ISO/IEC/IEEE ~~TC JTC1/SC 7 N xxxx~~

~~Date: 2022-12-14~~

~~ISO/IEC/IEEE~~ **FDIS 24748-6:2023(E)**

Date: 2023-02-16

ISO/IEC TC JTC1/SC 7/WG 7 **N2928**

Secretariat: BIS

Systems and software engineering — Life cycle management — Part 6: System and software integration

Ingénierie des systèmes et du logiciel — Gestion du cycle de vie — Partie 6: Ligne directrices pour l'intégration du système et du logiciel

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

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/IEC 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 or www.iec.ch/members_experts/refdocs).

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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. In the IEC, see www.iec.ch/understanding-standards.

ISO/IEC/IEEE 24748-6 was prepared by Joint Technical Committee ISO/~~TC~~IEC JTC 1, *Information* ~~*Technology*~~*technology*, Subcommittee SC 7, ~~*Systems*~~*Software and* ~~*software*~~*systems engineering*, in cooperation with the Systems and Software Engineering Standards Committee of the IEEE Computer Society, under the Partner Standards Development Organization cooperation agreement between ISO and IEEE.

This first edition cancels and replaces ISO/IEC TS 24748-6:2016, which has been technically revised.

The main changes are as follows:

— changed from a Technical Specification to an International Standard;

— updated to reflect the process requirements of ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288~~:~~ ~~—;~~:—;

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— added material specific to software integration and systems-of-systems integration, as well as system aggregation.

A list of all parts in the ISO/IEC/IEEE 24748 series can be found on the ISO and IEC website.

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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 and www.iec.ch/national-committees.

Introduction

Both ISO/IEC/IEEE 15288~~: —~~ and ISO/IEC/IEEE 12207~~:2017~~ include an integration process that focuses on aggregating the elements comprising a system. The integration process depends on a clear understanding of interfaces of all kinds and the use, possibly repeated, of the verification process and the validation process.

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Systems that this document are concerned with are as described in ISO/IEC/IEEE 12207~~:2017~~ and ISO/IEC/IEEE 15288~~: —~~, i.e~~.,~~. systems that are human-made, comprised of any mixture of products and services and can be configured with one or more of the following: hardware, software, data, humans, processes (e.g~~.,~~. a review process or processes for providing service to users), procedures (e.g~~.,~~. operator instructions), facilities, materials and naturally occurring entities (e.g~~.,~~. water, organisms, minerals).

The purpose of this document is to elaborate and facilitate the usage of the integration process given in ISO/IEC/IEEE 12207~~:2017~~ and ISO/IEC/IEEE 15288~~: —~~ by providing requirements and guidance for the planning and performing of that process, including requirements for the information items to be provided for systems and software integration, considering:

— the underlying concepts of aggregation, integration, interface, synthesis, verification, and validation~~,~~;

— the possible composition of that human-made system~~,~~;

— the life cycle stages of a system at which one or more parts of the integration process can occur~~, and~~;

— the context of the domain in which the system functions.

For life cycle process information items (documentation) described in ISO/IEC/IEEE 15288~~: —~~ and ISO/IEC/IEEE 12207~~:2017~~, ISO/IEC/IEEE 15289 summarises requirements for their content and provides guidance on their development. Although this document identifies additional required information items with related content for the integration process, it does not require a specific name, format, recording media or explicit details for population of the information item's required content.

NOTE This document is intended to be consistent with the other parts of the ISO/IEC/IEEE 24748 series.

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Systems and software engineering — Life cycle management — Part 6: System and software integration

1 Scope

This document:

— provides supplemental requirements and guidance for the planning and performing of the integration processes given in ISO/IEC/IEEE 15288~~:—~~ ~~[1]~~ and ISO/IEC/IEEE 12207~~:2017~~;

— provides guidance on the relationship between the integration process and other life cycle processes.

— specifies requirements for information items to be produced as a result of using the integration process, including the content of the information items.

This document is applicable to:

— those who use or plan to use ISO/IEC/IEEE 12207~~:2017~~ or ISO/IEC/IEEE 15288~~:—~~, or both, on projects dealing with human-made systems, software-intensive systems, and products and services related to those systems, regardless of the project scope, methodology, size, or complexity;

— anyone planning or performing integration activities to aid in ensuring that the application of the integration process and its relationships to other system life cycle processes conform to ISO/IEC/IEEE 15288~~:—~~ or ISO/IEC/IEEE 12207~~:2017~~.

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.

<std>ISO/IEC/IEEE 12207:2017, *Systems and software engineering — Software life cycle processes*</std>

<std>ISO/IEC/IEEE 15288~~:—~~:—[2], *Systems and software engineering — System life cycle processes*</std>

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC/IEEE 15288~~:—~~, ISO/IEC/IEEE 12207~~:2017~~ and the following apply.

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~~[1] Under preparation~~

[2] Under preparation.

ISO, IEC and IEEE 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/

— IEEE Standards Dictionary Online: available at: http://dictionary.ieee.org

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NOTE For additional terms and definitions in the field of systems and software engineering, see ISO/IEC/IEEE 24765, which is published periodically as a "snapshot" of the Systems and software Engineering Vocabulary (SEVOCAB) database and is publicly accessible at www.computer.org/sevocab~~.~~.

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3.1.1
aggregate, noun
result of combining one or more physical, logical, or both, system elements

3.1.2
driver
launcher
external dynamic component or simulator that activates the performing of functions of an *aggregate* (3.1.1) of system elements

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3.1.3
interface
point at which two or more logical, physical, or both, system elements or software system elements meet and act on or communicate with each other

3.1.4
integration
process of planning for and aggregating a progressively more complete set of physical, logical, or both, system elements and activating their *interfaces* (3.1.3) to synthesize a system or part of a system whose properties can be verified and possibly validated

Note 1 to entry: An outcome of integration is a system whose properties can be verified and possibly validated.

3.1.5
logical interface
input-output flow between two or more system elements or software system elements and the function that determines it

Note 1 to entry: A logical interface can be functional (as in process steps), informational (as in a communications link,) or other.

3.1.6
physical interface
physical link between two or more system elements

Note 1 to entry: A physical interface can be solid, liquid, gas, vacuum, thermal, electromagnetic field, or other.

3.1.7
stub
computer programs and data files built to support software development and testing, but not intended to be included in the final product

3.1.8
synthesis

result of combining the constituent elements of separate physical or logical, or both, entities into a single or unified entity

3.2 Abbreviated terms

API	application program interface
ISC	integration services components
~~API~~	~~application program interfaceintegration services components~~model-based systems engineering
~~ISC~~	
MBSE	
NDI	non-developmental item
QA	quality assurance
SDP	software development plan
SEMP	systems engineering management plan
SoI	system-of-interest

4 Conformance

4.1 Conformance to processes

Conformance requirements for the integration process are specified in ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288:— and further elaborated in 6.3. One supplemental integration process outcome is added in 6.3.3. If using ISO/IEC/IEEE 15288:— outcomes, it would become outcome h). If using ISO/IEC/IEEE 12207:2017 outcomes. It would become outcome i).

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4.2 Conformance to information item content

Clause 7 provides requirements for a number of information items to be produced during the life cycle of a system.

A claim of conformance to the information item provisions of this document means that

— the required information items stated in this document are produced, and

— the information items produced demonstrate conformity to the content requirements defined in this document.

Clause 7 contains the requirements for the content of the information items in this document.

In this document, each information item is described as if it were published as a separate document. However, information items are considered to be conforming if the information items are unpublished but available in a repository for reference, divided into separate documents or volumes, or combined with other information items into one document. It is not required to treat every topic in this document in the same order, using the same wording as its title, or with the same level of detail. That depends on the nature of the system, implementation methods, life cycle model, and scope of the project.

4.3 Full conformance

A claim of full conformance to this document is equivalent to claiming conformance to the integration process requirements identified in 4.1 and the requirements for the information items cited in 4.2.

4.4 Tailored conformance

4.4.1 Processes

This document makes the following provision for a claim of tailored conformance to the integration process: ISO/IEC/IEEE 12207:2017, Annex A and ISO/IEC/IEEE 15288:—:—, Annex A provide requirements regarding the tailoring of system and software life cycle processes. Those provisions should be used to tailor the integration process requirements identified in 4.1 as the basis for a claim of tailored conformance to the integration process as elaborated in this document.

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4.4.2 Information items

When this document is used as a basis for establishing a set of information items that do not qualify for full conformance, the requirements in Clause 7 are selected or modified in accordance with this clause. The tailored text, for which tailored conformance is claimed, shall be declared. Tailored conformance is achieved by demonstrating that requirements for the information items, as tailored, are satisfied.

5 Integration concepts

5.1 General

This clause presents the concepts that apply to system integration, including software systems. These concepts embody the definitions in ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288:— and set the basis for explaining the application of those concepts. The central concepts that this clause presents are those of interface, aggregation, synthesis, and integration.

There are conceptual relationships between the integration process and system and software life cycle processes of ISO/IEC/IEEE 15288:— and ISO/IEC/IEEE 12207:2017, which this clause presents. This clause also presents the concepts associated with system integration as a process over the life cycle of a system, including software systems.

Finally, this clause presents concepts on iteration and recursion in integration, and regression testing.

5.2 Interface concept

An interface has a set of logical or physical characteristics required to exist at a common boundary or connection between system elements, systems, or the environment external to the SoI.

NOTE 1 Throughout this document, statements referring to "system elements" inferentially can include elements of other systems, or the external environment.

A physical interface is a physical link that binds two or more system elements within the SoI, or one system element of the SoI with one or more elements external to the SoI. A physical interface can be considered a system element.

A logical interface consists of an output flow, or an input flow, or a bi-directional, i.e. transactional, flow between two or more elements of the system so that the elements can exchange some mix of energy or information items.

NOTE 2 Table 1 provides examples of system element integration involving physical interfaces (e.g. material and thermal example of Table 1) and logical interfaces (e.g. the software-to-software example of Table 1).

The progressive definition of interfaces is an intrinsic part of applying the technical processes of ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288:— and is critical to the success of integration. Inadequately defined interfaces are common failure points in complex systems. Such inadequately defined interfaces commonly include the points where independent systems or system elements not necessarily made of the same technology meet and communicate with each other. Consideration for indirectly coupled elements (e.g. via control mechanisms or shared memory in software systems) often involves complex analysis. Technical processes' activities and decisions should fully define interfaces so that integration, and subsequent verification of system elements' properties, can be planned and performed successfully.

ISO/IEC/IEEE 12207:2017, E.5 and ISO/IEC/IEEE 24748-1:2018, D.5 provide a process view for the management of interfaces and identify the purpose and outcomes with selected life cycle process activities and tasks to facilitate the identification, definition, design, and management of interfaces of the SoI.

5.3 Aggregation and synthesis concepts

The integration of a system is based on the notions of aggregation and synthesis. For example, wings, body, engines, hardware and software controls, air traffic procedures, and information items, are aggregated along with other elements not listed here to synthesize an aircraft operating in its intended environment. A synthesis performs functions not possible from the individual elements that are aggregated. An aggregate has a functional consistency that allows the performance of subsequent verification actions and possibly validation actions. Each aggregate is characterized by a configuration that specifies the implemented system or software elements that are aggregated and their configuration status. Aggregation can be done iteratively or recursively.

5.4 Integration concept

Integration encompasses planning for and aggregating a progressively more complete set of elements and activating their interfaces to synthesize a part of a system that can be verified and possibly validated in keeping with strategy decisions for validation process implementation. Integration enables interoperation among some set of elements to satisfy their requirements and provide a basis for integrating a yet more complete part of the system. The end result is a system or software system that is integrated within itself and at its interfaces for the system's intended purpose and use.

Integration of the system can involve a mix of the hardware, software, data, humans, processes (e.g. processes for providing service to users), procedures (e.g. operator instructions), facilities, materials and naturally occurring entities of which the system is composed. Hence, system integration can involve interfacing and interoperating such things as mechanical items (e.g. assembly), functions (e.g. software-based functions), people and equipment, thermal flows, sets of processes, human constructs to naturally occurring entities.

NOTE 1 ISO/IEC/IEEE 15288:—, :—, 5.2.3 further explains concepts for interfacing systems and interoperating systems.

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A nuclear power facility is an example of a system that includes a mix of every type of elements considered in ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288:— and involves both products and services. Table 1 gives illustrative examples of the types of elements that are to be integrated for the system to function properly in its operational environment over its life cycle. Table 1 illustrates the point that verification is typically done following integration, depending on the verification strategy and priorities, whereas validation can depend on factors other than successful confirmation that the interface has been established and checked, and its properties verified.

Table 1 — Integration examples

System elements being integrated	Types of interfaces involved	Verification follows?	Validation follows?
Fuel and cladding to make reactor control rods	Material, thermal	Yes	Yes, but most likely done as part of validating the assembled reactor.
Operator control panels	Mechanical, electrical, functional, human-machine interface, procedural	Yes	Most likely yes. Each type of control can be verified individually, then some combination of controls can be validated, that is, validation can occur at a higher level in the system.
Reactor control and monitoring operating system	Software, human-machine interface, procedural	Yes	Most likely yes. Each type of control can be verified individually, then some combination of controls can be validated, that is, validation can occur at a higher level in the system.
Reactor rod control software to flux density monitoring software	Software to software	Yes	No, but validated at a higher level, such as software to display
Facility server farm	Hardware, software, data, thermal, facilities, processes	Yes	Probably, at several points
Reactor to cooling medium, such as a lake or river	Naturally occurring entity, facility, thermal	Yes	Probably
Reactor generator to power grid	Hardware, functional	Yes	Yes

NOTE 2 Some of the integration results in products, some in services. In this example, electrical power to the grid is a product of the reactor, while electrical power from the grid at the point of use is a service. Table 1 is notional, for illustrative purposes only, and is not intended to be exhaustive.

NOTE 3 IEEE 1012 provides requirements and guidance for system, software, and hardware verification and validation processes while the ISO/IEC/IEEE 29119 series provides detailed support for software testing.

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Enabling systems are integrated, just as systems-of-interest, and an SoI and its enabling systems are interfaced. If an SoI and its enabling system are interfaced the SoI and its enabling system can be considered as a system-of-systems, or two systems, or as a new SoI, as a matter of perspective, per the treatment in ISO/IEC/IEEE 15288~~:—~~ and ISO/IEC/IEEE 24748-1.

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Integration can be considered successfully completed when all of the required interfaces are checked and passed the required interface specifications for the integration step. Additional confirmation of the successful completion of integration is when subsequent verification and possibly validation of the interface properties is successful.

Planning and performing of integration is done in conjunction with other system or software life cycle processes. Integration planning is mostly done in conjunction with requirements, architecture, design, and test processes, while performing integration is mostly done in conjunction with verification and validation processes.

A system can be integrated during a single stage, or involve multiple stages, of its life cycle and can be integrated more than once within a single life cycle stage, such as when a system is repeatedly modified during a lengthy stage of operation and maintenance, or when capabilities are added in discrete increments.

5.5 Relationship of integration to life cycle processes

ISO/IEC/IEEE 15288:— and ISO/IEC/IEEE 12207:2017 recognize that any process can be invoked by any other process and, conceptually, that applies to the integration process. In practice, the extent to which integration is addressed when planning or performing other processes, as well as the extent to which other processes are addressed when planning or performing the integration process, varies extensively. Table 2 shows the relationship of some the other processes to the Integration process at a conceptual level. Clause 6 addresses more specifics to consider as part of the integration planning or performing guidelines.

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Table 2 — Conceptual relationship of integration to life cycle processes

ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288:— process groups	Relationship to integration process when planning integration	Relationship to integration process when performing integration
Agreement processes	Agreements for system or software elements obtained from a supplier, or elements provided to a supplier, include requirements to be satisfied for integration that supports successful verification, validation and deployment. Agreement of interfaces between supplier and customer.	System or software elements obtained from a supplier are checked as specified in the agreement before acceptance for integration with the SoI.
Organizational project-enabling processes	Provisions of the life cycle model management process, infrastructure management process, quality management process, and knowledge management process include capabilities for any interaction with the Integration process during preparation, performing, or outcome handling.	Integration draws on the infrastructure and provisions of the quality management process. The lessons learned from a specific integration effort are captured and made use of through the knowledge management process.
Technical management processes	Management of the intended integration effort is reflected in the specific framework of each of these processes: integration uses or provides input to each of these processes.	Management of the actual integration effort uses or provides input to each of these processes.
Technical processes	Integration concepts, requirements, and solutions emerge from the business or mission analysis, systems requirements, architecture definition, and design definition processes, drawing on the system analysis process	Implementation, verification, transition, validation, operation, maintenance, and disposal processes all draw on or are supported by the integration process over the life cycle of the system.

NOTE The relationships in Table 2 also apply to enabling systems.

5.6 Progressive interface definition

Interfaces are progressively defined, with the first descriptions at a high level commonly occurring with application of the business or mission analysis process, then throughout the application of the requirements, architecture and design processes. The integration process coordinates with those processes to check that the interface definitions, as implemented and integrated, are adequate and that the processes consider the integration needs.