipment is a physical element that carries out an operation that is directly or indirectly involved in manufacturing processes. Examples of equipment are hand tools, a CNC machine, a conveyer belt, robots, etc.

4.5.1.3 Material

Material is physical matter that becomes a part or the whole of a product i.e., metal block, glass panel, etc., or is used to aid manufacturing processes, i.e., cleaning fluid, coolant, etc.

4.5.1.4 Process

A process is an observable physical operation within manufacturing. Processes are inclusive of manufacturing processes, maintenance processes, management processes, etc.

4.5.1.5 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.

4.5.1.6 Environment

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

4.5.1.7 Product

Product is a desired output or by-product of 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.

4.5.1.8 Supporting document

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

4.5.2 Digital elements

4.5.2.1 Application of Digital Twin for manufacturing

An application operating on the Digital Twin for manufacturing reports on, makes predictions about, or executes adjustments to the current state of manufacturing elements.

4.5.2.2 Product definition

A product definition is specifications or properties of a product that are necessary to characterise it such as dimensions, tolerances, surface finish, etc.

4.5.2.3 Process definition

A process definition is a specification of the personnel, equipment, material resources, and operations that are required to perform a manufacturing process.

5 General principles of 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, specifies how applications can interoperate, and how data from different sources can be integrated. However, it does not specify any implementation technologies.

5.2 Standardization Scope of Digital Twin framework for manufacturing

5.2.1 Limitations and boundaries

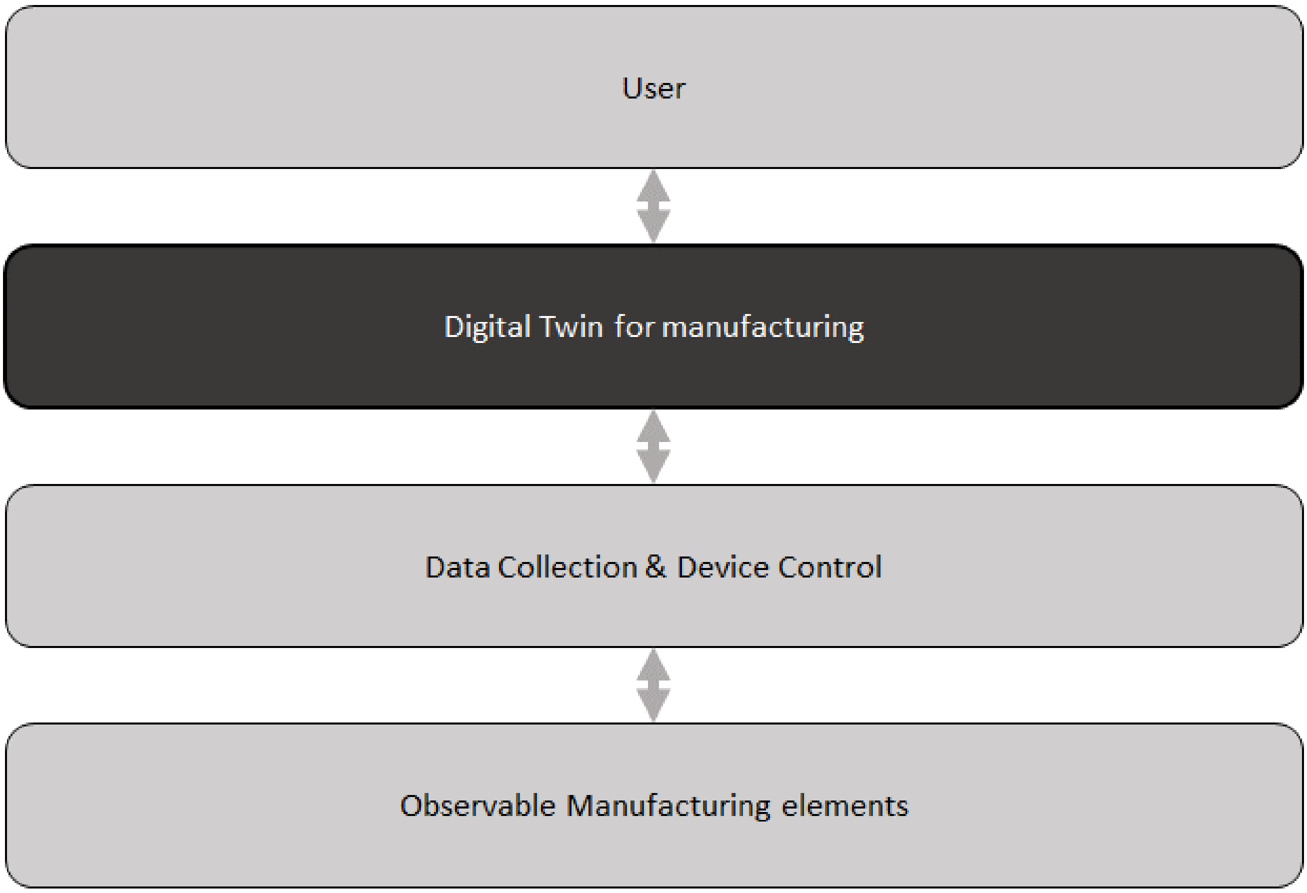

Figure 2 – High-level Concept of Digital Twin framework for manufacturing

Figure 2 shows the high-level concept of Digital Twin framework for manufacturing. Digital Twin and the physical world, depicted as Physical Manufacturing, are connected and synchronized through Data Collection & Device Control medium. Synchronization between digital entities and physical manufacturing elements, either online or offline, ensures that the manufacturing systems are constantly optimized 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 objective and scope. The integration between model components within a Digital Twin is enabled through application of relevant interoperability standards.

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.

5.3 Requirements of Digital Twin for manufacturing

5.3.1 General requirements

5.3.1.1 Data acquisition

A Digital Twin for manufacturing shall collect sensory data using sensors installed on or around manufacturing equipment.

NOTE Sensors for the identification and/or detection of presence of personnel might be installed in specific access control facilities

5.3.1.2 Communication

Communication shall transfer data or information between elements of Digital Twin for manufacturing.

5.3.1.3 Presentation

Information shall be represented in a format that human or computer can recognize. Examples of a recognizable format are audio, video, image, text, data bitstream, etc.

5.3.1.4 Data analysis

Data acquired in manufacturing processes shall be analysed to understand the state of observable manufacturing elements.

5.3.1.5 Management

Digital Twins shall be managed as necessary to optimize resources and maximize benefits.

5.3.1.6 Synchronization

In Digital Twin implementation, virtual elements and the associated data shall be timely coupled with the corresponding physical or functional element and data.

5.3.1.7 Data store

A data store shall be present to store data permanently or temporarily for the purpose of data modelling, exchange, analysis, or archiving, etc.

5.3.1.8 Simulation

A Digital Twin shall simulate manufacturing elements in operation.

5.3.1.9 Viewpoint

Digital Twin shall support different views for different objectives.

5.3.2 Digital Twin modelling requirements

5.3.2.1 Fidelity

A digital model shall accurately describe the relevant aspects of its physical counterpart.

5.3.2.2 Extensibility

Digital model of the physical element shall be extensible to support integration, addition, or enhancement.

5.3.2.3 Interoperability

Digital model of the physical element shall be compatible to other types of digital models, within a given Digital Twin manufacturing system.

5.3.2.4 Granularity

Digital model of the physical element shall provide an insight at different levels of granularity.

5.3.3 Information exchange requirements

5.3.3.1 Timely-manner networking

In Digital Twin manufacturing, information shall be exchanged between Digital Twin manufacturing system entities within a given time and frequency using appropriate networking protocols.

5.3.3.2 Synchronization

The status of the digital entities in Digital Twin shall be synchronized with the status of the observable manufacturing elements, or vice versa, using timely-manner networking.

5.3.3.3 Accuracy

Information shall be kept accurate for exchange.

5.3.3.4 Integrity

Information shall be maintained unchanged in exchange procedure.

5.4 Hierarchical modelling of Digital Twin for manufacturing

A Digital Twin for manufacturing may be purposely realized in different abstraction levels, e.g., machine level, area level, site level, and enterprise level. Digital Twin framework for manufacturing may apply to all the levels of the functional and role-based hierarchy defined in IEC 62264-1[5].

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