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Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



DRAFT International Standard

ISO/DIS 23704-4

General requirements for cyber-physically controlled smart machine tool systems (CPSMT) —

Part 4: Requirements and guidelines for implementing reference architecture of CPSMT for subtractive manufacturing

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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).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 184 *Automation systems and integration*, Subcommittee SC 1, *Physical device control*.

A list of all parts in the ISO 23704 series can be found on the ISO website.

Introduction

Since Industry 4.0 and Smart Factory were announced/proposed by the German Government in 2011, worldwide attention has been focused on this topic. To cope with the megatrend, enabling technologies have been under development by Industry and R&D institutions. From the market perspective there is a variety of so called ‘smart machine tools’ incorporating Internet of Things (IoT), Information and Communication Technology (ICT), smart Services, based on individual concepts and using local terminologies by Machine Tool Builders (MTBs), machine tool control, e.g. computerized numerical control (CNC) vendors, solution vendors, and service providers, which is confusing for the stakeholders including end-users. Many institutions have long been devoted to technological development to reduce downtime, defects, and increase reliability, reproducibility, productivity, etc. Nowadays, smart technologies such as the Internet-of-Things (IoT) have gained attention as a new means for this.

At present:

- From the market perspective, the abovementioned variety of solutions requires substantial modeling to establish smart machine tools for Industry 4.0.
- From the standards perspective, there are some standards on a high level, such as RAMI 4.0 (IEC PAS 63088^[26]), TR-SMRM,^[27] and related standards in parts under development by ISO/IEC.
- As far as smart machine tool is concerned, the ISO 23704 series has been under development by ISO/TC 184/SC 1/WG 11 since 2018

The ISO 23704 series specifies general requirements on smart machine tools for supporting smart manufacturing in the shop floor via cyber-physical system control scheme, namely cyber-physically controlled smart machine tool systems (CPSMT).

Drivers or necessities for ISO 23704-4 include:

- The reference architecture specified in ISO 23704-1, 2 is on a functional level and the question of how to implement the functional architecture into a physical realization of a CPSMT is a key issue raised by stakeholders including CNC and MTB vendors.
- In other words, it is necessary to develop some sort of guideline for implementing reference architecture of CPSMT for the sake of physical realization of CPSMT in industry.
- Timing wise, now is appropriate as ISO 23704-1 and ISO 23704-2 have been published in June 2022, so that ISO 23704-4 can be used as a guideline for stakeholders implementing CPSMT for Industry 4.0

[Figure 1](#) shows the overall structure of the ISO 23704 series, including:

- Overview and fundamental principles of a CPSMT in ISO 23704-1: 2022,
- Reference architecture of a CPSMT for subtractive manufacturing in ISO 23704-2: 2022,
- Reference architecture of a CPSMT for additive manufacturing in ISO 23704-3: 2023, and
- Requirements and guidelines for implementing a CPSMT for subtractive manufacturing in ISO 23704-4.

Part 4 and Part 2 are related in that they both deal with subtractive manufacturing but are different aspects of CPSMTs. Part 2 defines the functional architecture while Part 4 defines the implementation architecture and guidelines for a CPSMT for subtractive manufacturing given in Part 2.

Other related parts such as implementation architecture and guidelines or reference architectures for other types of manufacturing will be added if and when necessary.

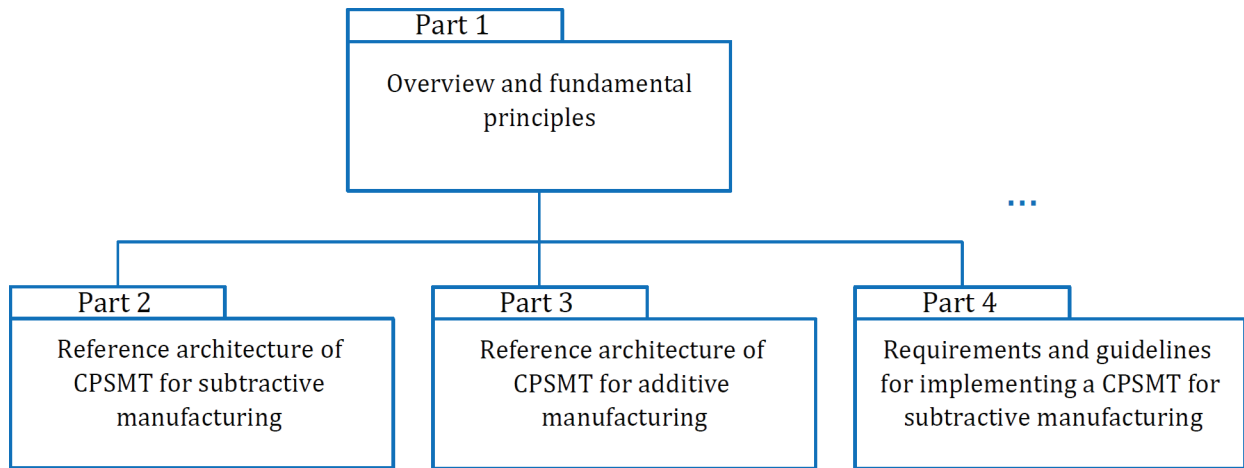


Figure 1 — Overall structure of the ISO 23704 series on general requirements for cyber-physically controlled smart machine tool systems (CPSMT)

Expected impact of this standard includes:

- a) To promote clear and unambiguous communication between all interested parties of smart machine tools for implementation for Industry 4.0
- b) To promote the interoperability of smart machine tools with related hardware devices, software, service, and manufacturing systems for implementation for Industry 4.0
- c) To promote the quality/capability of smart machine tools for Industry 4.0
- d) To promote systematic development, modification of smart machine tools for implementation for Industry 4.0, and
- e) To promote use by e.g. factory operators, of smart machine tools for Industry 4.0.

The objectives of ISO 23704-4 are twofold. Firstly, to define requirements for implementations of Cyber-Physically controlled Smart Machine Tools (CPSMT). Secondly, to provide guidelines for implementors.

This standard can be used as a reference and guidelines for stakeholders such as, but not limited to:

- a) Design engineers in the area of the smart subtractive manufacturing systems,
- b) System architects in the area of the smart subtractive manufacturing systems,
- c) Software engineers at the subtractive manufacturing machine builders in the area of the smart subtractive manufacturing systems,
- d) CNC vendors in the area of the smart subtractive manufacturing systems,
- e) Solution and service providers in the area of the smart subtractive manufacturing systems, and
- f) End users like factory operators working with the smart subtractive manufacturing systems.

General requirements for cyber-physically controlled smart machine tool systems (CPSMT) —

Part 4:

Requirements and guidelines for implementing reference architecture of CPSMT for subtractive manufacturing

1 Scope

The goal and objective of ISO 23704-4 is to provide the functional framework for implementation of the reference architecture. The reference architecture for subtractive manufacturing specified in ISO 23704-2 contains the architecture elements that should be present in an implementation but does not specify their functionality. This document deals with how the elements should function in terms of implementation architecture (IA), information guideline (IG) including information model, communication model, integration model, etc.

Specifically, this document specifies the implementation architecture (IA) including:

- cyber-physically controlled machine tools (CPCM) for subtractive manufacturing, and
- cyber-supporting system for machine tools (CSSM) for subtractive manufacturing.

Also, this document provides implementation guidelines (IG) including:

- information model of CPSMT for subtractive manufacturing,
- communication model of CPSMT for subtractive manufacturing, and
- integration model of CPSMT for subtractive manufacturing.

As informative, the following are given in the Annexes:

- systems engineering (SE) including SE-vee model and stakeholder requirements for subtractive manufacturing,
- use case of IA and IG of CPSMT for subtractive manufacturing, and
- An implementation use case for CPSMT

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 for 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 23704-1:2022, *General requirements for cyber-physically controlled smart machine tool systems (CPSMT) — Part 1: Overview and fundamental principles*

ISO 23704-2:2022, *General requirements for cyber-physically controlled smart machine tool systems (CPSMT) — Part 2: Reference architecture of CPSMT for subtractive manufacturing*

3 Terms, definitions and abbreviations

For the purposes of this document, the terms and definitions given in ISO 23704-1, 2, 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 <http://www.electropedia.org/>

3.1 Terms, definitions and abbreviated terms

3.1.1

asset administration shell

AAS

virtual digital and active representation of an Industry 4.0 component in the Industry 4.0 system

Note 1 to entry: The definition is based on that in^[26]

Note 2 to entry: Administration shell (AS) is defined in ISO 23704-1, but AAS is also used in the Industry 4.0 paradigm.

Note 3 to entry: The AAS defines the accessible functionality of an asset. An asset will often have other functionality to support the accessible functionality which should only be used in the context of the accessible functions and should not be invoked separately.

3.1.2

big data

BD

technologies addressing data sets that are so large and complicated that traditional data-processing application software are inadequate for management and utilization of the data

Note 1 to entry: The definition comes from^[27]

Note 2 to entry: Big data is dealt with by CSSM in a systematic way via DPU (Data Processing Unit), in particular.

3.1.3

cloud computing

technology that enables ubiquitous access to distributed and shared pools of system resources and services with minimal management effort

Note 1 to entry: The definition comes from^[27]

Note 2 to entry: Cloud computing together with edge computing ([3.1.9](#)) and fog computing ([3.1.10](#)) is reflected in the Integration model of CPSMT in [Clause 11](#).

3.1.4

communication model

A formalized conceptual representation of the process of communication

Note 1 to entry: See [clause 10](#) for more on communication models for the CPSMT.

3.1.5

communication protocol

formalization of communication between two functional elements including syntax, meaning and other information relevant to the type of communication

Note 1 to entry: Different protocols are relevant for different tasks and examples of relevant protocols are given where appropriate

Note 2 to entry: The term protocol strictly refers to the transport layer for instance in OSI model ([3.1.19](#))

3.1.6

concern

subject that is the result of a perspective or use case

Note 1 to entry: The definition comes from 6.4.2.5 of [\[27\]](#)

3.1.7

digitalization

the use of digital technologies to change a business model and provide new revenue and value-producing opportunities; it is the process of moving to a digital business.

Note 1 to entry: The definition comes from Gartner glossary [\[48\]](#)

Note 2 to entry: Digitalization of physical asset can be done via AAS ([3.1.1](#)), etc.

Note 3 to entry: See [\[48\]](#) for comparison with digitalization and digital transformation compared with digitization.

3.1.8

edge computing

methods for optimizing computing systems by placing control in applications/services with direct contact with the physical world, rather than in central nodes

Note 1 to entry: The definition comes from [\[27\]](#)

Note 2 to entry: edge computing together with *fog computing* ([3.1.9](#)) and cloud computing ([3.1.3](#)) is reflected in the Integration model of CPSMT in [Clause 11](#)

3.1.9

fog computing

computer architecture using edge computing for computation, storage and communication

Note 1 to entry: The definition comes from [\[27\]](#)

Note 2 to entry: fog computing together with edge computing ([3.1.9](#)) and cloud computing ([3.1.3](#)) is reflected in the Integration model of CPSMT in [Clause 11](#)

3.1.10

functional architecture

FA

arrangement of functions and their subfunctions and interfaces (internal and external) that defines the execution sequencing, conditions for control or data flow, and the performance requirements to satisfy the requirements baseline

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

3.1.11

human-machine interface

HMI

design and implementation of systems interacting with humans

Note 1 to entry: The HMI for the CPSMT is necessary but an exact definition is out of scope for this document

Note 2 to entry: HMI is dealt with in the use case described in Annex C.2 of ISO 23704-2

3.1.12

ICOM

abbreviation of Input, Consideration/constraints, Output, Method/mechanism

method used for defining context or requirements ([3.1.24](#)) of System of Interest (SoI) in systems engineering, an advanced methodology for developing complex systems based on IDEF0.

Note 1 to entry: For details on systems engineering, See ISO/IEC/IEEE 15288 [\[16\]](#), ISO/IEC/IEEE 12207, [\[5\]](#) ISO/IEC/IEEE 42010 [\[22\]](#)

Note 2 to entry: IDEF0 may be used to model a wide variety of automated and non-automated systems. For new systems, it may be used first to define the requirements and specify the functions, and then to design an implementation that meets the requirements and performs the functions. For existing systems, IDEF0 can be used to analyze the functions the system performs and to record the mechanisms (means) by which these are done^[34]

Note 3 to entry: In this document, the ICOM method is performed to identify Input, Consideration/Control, Output, and Method for every functional element specified in ISO 23704-2, for the sake of developing the implementation architecture, information model, computing model, and integration model for CPSMT.

3.1.13 implementation architecture

IA

arrangement of functional architecture for implementation of a CPSMT

Note 1 to entry: The implementation architecture includes functional flow based on ICOM analysis ^(3.1.12) of functional elements specified in ISO 23704-2 including input, output to group of related elements

3.1.14 implementation guideline

IG

recommendation of recognized practice to be considered for translating a design/specification into hardware components and/or software components

Note 1 to entry: In this document, implementation guidelines take into consideration market practice, industry standards, CPSMT principles, etc., so that the system considered can become operational.

Note 2 to entry: According to layer-axis between functional layer and physical layer of RAMI4.0, implementation guideline for CPSMT includes information model, communication model, and integration model, etc.

3.1.15 information model

representation of concepts and the relationships, constraints, rules, and operations to specify data semantics for a chosen domain of discourse

Note 1 to entry: In software engineering this typically specifies relations between kinds of things, but may also include relations with individual things. It can provide sharable, stable, and organized structure of information requirements or knowledge for the domain context^[37]

Note 2 to entry: In this document, information model specified by OPC UA IEC 62541-5^[24], and its companion standard: information model for CNC systems^[29] is referenced as an information model for CPSMT

3.1.16 open platform communications unified architecture

OPC UA

cross-platform, open-source, standard for data exchange from sensors to cloud applications developed by the OPC Foundation

3.1.17 OPC UA CNC interface

specification for information model (see ^{3.1.15}) for CNC systems

Note 1 to entry: The CNC interface is a companion to OPC UA according to OPC UA published by OPC foundation and VDW, as OPC 40502-1^[29]

3.1.18 open systems interconnection model

OSI model

layer scheme of communication protocol (see ^{3.1.5}) defined by ISO.

Note 1 to entry: the layering scheme from the IETF is called Internet layering or TCP/IP layering (see 3.1.29)

Note 2 to entry: OSI is a designation of ISO/IEC 7498:1994 subtitled Basic Reference Model: a four part document that is also published as ITU-T Recommendation X.200^[3]

Note 3 to entry: OSI is composed of 7 layers: 1) Physical layer, 2) Data link layer, 3) Network layer, 4) Transport layer, 5) Session layer, 6) Presentation layer, and 7) Application layer

3.1.19

perspective

stakeholder's responsibility, authority and accountability related to smart manufacturing where the practitioner perspective is the origin of one or more use-cases, the purpose of which is to articulate a specific collection of practitioner concerns, and the standard developer perspective is the origin of one or more viewpoints, which capture the particular concerns of the standard developer and the practitioner concerns articulated by a use-case, thereby addressing that use-case^[27]

3.1.20

predictive maintenance

using sensing and analysis of measured data for systematic detection of trends and prediction of incipient failures to prevent faults from occurring^[27]

3.1.21

prototype

PT

preliminary type, form, or instance of a system that serves as a model for later stages or for the final, complete version of the system

Note 1 to entry: A method of obtaining early feedback on requirements by providing a working model of the expected product before actually building it

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

Note 2 to entry: Model or preliminary implementation suitable for evaluation of system design, performance, and production potential, or for better understanding or determination of the requirements

[SOURCE: ISO/IEC 2382:2015]

3.1.22

reference model

model that is generally used and recognized as being suitable (has recommendation character) for deriving specific models

[SOURCE: IEC/PAS 63088:2016-10]

Note 1 to entry: Framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting environment^[27]

3.1.23

requirement

desired feature, property, or behavior of an element as part of a system

[SOURCE: ISO/IEC 19501:2005]

3.1.24

smart machines

autonomously operating, communicating, adaptive and possibly learning systems able to solve problems and make decisions independent of people

Note 1 to entry: CPSMT of whole series of ISO 23704 is smart machine tool systems for Industry 4.0

3.1.25

stakeholder

individual, organization, or classes thereof, having an interest in a system

[SOURCE: ISO/IEC/IEEE 42010:2011]

Note 1 to entry: See [Annex A](#) for the stakeholders of CPSMT

3.1.26**Transmission Control Protocol Internet Protocol
TCP/IP**

framework for organizing the set of communication protocol commonly known as Internet protocol suite, used in the Internet and similar computer networking according to functional criteria

3.2 Abbreviations

AAS	asset administration shell
AI	artificial intelligence
BD	big data
CAX	computer-aided-x
CNC	computerized numerical control
CPCM	cyber-physically controlled machine tool
CPSMT	cyber-physically controlled smart machine tool
CSSM	cyber supporting system for machine tool
DPU	data processing unit
DTU	digital twin unit
FA	functional architecture
HMI	human machine interface
IA	implementation architecture
ICID	information, communication, integration, digitalization
ICOM	inputs, controls, outputs, and mechanisms
ICT	information and communication technology
IDEF0	Icam DEFinition for Function Modeling
IG	Implementation guideline
IoT	internet of things
MAPE	monitoring, analysis, planning, execution
MTU	machine tool unit
NCK	numerical control kernel
OPC UA	open platform communication unified architecture
OSI	open system interconnection
PI	physical implementation
PLC	programmable logic controller
PT	prototype
SE	systems engineering
SFCS	shop floor control system
SFDS	shop floor device system
SM	subtractive manufacturing
TCP/IP	transmission control protocol internet protocol
UIS	unified interface system

4 Conformance with requirements and guidelines for implementation of a CPSMT for subtractive manufacturing

ISO 23704-4 is based on the reference architecture defined in ISO 23704-1 and 2.