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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

Exigences générales relatives aux systèmes de machines-outils intelligents à commandes cyber-physiques (CPSMT) —

Partie 4: Exigences et lignes directrices pour la mise en œuvre de l'architecture de référence des CPSMT pour la fabrication soustractive

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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 1, *Industrial cyber and physical device control*.

A list of all parts in the ISO 23704 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

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 the 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. These tools are based on individual concepts and use local terminologies by machine tool builders (MTBs), as can be seen in the topic of machine tool control, e.g. computerized numerical control (CNC) vendors, solution vendors, and service providers, which is confusing for the stakeholders including end-users.

From the standards perspective, RAMI 4.0 (IEC PAS 63088) and IEC TR 63319 provide a reference model for Industry 4.0 and smart manufacturing on a high level. ISO 23247 series defines a generic framework to support the creation of a digital twin of observable manufacturing elements. Furthermore, although some existing standards deal with Industry 4.0 enabling technologies, e.g. OPC-UA (IEC TR 62541-1), MTConnect (ANSI/MTC1.4-2018),[31]ISO/IEC 30141, the IEC 62769 series, and many machine tool standards from ISO/TC 39, no standard yet exists for smart machine tools for realizing smart manufacturing/Industry 4.0 in the shop floor via cyber-physical systems (CPSs). 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).

Figure 1 shows the overall structure of the ISO 23704 series, including:

— overview and fundamental principles of a CPSMT in ISO 23704-1;

— reference architecture of a CPSMT for subtractive manufacturing (SM) in ISO 23704-2;

— reference architecture of a CPSMT for additive manufacturing in ISO 23704-3;

— requirements and guidelines for implementing a CPSMT for SM in this document;

— requirements and guidelines for implementing a CPSMT for additive manufacturing in ISO 23704-5.

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

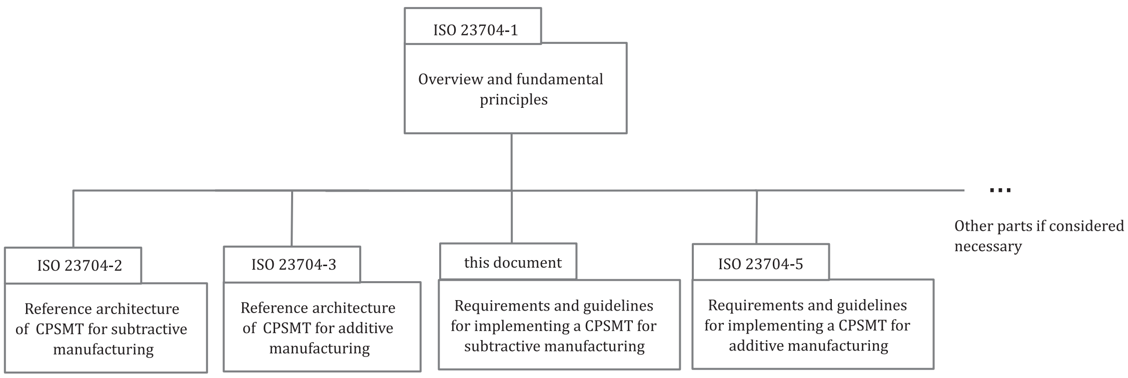

Figure 1 — Overall structure of the ISO 23704 series on general requirements for cyber-physically controlled smart machine tool systems (CPSMT)

This document and ISO 23704-2 are related in that they both deal with SM but are different aspects of CPSMTs. ISO 23704-2 defines the functional architecture while this document defines the implementation architecture and guidelines for a CPSMT for SM given in ISO 23704-2.

The objectives of this document are twofold. Firstly, to define requirements for implementations of cyber-physically controlled smart machine tools (CPSMT) for SM. Secondly, to provide guidelines for implementors of CPSMT for SM.

Expected impact of this document includes:

a) the promotion of clear and unambiguous communication between all interested parties of smart machine tools for implementation for Industry 4.0;

b) the promotion of the interoperability of smart machine tools with related hardware devices, software, service, and manufacturing systems for implementation for Industry 4.0;

c) the promotion of the quality/capability of smart machine tools for Industry 4.0;

d) the promotion of systematic development, modification of smart machine tools for implementation for Industry 4.0;

e) the promotion of use, e.g. by factory operators, of smart machine tools for Industry 4.0.

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

— design engineers in the area of the smart SM systems;

— system architects in the area of the smart SM systems;

— software engineers at the SM machine builders in the area of the smart SM systems;

— CNC vendors in the area of the smart SM systems;

— solution and service providers in the area of the smart SM systems;

— end users such as factory operators working with the smart SM 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

This document specifies requirements and guidelines for implementing the reference architecture given in ISO 23704-2.

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

— cyber-physically controlled machine tools (CPCM) for subtractive manufacturing (SM);

— cyber-supporting system for machine tools (CSSM) for SM.

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

— information model of CPSMT for SM;

— communication model of CPSMT for SM;

— integration model of CPSMT for SM.

As information, the following are included in the annexes:

— systems engineering (SE) including SE-vee model and stakeholder requirements for SM (see Annex A);

— use case of IA and IG of CPSMT for SM (see Annex B);

— an implementation use case for CPSMT (see Annex C).

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

ISO 23704-2, *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 and ISO 23704-2 and the following 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 Terms and definitions

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

Note 2 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.

[SOURCE: IEC PAS 63088:2017[1)], 3.1, modified — The term was changed from "administration shell" to "asset administration shell"; Note 1 to entry was changed and Note 2 to entry was added.]

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: Big data is dealt with by CSSM in a systematic way via DPU (data processing unit), in particular.

Note 2 to entry: Adapted from IEC TR 63319:2025, 4.3.4.

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: Cloud computing together with *edge computing* (3.1.8) and *fog computing* (3.1.9) is reflected in the Integration model of cyber-physically controlled smart machine tool (CPSMT) in Clause 11.

Note 2 to entry: Adapted from IEC TR 63319:2025, 4.3.4.

3.1.4
communication model
formalized conceptual representation of the process of communication

Note 1 to entry: See Clause 10 for more on communication models for the cyber-physically controlled smart machine tool (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.

1) Withdrawn.

3.1.6
concern
subject that is the result of a *perspective* (3.1.18) or use case

Note 1 to entry: Adapted from IEC TR 63319:2025, 6.4.2.5.

3.1.7
digitalization
use of digital technologies to move a business model to a digital system and provide new revenue and value-producing opportunities

Note 1 to entry: Digitalization of physical asset can be done via *asset administration shell (AAS)* (3.1.1), etc.

Note 2 to entry: See [49] for a comparison of digitalization and digital transformation 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: Edge computing together with *fog computing* (3.1.9) and *cloud computing* (3.1.3) is reflected in the Integration model of cyber-physically controlled smart machine tool (CPSMT) in Clause 11.

Note 2 to entry: Adapted from IEC TR 63319:2025, 4.3.4.

3.1.9
fog computing
computer architecture using *edge computing* (3.1.8) for computation, storage and communication

Note 1 to entry: Fog computing together with edge computing and *cloud computing* (3.1.3) is reflected in the Integration model of cyber-physically controlled smart machine tool (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* (3.1.21) to satisfy the requirements baseline

[SOURCE: ISO/IEC/IEEE 24765:2017, 3.1687.1]

3.1.11
human-machine interface
HMI
design and implementation of systems interacting with humans

Note 1 to entry: The HMI for the cyber-physically controlled smart machine tool (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 ISO 23704-2:2022, Clause C.2.

3.1.12
input, consideration/constraints, output, method/mechanism
ICOM
method used for defining context or *requirements* (3.1.21) of system of interest (SoI) in systems engineering

Note 1 to entry: ICOM is an advanced methodology for developing complex systems based on Icam DEFinition for Function Modeling (IDEF0).

Note 2 to entry: For details on systems engineering, see ISO/IEC/IEEE 15288, ISO/IEC/IEEE 12207,ISO/IEC/IEEE 42010.

Note 3 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[35].

Note 4 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* (3.1.13), *information model* (3.1.15), computing model, and integration model for cyber-physically controlled smart machine tool (CPSMT).

3.1.13
implementation architecture
IA
arrangement of *functional architecture* (3.1.10) for implementation of a cyber-physically controlled smart machine tool (CPSMT)

Note 1 to entry: The implementation architecture includes functional flow based on *ICOM* (3.1.12) analysis 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 either hardware components or software components, or both

Note 1 to entry: In this document, implementation guidelines take into consideration market practice, industry standards, cyber-physically controlled smart machine tool (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* (3.1.15), *communication model* (3.1.4), 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* (3.1.21) or knowledge for the domain context[38].

Note 2 to entry: In this document, information model specified by OPC UA (see IEC 62541-5) and its companion standard, OPC 40502-1[30] is referenced and represented by the notion of UML (see ISO/IEC 19501) as an information model for cyber-physically controlled smart machine tool (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
open platform communications unified architecture computerized numerical control interface
OPC UA CNC interface
specification for *information model* (3.1.15) for computerized numerical control (CNC) systems

Note 1 to entry: The CNC interface is a companion to *OPC UA* (3.1.16) according to OPC UA published by OPC foundation and VDW, as OPC 40502-1[30].

3.1.18
perspective
orientation of a *stakeholder* (3.1.23) within a smart manufacturing domain

Note 1 to entry: Stakeholder has its own perspective arising from their knowledge, expertise, responsibility, authority and accountability relative to a smart manufacturing effort.

Note 2 to entry: Adapted from IEC TR 63319:2025, 6.4.2.3.

3.1.19
predictive maintenance
process that uses sensing and analysis of measured data for systematic detection of trends and prediction of incipient failures to prevent faults from occurring

3.1.20
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 prototype is a method of obtaining early feedback on *requirements* (3.1.21) by providing a working model of the expected product before actually building it.

3.1.21
requirement
desired feature, property, or behavior of an element as part of a system

3.1.22
smart machine
autonomously operating, communicating, adaptive and possibly learning system able to solve problems and make decisions independently of people

Note 1 to entry: The cyber-physically controlled smart machine tool (CPSMT) of the ISO 23704 series is smart machine tool systems for Industry 4.0.

3.1.23
stakeholder
individual, organization, or classes thereof, having an interest in a system

Note 1 to entry: See Annex A for the stakeholders of cyber-physically controlled smart machine tool (CPSMT).

[SOURCE: ISO/IEC/IEEE 42010:2022, 3.17, modified — “role” and “position” were removed from the start of the definition; “an interest right, share, or claim, in an entity of interest” was changed to “an interest in a system”; the Example was removed and Note 1 to entry was added.]

3.1.24
transmission control protocol/internet protocol
TCP/IP
framework for organizing the set of *communication protocol* (3.1.5) commonly known as Internet protocol suite, used in the Internet and similar computer networking according to functional criteria

3.2 Abbreviated terms

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
ICOM	inputs, controls, outputs, and mechanisms
IG	implementation guideline
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