TECHNICAL SPECIFICATION

ISO/IEC TS 24748-6

First edition
2016-12-01

Systems and software engineering — Life cycle management —

Part 6: System integration engineering

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

Reference number
ISO/IEC TS 24748-6:2016(E)

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Foreword

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The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, Subcommittee SC 7, *Systems and software engineering*.

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

Introduction

This document was developed in response to a need for consistent terminology, definitions and guidance that elaborates the area of system integration, taking into account the context of use and the proven practices for the development of systems.

ISO/IEC/IEEE 15288 includes an integration process that focuses on physically assembling the implemented system elements composing a system to obtain an "integrated system". This process interfaces directly to other technical processes and indirectly to activities and tasks of other technical processes, in particular, the processes that define the system requirements, architecture and design.

The purpose of this document is to facilitate the usage of the integration process of the latest revision of ISO/IEC/IEEE 15288 by providing guidance on system integration.

This document describes the integration engineering activities dealing with planning, performing and managing the integration of a system, including the related activities of other technical processes, in particular, verification and validation processes. These are real practices in industry, i.e. the integration of a system is technically engineered and managed as a project (included in the system development project). Although these practices are performed, they were not formalized in a standard or a guide when this document was written.

Systems and software engineering — Life cycle management —

Part 6: System integration engineering

1 Scope

This document

— specifies activities and processes to be implemented for engineering the integration of systems-of-interest throughout the life cycle (systems made of products and/or services; see Note 1),

— provides guidance for the integration process and its relationships to other system life cycle processes as described in ISO/IEC/IEEE 15288,

— specifies the information items to be produced through the implementation of the integration engineering (integration process and its relationships to other system life cycle processes),

— specifies the contents of the information items, and

— provides guidelines for the format of the information items.

This document can be applied to

— those who use or plan to use ISO/IEC/IEEE 15288 on projects dealing with man-made systems, software-intensive systems, products and services related to those systems, regardless of project scope, methodology, size or complexity, and

— anyone performing integration engineering 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.

NOTE 1 Systems concerned within this document are those as defined in ISO/IEC/IEEE 15288, i.e. systems that are man-made and can be configured with one or more of the following: hardware, software, data, humans, processes (e.g. processes for providing service to users), procedures (e.g. operator instructions), facilities, materials and naturally occurring entities.

NOTE 2 This document is intended to be consistent with the other parts of ISO/IEC 24748.

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/IEC/IEEE 15288:2015, *Systems and software engineering — System life cycle processes*

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 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp/

3.1.1
acquirer
stakeholder that acquires or procures a product or service from a *supplier* (3.1.9)

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.1]

3.1.2
aggregate
composition of several implemented *system elements* (3.1.11) that are *assembled* (3.1.3), on which a set of *verification actions* (3.1.17) and/or *validation actions* (3.1.15) is applied

3.1.3
assemble
activities for combining and connecting implemented *system elements* (3.1.11) or *aggregates* (3.1.2) to support specific goals, i.e. *integration* (3.1.5), *verification* (3.1.16), *validation* (3.1.14), manufacturing and production.

3.1.4
enabling system
system (3.1.10) that supports a *system-of-interest* (3.1.12) during its life cycle stages, but does not necessarily contribute directly to its function during operation

EXAMPLE When a system-of-interest enters the production stage, a production enabling system is required.

Note 1 to entry: Each enabling system has a life cycle of its own. ISO/IEC/IEEE 15288 is applicable to each enabling system when, in its own right, it is treated as a system-of-interest.

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.18]

3.1.5
integration
activities of combining several implemented *system elements* (3.1.11) and activating the *interfaces* (3.1.8) to form a realized system (product or service) that enables interoperation between the system elements and with other *systems* (3.1.10) to satisfy system requirements, architecture characteristics and design properties

Note 1 to entry: In this document, the term "integration" is limited to the integration of the implemented system elements which compose a system and the necessary life cycle related activities. Integration may occur to connect a *system-of-interest* (3.1.12) with external interoperating systems and/or *enabling systems* (3.1.4).

Note 2 to entry: The process of combining software components, hardware components or both into an overall system (ISO/IEC/IEEE 24765).

3.1.6
integration engineering
set of activities that defines, analyzes and executes *integration* (3.1.5) across the life cycle, including interactions with other life cycle processes

Note 1 to entry: The application of the system life cycle processes and knowledge of the *system-of-interest* (3.1.12) are necessary in order to integrate a set of *system elements* (3.1.11) into a *system* (3.1.10).

3.1.7
integration management
set of activities that plans, assesses and controls the integration activities and all related activities

Note 1 to entry: It helps ensure that the process outcomes are achieved and that the integration related information items are identified, documented, maintained, communicated and traced throughout the life cycle of the concerned *system* (3.1.10).

3.1.8
interface
set of logical and/or physical characteristics required to exist at a common boundary or connection between *system elements* (3.1.11)

Note 1 to entry: As examples of interface definition, refer to ISO/IEC/IEEE 24765.

3.1.9
supplier
organization or individual that enters into an agreement with the *acquirer* (3.1.1) for the supply of a product or service

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.45]

3.1.10
system
combination of interacting elements organized to achieve one or more stated purposes

Note 1 to entry: A system may be considered as a product or as the services it provides.

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.46]

3.1.11
system element
member of a set of elements that constitute a *system* (3.1.10)

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.47]

3.1.12
system-of-interest
system (3.1.10) whose life cycle is under consideration in the context of this document

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.48]

3.1.13
user
individual or a group that benefits from a *system* (3.1.10) during its utilization

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.52, modified]

3.1.14
validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

Note 1 to entry: A *system* (3.1.10) is able to accomplish its intended use, goals and objectives (i.e. meet stakeholder requirements) in the intended operational environment. The right system was built.

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.53]

3.1.15
validation action
action that describes what is to be validated (the element as reference), on which item the action is performed, the expected result from the performance of the action, the validation technique to apply and at which level of decomposition of the *system-of-interest* (3.1.12)

3.1.16
verification
confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

[SOURCE: ISO/IEC/IEEE 15288:2015, 4.1.54]

3.1.17
verification action
action that describes what is to be verified (the element as reference), on which item the action is performed, the expected result from the performance of the action, the verification technique to apply and at which level of decomposition of the *system-of-interest* (3.1.12)

3.2 Abbreviatied terms

IES Integration Enabling System

NDI Non-Developmental Item

SEI Software Engineering Institute

SoI System-of-Interest

4 Conformance

4.1 Intended usage

This document provides requirements and guidance for the execution of ISO/IEC/IEEE 15288 processes and activities that deal with integration engineering. This document also provides definition of the content and recommendations for the format of the information items or documentation that result from the implementation of the related processes.

4.2 Conformance to processes

This document provides requirements and recommendations for a number of integration engineering processes and related activities suitable for usage during the life cycle of a system (made of products and/or services).

The requirements and recommendations for processes in this document are contained in Clause 6.

4.3 Conformance to information item content

This document provides requirements and recommendations for a number of integration engineering information items to be produced during the life cycle of a system (made of products and/or services).

The requirements and recommendations for information items in this document are contained in Clause 7.

NOTE In this document, for simplicity of reference, each information item is described as if it were published as a separate document. However, information items are considered as conforming if they 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. This will depend on the nature of the system, implementation methods, life cycle model and scope of the project; for example, test and Integration plan, a system engineering management plan containing integration plan information.

4.4 Full conformance

A claim of full conformance to this document is equivalent to claiming conformance

— to the provisions contained in 6.2 and 6.3, and

— to the information items cited in Clause 7.

4.5 Tailored conformance

4.5.1 Processes

This document does not make provision for tailoring processes. ISO/IEC/IEEE 15288:2015, Annex A provides normative direction regarding the tailoring of system life cycle process.

4.5.2 Information items

Information items described in this document are requirements and recommendations that can be adapted depending on the type of system, implementation methods, life cycle model and scope of the project.

5 Concepts and principles

5.1 General

This clause presents concepts and principles that apply to integration engineering and to the information items generated at all levels of the system-of-interest during the execution of the concerned processes. They also apply to the processes used in the integration itself and to management of the integration of a system.

5.2 Integration fundamentals

5.2.1 Terms and approaches

5.2.1.1 Fundamental concept behind the term “integration”

As stated in 3.1.5, the term “integration” is defined as activities of combining several implemented system elements and activating the interfaces to form a realized system (product or service) that enables interoperation between the system elements and with other systems to satisfy system requirements, architecture characteristics and design properties. The execution of these activities provides something integrated that becomes a whole. Integration of the system involves its functions.

EXAMPLES

— The engine is integrated with chassis and suspension to form the vehicle.

— Integrated repository: a repository for storing all information pertinent to the System Engineering Plan (SEP) to include all data, schema, models, tools, technical management decisions, process analysis information, requirement changes, process and product metrics and trade-offs (IEEE 1220-2005, 3.1.18).

— Integrated team: group of people with complementary skills and expertise who are committed to delivering specified work products in timely collaboration (ISO/IEC/IEEE 24765).

— Integrated circuit: a small piece of semiconductive material that contains interconnected electronic elements (ISO/IEC 2382)

The opposite of the verb “to integrate” is “to segregate” which means to take apart (synonyms: disassemble, separate).

To make the link with the term “system”, it is notable that a system deals with a whole, without using explicitly the term whole in its ISO/IEC/IEEE 15288 definition (combination of interacting elements organized to achieve one or more stated purposes; see 3.1.10).

5.2.1.2 Integration engineering approach

The concept of wholeness is key to integration engineering. Holistically, a system is more than the sum of its parts. So too, integration is more than mere assembly.

Integration engineering encompasses all activities throughout the life cycle of a system-of-interest that are linked to the integration of the implemented system elements to form the system-of-interest. This includes the following:

— the definition, preparation and performance of the assembly of the implemented system elements to form aggregates until obtaining the defined system-of-interest;

— the definition and performance of actions applied to aggregates in order to check the assembly focusing in particular on interfaces;

— the definition and performance of verification and validation actions applied to aggregates in order to check conformance of the assembly to the system requirements, architecture and design;

— the integration of the formed system into its context of use (environmental context); integration is recursive and so applies to the integration of the system-of-interest into the next level of the system structure.

It also includes the activities of other technical processes that influence and/or constrain, guide, serve and enable these previous activities.

It also includes the integration of the system-of-interest with interoperating systems and enabling systems. It is related to the engineering of enabling systems (set of enabling products and/or services) that support the integration of the system-of-interest (see 5.3.2).

The management of all these activities is part of the overall project management of the system-of-interest.

NOTE The system-of-interest can be composed of layers of system elements. A system element can be considered as a system or as a non-decomposable element. The system-of-interest is the highest abstraction in the decomposition into levels of systems.

While the system-of-interest is the highest level of abstraction in the decomposition of a particular system structure, systems can be abstracted up with respect to their interactions as part of one or more systems-of-systems. This perspective is necessary to aid the integration of the system-of-interest with the interoperating systems and enabling systems of its environment.

A system element is a discrete part of a system that can be implemented to fulfil specified requirements (for example, hardware, software, data, humans, processes, procedures, facilities, materials or any combination thereof).

5.2.1.3 Integration versus mass production

System integration is a part of the effort related to the realization of prototypes or one-shot-systems. The integration activity is different from the mounting of end products on a production or manufacturing line.

For mass/series production, an assembly line does not necessarily use the same assembly order of implemented system elements as it is done for prototypes within the integration process. Integration of prototypes composes systems, through aggregates (see 5.2.2.1), in order to verify and possibly validate those aggregates and their interfaces, almost separately (see 5.2.4).

Mass/series production is not interested in systems, but rather in sets of components (implemented system elements) to optimize the time and production effort. Nevertheless, the integration of a prototype often provides pertinent lessons to engineer a production line that repeats the prototype, in particular, about the order of assembly of the implemented system elements.

5.2.2 Notions of aggregate and of interface

5.2.2.1 Aggregate

The integration of a system is based on the notion of "aggregate". An aggregate is an assembled set of two or several implemented system elements and their interfaces as they are defined in the system architecture and design. An aggregate has a functional consistency that allows the performance of verification actions and possibly validation actions. Each aggregate is characterized by a configuration that specifies the implemented system elements that are physically assembled and their configuration status.

NOTE An aggregate, in the context of integration, does not necessarily represent a system as defined in the physical view of architecture or in the hierarchy decomposition of the system-of-interest. For the purpose of efficient integration and validation of the system, different sets of aggregates may be temporarily considered depending on the integration techniques or methods (see 5.2.6.1) that have been selected to define the integration, verification and validation strategies (see 5.2.9). The validation strategy is of concern because the validation of the implementation of certain requirements is not possible using the complete system due to, for example, security, physical or economical constraints. This is addressed by forming temporary aggregates in order to exercise the concerned requirements.

5.2.2.2 Interface

An "interface" is a concept, in the sense that any system element that binds two system elements may be considered to be an interface from an architectural perspective. An interface generally includes two aspects:

— a logical aspect, i.e. the input-output flow and the function that carries it;

— a physical aspect, i.e. the physical link, made of technology, that transports the input-output flow.

A logical interface consists of an input flow, an output flow or a bi-directional flow (transactional flow) between two functions of the system so that they may exchange material, energy and/or information.

A physical interface is a physical link or port that binds two system elements within the system-of-interest or one system element of the system-of-interest with an element external to the system-of-interest. A physical interface may be considered a system element.

The definition of interfaces is an intrinsic part of the system architecture and design definition and is critical to the success of integration. Interfaces are common failure points in complex systems. They are the points where independent systems or system elements (not necessarily made of the same technology) meet and communicate with each other. This is the reason why architecture and design definition activities and decisions have to consider how the integration (assembly of system elements and verification of the assembly) will be performed.

