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Systems and software engineering — Life cycle management —

Part 2: Guidelines for the application of ISO/IEC/IEEE 15288 (system life cycle processes)

Ingénierie des systèmes et du logiciel — Gestion du cycle de vie —

Partie 2: Lignes directrices pour l'application de l'ISO/IEC/IEEE 15288 (processus du cycle de vie du système)

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Foreword

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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 document 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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This document was prepared by Joint Technical Committee ISO/JTC 1, *Information technology,* Subcommittee SC 7, *Software and systems engineering,* in cooperation with the IEEE Computer Society Systems and Software Engineering Standards Committee, under the Partner Standards Development Organization cooperation agreement between ISO and IEEE.

This second edition cancels and replaces the first edition (ISO/IEC/IEEE 24748-2:2018), which has been technically revised.

The main changes are as follows:

— updated 4.4 to reflect changes to ISO/IEC/IEEE 15288;

— reworked interfacing, enabling and interoperating systems;

— added considerations on agile and DevOps;

— reworked 6.5;

— reworked 6.7 to reflect changes to ISO/IEC/IEEE 15288;

— reworked 6.8 to reflect changes to ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 24748-1;

— removed the former Annex A (guide on transitioning from former version);

— added a new Annex B to include an example on interfacing, enabling and interoperating systems;

— removed the former Annex C (engineering views and the Vee);

— added a new Annex C on model-based systems engineering.

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

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

This document and its companion, ISO/IEC/IEEE 24748-3, specifically support the use of ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207, respectively. This document and ISO/IEC/IEEE 24748-3 reflect the alignment effort evident in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207. Terminology, structure and content in this document and ISO/IEC/IEEE 24748-3 are aligned consistent with those in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207. Consequently, the users of ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 benefit from having documents complementarily addressing all aspects of services or products over their life cycle.

This document is intended to be consistent with both ISO/IEC/IEEE 24748-1 and ISO/IEC/IEEE 15288 in its treatment of life cycle concepts and systems engineering processes.

NOTE Systems engineering for defence projects is addressed in ISO/IEC/IEEE 24748-7.

There is also increasing recognition of the importance of ensuring that all life cycle stages, and all aspects within each stage, are supported with thorough guidance enabling alignment with process documents that focus on areas besides systems and software. These can include hardware, humans, data, processes (e.g., review process), procedures (e.g., operator instructions), facilities and naturally occurring entities (e.g., water, organisms, minerals). The concept and structure of the ISO/IEC/IEEE 24748 series is intended to allow its extension to such additional domains where that will provide value to users.

Systems and software engineering — Life cycle management —

Part 2: Guidelines for the application of ISO/IEC/IEEE 15288 (system life cycle processes)

1 Scope

This document provides guidance on the application of ISO/IEC/IEEE 15288. It addresses the application of system, life cycle, organizational, project, process, and conformance and adaption concepts, principally through references to ISO/IEC/IEEE 24748-1 and ISO/IEC/IEEE 15288. This document gives guidance on applying ISO/IEC/IEEE 15288 from the aspects of strategy, planning, application in organizations and application on projects. It also provides a comparison of the differences between ISO/IEC/IEEE 15288:2023 and ISO/IEC/IEEE 15288:2015.

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, *Systems and software engineering — System life cycle processes*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC/IEEE 15288 apply.

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

NOTE Definitions for other systems and software engineering terms typically can be found in ISO/IEC/IEEE 24765, available at www.computer.org/sevocab.

4 Overview of ISO/IEC/IEEE 15288

4.1 General

ISO/IEC/IEEE 15288 defines a set of processes to facilitate system development and information exchange among acquirers, suppliers and other stakeholders in the life cycle of a system. It applies to the acquisition of systems, which can be comprised of products, services or both, as well as to the supply, development, operation, maintenance and disposal of systems, whether performed internally or externally to an organization.

In the context of this document, ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207, there is a continuum of human-made systems from those that use little or no software to those in which software is the primary interest. When software is the predominant system or element of interest, ISO/IEC/IEEE 12207 should be used. Both documents have the same process model, share most activities and tasks and differ primarily in descriptive notes. The determination of the applicability of ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 should be decided by the nature of the system and its enabling systems. Often, a mixed tailoring of each standard can be appropriate.

The purpose of ISO/IEC/IEEE 15288 is to provide a defined set of processes to facilitate communication among acquirers, suppliers and other stakeholders in the life cycle of a system. ISO/IEC/IEEE 15288 is written for acquirers of systems and other stakeholders like suppliers, developers, operators, maintainers, managers, quality assurance managers and users of systems.

4.2 Structure of ISO/IEC/IEEE 15288

ISO/IEC/IEEE 15288 contains requirements in two clauses:

a) ISO/IEC/IEEE 15288:2023, Clause 6 defines the requirements for the system life cycle processes;

b) ISO/IEC/IEEE 15288:2023, Annex A provides requirements for tailoring of ISO/IEC/IEEE 15288.

See ISO/IEC/IEEE 15288:2023, Clause 5 for key concepts used in that International Standard.

Three informative annexes support the use of ISO/IEC/IEEE 15288:

— ISO/IEC/IEEE 15288:2023, Annex B provides information on possible information items that can be associated with each process in ISO/IEC/IEEE 15288;

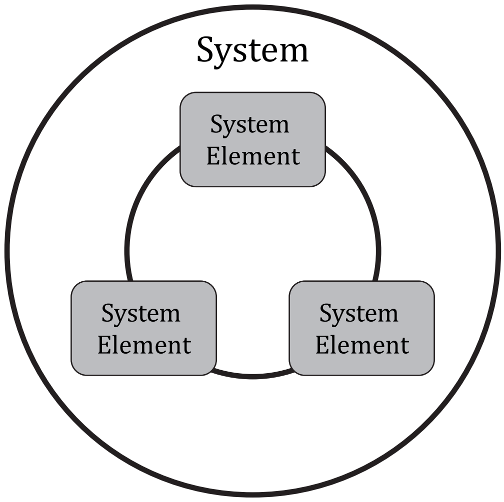
— ISO/IEC/IEEE 15288:2023, Annex C provides information about use of the ISO/IEC/IEEE 15288 system life cycle processes as a process reference model to support process assessment;

— ISO/IEC/IEEE 15288:2023, Annex D provides an informative description of the implementation of system life cycle processes in an MBSE approach.

4.3 Context of ISO/IEC/IEEE 15288

ISO/IEC/IEEE 15288 focuses on the processes that are used by or for a project that exists in a defined relationship with the organization, other projects and enabling systems. Typically, a project is assigned responsibility that encompasses one or more life cycle stages of the system-of-interest (SoI). ISO/IEC/IEEE 15288 is applicable to organizations and projects whether they act as the acquirer or the supplier of a system and whether the system is comprised of products, services or a combination of both.

The ISO/IEC/IEEE 15288 processes are described in relation to a system, see Figure 1. As shown in Figure 1, a system is composed of a set of interacting system elements. System elements may include software elements, hardware elements, services, and utilization and support resources.



NOTE See ISO/IEC/IEEE 15288:2023, Figure 1.

Figure 1 — System and system element relationship

When an organization applies ISO/IEC/IEEE 15288 to a particular system that system becomes the SoI. The SoI has a life cycle that consists of multiple stages through which the system passes during its lifetime. These stages are not necessarily sequential and their execution can be completely or partially in parallel, as well as iterative or recursive. Examples of typical stages are:

— concept;

— development;

— production;

— utilization;

— support;

— retirement.

NOTE 1 Stages are described in ISO/IEC/IEEE 15288:2023, 5.5.2 and in ISO/IEC/IEEE 24748-1:2024, 4.3.2 and Clause 5.

NOTE 2 The management of the transition from one stage to another is not necessarily a linear, sequential, progression and engineering activities are associated with providing appropriate work products and decision-making information in each stage.

A number of enabling systems are deployed throughout the system life cycle to provide the SoI with support as needed. Each life cycle stage can require one or more enabling systems. An enabling system has its own life cycle and when ISO/IEC/IEEE 15288 is applied to it, it then becomes an SoI.

NOTE 3 The role and use of enabling systems are described in 6.3.5.

NOTE 4 For related material on enabling systems, see also ISO/IEC/IEEE 15288:2023, 5.2.3 and ISO/IEC/IEEE 24748-1:2024, 4.2.4.

ISO/IEC/IEEE 15288 is applicable at any level of the structure associated with an SoI. As a system is decomposed recursively into its system elements, the processes of ISO/IEC/IEEE 15288 may be used for each system and system element in the system structure, including enabling systems. Each system and system element has a life cycle of its own and its own set of enabling systems.

NOTE 5 For related material on system structure, see ISO/IEC/IEEE 15288:2023, 5.2.2 and ISO/IEC/IEEE 24748-1:2024, 4.2.3.

In order to perform needed operations and transformations upon systems during their life cycles, the organization creates and monitors projects. Projects have a defined scope, resources (including time) and focus. The scope can involve managing all of the stages of the life cycle, a subset of the stages, one or more defined processes or one or more process activities. The time scale can be of varying duration, for example a few weeks or tens of years. The focus of the project is related to the SoI and its systems and system elements in some form of system structure or stage partitioning.

NOTE 6 System life cycle concepts are described in ISO/IEC/IEEE 24748-1:2024, 4.3.

Organizations focus on systems that are created or transformed by projects within the organization or in conjunction with other organizations. Projects have a span of interest that includes the SoI and its related enabling systems. Some enabling systems are under direct control of the project. The SoI and those enabling systems make up the project span of control.

The work performed by projects is on or with the SoI within one or more life cycle stages. ISO/IEC/IEEE 15288 includes the requirement to define an appropriate life cycle for a system, the selection of processes to be applied throughout the life cycle and the application of these processes to fulfil agreements and achieve customer satisfaction.

ISO/IEC/IEEE 15288 can be applied to all types of product- or service-focused systems and system elements consisting of one or more of the following: hardware, software, humans, processes, procedures, facilities and naturally occurring entities. The use of ISO/IEC/IEEE 15288 for systems within this broad scope is one of its main advantages.

The use of the standard may be adapted to accommodate the varying project requirements in treating system life cycles.

NOTE 7 This can be performed by adapting the life cycle as described in ISO/IEC/IEEE 24748-1:2024, Clause 5 and tailoring described in ISO/IEC/IEEE 15288:2023, Annex A.

4.4 Comparison of ISO/IEC/IEEE 15288 to prior version

This subclause compares ISO/IEC/IEEE 15288:2023 with ISO/IEC/IEEE 15288:2015. For a more detailed comparison, see Annex A. The main changes are:

— improvements to selected technical processes including business or mission analysis process, system architecture definition process (renamed from architecture definition process), design definition process, implementation process, integration process and maintenance process;

— improvements to selected technical management processes, including risk management process and configuration management process;

— except for these changes, the process groups and life cycle processes are the same as the prior version;

— emphasized importance of system of systems (SoS), moved content from ISO/IEC/IEEE 15288:2015, Annex G to ISO/IEC/IEEE 15288:2023, 5.4 and added several notes throughout the document;

— addition of ISO/IEC/IEEE 15288:2034, Annex D addressing model-based systems engineering (MBSE);

— updates to ISO/IEC/IEEE 15288:2015, Clause 5, including a better description of iteration and recursion and expanded content on process application and system concepts;

— new content in ISO/IEC/IEEE 15288:2023, Clause 5 on collaborative activities, concept and system definition, assurance and quality characteristics;

— updates to the terms and definitions;

— removed ISO/IEC/IEEE 15288:2015, Annex D "Process integration and process constructs", Annex E "Process views", Annex F "Architecture modelling" and Annex G "Application of system life cycle processes to a system of systems".

5 Application concepts

This document provides guidelines for life cycle management in the field of systems. This clause lists essential concepts on which this document is based and provides references for further reading and applying. Essential concepts are:

— life cycle management: ISO/IEC/IEEE 24748-1 provides more information on concepts related to life cycle management in general;

— system concepts: system concepts for systems that are any mix of products and services are introduced in ISO/IEC/IEEE 15288:2023, 5.2; additional discussion is in ISO/IEC/IEEE 24748-1:2024, 4.2;

— organizational concepts: organizational concepts are introduced in ISO/IEC/IEEE 15288:2023, 5.3; additional discussion is in ISO/IEC/IEEE 24748-1:2024, Annex B;

— system of systems concepts: SoS concepts are introduced in ISO/IEC/IEEE 15288:2023, 5.4; additional discussion is in ISO/IEC/IEEE 21839, ISO/IEC/IEEE 21840 and ISO/IEC/IEEE 21841;

— life cycle concepts: life cycle concepts are introduced in ISO/IEC/IEEE 15288:2023, 5.5; additional discussion is in ISO/IEC/IEEE 24748-1:2024, 4.3;

— process concepts: process concepts are introduced in ISO/IEC/IEEE 15288:2023, 5.6; additional discussion is in ISO/IEC/IEEE 24748-1:2024, Annex A;

— project concepts: project concepts are introduced in ISO/IEC/IEEE 15288:2023, 5.3.2; additional discussion is in ISO/IEC/IEEE 24748-1:2024, Annex C.

6 Applying ISO/IEC/IEEE 15288

6.1 Overview

Throughout ISO/IEC/IEEE 15288, “shall” is used to express a provision that is binding between two or more parties, “should” to express a recommendation among possibilities and “may” to indicate a course of action permissible within the limits of ISO/IEC/IEEE 15288. This document provides guidance to assist in understanding how the provisions of ISO/IEC/IEEE 15288 apply. No new requirements are introduced in the guidance text (no “shall”). Where “should” is used, it is a recommendation of a requirement of ISO/IEC/IEEE 15288.

Understanding concepts does not give the ability to immediately apply them without further thought and work. 6.2 to 6.8 give guidance on what should be done to bridge the gap between concept and practical use in different organizational, life cycle and project environments, starting with planning the application of ISO/IEC/IEEE 15288.

Modern organizations strive to develop a robust set of life cycle processes that are applied repeatedly to the projects of the organization. To accommodate that need, ISO/IEC/IEEE 15288 is intended to be useful for application at either the organization level or at the project level. An organization should adopt the standard and supplement it with appropriate policies, life cycle processes, life cycle models and procedures. A project of the organization should typically conform to the organization's processes rather than conform directly to ISO/IEC/IEEE 15288.

In some cases, projects can be executed by an organization that does not have an appropriate set of processes adopted at the organizational level. Such a project may directly adopt the provisions of ISO/IEC/IEEE 15288.

6.2 Application strategy

6.2.1 Overview

ISO/IEC/IEEE 15288 can be applied for a variety of reasons, such as to:

a) define the processes, activities and tasks required for use on a specific project;

b) improve processes used by an organization across multiple projects;

c) provide guidance on system life cycle processes usable within a larger process, such as an organization's acquisition process or maintenance process.

Whatever the reason for application of ISO/IEC/IEEE 15288 is, a suggested application strategy consists of the following:

— plan the application;

— adapt ISO/IEC/IEEE 15288, if applicable;

— conduct pilot project(s);

— formalise the approach;

— institutionalise the approach.

This strategy is typical of the approach that should be followed when introducing changes into an organization or project. The application strategy can be repeated several times across an organization or within a project as additional processes are addressed or improved.

Whether the basis for the existing system life cycle processes is ISO/IEC 15288:2015 or some other reference point, the fundamental starting point is to identify all the changes to go from that basis to ISO/IEC/IEEE 15288.

Coordinating with stakeholders in this effort is critical: even one area left out that should have been in the planning can materially disrupt applying the new basis. One way of proceeding is for a small group to develop a high-level list of items that should be considered and changed in applying ISO/IEC/IEEE 15288. This may include, and possibly will not be limited to:

— process and procedure changes, including flow and nomenclature;

— staff training needs;

— responsibility changes, including need for new or modified agreements;

— impacts on procedures and tools;

— an approach applied across the organization

— improved processes.

A more detailed set of changes should then be developed by a wide group of affected stakeholders.

Once there is a detailed listing of the changes, the time and cost impacts of each should be assessed and adjusted for the risks of each change and various groupings of change. Changes should be phased to minimise cost, project disruption and the potential for adverse human reactions. Readiness criteria should be developed for the phase-in, as well as checks for successful completion of the changes. Quantitative and qualitative measures should be developed and used.

Throughout, a core group should be maintained to oversee the change from one basis to another, with periodic coordination with the entire group of stakeholders. This coordination is very important to repeatedly communicate the goals of the change, to show progress and to recognise progress.

When an organization or project already has established processes that have been institutionalised, then the implementation strategy can be shortened and should probably include the following:

— plan the application;

— adapt ISO/IEC/IEEE 15288, if applicable (for the risk level of the work);

— conduct the project(s).

6.2.2 Planning the application

Applying ISO/IEC/IEEE 15288 should be considered as a specific project and planned as such.

The following are examples of items to consider while planning the application project:

a) Define the scope of the application project. Possibilities include the following.

   1) A single project that is either internal to an organization or as part of a two-party agreement.

   2) Concentration on some key processes or even a single process where there is expected to be some gain for an organization. This approach can be used where a weakness has been detected previously. It can lead to a full application of ISO/IEC/IEEE 15288 at some future point. Conversely, the approach can be of benefit where significant process refinements or additions have been made, so that in depth revisions of a single process are necessary.

   3) Adoption of ISO/IEC/IEEE 15288 within an organization or across a range of projects. This generally involves a staged introduction. This generally occurs when an organization has multiple processes that are not aligned with ISO/IEC/IEEE 15288.

   4) Adoption of ISO/IEC/IEEE 15288 across all projects and within all parts of the organization. This sometimes occurs with a new subsidiary of an existing organization that has previously adopted ISO/IEC/IEEE 15288.

b) Identify the 15288 application project goals and determine how they fit into the organization-wide business goals. If no obvious link is established between this application project and the organization's business focus, then lasting commitment to achieve the application project goals will be difficult if not impossible to maintain.

c) Identify roles and responsibilities of the application project team, assigning a point of responsibility for each process.

d) Identify the resources available for the application of ISO/IEC/IEEE 15288, such as time, funding, people and enabling systems and services. Also estimate the resources and infrastructure needed to sustain the process development and improvement process once the initial processes are institutionalized.

e) Create and record the application project management strategy for applying ISO/IEC/IEEE 15288.

f) Plan for regular coordination with stakeholders involved in the application project. It is key to every application project to communicate with stakeholders, in particular those that are supposed to apply the updated set of processes.

g) Identify the impact of process tailoring on certifications and the impact of certifications on process tailoring.

6.2.3 Conduct pilot project(s)

When introducing ISO/IEC/IEEE 15288 in an organization across many projects, employing some pilot usage in key areas and processes helps remove emotional barriers, facilitate adoptions and limit the risk exposure of the organization. A successful introduction should usually include such approaches as the following.

a) Identify pilot projects that can use the selected processes. These pilot projects should be chosen on the basis of high priority work that will result in significant improvements, with a high probability of success, or that can be expected to provide quick, visible results.

b) Select a team of early adopters to conduct the pilot projects then publicise and reward their efforts.

c) Plan the pilot projects and identify critical success factors and measures of success.

d) Train everybody involved. Awareness can be aided by regular communication of progress in the implementation process, in addition to formal training classes.

e) For each pilot project, incorporate the selected adapted process or processes into the application project management strategy. Reference or include as appropriate, the necessary records, including the adaptation decisions and rationale.

f) Execute the pilot project(s). Track and record performance against the critical success factors.

g) Capture knowledge gained from each pilot project in the knowledge management process, including lessons learned throughout the pilot project(s). Incorporate the lessons learned into revised processes.

6.2.4 Formalise the approach

Formalizing involves the introduction of a new process across the organization or across several projects. This includes the development of training, procedures, provision of enabling systems and services, such as tools for the processes, and the tracking and oversight of the new processes use and acceptance. Planning for the transition to the new processes should be addressed for any project that is already up and running.

NOTE Improvements can be made within a project by monitoring at the project level. They can also be made by comparing one project against another to determine approaches which were successful and which can be applicable and to be incorporated into future projects.

6.2.5 Institutionalise the approach

Institutionalisation involves the introduction of new processes across any areas and remaining projects of the organization. It includes a focus on ensuring that processes are used consistently and automatically throughout the organization or project. This also involves measuring performance of the process, and continuing to implement process improvement as necessary. These can be instituted using process work product review and approval such as decision gates as described in 6.4.2.

6.3 Application of system concepts

6.3.1 General

ISO/IEC/IEEE 15288 defines a set of processes to facilitate system development and information exchange among acquirers, suppliers and other stakeholders in the life cycle of a system. It applies to the full life cycle of systems, including concept, development, production, utilization, support and retirement of systems, and to the acquisition and supply of systems, whether performed internally or externally to an organization. This subclause focuses on those processes that most directly apply the system concepts stated in ISO/IEC/IEEE 15288:2023, 5.2 and expanded in ISO/IEC/IEEE 24748-1:2024, 4.2.

6.3.2 Systems

To determine how to provide products or services for the benefit of users and other stakeholders, the starting point should be to define the purpose of the system, its boundaries (including human interactions) and those who should be its stakeholders. The same idea should be followed in case the task is to upgrade or add capabilities to an existing system. In many cases, the structure or the composition of the final system are not known, and are not the focus of interest. For those reasons, users of ISO/IEC/IEEE 15288 should start with an analysis of the business or mission of the proposed system, applying the process defined in ISO/IEC/IEEE 15288:2023, 6.4.1, then use this as a bounding framework to define stakeholder needs and requirements, applying the process defined in ISO/IEC/IEEE 15288:2023, 6.4.2. These processes can be applied iteratively, or recursively and can be applied to new systems, existing systems where changes are being considered and enabling systems. This work focuses on purpose, scenarios, use cases and user stories. It is critical to identify and meaningfully involve all who will be stakeholders over the systems life cycle.

Applying a systems concept should mean that the analysis and determination are then used to define the requirements of some collection of interacting elements. This collection should satisfy the analysis and determination by applying the system requirements definition process defined in ISO/IEC/IEEE 15288:2023, 6.4.3. The specific structure of the system is not known at this point, nor is the manner in which that structure will be implemented (i.e. hardware, software, humans, processes, procedures, facilities or naturally occurring entities). The user should determine, possibly iteratively or recursively, the functional, logical, timing, thermal, mass and other properties of the SoI and its enabling systems. Model-based systems engineering (MBSE), see Annex C, can help understand and specify these properties. Maintaining stakeholder involvement throughout is still critical. Depending on the results, revision of the work described in 6.3.2 can be required.

For any of this work, the system analysis process defined in ISO/IEC/IEEE 15288:2023, 6.4.6 can be useful to apply.

6.3.3 System structure

With a thorough understanding of the purpose and benefits of the SoI, its boundaries and stakeholders, as well as their needs and requirements, plus the resulting system requirements that have been derived from these, the user of ISO/IEC/IEEE 15288 should apply the technical processes for system definition (see 6.7.5.3) to progressively define the structure of the system (its architecture) and the specific ways in which that architecture can be realised.

More specifically, the user of ISO/IEC/IEEE 15288 should apply the system architecture definition process (ISO/IEC/IEEE 15288:2023, 6.4.4) and the design definition process (ISO/IEC/IEEE 15288:2023, 6.4.5). In applying these processes, probably iteratively and recursively, characteristic properties at a system's boundary arise from the interactions between system elements and external systems. What this means in practice is that the interfaces between parts of the system should be understood first, then the parts themselves should be architected and then designed to respond to the requirements imposed by the interface. This process should be continued from the most general understanding of the system structure progressively to the most detailed level. Due to the huge amount of information that is gathered when applying the processes, model-based approaches (MBSE) should be taken to help keeping the artefacts consistent, also see Annex C.

Briefly stated, the user of ISO/IEC/IEEE 15288 should work from the interfaces inward, and from the most general to the most specific and detailed aspects of the requirements, architecture and design. This applies to the SoI and its enabling systems, whether new or under consideration for change. Accordingly, the application of the processes can be done at any stage of a system's life cycle.

For any of this work, the systems analysis process defined in ISO/IEC/IEEE 15288:2023, 6.4.6 can be useful to apply.

6.3.4 Structure in systems and projects

The user of ISO/IEC/IEEE 15288 should determine the project scope, or the scopes of the set of projects, that best supports definition, realization and use of the SoI and its enabling systems. To do this, the user of ISO/IEC/IEEE 15288 should draw on the results of applying, directly or with adaptation, the agreement processes (ISO/IEC/IEEE 15288:2023, 6.1), organizational project-enabling processes (ISO/IEC/IEEE 15288:2023, 6.2) and technical management processes (ISO/IEC/IEEE 15288:2023, 6.3) that are already in place for the organization within which the projects will be executed. For example, the possible need to define a new system should result in reconsideration of the organization's infrastructure, portfolio, human resource, quality and knowledge management capabilities under various possible project structures to find the best relationship of the set of projects versus the possible scope of the SoI and its enabling systems.

6.3.5 Interfacing, enabling and interoperating systems

Typically, systems break at the interfaces because of lack of quality or maturity of these interfaces. When developing an SoI, it is not only the interfaces that this SoI has in operation that should be taken into account. There are other interfaces to be considered along the entire life cycle. Therefore, it is important to understand the concept of interfacing, enabling and interoperating systems.

When teams begin to identify the external interfaces of the SoI, they often start with the systems that the SoI interacts with in operation. Often, a system boundary diagram is used to document data or information, energy, material and physical flows. Immediately thereafter, other life cycle stages should be considered to identify all systems that interact with the SoI to perform a function. This almost always occurs in an SoS environment where constituent systems interact with each other to realise SoS functions. Also included are cases where external systems exchange data or information with the SoI for further processing. The total set of these external systems is referred to as the interoperating systems associated with the SoI.

These interoperating systems are a subset of the interfacing systems. The interfacing systems also include those external systems having purely physical interfaces with the SoI, in which no data or information is exchanged to support any system functionality, neither on the part of the SoI nor on the external system. In most cases, these are physical interfaces between the SoI and the external system.

Enabling systems are systems that support the SoI at various points along its life cycle. Consequently, they apply to all parts of the life cycle and potentially support any process. Some enabling systems have a physical interface to the SoI (e.g. maintenance laptop) while some do not (e.g. training system). Also, enabling systems can be either inside or outside the boundary for which a project is responsible. Whether a particular enabling system is inside or outside the project boundary, the enabling system is within the span of interest of a project because of interface and scheduling constraints. Thus, enabling systems should be considered especially whenever there are changes to the design of the SoI. If the interface to one of the enabling systems can no longer be supported as a result of the change to the SoI, it can lead to cost-intensive changes to this enabling system. In such a case, it is advisable to perform a trade-off study to weigh the consequences of making the proposed change. If it is necessary to develop enabling systems to support the SoI, care should be taken to ensure that the schedules of these two development projects are closely aligned. Failure to provide a necessary enabling system in a timely manner can have a massive impact on the schedule of the SoI.

In case the enabling system is inside the project boundary, for each architecture or design solution in the SoI or system element, the enabling system requirements should be identified. The enabling system requirements should be satisfied either by engineering the enabling systems that need to be developed or by acquisition or scheduling the existing and available enabling systems. These actions should be carried out to help ensure that required enabling system services or products are available when needed to support the SoI or systems elements during the applicable life cycle stage.

The requirements for each enabling system should be provided to the concept definition and system definition processes of the applicable SoI and system elements. Requirements can include allowable tolerances and types of materials and material processing such as cutting, milling and stamping. Additionally, the concept of operations (or strategy) for implementation should be available as well as any implementation constraints to include special techniques to be used. An enabling system can be defined as an SoI and can also have its own set of enabling systems to provide appropriate life cycle support.

Annex B provides examples with explanations of interfacing, enabling and interoperating systems.

6.4 Application of life cycle concepts

6.4.1 Overview

ISO/IEC/IEEE 15288:2023, 6.2.1.3 a) requires the establishment of a life cycle model to provide a framework in which the processes of ISO/IEC/IEEE 15288 are performed. It also requires the definition of purpose and outcomes for each stage in the established life cycle model. ISO/IEC/IEEE 24748-1:2024, Clause 4 provides a description, including the purpose and outcomes, of a life cycle model with a set of six life cycle stages. This model is included in Figure 2.

NOTE 1 For simplicity of exposition, the life cycle model in Figure 2 is drawn as if the stages were sequential and equal in length. As described in ISO/IEC/IEEE 24748-1:2024, 4.3.1, stages can be interdependent and overlapping, can be of differing durations and can iterate or be applied recursively.

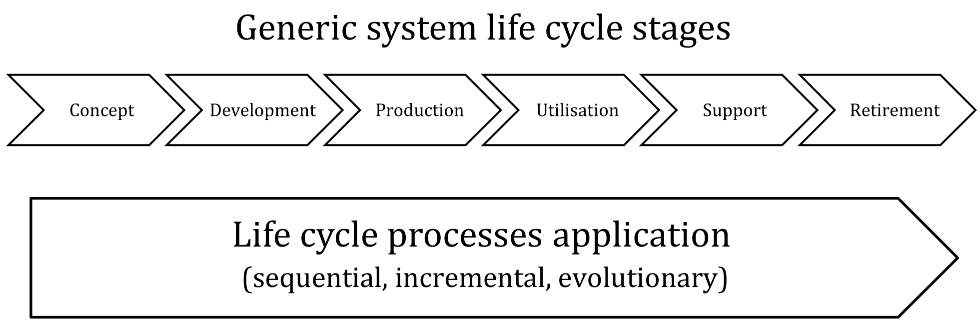


Figure 2 — Generic system life cycle model

The system life cycle model illustrated in Figure 2 does not imply any application precedence or sequence for the application of ISO/IEC/IEEE 15288 life cycle processes. The use of the life cycle processes is influenced by multiple factors such as social responsibilities, world trade laws, organizational cultures and technical considerations. Each of these factors can vary during the life of a system. A manager of a system life cycle stage typically selects the appropriate set of life cycle processes to meet entry or exit criteria and other stage objectives. For example, during any of the later life cycle stages a manager can use the operation process, maintenance process and disposal process to manage the system while it performs its required functions or is serviced to meet system requirements. During earlier life cycle stages the same processes can be used to help manage the development of the system as well as affect the disposal of waste products or work products that are no longer needed.

To determine which processes to select and apply during a system life cycle stage, a user of ISO/IEC/IEEE 15288 is guided by the purpose and outcomes for each of the stages (see ISO/IEC/IEEE 24748-1:2024, Clause 5). The selection of the appropriate processes enables the system's progression through its life cycle to be managed. The system life cycle model of Figure 2 can be considered as an illustration of an orderly passage associated with a system going from one stage of life to another.

An organization (e.g. an automobile company or medical equipment supplier) or a domain group of an organization (e.g. a government defence agency or industry group) often has a unique view of the system life cycle to control the passage from one system life cycle stage to the next. From an organizational perspective, the focus is more on management-focused activities that are used to form both milestones and decision gates.

The organization uses these milestones and gates as decision points where investment decisions can be made as to whether a system should remain in the current stage, be continued to another system life cycle stage, have the plans for the other stages revised before approval, be cancelled or be retired. These milestones and decision gates can be used by organizations to contain the inherent uncertainties and risks associated with costs, schedule and functionality when a system is created or utilised.

There are different approaches that can be used to meet organization goals and objectives. In order to meet the exit criteria of a decision gate, the appropriate artefacts should be produced to provide decision-making information and required deliverables. Thus, planned engineering activities should take place during each system life cycle stage to obtain the outcomes and meet the purpose of the stage or a set of stages.

Some system life cycle models, particularly those related to incremental or evolutionary approaches, feature the iterative execution of several of the life cycle stages shown in Figure 2. For example, a small improvement to an existing system can be conceived, developed and produced within a "timebox" of a few weeks. Subsequent improvements use the same approach in consecutive future "timeboxes". In this environment, it may not be practical to align certain key concepts to the completion of a stage, such as decision gates (6.4.2) and technical reviews. Instead, an alternate alignment strategy, such as the completion of one or more iterations, can be necessary. However, the intent of these key concepts should be retained.

6.4.2 Decision gates

Although there are many different approaches to develop systems, there is an underlying notional set of characteristic milestones and decision gates that exists. Each milestone and decision gate has a distinct purpose and contribution to the system life cycle. These milestones and decision gates should be considered when planning and executing the system life cycle. Cognizant governance should specify the mechanism to arriving at a decision.

NOTE 1 Examples of decision options and their purpose for each stage of a life cycle are shown in ISO/IEC/IEEE 24748-1:2024, Table 1.

Milestones provide an opportunity for management to review progress and decide to declare that milestone as satisfactorily completed and proceed to the next milestone. If the milestone marks the end of a stage, then a decision gate is reached. The decision gates provide a framework within which organization management has high-level visibility and control of the project.

NOTE 2 Some approaches, such as agile and DevOps, accomplish their reviews in a different cadence and tend to avoid the terms “milestones” and “decision gates.”

During each system life cycle stage, management can use established decision gates to determine whether the objectives (financial as well as technical) of that system life stage were satisfactorily completed and the way forward.

The specific rationale for the decision can vary for each stage. For example, during life cycle stages while the system is being used (utilization and support), the decision as to whether to continue in that stage or if the system should be appropriately retired (move to the retirement stage) can be based on:

a) whether system technology should and can be refreshed (change to the baseline configuration without changing performance);

b) whether new system technology should and can be inserted (change to system performance).

Decision gates to move to another stage can occur at more than one point in a given stage. Examples of when decision gates can be appropriate for the concept stage are:

— after a period of pre-study;

— after studying the feasibility of the alternative concepts.

The considerations given can be applied not only to the SoI but also to its system elements as well as enabling systems. If the SoI is an SoS, the considerations can be applied to the constituent systems. Different organizations can be responsible for different systems of the system structure. Also, individual systems or system elements can have a shorter life than the SoI in which they are embedded, so there can be a need to replace these individual systems or system elements with improved ones during the life of the SoI.

6.4.3 Application approaches

6.4.3.1 General

Organizations employ different approaches to satisfy contrasting business and risk resolution strategies. Sequential, incremental, evolutionary or agile approaches are frequently used. These approaches are discussed in 6.4.3.2 to 6.4.3.5. Alternatively, a suitable hybrid of these approaches can be developed.

The selection, development and use of one of these approaches by an organization depend on several factors such as the following:

a) the acquisition policy of the organization;

b) the nature and complexity of the system;

c) the stability or feasibility of system requirements;

d) technological opportunities;

e) the need for different system capabilities at different times;

f) the availability of resources.

A careful selection of an appropriate application approach should be made as it:

— affects the plans and controls for the project;

— forms the basis for project cost and schedule estimates;

— determines the work relationship between acquirer and supplier;

— defines how the team works together;

— shapes what types of informal and formal reviews are established.

6.4.3.2 Sequential approach

6.4.3.2.1 General

For systems that have long development cycles before delivery of the first system, a sequential approach can be appropriate. Many systems, such as produced by the automotive industry, use a similar approach with development taking up to three years before a new automobile model is introduced. Projects using this approach faces many challenges including cost control, funding changes, technology changes, workforce retention and final customer or acquirer requirements satisfaction. These challenges are created because of the long period from establishing the initial requirements for the system to the deploying of the system in the marketplace.

The sequential approach has defined decision gates so that an organization can manage an orderly progression of the system from concept through retirement. For systems that rely heavily on off-the-shelf system elements, development is often started without doing concept studies. In this case, the project needs to be aware of the risks of starting development without doing the risk reduction engineering of earlier studies. Use of off-the shelf system elements does not replace system feasibility analyses or the risk reduction analyses and effectiveness assessments needed to confirm that interfaces are compatible. This off-the-shelf approach can reduce the need to go through earlier decision gates, but it does not eliminate the analysis necessary to reduce risks.

The sequential approach can be very effective and efficient for engineering systems where the requirements are well known and stable, or for updates to existing systems.

6.4.3.2.2 Applicable systems

This approach can be applied to systems that are one or a few of a kind or those that have large quantities produced. Examples of systems for which this approach can apply are infrastructure information technology systems, a manufacturing system modification, automobiles, control systems and consumer products. During the production stage either one or a few systems can be produced and delivered, or a large quantity production can be initiated that can continue into the utilization and support stages. The utilization and support stages are typically the longest period of this life cycle and can last for many years. Major systems realised using this approach often have an operation life of tens of years with modifications using technology refreshments and technology insertions made to sustain the system and lengthen its useful life.

This sequential approach can be applied to modernization of legacy systems. The engineering, however, is done on the system being enhanced and its related lower-level systems and system elements of the system structure. The impact on the SoI should be analysed and where conflicts are revealed, the changes to higher-level systems and the SoI should be made or the requirements for the applicable system should be revised.

6.4.3.2.3 Risks

Because of the long duration of development using the sequential approach, several risks such as the following should be considered and resolved before adoption:

a) expectations and requirements related to the system can change over the years of development;

b) knowledgeable workers on teams can turn over;

c) decision-making personnel in the organization can change;

d) customer personnel in the acquirer’s organization can change;

e) suppliers of system elements and related services can go out of business or change technologies;

f) obsolescence can arise during a long development;

g) disruptive changes of events or the environment can impact the project.

6.4.3.2.4 Opportunities

The opportunities such as the following can be associated with the sequential approach.

a) The deliberate, stepwise refinement approach, whereby the progress of system development is carefully evaluated at each milestone allows system quality and risks to be evaluated and investment decisions confirmed before progressing to the next stage of development, production lot or delivery to market.

b) All system capabilities can be delivered at the same time.

c) In-service modification decisions allow determination of whether to do maintenance, a major modification or to retire the system from service.

d) Old systems can be simultaneously retired from service or withdrawn from the market.

6.4.3.3 Incremental approach

6.4.3.3.1 General

The incremental approach can be applied to organizations that market new versions of a product. Milestones are established at planned intervals to introduce a planned version of the system that can be released to the market. The system realised as a result of the concept stage can be a first version.

The overall capabilities of the last version to be marketed can be known at the start of system development. However, a limited set of capabilities is allocated to the first version. With each successive version, more capabilities are added until the last release fully incorporates the overall capabilities.

The application of ISO/IEC/IEEE 15288 life cycle processes, further described in 6.7, is performed to realise each version. The operation and support of each version is done in parallel with the development, utilization and support of successive versions. Early versions of the system and support for those versions can be phased out as newer versions are bought and used by the customer base or a block modification to earlier versions can be made to incorporate the new capabilities of a later version.

6.4.3.3.2 Applicable systems

This approach can be applied to systems that rely on new, enhanced capability versions of the system to be introduced in short intervals so as to remain competitive in the marketplace. Examples include information technology systems such as business systems, medical systems and routing and firewall systems.

6.4.3.3.3 Risks

The incremental approach has associated risks such as the following that should be considered and resolved before adopting this approach.

a) Initial versions of the system can have such a limited set of capabilities that customers can be dissatisfied and not be interested in buying the next version.

b) Versions marketed with too short an interval can cause customer dissatisfaction with the cost to upgrade or the retraining costs.

c) Costs for training (time and money) to move from one version to the next can be unacceptable.

d) It is not always possible to meet expectations if customers desire the full capabilities in the first version.

e) If requirements are not as well understood as originally thought, this can lead to poor results.

f) Unplanned technology changes or competitor system capabilities can require re-direction of the development and have a significant impact upon costs and schedule for subsequent versions.

g) It is possible that the customer changes the requirements as the development progresses.

6.4.3.3.4 Opportunities

The opportunities such as the following can be associated with the incremental approach.

a) Acquirer requirements for early capabilities can be satisfied.

b) The prototypes developed for each early milestone can have a place in the market.

c) Early introduction of the system, even with limited capabilities, can enable exploitation of the marketplace by beating the competition to market.

d) Emerging technologies can be taken advantage of.

6.4.3.4 Evolutionary approach

6.4.3.4.1 General

The evolutionary approach can be applied by organizations that market new versions of a product at regular or pre-planned intervals. The major difference of this approach with the incremental approach is that the full capabilities of the last version of the system are not known when an evolutionary development is undertaken.

Initially the requirements for the system are partially defined and then refined with each successive version of the system as lessons learned from the use of an early version are translated into new desired capabilities. Each increment can produce artefacts that demonstrate capabilities and build up the necessary evidence for technical reviews.

The ISO/IEC/IEEE 15288 life cycle processes, further described in 6.7, are applied to realize each version. In this case, development of new versions can be done serially or in parallel with partial overlapping. As with versions developed using the incremental approach, different versions can be operated and supported in parallel. Particular care should be taken, however, to maintain configuration control of each version so that operation, training and support procedures are appropriate to the version being used.

Often, a new version with enhanced capabilities can replace an earlier version, or a block modification can be made to the earlier version to incorporate the new capabilities of a later version.

Beyond basic version control, for some SoIs, it is important to plan and to project version compatibility with respect to forward and backward compatibility. This can have both technical impacts and customer acceptability impacts.

6.4.3.4.2 Applicable systems

This approach can be applied to complex systems for which requirements are not well understood even though the need for the system is understood and approved. These are typically one of a kind or low quantity production systems. Example systems can include custom information technology systems, military information technology systems and specific information technology security systems.

6.4.3.4.3 Risks

The evolutionary approach has associated risks such as the following that should be considered and resolved before adopting this approach.

a) All capabilities can have the same priority.

b) Training costs can be unacceptable for moving to the next version.

c) There can be uncertainties related to determining future requirements.

d) There can be uncertainties with respect to planning the schedule release of the next version.

e) With different versions operated and supported in parallel, configuration control can be a challenge.

f) A product prototype can be used too early or inappropriately.

g) Capabilities and technologies in later versions are identified after the former versions are deployed and some learning is available. The additional or changed capabilities and technologies are then tied to the (stakeholder) needs gathered.

6.4.3.4.4 Opportunities

The opportunities such as the following can be associated with the evolutionary approach.

a) Acquirer requirements for an early capability, such as a minimum viable product, can be satisfied.

b) Steady customer feedback can be used to enhance the capabilities of a future version of the system.

c) The prototypes developed to satisfy an early milestone can have a use in the market.

d) Early introduction of a limited capability system can enable countering a competitor threat.

e) Emerging technologies can be taken advantage of.

f) Incremental verification can be used to quickly find problems.

g) User or operator training can be developed gradually over time, often at low, manageable funding levels, with potential for just-in-time training.

6.4.3.5 Agile and DevOps

6.4.3.5.1 General

Agile is an iterative and incremental approach to software delivery (ISO/IEC/IEEE 24748-1:2024, 3.4). DevOps (development and operations) is the set of principles and practices which enable better communication and collaboration between relevant stakeholders for the purpose of specifying, developing, and operating software and systems products and services, and continuous improvements in all aspects of the life cycle (IEEE 2675:2021, 3.1). Agile is a development approach. It is not a life cycle model. In most life cycle models, development is just one stage of many. With similar objectives, agile and DevOps approaches are frequently combined.

6.4.3.5.2 Applicable systems

Agile and DevOps apply well to small software systems with stable hardware platforms, but have been adapted to larger and non-software systems. Different agile methods exist that can be tailored to the project needs. Agile is also well suited for projects for which there is substantial customer uncertainty about the intended final product.

6.4.3.5.3 Risks

Agile and DevOps have associated risks such as the following that should be considered and resolved before adopting them:

a) uses different and varying terminology;

b) has challenges scaling to large systems;

c) difficult to measure true progress;

d) poor resource planning;

e) less documentation;

f) fragmented output;

g) no finite end.

6.4.3.5.4 Opportunities

The opportunities such as the following can be associated with agile and DevOps:

a) can be used with various life cycle models;

b) different methods can be used at different points in the life cycle;

c) can be extended to focus on key foundational concerns such as security (called DevSecOps);

d) deliverable and useful capabilities available much sooner and more frequently;

e) frequently evolving capabilities enables rapid customer feedback;

f) incremental planning incorporating frequent feedback enables greater responsiveness to changing needs.

6.5 Application of organizational concepts

6.5.1 Overview

Organizations are producers and consumers of systems; that is, they exchange products and services. The processes in ISO/IEC/IEEE 15288 are used by organizations that:

a) acquire and use a system;

b) create and supply a system; or

c) create and use a system.

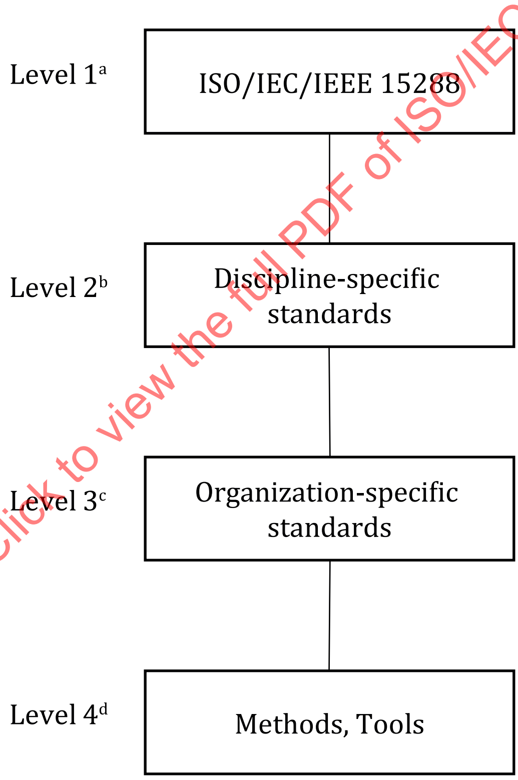
Any of the processes apply at any level in a system structure during any applicable stage of the system life cycle and to any organization assigned responsibility for a system. How they are applied, possibly with adaptation, varies depending on such factors as the project, organization and life cycle model. The outputs of one level, whether information, products or services, are an input to the level below (and can feed back to the level above) and result in a corresponding response including information, products or services. The use (recursively) of the same underlying set of processes to describe an organization's business, project and technical actions at each level of detail in a system structure is a key aspect of the application of ISO/IEC/IEEE 15288.

Additionally, a management group of a multi-organization project working on the same system can use ISO/IEC/IEEE 15288 to provide a common set of processes, an integrated system life cycle model and a common basis for communication and for working together.

The processes in ISO/IEC/IEEE 15288 form a comprehensive set to cater to a wide variety of organizations. An organization, small or large, depending on its business purpose, can select an appropriate subset of the processes (and associated activities and tasks) to fulfil that purpose. ISO/IEC/IEEE 15288 is intended to be applied internally by an organization or through an agreement by two or more organizations. In order to facilitate application of ISO/IEC/IEEE 15288 either internally or through an agreement, the tasks are expressed in agreement language. When applied internally, the agreement language is interpreted as self-imposed tasks.

The application of ISO/IEC/IEEE 15288 may involve adoption of new organizational policies and governance structures which can differ from the informal or implicit practices previously in use. In other cases, the application of ISO/IEC/IEEE 15288 may be harmonised with an organization's policies and standards that are already in place. It is usually the case that an organization has been utilizing its own existing standards and specific techniques. When applying ISO/IEC/IEEE 15288 within an organization, it is therefore important to clarify the relationship between ISO/IEC/IEEE 15288, the organization's own standards and the various techniques that have been employed.

Figure 3 shows one possible example of such relationships that can be useful when applying ISO/IEC/IEEE 15288 within an organization. ISO/IEC/IEEE 15288 is located at the first level, standards for the discipline are located at the second level and the third level is for standards specific to an organization. The final level includes the activities and tasks specific to the project. At each successive level in the hierarchy, the outcomes, activities and tasks can be adapted to the specific context of the discipline, organization or project.



a Details outcomes and activities/tasks in each process.

b Details outcomes and activities/tasks in each process, specific to the discipline, e.g. SAE ARP 4754A aircraft certification.

c Details outcomes and activities/tasks in each process, specific to the organization, e.g. aircraft company processes.

d Details outcomes and activities/tasks in each process, specific to the project, e.g. project-specific coding standard.

Figure 3 — Relationship with existing documents

At the project level, organizational policies and life cycle processes are adapted to project needs, and specific procedures and tools are identified. Some companies define preferred tools and tool sets to spread the costs of development, maintenance and learning across multiple projects. Resolution of any conflicts is left to the organization or project applying ISO/IEC/IEEE 15288 and can involve developing a mapping and if necessary, filling any gaps.

6.5.2 Methods and tools

Process execution typically is supported by methods and tools. The selection of methods and tools depends on many factors including stage in the life cycle, position in the system's hierarchy and application domain. As a result, neither ISO/IEC/IEEE 15288 nor this document includes discussions of specific methods and tools.

Nevertheless, there are some issues that should be considered when selecting and using methods and tools to accomplish life cycle process activities or related tasks, including the following.

a) The approach "form follows function follows purpose" also applies to methods and tools: "methods and tools follow processes follow purpose".

b) Selection of tools should consider connectivity to other tools that provide inputs or use outputs of the tool being considered for use. This also includes security, data storage duration and tool upgrade aspects.

c) The organization's culture and knowledge can affect determining appropriate tools and methods.

d) The training requirements for the effective application of the method or tool as well as administrative efforts should be considered.

e) Using sophisticated tools and methods does not relieve systems engineers of the need to think for themselves.

6.5.3 Considerations and techniques

The reasons for applying ISO/IEC/IEEE 15288 within an organization can include situations as:

a) establishing and sustaining good systems engineering processes across the organization to improve efficiency and effectiveness, and to reduce risk;

b) establishing neutral common ground for communication and discussion of process and procedures, across different organizations and approaches;

c) verifying the thoroughness of an existing process; this should usually be more relevant where the process was developed in-house or adopted and extensively modified;

d) adapting an existing process to cater to the risks associated with moves into new market sectors where more rigour is required because of perceived risks;

e) developing a new process to meet the needs of a new organization; this includes organizations created through mergers or business alliances; it can be necessary to maintain several process models to suit particular activities;

f) managing the introduction of new technology; examples include the automation of existing manual processes, or a change in the techniques used to implement a product or service. ISO/IEC/IEEE 15288 defines criteria which can be used to benchmark the completeness of the process before and after the technology is changed;

g) evaluating an internal capability of a party to meet agreed criteria, e.g. as part of the review process for a solicitation response;

h) establishing a baseline for process assessment and capability determination;

i) establishing a benchmark upon which improvement projects can be developed, e.g. audit against ISO/IEC/IEEE 15288.

NOTE The application of ISO/IEC/IEEE 15288 within an organization is based upon the same approaches as are used on projects, see 6.2.

6.5.4 Management commitment

As with any project which results in changes to work practices, it is essential that the stakeholders within the affected organization be visibly committed to implementing and supporting organization and project processes, and any necessary changes. In a two-party situation, selected process considerations may be recorded in an agreement. Then, as for general organizational use, it should be normal practice to establish policies or processes covering the relevant parties. Some agreements require supplier organizations to provide evidence of process definition and conformance.

6.5.5 Uses of ISO/IEC/IEEE 15288 within an organization

There are four key uses of ISO/IEC/IEEE 15288 within an organization. These uses are illustrated in Figure 3 and described below.

— Use 1 is a direct application of ISO/IEC/IEEE 15288 to an organization. ISO/IEC/IEEE 15288 describes the life cycle processes in terms of process name, purpose, outcomes and activities and tasks. Thus, direct application is the application of a set of selected life cycle processes to the organization during a life cycle stage to achieve the process outcomes and satisfy stage objectives and exit criteria. Processes are typically adapted to the organizational context, and activities and tasks may be enhanced to meet needs. Procedures and tools are determined and typical outputs are defined based on organization size, life cycle stage exit criteria, agreement deliverables, knowledge management system, resources available and any other influencing factors identified.

— Use 2 is for the purpose of creating and applying discipline- and domain-specific standards. These standards can be derived from the applicable concepts and requirements of ISO/IEC/IEEE 15288 in order to standardise processes for use in disciplines such as software, mechanical, chemical, electrical, as well as domains such as aerospace, automotive, medical equipment. In this use it should be an adaptation of the scope of ISO/IEC/IEEE 15288 to the applicable discipline, domain or both. Use 2 type standards should be more focused to the business of the discipline and application domains. As in Use 1, the activities and tasks can be adapted, procedures and tools specific to the discipline or domain may be defined, and relevant terminology may be provided. Discipline and domain members should be trained on the application of the appropriate standards, procedures and tools before attempting to apply the standards, procedures and tools to any project.

— Use 3 is for the purpose of creating organizational standards and guidance. In this use, the organization can adapt ISO/IEC/IEEE 15288, and discipline or domain standards or both. As in Uses 1 and 2, the activities and tasks are adapted to the organizational context, procedures and tools specific to the organization may be defined, and relevant terminology may be provided. Organization members should be trained in the appropriate standard and the applicable procedures and tools prior to applying on a project.

— Use 4 is the use of ISO/IEC/IEEE 15288, discipline/domain-specific or organizational processes on an SoI. The activities and tasks are adapted to the project context, procedures and tools specific to the project may be defined, and relevant terminology may be provided. Appropriate training on the applicable documents is necessary prior to application on an SoI. For SoIs that are part of an SoS, other standards can also be relevant and applicable (e.g. ISO/IEC/IEEE 21839 and ISO/IEC/IEEE 21840).

6.6 Application of project concepts

ISO/IEC/IEEE 15288 life cycle processes can be used by a project for at least four purposes:

a) to establish agreements with organizational entities external and internal to the project to acquire or supply a product or service (agreement processes);

b) to establish the organization's capability to acquire and supply products or services through the initiation, support and control of projects (organizational project-enabling processes);

c) to establish and evolve project plans, to execute the project plans, to assess actual achievement and progress against the plans and to control execution of the project through to fulfilment (technical management processes);

d) to contribute to the satisfaction of technical objectives for one or more life cycle stages (technical processes).

The requirement to perform ISO/IEC/IEEE 15288 life cycle processes is independent of system size or complexity. Instead, factors such as the system requirements and the concept of operation affect the system size and complexity. Thus, the outcomes and activities from the ISO/IEC/IEEE 15288 life cycle processes are meant to be generic and applicable to the engineering of any system within the scope of ISO/IEC/IEEE 15288. The size and complexity of a system can affect the work of a project, for example the tasks performed to accomplish an activity of a system life cycle process or the type and form of work products from application of the processes can be affected.

6.7 Application of process concepts

6.7.1 General

This subclause provides guidance to consider in executing the activities and tasks of the processes stated in ISO/IEC/IEEE 15288 in order to better obtain the intended outcomes of the processes and achieve their purpose.

In the following, the processes defined in ISO/IEC/IEEE 15288 are discussed as per the grouping shown in ISO/IEC/IEEE 15288:2023, Figure 5. The technical processes are divided into concept definition, system definition, system realization, and system deployment and use. The figure also shows the interrelationships among the processes defined in ISO/IEC/IEEE 15288.

6.7.2 Application of agreement processes (ISO/IEC/IEEE 15288:2023, 6.1)

6.7.2.1 General

The processes of ISO/IEC/IEEE 15288 can be used to attain an agreement. Agreements can be between organizations, between projects and for work efforts within a project.

An acquirer can look for a supplier to meet their needs, or can have internal personnel that can address needs. Independently, suppliers can look for acquirers that need their services or products. ISO/IEC/IEEE 15288 can be used in either case to improve the agreement process.

6.7.2.2 Application of acquisition process (ISO/IEC/IEEE 15288:2023, 6.1.1)

An appropriate team or individual, depending on the project size and complexity, should be assigned to develop a request for supply. For smaller projects a single individual can be assigned the responsibility to prepare the request for supply. In addition, the choice of system life cycle can affect the acquisition approach. For example, an evolutionary approach (see 6.4.3.4) cannot allow for an initial detailed understanding of scope compared to other approaches, which in turn can affect the detail in a request for supply.

Appropriate to the level of formality, a common basis for the acquirer and supplier to understand the project requirements should be established including:

a) system and service requirements;

b) expected deliverables;

c) development and delivery schedule milestones;

d) acceptance conditions, exception handling procedures, conditions requiring re-negotiation of the agreement, conditions required to lawfully terminate the agreement, conditions required to impose penalties or invoke bonuses and payment schedules;

e) rights and restrictions associated with technical data, intellectual property, copyrights and patents.

The level of formality of the monitoring of an agreement should be clearly established at a level appropriate to the scope and context of the agreement. This typically includes definition of:

— mutual responsibilities;

— methods how to manage project execution;

— reporting system;

— quality control;

— change management;

— risk management and monitoring.

The negotiation can be considered complete when the terms of agreement are acceptable to both the acquirer and supplier. It is essential that the criteria by which the acquirer will accept delivery from the supplier are clearly stated in the agreement. Early clarification on these criteria is in the interest of both the acquirer and the supplier.

Detailed acquisition planning can be supported by the project planning process from ISO/IEC/IEEE 15288:2023, 6.3.1 if the acquisition is treated as a project.

Typical solicitation documents include request for supply (also known as request for proposal, request for bid, request for information and request for quote), memorandum of intent, offer or directive.

For some agreements, especially government contracts subject to strict competitive laws, the acquirer develops acquisition requests for supply independently of the supplier. Newer evolutionary approaches (e.g. agile or DevOps approaches), prefer the involvement of suppliers to provide an optimum match of stakeholder needs with system requirements. This is especially helpful as requirements evolve over the course of the development. Similarly, when the supplier who developed an SoI will also provide maintenance under a separate agreement, they can also be involved in the development of a maintenance agreement.

Once the agreement is in place, the acquirer should actively monitor the agreement. Maintaining communication with the supplier and assessing progress of the agreement based on appropriate measures is essential to identify critical issues early.

It is also the acquirer's task to accept delivery of the products or services. Acceptance should be according to agreements as well as relevant laws and regulations.

6.7.2.3 Application of supply process (ISO/IEC/IEEE 15288:2023, 6.1.2)

The assigned team or individual should perform the activities of the supply process appropriate to establishing an agreement. First the team or individual should do the necessary planning to scope a strategy for the response preparation effort and to understand the capabilities required to do the requested work. The plan should include a schedule of milestones and decision criteria for submitting a response and consider the goals of the organization or project as well as applicable investment decision criteria. A supply strategy is defined using the project planning process from ISO/IEC/IEEE 15288:2023, 6.3.1.

An agreement is typically from an internal or external organization. It can be internal to the project. It does not need to be formal.

Organizations conduct market research in order to establish the opportunities available within a particular business sector.

Typically, in any supply situation there are several approaches or ways of doing something. An approach or way that best achieves the overall organizational and supply goals and constraints is desired. Considerations to include are:

a) applicable legislation and regulations that apply to the supplier;

b) organization goals;

c) competition;

d) organization environment and policies and procedures;

e) resource availability;

f) related management, technical and resource risks.

Within the constraints of required formality and regulations, acquirers and suppliers should work as closely as possible to document mutually acceptable definition of the scope of the work. This is particularly important when the supplier intends to involve other subcontractors. In this case, the potential subcontractors should be involved in the definition of the solicitation response and agreement negotiation, directly, indirectly or both, to provide an optimum match of capabilities with system requirements.

The level of formality of the monitoring should be clearly established at a level appropriate to the scope and context of the agreement, including mutual responsibilities, frequency and mode of monitoring and ways of evaluating acceptable execution of the agreement.

Establish who is authorised to accept the supplied distinguishable product or service and on what basis, including applicable verification and validation processes.

The level of formality for delivering and supporting the product or service, including closure, should be clearly established at a level appropriate to the scope and content of the agreement.

To determine whether to respond to the request for proposal or to determine the specifics of the response, the technical processes can be planned and performed to the level of the system structure appropriate to the nature and size of the system and the system life cycle stage. In addition, the scope of work, cost of the system and the feasibility of meeting requirements within given constraints should be determined. The application of the technical processes should be according to the plan and should be assessed and controlled using the appropriate technical management processes. The organizational project-enabling processes are implemented to the extent necessary to support the technical processes and monitor the outcomes and approve the response, as appropriate.

Typically, in any acquisition situation there are several approaches or ways of doing something. An approach or way that best achieves the overall acquisition goals and constraints is desired. Considerations to include are:

— aftermarket opportunities;

— business unit policies;

— organization environment;

— financial resource availability;

— quality characteristics;

— improvement strategy;

— obsolescence;

— competition;

— stakeholder goals;

— time-to-market constraints;

— potential risks for acquisition and supply.

6.7.3 Application of organizational project-enabling processes (ISO/IEC/IEEE 15288:2023, 6.2)

6.7.3.1 General

Only those subsets of organizational project-enabling processes that are necessary for the enabling of SoIs are addressed in ISO/IEC/IEEE 15288. As such, the selected outcomes, activities and tasks can be included as part of the definition of other processes, or an entire process can be subordinated to an activity level under another process.

6.7.3.2 Application of life cycle model management process (ISO/IEC/IEEE 15288:2023, 6.2.1)

ISO/IEC/IEEE 24748-1 contains information on common life cycle models.

6.7.3.3 Application of infrastructure management process (ISO/IEC/IEEE 15288:2023, 6.2.2)

Typically, infrastructure is established based on organizational strategic plan, capabilities, resources, risk levels, value to the acquirer and technology policies. For an organization, payoff goals, market segment, market position, investment and competitive advantage are also factors.

It is critical to establish, use and continually refine measures that show how well the infrastructure is supporting the needs of the organization in executing its mission, using resources that have demonstrated expertise in this area.

6.7.3.4 Application of portfolio management process (ISO/IEC/IEEE 15288:2023, 6.2.3)

The portfolio management process sets the environments for organizations in which multiple ongoing projects are accomplished to include applicable strategic and tactical plans, system life cycle models, and policies, procedures and standards. In addition, the process establishes constraints for technologies, product lines, and project management aids and provides communication paths with which projects interact with each other and the organization.

Policies and procedures that support and direct projects that perform the services and produce the organizational products, services or both, should be evaluated on a regular basis. Changes to policies and procedures are evaluated to realise continuous improvement of organizational maturity for satisfying its strategic and tactical objectives is realised.

The integrity level for different systems produced by projects can require separate sets of policies and procedures. Further information on integrity levels is provided in ISO/IEC 15026-3.

Appropriate management aids are typically established to enable availability of valid information for directing and enabling projects including project status, standardised automated tools, organizational products available for reuse, and the status of emerging technologies and related market opportunities and threats and the information databases in which captured data and documents are warehoused.

It is critical to establish, use and continually refine, measures that show how well projects, individually and in the aggregate, are achieving their objectives and those of the organization, using resources that have demonstrated expertise in this area.

6.7.3.5 Application of human resource management process (ISO/IEC/IEEE 15288:2023, 6.2.4)

This organization process includes establishment of human resource services that enable organizations to achieve their goals and objectives within legal, financial and other constraints and agreement requirements.

Human resource services include, but should not be limited to:

a) resource acquisition;

b) skill assessment;

c) skill development;

d) skill measurement;

e) effective skill deployment to organizational needs;

f) direct and indirect compensation;

g) knowledge capture, storage and re-deployment.

The infrastructure, skills and traits mix of personnel in projects, individually and in the aggregate, should be reviewed for consistency with organizational strategic and tactical objectives.

6.7.3.6 Application of quality management process (ISO/IEC/IEEE 15288:2023, 6.2.5)

This process is consistent with establishment of quality management approaches that lead to conformance with organizational and project quality objectives, and achieve customer satisfaction. In some organizations, ISO 9001 or AS9100 is used as the basis for quality conformance.

This process provides a sufficient level of confidence that system and service quality attributes for each project are adequately defined and activities are effectively and efficiently managed so that customer requirements are met and other parties interested in organizational success are satisfied.

6.7.3.7 Application of knowledge management process (ISO/IEC/IEEE 15288:2023, 6.2.6)

It is important that knowledge management is recognised in the organization as a strategic effort and that accumulated and used knowledge is therefore appreciated as a valuable asset. A well-functioning knowledge management is essential for every organization to mitigate the risks associated to losing knowledge due to retirements and attrition. For this reason, it is essential that teams can commit time to add knowledge to the organization's knowledge repository. The team capturing the knowledge should adhere to the knowledge management strategy to help ensure that other teams can find and retrieve the knowledge recorded previously. More information on knowledge management systems is provided in ISO 30401.

Participation in knowledge management in the organization should be widespread and participants should receive appropriate levels of training. When making knowledge available within the organization and sharing knowledge with stakeholders, acquirers and partners, intellectual property aspects should be considered carefully.

6.7.4 Application of technical management processes (ISO/IEC/IEEE 15288:2023, 6.3)

6.7.4.1 Application of project planning process (ISO/IEC/IEEE 15288:2023, 6.3.1)

Every successful project starts with thorough planning. The result is one or more plans that are used to guide project execution. At the same time, the plans also serve as a basis for project assessment and control. The team that creates the plans gains invaluable insight into the impact of assumptions that should be made in the early stages of the project.

Plans are constrained by organizational goals and objectives and stakeholder needs and plans constrain technical solutions.

Plans are developed to define project goals and objectives (why?), the work that needs to be accomplished (what?), the project schedule (when?), the project organizational structure (who?), and how the organization's processes, policies and procedures are adapted to match project-specific needs (how?). Plans should include the scope, tasks, methods, tools, measures, risks and resources for applicable system or system element implementation, integration, verification, transition and validation processes, so that each contingency option can be efficiently and effectively used.

The strategies defined in each of the other processes provide inputs and are integrated in the project planning process.

Contingency options are used in a plan when there are known risks or opportunities (for example significant changes in budget, schedule, requirements or technology or resource availability) that can cause the project or work effort to be redirected. In particular, assumptions that were made in the initial planning should be re-evaluated regularly.

Plans should be tailored as to the level and formality to suit project or work complexity, uncertainty and resources including funding.

A work breakdown structure (WBS) of the system structure and applicable non-system-structure-specific related technical management process activities is typically established. The initial WBS should be based on the system structure and the system life cycle processes. A WBS typically evolves to identify tasks and work packages associated with the specific system in parallel with the technical definition of the structure in which the system exists.

After approval by the appropriate authority the project schedules and planned budget are considered a baseline subject to change control according to organizational policies and procedures.

The list below should be used as a checklist for inclusion and completion of essential and applicable information in a plan:

a) the general problem to be solved;

b) the application context of the general problem to be solved;

c) the boundary of the general problem to be solved, denoting what can be controlled by the developer (inside) and what influences the development and is influenced by the development but not controlled by the developer (outside);

d) the required inputs and outputs including dependencies on enabling systems;

e) the system concerns with respect to critical quality characteristics;

f) project-specific adaptions of the organization's policies, processes and procedures;

g) how required resources and tools will be acquired and used;

h) the project organizing structure to be used for efficient and effective teamwork;

i) how the project will be staffed and managed;

j) key measures for product quality and how satisfaction will be determined;

k) key intermediate events and how such event achievement will be determined;

l) when, where and by whom activities and events will be completed;

m) key measures of project performance;

n) the risks (e.g., project and technical) involved and how risks will be managed;

o) potential opportunities and how the opportunities will be identified and tracked;

p) the completion criteria for the process activities.

NOTE Also relevant to the project planning process are ISO/IEC/IEEE 24748-4, ISO/IEC/IEEE 24748-5, ISO/IEC/IEEE 16326 and ISO/IEC/IEEE 15289.

6.7.4.2 Application of project assessment and control process (ISO/IEC/IEEE 15288:2023, 6.3.2)

The project assessment and control process evaluates the status of the project and redirects the efforts in case of deviations from plans. The assessments are based on the plans established in the project planning process.

Just like for project planning, the level of rigour to be applied in project assessment and control is directly dependent on the complexity of the SoI, the agreements and legal obligations. The items identified in 6.7.4.1, a) to p), should serve as an input to determine appropriate analyses and assessments.

The project assessment and control process should be used to select, assess and collect system and process measures to provide information for support of project management. Specifically, it includes determining:

a) progress of the project;

b) information for risk resolution;

c) meaningful financial and non-financial performance;

d) effectiveness and risk information for doing trade-off analyses and providing recommendations on actions to take and resulting impacts.

This information is further aggregated and used by the portfolio management process to justify, or redirect to justify, continued investment.

When variations are detected that impact cost, time or quality, the project planning process is re-initiated in order to plan and implement appropriate corrective actions. Any revision to plans needs to be approved.

Technical reviews, audits and inspections are conducted against technical plans according to defined schedules to demonstrate conformance of actions and outcomes to planned technical work.

The goal of reviews is to confirm that:

— increase in system maturity is within the defined threshold;

— the project deliverables satisfy the business case;

— the budget is sufficient to fund the next system life cycle stage;

— un-resolved issues are tracked and addressed;

— overall risk for conducting the next system life cycle stage is acceptable.

SoI level reviews can be done in conjunction with an organizational view milestone, decision gate or quality review. Non-conformance of deliverable work products, services and processes should be recorded and appropriate actions recommended to correct the out-of-conformance condition.

Technical reviews such as the following should be conducted for each project as appropriate to the development model used and consistent with project governance.

— A review held prior to performing the stakeholder needs and requirements definition process to confirm that the business and mission requirements are complete, consistent with the acquirer's intent, understood by the supplier and have been validated. This review can prevent proceeding with a less than acceptable set of the business and mission requirements.

— A review focused on preliminary concepts that helps ensure that the preferred concept has the potential of satisfying defined stakeholder requirements and is based on a set of viable, traceable technical requirements that are balanced with respect to cost, schedule and risk.

— An evaluation of the established requirements baseline to confirm that the set of technical requirements are balanced with respect to cost, schedule and risk.

— An evaluation of the established functional baseline to confirm that the system definition is based on achievement of technical requirements. It also can be used to confirm readiness to proceed with the preliminary design of each system of the system structure.

— A review conducted for the preliminary design of each system of the system structure to confirm that:

1) the specifications and other configuration descriptions are defined appropriately;

2) the design solution is consistent with the acquirer's requirements;

3) enabling system requirements are sufficiently defined to initiate enabling system developments, as required, or to acquire the applicable enabling systems;

4) approaches planned for developing detailed designs, including corresponding prototypes, are appropriately planned;

5) risks are identified and resolution plans are feasible and judged to be effective.

— A review conducted for the detailed design of each system of the system structure to demonstrate that:

1) specifications and drawings are appropriately defined to realise the design solution through implementation or integration, as appropriate;

2) the design solution is consistent with the acquirer requirements;

3) enabling system requirements to provide life cycle support have been adequately defined to initiate enabling system development or acquisition, as appropriate.

— Reviews conducted prior to each scheduled series of tests on an implemented or integrated test system to confirm test readiness by confirming that all test related enabling systems are in place and the test environment is prepared to accomplish test objectives.

— Reviews conducted prior to decisions for production, transition or operations to confirm that the system has demonstrated to meet its technical requirements through a combination of testing, analysis, demonstration and inspection.

— Reviews conducted prior to releasing each design solution for first system or batch production to confirm production readiness by confirming that production enabling systems and materials are in place and the production environment is prepared to accomplish production objectives.

After completion of the detailed design of each system in the system structure that is based on the allocated baseline, and with proof that the production system is ready and other enabling systems are ready or are expected to be available when needed, the system can be released for production. The system produced can be a one of a kind, the first of a limited version or the first of many that will be produced.

NOTE 1 IEEE 1028, ISO/IEC 20246 and IEC 61160 give additional detail on reviews. ISO/IEC/IEEE 24748-8 gives information on technical reviews for the defence sector.

NOTE 2 Iterative, evolutionary, agile and DevOps life cycles rely more on incremental reviews with demonstrations of working products.

6.7.4.3 Application of decision management process (ISO/IEC/IEEE 15288:2023, 6.3.3)

Trade-off analyses are conducted throughout implementation of technical management and technical processes to resolve conflicts (such as conflicting requirements) and select a recommended solution from a set of defined alternatives (such as optional actions to take for risk resolution, resolutions for requirement conflicts, alternative functional architecture design solutions and alternative physical architecture design solutions). Outcomes from a trade-off analysis include the recommended option, implementation considerations, impacts related to each option, basis of recommendation and assumptions made.

Decisions should be based on hard evidence and documented together with the rationale to help re-justify the decision in the future and to help in future decision situations. Any assumptions that were made should be checked regularly. In case assumptions turn out to be wrong, the trade-off study should be reassessed.

The types of trade-off analyses typically performed during performance of life cycle processes include:

a) formal — formally conducted, with results reviewed at technical reviews. Specific formal trade-off analyses are normally identified in an agreement;

b) informal — follows the same methodology of a formal trade-off analysis but requires less documentation and is of less importance to the acquirer;

c) judgmental — selection of a recommended option, based on judgement of the analyst or designer after a less rigorous analysis than that required by a formal trade-off analysis and for which the consequences are not as important. Used when one option is clearly superior to others, time is not available for a more formal approach or the risk of an incorrect choice is considered to be acceptable. Most trade-off analyses performed are of the judgmental type.

6.7.4.4 Application of risk management process (ISO/IEC/IEEE 15288:2023, 6.3.4)

ISO/IEC/IEEE 15288 is targeted to develop complex systems. Complexity always leads to uncertainty which needs to be addressed throughout the whole life cycle of the system. Risk management is an approach to ensure that uncertainties are properly covered.

Some sources define risk as the “effect of uncertainty on objectives”, so risks can have either positive or negative effect. ISO/IEC/IEEE 15288 uses the more common interpretation that risks have a negative effect on project objectives. This is also the focus of this document. Some guidance for opportunities, i.e., uncertainties with a positive effect is given in ISO/IEC/IEEE 15288.

The goal of risk management is to treat risks so that the expected consequences are acceptable. The definition of “acceptable” can vary. In many cases, proven frameworks are used to help ensure consistency.

In every project, one of the first tasks is to agree a common approach for risk management. This typically includes the definition of risk thresholds. In case a risk exceeds this threshold, appropriate treatment strategies are initiated.

Throughout the whole system life cycle, risks should be continuously identified and recorded in a risk profile. Risk identification has three dimensions: past, present and future. The past dimension of risk is based upon past experience and includes benchmarking project measures and lessons learned, measuring actual results with expected results, mapping available resources to requirements with respect to defining and doing the work and implementation of the plan to produce the product. The present dimension is governed by the issues the project is facing right now. Sometimes, these issues are called pain points. The future dimension is based on transformation of the project vision into goals and objectives used for establishing plans and being aware of the future from which risks and opportunities are identified and the ambiguities of available information and resources as well as the uncertainties uncovered during work. Brainstorming methods can help to identify those risks.

The context, conditions and consequences should be identified in risk statements. The following template can help to identify the root cause of a risk: If <situation> then <consequence> for <stakeholder>.

Risks that have been identified are analysed to determine the likelihood of occurrence and the consequences. This often results in a risk priority number that is evaluated against the thresholds defined. For risks, that exceed the threshold, recommended treatment strategies are defined and evaluated. The most efficient and effective treatment strategies that mitigate the risk to an acceptable level are implemented. According to ISO/IEC/IEEE 16085, typical treatment strategies can draw upon any combination of:

a) removing the risk source;

b) planning contingency actions for cases in which a risk is accepted;

c) taking or increasing the risk in order to pursue an opportunity;

d) sharing the risk (e.g., through contracts, buying insurance);

e) retaining the risk by informed decision.

As the likelihood of occurrence and the consequences of a risks can change over time, identified risks should be reassessed regularly. Risk evaluation and mitigation can involve other life cycle stages, and can include re-design to eliminate an unacceptable risk.

NOTE A more detailed discussion on risk management is provided in ISO/IEC/IEEE 16085.

6.7.4.5 Application of configuration management process (ISO/IEC/IEEE 15288:2023, 6.3.5)

The configuration management process facilitates orderly management of system and system element configurations throughout the entire system life cycle.

NOTE 1 System elements and artefacts under configuration management are often called configuration items.

Typically, configuration management includes the following elements:

a) configuration identification;

b) change control;

c) configuration status accounting,

d) configuration evaluation.

Configuration identification should be active in the very early stages of every project. To properly manage each configuration item's functional and physical characteristics a unique identifier should be assigned. Also, there should be a unique identifier for revisions of the configuration items. Configuration identification also includes the definition of baselines throughout the system life cycle to support the evolving configuration states of the configuration items.

Changes to configuration items are inevitable. At the same time, it is undesirable that unapproved changes are implemented. Effective and efficient change control that is in effect beginning at project initiation, can significantly help ensure integrity and consistency of the configuration items. As proposed changes can have significant negative impact on other system elements, changes should be reviewed diligently before approval. As proposed changes can have a significant negative impact on other system elements, a diligent review on system level should be conducted before approval. It is recommended to take advantage of system models and simulations when assessing proposed changes. Typically, a change control board (CCB) is implemented to provide a central point to coordinate, review, evaluate, and approve all proposed changes.

Configuration status accounting can be seen as the reward for all the work invested previously. When configuration identification and change control are properly conducted, status accounting can provide valid data on the status of the configuration items, e.g., approved documents, proposed changes, physical characteristics.

Configuration evaluation assesses whether the evolution of a product or service meets specifications, policies and agreements. Evaluation typically happens at the decision gates to help ensure that configuration management requirements, e.g., approved changes have been implemented, are satisfied.

Two types of configuration audits can be performed – functional audit and physical audit:

— A functional audit is used to demonstrate that system verification results compare favourably with the specifications against which verification was performed and that planned verification procedures were followed. This audit is also used to confirm that verification results compare favourably against configuration documentation such as drawings, authorised changes and "as-built" or "as-coded" records.

NOTE 2 A pre-production prototype or the first system produced is typically used for verification. This audit is typically completed before release of the system for initial production.

— A physical audit is performed to examine the "as-built"" system against its configuration documentation such as drawings, bill of materials, specifications, code lists, manuals, verification procedures and acceptance data. The "as-built" system examined should be one or more of the first set of systems produced during the initial production. Selection of the systems to be used in the audit should be done at random by the auditors. The purposes of the physical audit are given below:

    1) to confirm that the system has been realised correctly according to its drawings or specifications;

    2) to confirm that the information database represents the essential set of work products or artefacts from the engineering effort;

    3) to confirm that required changes to previously completed specifications have been included;

4) to confirm that enabling systems for future system life cycle stages will be available, can be executed and meet stakeholder requirements;

5) to provide the basis for approval of further production of the system, if applicable.

NOTE 3 Additional guidance regarding configuration management activities can be found in ISO 10007, IEEE Std 828, ANSI EIA-649 and SAE ARP4754A.

6.7.4.6 Application of information management process (ISO/IEC/IEEE 15288:2023, 6.3.6)

Information management supports all aspects regarding information that is generated by and for a project. At the beginning of a project, information management should be thoroughly considered, preferably before the first information items are created. In many cases, especially for safety-critical systems, legal requirements can make it necessary to retain data for a considerable period of time. Also, information should be exchanged with many other organizations, creating the need to investigate potential issues such as validity of file formats, accessibility of information, definition of exchange formats and protection of confidential information.

Typically, projects store large amounts of data. This requires search algorithms to retrieve specific data. Proven and standardised exchange formats should be used in as many places as possible. However, open exchange formats can be problematic in certain situations for data protection reasons. The information items that are processed as part of information management constitute a portion of the knowledge assets of an organization. Thus, it is also necessary to identify invalid or obsolete data as such on a regular basis.

NOTE See ISO/IEC/IEEE 15289 for the life cycle content of information items and ISO/IEC/IEEE 26531 for content management for life cycle, user and service management documentation.

6.7.4.7 Application of measurement process (ISO/IEC/IEEE 15288:2023, 6.3.7)

Measures are used to assess stakeholder satisfaction and to deliver an ever-improving value to the acquirers and suppliers of system products and services. These measures provide stakeholders fact-based decision information that the concept definition, system definition and system realization processes are producing an acceptable solution. They also provide quantitative information on the system deployment and use processes.

Measures provide fact-based decision information in multiple categories including:

— schedule and progress (e.g. milestone completion, progress, backlog, incremental capability);

— resources and cost (e.g. financial, personnel, facilities and infrastructure);

— product size and stability (e.g. physical and functional);

— product quality (e.g. anomalies, supportability, efficiency, dependability, usability, assurance);

— process performance (e.g. conformance, efficiency, effectiveness);

— technology effectiveness (e.g. suitability, maturity, volatility);

— customer satisfaction (e.g. value, feedback and support).

Measures should be selected to address identified information needs of the system or organization, as specified by stakeholders. The measures should be tailored to project or enterprise processes and infrastructure. There is a cost to collect and review measures, so a careful selection provides balance of valuable information and acceptable cost. In many cases, the following are used[39].

— Measures of effectiveness (MOEs): The "operational" measures of success that are closely related to the achievement of the mission or operational objective being evaluated, in the intended operational environment under a specified set of conditions; i.e., how well the solution achieves the intended purpose.

— Measures of performance (MOPs): The measures that characterize physical or functional attributes relating to the system operation, measured or estimated under specified testing and/or operational environment conditions.

— Technical performance measures (TPMs): TPMs measure attributes of a system element to determine how well a system or system element is satisfying or expected to satisfy a technical requirement or goal.

TPMs are used to assess design progress, conformance to performance requirements and technical risks for critical performance parameters. Selection of TPMs should be limited to critical technical thresholds or parameters that, if not met, put the project at cost, schedule or performance risk. A TPM provides an early warning of the adequacy of an architecture and design in terms of satisfying selected critical technical parameter requirements.

Early in the life cycle the performance values can be estimated, based on simulation and modelling. As the life cycle proceeds, actual data replaces estimates and increases the fidelity of the information. This measurement of the design solution as it evolves allows action to be taken early in the process. Measures can be adapted to the organization. If they are, they should be limited to only those few at each level that are truly incisive and that will actually be used as the basis for decisions. The feasibility and effort to collect data should be considered carefully before implementing any measurement effort.

The general recommendation is that the project should begin with a few selected measures and then expand once the results have proven useful. Any measures utilised should be periodically evaluated to ensure that they provide useful information and are used for decision making.

NOTE Refer to ISO/IEC/IEEE 15939 for more specialised guidance and requirements.

6.7.4.8 Application of quality assurance process (ISO/IEC/IEEE 15288:2023, 6.3.8)

Quality assurance helps to ensure that the quality management guidelines are implemented in the projects of an organization. It is therefore necessary to break down these guidelines into project objectives and the definition of measures that can be used to evaluate progress in relation to the guidelines. The measures are recorded using the measurement process. It is important that all project members are committed to quality assurance. It is an integrated activity. In many cases, it is not enough to have one person fill the role of the quality assurance manager. When the recorded measures deviate from the planned target, the situation should be investigated and, if necessary, corrective action initiated, searching for and mitigating the root cause that led to the deviation. Quality assurance is needed to validate tools, especially those related to safety-critical systems. In this context, proving that enabling systems do not inject errors into the SoI can be very costly and time-consuming.

6.7.5 Application of technical processes (ISO/IEC/IEEE 15288:2023, 6.4)

6.7.5.1 General

The technical processes provide a means to explore new concepts or add capabilities to an existing solution. They help define an SoI that will address the problem, opportunity or need of the stakeholders. This is done through a progression and iteration of concept definition, system definition, system realization and system deployment and use. ISO/IEC/IEEE 15288:2023, Figure 5 provides a model for the application of the technical processes of ISO/IEC/IEEE 15288.

In the discussions below on the technical process model for engineering a system, process application will be to an SoI, whether it is an SoS, a constituent system, a standalone system, a system element or an enabling system. Although an SoI can be addressed over its full life cycle, it is common for projects to span only portions of that life cycle. For example, one project can analyse the business needs and stakeholders for a new or modified system, while a second project can define the system and yet a third project can turn the design into a realized system.

6.7.5.2, concept definition, discusses understanding the need for a system. 6.7.5.3, system definition, translates concepts and needs into a description of a technical solution. 6.7.5.4, system realization, discusses the implementation and preparation for acceptance of the SoI. 6.7.5.5, deployment and use, defines how the system will be deployed, used and supported during the operational use of the system.

All of the processes are intended to be applied iteratively, recursively and concurrently, as needed, to the SoI, its system elements and any enabling systems. The life cycle model being used can impact how the processes are applied. The processes apply in any stage and in conjunction with, or with consideration of, the other processes of ISO/IEC/IEEE 15288 or ISO/IEC/IEEE 12207.

NOTE See ISO/IEC/IEEE 24748-1:2024, A.9 for discussion of iteration and recursion.

6.7.5.2 Application of technical processes for concept definition

6.7.5.2.1 General

The business or mission analysis process, and stakeholder needs and requirements definition process are used, together with the system analysis process, to gain understanding of the fundamental need for a system, possible directions for a solution, along with its boundaries, and its stakeholders.

NOTE More guidance for applying the requirements and requirements-related processes are provided in ISO/IEC/IEEE 29148.

6.7.5.2.2 Application of business or mission analysis process (ISO/IEC/IEEE 15288:2023, 6.4.1)

The business or mission analysis process should first carefully define the problem or opportunity to be solved for the organization, and the reasons why it is beneficial to the organization, before effort is put into any specific solution. Therefore, it begins with the business vision and concept of operations (ConOps), and other organization strategic goals and objectives including the mission (or business function). This process should be used to compare various types of conceivable solutions, in general terms, but only after a clear understanding of the business or mission problem or opportunity has been obtained through such things as:

a) soliciting and analysing feedback on current and projected results compared to what is desired from a strategic business or mission viewpoint;

b) consideration of the organization's current and planned portfolio and resources, particularly the mix of positive and negative impacts that can result from changing the current direction;

c) a thorough assessment of risks and benefits associated with following the possible solution avenues (or making no change at all);

d) identification of relevant stakeholders and their involvement from the start of the application of the business or mission analysis process.

The business or mission analysis process is usually applied most intensively during the concept stage of a system's life cycle. However, as with all ISO/IEC/IEEE 15288 processes, it can be invoked at any stage, by itself or in conjunction with other processes, especially the system analysis process and the decision management process. The business or mission analysis process applies to both the SoI and any enabling systems.

The organization should consider obtaining independent outside as well as inside views and expertise to support the business or mission analysis process for the business as well as enabling systems. The primary products are business or mission needs, which are supported by preliminary life-cycle concepts – including a preliminary acquisition concept, a preliminary operational concept (OpsCon), a preliminary deployment concept, a preliminary support concept and a preliminary retirement concept. The preliminary operational concept includes the operational scenarios for the mission and the context in which the solution will exist.

The business or mission analysis process should be repeated on a periodic basis, and performed on an ad hoc or as needed basis to respond to changes in internal and external factors. Concept applicability and impact should be considered across stages as well as within any particular stage.

The linkage between the organization's business or mission analysis process and its knowledge management process from ISO/IEC/IEEE 15288:2023, 6.2.6 should be thorough and explicit. The problem or opportunity statement, risks and benefits, list of stakeholders, business or mission needs and preliminary life cycle concepts should be recorded and maintained throughout the system life cycle.

6.7.5.2.3 Application of stakeholder needs and requirements definition process (ISO/IEC/IEEE 15288:2023, 6.4.2)

The stakeholder needs and requirements definition process can be used to identify, collect and appropriately define stakeholder needs and then use them to develop stakeholder requirements. The acquirer and other interested parties together form the stakeholders related to the system being engineered. Interest in a system does not need to be positive, and not all interested parties have a positive interest in the system. For example, hackers can have a malicious interest in a financial system and thus be considered stakeholders. In many cases, the acquirer provides the initial set of needs and requirements for each system in the system structure. Additional needs and requirements that can influence the understanding of the system and the eventual solution can be derived when considering other interested parties. Examples are given in the list below:

a) interfaces with associated enabling systems or interfaces with other systems in the intended operational environment;

b) critical quality characteristics such as safety, security, producibility, reliability, availability, usability and maintainability;

c) operator and user needs, skills, competencies and working environments;

d) motives of stakeholders with the intention to harm the system.

It can happen that the acquirer or other stakeholders are not familiar with the concept of "good" requirements. It can also be the case that the acquirer does not have a clear understanding of the real needs. In situations like this, it has proven to be very effective and efficient to further elaborate the preliminary life cycle concepts. A life cycle concept typically describes characteristics of the SoI from the stakeholders' perspective. High-level scenarios, use cases and user stories (in the case of an Agile approach) in an easy-to-understand format can support common understanding of the needs.

The resulting set of stakeholder needs and the stakeholder requirements derived from them represents a collection of requirements placed on the engineering of a system. These stakeholder requirements include the functions, as viewed by the stakeholders, that are required to be performed, how well they should be performed, the environment in which they are to be performed, any required characteristics of the system and any services related to enabling systems. To help ensure that all possible sources of stakeholder requirements have been considered, all the processes in ISO/IEC/IEEE 15288 should be examined. As specific examples, the appropriate activities of the implementation process, integration process, verification process, transition process, validation process, operation process, maintenance process and disposal process can each generate needs and requirements, as perceived by specific stakeholders, otherwise overlooked that will influence the system being engineered. Likewise, the activities of non-technical processes should also be examined to see if they generate stakeholder needs and requirements.

After the set of stakeholder needs and requirements is defined, upward and downward traceability (or completeness and consistency checks) between the stakeholder needs and stakeholder requirements should be performed to confirm that no requirements have been omitted or added without accountability.

The set of stakeholder requirements is the basis for performing the validation process after the system has been implemented or integrated and verified. It is important to take into account the requirements for the operation of the system and the business when addressing the stakeholder needs and requirements definition process.

Stakeholder needs and requirements reflect the operational view of the opportunity or problem to be solved and the desired life cycle concepts. This can include a new concept or modification of an existing system based on usage or business feedback.

Stakeholders can be internal to the acquiring organization, such as related project, marketing organization, product team, user, operator or manager; or external to the acquiring organization, such as a procurement agency, prime contractor, another organization or purchaser.

Interested parties are also referred to as “other stakeholders,” or parties other than the acquirer interested in the outcome of the engineering or reengineering work. Other interested party requirements, not necessarily provided by the acquirer in the agreement, include:

— organizational and project requirements such as those that deal with system markets and organizational processes;

— environmental, local, national, and international regulations and laws;

— life cycle constraints for system development and integration, production, test, operations, and logistics (deployment, training, maintenance and disposal).

Stakeholder needs are generally expressed as statements like “here is what I want done.” The statement may, but often does not, initially say why the stakeholder has that need. Stakeholder needs elicitation generally will take a number of iterations for several reasons:

— the stakeholder need can become clearer after the need has been formally stated and then questioned by others;

— the perceived need can evolve as the stakeholder understands the needs of other stakeholders, including potential conflicts of needs and compromises among stakeholders;

— developing stakeholder requirements from the initial stakeholder needs can raise questions, leading to re-examination and changes in stakeholder needs that then flow back into revised stakeholder requirements.

A requirement is typically made up of what has to be done (a function) and how well it has to be done. A function is typically a statement with an actor (who wants to accomplish something), an action (what they want to accomplish) and an object (why they want to accomplish that thing) of the action. For example, “The actuator opens the door within 10 seconds to enable access.”

NOTE 1 Agile often avoids the term requirement and prefers the term user story instead. The agile user story pattern is “As a <role (who wants to accomplish something)>, I want to <activity (what they want to accomplish)> so that <business value (why they want to accomplish that thing)>.

A requirement can also be non-functional, e.g. a design constraint, such as weight or colour.

NOTE 2 Non-functional requirements are also sometimes referred to as critical quality requirements, see ISO/IEC/IEEE 29148.

This process includes activities and tasks performed by or for a supplier in the capture and expression of requirements to be met and goals to be pursued in the supply of the system and related services.

Cost can be a requirement stated as a fixed cost (independent variable) or maximum cost (constraint).

This process involves assuring that requirements for system life cycle concerns affecting system functionality, such as production, test, operations and logistics are identified.

The context of use description is a collection of information about the physical, technical, social and cultural elements surrounding a system and an analysis of how they affect (or will affect) the way the system is used. The context of use description is a useful collection of supporting information when preparing the system user and operational requirements. It provides guidance on how and where a system will be used to the designers of the system in considering design alternatives. It is a reference document for the design of validation activities for a system (see ISO/IEC/IEEE 15288:2023, 6.4.11). It is the most detailed source of information about the users of the system and their working environment and is used as the primary guidance when selecting users for trials and tests.

NOTE 3 See ISO/IEC 25063 for more information on defining and analysing context of use.

ISO/IEC/IEEE 24748-7000 includes processes for eliciting ethical values related to stakeholder needs and realizing those requirements in ethically aligned design.

It is usually not possible to meet all acquirer and other interested stakeholder requirements for a particular system since various stakeholders can have conflicting requirements relative to one another. These conflicts should be identified and resolved when performing this process, or as soon as a conflict is identified when performing one of the other technical processes. The effectiveness assessment, trade-off analysis and risk analysis activities should be used to resolve conflicts.

Measures of effectiveness (MOEs) should be explicitly identified for each system in the system structure. An MOE is an "operational" measure of success that is closely related to the achievement of the operational objective being evaluated, in the intended operational environment under a specified set of conditions; for example, how well the solution achieves the intended purpose. MOEs, which are stated from the user/acquirer viewpoint, are the acquirer's key indicators of achieving the objectives for performance, suitability and affordability across the life cycle.

The stakeholder requirements are the basis for validating the implemented or integrated system that is developed using the technical processes.

Requirement traceability is initiated at this point for tracking requirements and changes to requirements from the stakeholder initial inputs through system architecture definition and design definition. The stakeholder needs, stakeholder requirements, traceability from stakeholder requirements to stakeholder needs, contexts of use and MOEs should be recorded and maintained throughout the system life cycle.

6.7.5.2.4 Application of system analysis process (ISO/IEC/IEEE 15288:2023, 6.4.6)

The system analysis process is used throughout the concept definition processes. However, since it is equally used for the system definition, described in the next subclause, discussion of the system analysis process is deferred to 6.7.5.3.5. See ISO/IEC 26550 for guidance and considerations related to product line engineering and management.

6.7.5.3 Application of technical processes for system definition

6.7.5.3.1 General

The system requirements definition process, system architecture definition process and the design definition process are used in conjunction with the system analysis process to define specific, feasible solutions for an SoI and all system elements. Application of these processes can be highly iterative in order to arrive at the solution.

NOTE More guidance for applying the requirements and requirements-related processes are provided in ISO/IEC/IEEE 29148.

6.7.5.3.2 Application of system requirements definition process (ISO/IEC/IEEE 15288:2023, 6.4.3)

Stakeholder requirements are stated from the point of view of the various stakeholders, and not from the point of view of the system that responds to them. Accordingly, the stakeholder requirements tend to be stated more from a user or an operational point of view rather than being stated in technical terms and consequently are often not directly usable for architecture definition and subsequent design definition. The system requirements definition process can be used to perform an analysis of the stakeholder requirements and transform the stakeholder requirements into a set of usable system requirements. This includes the identification and analysis of external interface requirements, as well as the quantitative and qualitative statements of the system's functional, performance, process and quality or non-functional (e.g. thermal, reliability, finish) requirements and the constraints on them.

NOTE External interface requirements are not only limited to systems interfacing with the SoI in the operating environment. Therefore, identification of the system boundary and type of boundary is critical, see also 6.3.5.

The resulting set of system requirements should be checked for upward and downward traceability to help ensure that no stakeholder requirement has been omitted, that all stakeholder requirements have child technical requirements and that all system requirements have a parent stakeholder requirement. The resulting set of technical requirements should be checked for non-singular requirements containing multiple parts, which should then be decomposed into individual (singular) requirements. As a set the requirements should also be checked for consistency. See the list of requirement characteristics in ISO/IEC/IEEE 29148:2018, 5.2.5: necessary, appropriate, unambiguous, complete, singular, feasible, verifiable, correct and conforming.

During the application of the technical processes, learning occurs about the operational needs and the technical solution. That learning often requires iterating between processes to incorporate that learning into activities and task that have already been taken such as the definition of requirements. This is done to ensure a feasible and balanced solution.

In the context of SoS, see ISO/IEC/IEEE 21840:2019, 6.4.4 for elaboration and guidance on the utilization of ISO/IEC/IEEE 15288:2023, 6.4.3 system requirements definition process. The "as-specified" configuration should be recorded and maintained throughout the system life cycle, including the system requirements and requirements traceability.

6.7.5.3.3 Application of system architecture definition process (ISO/IEC/IEEE 15288:2023, 6.4.4)

The system architecture definition process is used to define fundamental concepts or properties of a system in its environment and governing principles for the realization and evolution of a system. While architecting applies to all types of systems, an analogy with architecting a building is useful: a building architecture will show the general shape of a building – stakeholders can see a drawing or model of the building and look at it from various viewpoints. The system architecture definition process together with the design definition process both can allocate the responsibility for satisfying system requirements to system elements. The difference is that during the system definition process, that allocation is accomplished within the functional and physical architectures at a moderate level of detail, while during the design definition process the allocation is completed down to the detailed system components in accordance with the system architecture. The primary purpose of the system architecture definition process is to transform stakeholder concerns and requirements, and system requirements and constraints into the fundamental concepts and properties of the system in the form of architectural entities, their interrelationships and their behaviour. The design definition process transforms architecture and requirements into a design of the system that can be realised to enable implementation consistent with architectural entities defined in models and views of the system architecture. In practice, the design definition process and system architecture definition process interact with each other iteratively: it can be necessary to develop design detail from a specific viewpoint to help ensure that an assumed architecture does indeed respond to a particular stakeholder's requirements. Throughout, the system analysis process should be used to support the system architecture definition process.

As the architecture evolves, the requirements of the SoI, its system elements and enabling systems can evolve concurrently. Likewise, as stakeholder or system requirements change, this can require changes to the architecture.

When developing an architecture, existing systems and system elements, as well as new technology, should be considered. The use of existing systems helps reduce time and cost of development but can increase complexity or have impacts on long-term maintainability. Use of new technologies can provide a competitive edge but can also increase risk. In any of these cases, new interfaces can be introduced, and can require changes to system requirements and an iteration of the system requirements definition process.

Architecture definition is concerned with developing potentially feasible solutions for the set of derived system requirements, as assessed from multiple viewpoints, and assuring system concept configuration integrity throughout utilization and support stages. The completed architecture should be used throughout the system life cycle to predict and track fitness for use and for assessing changes to the system.

Functional architecture definition includes looking at various logical decompositions and other representations of system requirements. There is no set format or form for the various representations. The format or form selected is that which best defines the functional, behaviour or data flow or data structure, as appropriate, and that allows best assignment to potential physical elements, manual operations or enabling systems for generating alternative physical architecture design solutions. The focus of developing the functional architecture is on understanding the SoI's behaviour, identifying architectural entities and their interrelationships. The focus of developing the physical architecture is on identifying and developing alternative solutions which are distinguished by their configuration of architectural entities and the level of performance of each alternative in meeting performance requirements.

In arriving at an architecture definition solution that involves humans and human constraints such as physical space limits, climatic limits, eye movement, arm or finger reach, information rates and ergonomics should be considered. Also, human usability factors should be analysed. These factors affect human interactions with other systems and human interfaces to the system throughout the system life.

Scale models, purpose models, behavioural models, mathematical models and managerial models can be used during architecture definition to develop and communicate candidate solutions. The specific type of model depends on the applicable system life cycle stage, its purpose or agreement requirements.

During architecture definition, it can be necessary to repeat the stakeholder needs and requirements definition process and system requirements definition process, if it is determined that requirements cannot be met because of unresolved issues related to the solution factors (see architecture design expected outcomes) or adverse cost, schedule, performance or risk impacts for available alternatives.

In determining the preferred architectural candidate, analyses of each alternative are made with the following considerations:

a) physical and logical interfaces (human, form, fit, function, data flow and interoperability):

   1) among identified physical elements of the physical design solution;

   2) with other system elements of the system structure;

   3) with enabling systems;

   4) with external systems;

   NOTE If the SoI is an SoS or a constituent system (CS) of a larger SoS, additional architectural considerations related to interfaces can apply.

b) the variability and the sensitivity to variability for each identified critical performance parameter;

c) technological needs necessary to make an alternative solution effective, the risks associated with introduction of new or advanced technologies to meet derived technical requirements and alternative lower-risk technologies that can be substituted for unacceptable higher risk technologies.;

d) availability of off-the-shelf end products (non-developmental hardware or reusable software). If not exactly suitable, determine the cost and risks in modifying an off-the-shelf system element to satisfy design and interface requirements;

e) effect of design considerations to maintain or make a physical solution alternative competitive with potential or existing competitor products;

f) further design efforts that can be needed to accommodate redundancy and to support graceful degradation when the results of failure mode, effects and criticality analyses (FMECA) have an unacceptable or high criticality rating;

g) degree to which the specified level of performance of the derived technical requirements is satisfied by each alternative physical solution;

h) degree to which attributes of security, safety, producibility, testability, ease of deployment, installability, operability, supportability, maintainability, trainability and disposability are capable of being designed in;

i) needs, requirements and constraints for enabling systems;

j) capacity to evolve, or be re-engineered, incorporate new technologies, enhance performance, increase functionality or other cost-effective or competitive improvements, when the system is in production or in the marketplace;

k) limitations that can preclude the capability of the SoI or system element and related services to evolve (technology refresh or technology insert);

l) advantages and disadvantages of implementing the system element or of doing integration within the organization or going to an established supplier;

m) advantages and disadvantages of using standardised system elements, protocols, interfaces, etc.;

n) integration concerns that can include:

   1) potential hazards to other systems, operators or the environment;

   2) built-in test and fault-isolation test requirements;

   3) ease of access, ready disassembly, use of common tools, part count effect, advantage of modularity, standardization and user-friendliness;

   4) dynamic or static conflicts, inconsistencies and improper functionality of the integrated elements that make up the solution.

It also can be necessary to re-engineer the selected system architecture for systems higher in the system structure than the one being engineered or re-engineered.

The “as-architected” configuration should be recorded and maintained throughout the system life cycle, including the architecture model(s) and the architecture description document.

The results of the system architecture definition process may be captured in an architecture description as defined by ISO/IEC/IEEE 42010. In this case, “stakeholder” and “concern” as defined by ISO/IEC/IEEE 42010 are likely to be produced during the stakeholder needs and requirements definition process and system requirements definition process. Architecture description frameworks, as defined in ISO/IEC/IEEE 42010 establish a common practice for creating, interpreting, analysing and using architectures within a particular domain of interest, including the identification of stakeholders, concerns and viewpoints.

The activities can be supported by an MBSE approach, see Annex C.

6.7.5.3.4 Application of design definition process (ISO/IEC/IEEE 15288:2023, 6.4.5)

The design definition process transforms the set of system requirements that have been allocated to a system architecture into a fully detailed set of system information that can then be implemented with specific hardware, software, etc. Following the analogy of a building, this process should take the information from the views of the proposed structure, and any models, and translate them into a full set of blueprints with all details on dimensions, materials, critical characteristics, etc., to the point that the results of the design definition process can be used to begin implementation.

The design definition process continues until the implementable level of detail is achieved for the SoI down to the lowest system element, including all enabling systems. As with the other ISO/IEC/IEEE 15288 processes, iterative and recursive use of the design definition process, and application of other ISO/IEC/IEEE 15288 processes will occur as needed. Throughout, the system analysis process should be used to support the design definition process.

The features incorporated in the system design should be checked for upward and downward traceability with respect to the set of system requirements. Each feature should in turn be traceable to one or more stakeholder requirements. Design features that are not specifically supported by previously agreed requirements should be discussed with stakeholders.

Recursive application of the process is continued until all system elements of the SoI have been defined and no additional systems or system elements should be defined. The SoI for one organization can be the system that will be purchased by a consumer in a commercial market, such as an automobile. The SoI for another organization can be a system element within another system such as a motor that will be assembled into an automobile by another organization.

Also, at any level, a system element can be identified as having a unique standard that may be used for implementation of that system. For example, one software system element may be developed using ISO/IEC/IEEE 12207.

The recursive application of the technical processes is repeated as needed for the SoI system definition, system elements and any enabling systems.

Using the architecture, system requirements are assigned to design solutions, considering whether they can best be done:

— by hardware, software and firmware physical elements (new or existing);

— manually or by facilities, material or data; or

— by enabling systems associated with development and integration, production, test, operations, support or retirement;

The design definition process is applied to the SoI, each system element and any enabling systems, until the defined system element can be built, reused, repurposed or purchased. Reused system elements are taken from one system and reused in another system for the same purpose. Repurposed system elements are taken from one system and modified to be used for a different purpose in another or the same system. Software systems and software-intensive subsystems in an SoI, can themselves be treated as the SoI and developed using ISO/IEC/IEEE 12207.

In arriving at a design solution that involves humans and human constraints such as physical space limits, climatic limits, eye movement, arm or finger reach, information rates and ergonomics should be considered. Also, human usability factors should be analysed. These factors affect human interactions with other systems and human interfaces to the system throughout the system life.

The architecture can establish a specific level of required system performance without saying how that performance is to be achieved. This is termed a performance (or performance-focused) specification. A design goes into more detail, including specific ways in which the performance should be achieved. Which kind of design is generated is generally dependent on the next step in development or how it will be used. If the next step is development of a system element and it is desired that the suppliers have flexibility to be innovative in providing an acceptable solution, performance specifications are used.

Performance specifications are used when it is appropriate to state requirements in terms of:

— the required results without stating the method for achieving the required results;

— function (what should be accomplished) and performance (how well each function should be performed);

— the environment in which the SoI or system element should perform these functions;

— the interface and inter-changeability characteristics;

— the means for verifying conformance.

Detail specifications should be used when it is appropriate to state design requirements in terms of one or more of the following:

— material to be used;

— how a requirement should be achieved;

— how a system should be fabricated or constructed.

The initial or "design to" specifications provide the input design for initiating development of the systems. These initial specifications are provided by the system requirements definition process and are revised during the system definition processes for the SoI and system elements. Specifications describe the required characteristics of system elements in the SoI and include the functional and performance requirements, interface requirements, the environments in which the system elements are required to perform their functions, physical characteristics and attributes, the basis for evaluating verification and validation test systems, the methods for verifying conformance, intended uses and enabling system requirements.

The final or "build-to" specifications that are created using the system requirements definition process provide the output design for initiating implementation of the system and its elements. The “built-to” configuration should be recorded and maintained throughout the system life cycle.

The activities can be supported by an MBSE approach, see Annex C.

6.7.5.3.5 Application of system analysis process (ISO/IEC/IEEE 15288:2023, 6.4.6)

The system analysis process is used throughout the application of the ISO/IEC/IEEE 15288 processes. In many cases, the system analysis process supports the processes described in 6.7.5.2 for understanding stakeholder needs and requirements and is similarly applied throughout the use of the system definition processes described in 6.7.5.3.

When information is needed to monitor whether the system meets its objectives, the results of system analysis are reported to the project assessment and control process.

The user, and indeed all stakeholders in the SoI, should ensure that their system analysis process includes:

a) analytical methods adequate to address all of the types of analyses that may be required throughout the application of ISO/IEC/IEEE 15288 processes;

b) explicit steps to identify and validate analysis assumptions;

c) techniques that inherently provide a range of possible responses, rather than single point solutions;

d) methods to assess risks of the analyses and their results;

e) outputs that clearly communicate analytical results to all types of stakeholders who have an interest in those results;

f) tools that support analyses without forcing unacceptable constraints on the analysis;

g) methods to capture, accumulate and retrieve knowledge of current and prior analyses;

h) human resources who have a deep understanding of the inherent limitations and fallacies of system analysis.

6.7.5.4 Application of technical processes for system realization

6.7.5.4.1 General

The implementation process, integration process, verification process and validation process are used to realise the system for each system element and for the SoI. These processes are applied throughout the system lifecycle. Examples are as follows.

— The implementation process is also used to realise prototypes.

— The integration process is also used to virtually integrate systems based on models.

— The verification process is also used to prove in the concept phase, with the help of simulations, that the final system is likely to meet the required performance.

— The validation process is also used to help ensure that system requirements accurately reflect stakeholder requirements.

The focus of the processes is to build, integrate, and evaluate the system to be ready for deployment, based on the system definition. This includes verifying that the system meets the system requirements, architecture, and design; and validating that it meets stakeholder needs and requirements.

6.7.5.4.2 Application of implementation process (ISO/IEC/IEEE 15288:2023, 6.4.7)

The implementation process can be applied for each system element defined as part of an architecture and design solution. This includes any kind of preliminary products or services such as prototypes or mock-ups. The implementation process should be used to transform such system element definitions into products or services appropriate to the applicable life cycle stage. The implemented system element can be either a single product or a composite product depending on the SoI and its ability to be appropriately modelled, built, bought or reused.

Aspects to consider in forming the implementation strategy include:

a) whether implementation produces a novel system element, or a system element that is reproduced according to existing architecture, design and implementation data or is an adaptation of an existing system element;

b) standard practices that govern the relevant implementation technology, technical discipline or product sector;

c) safety, security, privacy and environmental factors;

d) implementation location and environment;

e) implementation skills, their availability and sustainability;

f) the materials selected for fabrication, consumable materials and by-products;

g) operator characteristics;

h) period over which repeated instances of implementation are required.

The system element is either a single product (e.g. component or part) or composite of products (e.g. subassembly, line replaceable unit) depending on its level in the system structure and its ability to be purchased or implemented.

System elements consisting solely of hardware items can be:

— purchased off-the-shelf from a supplier or vendor;

— fabricated in-house;

— from in-house, off-the-shelf supply.

System elements consisting solely of software items can be:

— acquired from a supplier as commercial-off-the-shelf (COTS) or open source;

— developed by an outsourced software developer or in-house;

— assembled from existing software libraries.

System elements that are composites of hardware and software, but exist as off-the-shelf items, can be purchased from a supplier or reused.

System elements that are services or products other than hardware or software, such as data, humans, processes (e.g. processes for providing service to users), procedures (e.g. operator instructions), facilities, materials and naturally occurring entities, can either be obtained from a supplier or through in-house capabilities.

The implemented system elements are usually verified using the appropriate process prior to delivery to an acquirer. Validation can be performed before delivery or prior to completion of the integration process based on agreement obligations.

The “as-built” configuration should be recorded and maintained throughout the system life cycle.

6.7.5.4.3 Application of integration process (ISO/IEC/IEEE 15288:2023, 6.4.8)

The integration process is used every time system elements or artefacts are available for integration throughout the system structure. The integration is performed according to the configuration descriptions developed for that system element. This newly integrated system, system elements or artefacts are verified using the verification process and validated using the validation process. Integration activities occur until the SoI is realised. The SoI can be transitioned using the transition process.

The integration strategy should address all system elements, including all services and products. These can be composed of any combination of hardware, software, data, humans, processes (e.g. processes for providing service to users), procedures (e.g. operator instructions), facilities, materials and naturally occurring entities.

The integration strategy should include methods to assess all interfaces after each stage of integration to check for and address possible changes.

When the SoI is a CS of an SoS, the SoI can participate or is involved in integration, verification and validation of the SoS, in conjunction with utilization of the SoI. When the SoI is an SoS, integration, verification and validation of the SoS with CSs are possibly conducted incrementally or on an as-requested basis because the SoS depends on the product life cycle of individual CS and/or strategic evolution of available service scope of the SoS.

System validation test results, records and procedures, as appropriate, should be reviewed prior to integration being performed.

Further information on integration is provided in ISO/IEC/IEEE 24748-6.

6.7.5.4.4 Application of verification process (ISO/IEC/IEEE 15288:2023, 6.4.9)

As per ISO/IEC/IEEE 15288:2023, 6.4.9.1, the purpose of the verification process is to provide objective evidence that a system, system element, or artefact fulfils its specified requirements and characteristics. This process can be performed multiple times throughout the system life cycle.

This verification should be performed according to a verification strategy. Verification can be dependent on the type of system, on the decisions made regarding life cycle stage entry and exit criteria, as well as the specific life cycle stage. Example methods of verification are the following:

a) inspection (e.g. review of system elements versus the architecture or design);

b) analysis (e.g. using mathematical modelling, simulation or a virtual reality prototype);

c) demonstration (e.g. prototypes, operations);

d) test (e.g. using physical products, prototypes, breadboards or brassboards).

The system implemented or integrated should be used for performing verification. During early stages of a system life cycle, inspection, analysis or demonstration can be used for verification. For later stages, operation or testing can be used. However, use of inspection, analysis (including simulations) and demonstration for verification during any life cycle stage can be more effective than physical testing, e.g. destructive or hazardous testing.

Generally, verifications are conducted under controlled conditions. As such, actual operational environments and use of operators is not a factor. If the operational environment is a factor for a specific performance requirement, then it should be included in any modelling, simulation or other form of verification.

Verification failure can result from failure to meet requirements, improper implementation or integration of the system, and also from poor conduct of the verification method. Anomalies that are discovered during verification of the SoI or a system element should be appropriately resolved prior to the transition of the system to the acquirer.

It can be necessary to have the supplier re-engineer a defective system or system element being verified. This can require iteration through the concept definition or system definition processes. This can also create the need for re-engineering system elements in the SoI being verified, and then iteration of the verification or other system realization processes.

6.7.5.4.5 Application of validation process (ISO/IEC/IEEE 15288:2023, 6.4.11)

As per ISO/IEC/IEEE 15288:2023, 6.4.11.1, the purpose of the validation process is to provide objective evidence that the system, when in use, fulfils its business or mission objectives and stakeholder needs and requirements, achieving its intended use in its intended operational environment. This process can be performed multiple times throughout the system life cycle.

Validation can be done with simulation or mathematical modelling, with a technology prototype, with a pre-production prototype or with a delivered or installed system, as appropriate to satisfy the entry or exit criteria of the applicable system life cycle stage and the agreement. The validation should be performed using anticipated operators or users when possible and appropriate.

Validation can be completed either prior to transition to the acquirer or after transition as specified in the agreement. If validation of the system is performed before transition, then the supplier often does this, with some level of stakeholder involvement. Otherwise, the acquirer generally validates the “as-delivered” system prior to the integration with other acquired systems and system elements applicable to the SoI. The validation process can be performed using a mathematical or simulation model when cost of validation is a factor or where operational environments are not readily accessible.

There are several approaches for performing the validation process:

a) validation against acquirer and applicable stakeholder requirements using the same methods as used for verification, i.e. analysis (including simulation or mathematical modelling), inspection, demonstration or test;

b) certification tests against established requirements;

c) acceptance tests using operational processes and personnel in an operational environment;

d) as specified in the agreement.

The approach used is dependent on the system life cycle stage in which validation is conducted as well as cost, schedule, level within the system structure and available resources.

Validation failure can result from failure to fully understand stakeholder expectations, improperly transforming the stakeholder requirements into the preferred system requirements, architecture and design, poor implementation or integration, or also from poor conduct of the validation. Anomalies discovered during validation should be appropriately resolved prior to operational use of the SoI or system element, or prior to integration with other systems or SoSs.

Simulation and modelling can be useful for studying system performance in the operational environment and for saving costs when live testing is destructive or otherwise impractical. In such cases, it can be necessary to validate the simulation as well to confirm it adequately describes the simulated environment in which the system model will be exercised and evaluated.

The final customer for the SoI validates the delivered products using the validation process against the stakeholder needs and requirements. This can take the form of acceptance tests or initial operational test and evaluation.

Non-conformance resolution is conducted at a level consistent with cost effective remediation actions, including re-validation following resolution or organizational quality improvement actions.

6.7.5.5 Application of technical processes for system deployment and use

6.7.5.5.1 General

The transition process, operation process and maintenance process allow the stakeholders to achieve the service and/or product benefits of the SoI, at the level desired and over the extent of time intended. The disposal process is used to remove the system from service and, if appropriate, physically dispose of it in a manner that helps ensure that no safety, environmental, operational or other hazards are created, or allow for it to be repurposed.

The deployment and use technical processes should be considered even before a system is transitioned. They should be considered during concept definition, system definition and system realization to help ensure that the needs for transition, operation, and maintenance have been considered in requirements, architecture and design, and implemented in the SoI and system elements. This allows for an effective and efficient deployment and use of the SoI.

6.7.5.5.2 Application of transition process (ISO/IEC/IEEE 15288:2023, 6.4.10)

Transition occurs whenever the SoI or its systems elements move from one environment to another such as to the implementation environment, the installation site or the environment of use. The transition process is used to deliver to the acquirer a fully integrated and verified SoI. The delivered system can also be validated if the agreement requires validation to be accomplished by the supplier before transition. Appropriate transition should be performed for each system element and the SoI. With modern software system development approaches, systems can be transitioned from one environment, such as development environment or test environment, to another environment, such as production or operational environments, multiple times a day. The system will require a higher level of automation to speed up the transition activities while providing effective quality assurance activities,

Considerations for transition should include, as appropriate, packaging and handling, storage, transportation, installation, and ensuring that each site is properly prepared for either the installation or receipt, or both, of the system. Transition activities will be dependent on the life cycle stage and the interrelationships with other system elements within the SoI. Transition can occur incrementally, as the SoI evolves from an initial capability to its full intended capability.

User or operator-training can be provided during the transition process to prepare the users and operators for the operation of the SoI. Any necessary training materials are prepared in the implementation process.

There are situations where it is necessary to continue to operate some systems while they are being replaced and while installing and certifying the new system and training operators for the new system.

When the SoI is a CS of an SoS, the transition process on the SoI is possibly conducted iteratively to participate in the transition process of the SoS, even during utilization stage of the SoI. Such CS transitions of the SoS are usually known in directed, acknowledged and collaborative SoS, but possibly not known in virtual SoS. Additionally, the transition process on a CS is possibly requested to be conducted with sophisticated migration such that it operates the legacy system and the new one until the SoS addresses and resolves those replacements and changes. When the SoI is an SoS, the transition process on the SoI is possibly conducted iteratively to upgrade the SoS, when a CS is modified or maintained, or a new CS is incorporated into the SoS, even during the utilization stage of the SoI.

6.7.5.5.3 Application of operation process (ISO/IEC/IEEE 15288:2023, 6.4.12)

The operation process is used whenever the system realization is sufficiently advanced for the system to provide capabilities desired by the stakeholders, even if this is below full intended capability. It is increasingly common for systems to mature and evolve in some incremental fashion starting from an initial subset of capabilities. This allows the stakeholder to realise a beneficial return on their investment earlier than would otherwise occur. At the same time, early use of the operation process allows learning on the part of the operators, those who receive the functional benefits of the system and those who support the system under the maintenance process. This opportunity for learning and refinement of the requirements for the final system can be formalized under an incremental build concept.

The operation process can be applied for much longer spans of time, and in different environments, than any of the product definition or realisation processes.

The operation process is used in any one of the system life cycle stages for the operation of the system and the applicable enabling systems to accomplish the functionality objectives of a particular stage.

Each life cycle stage has an operation function to carry out the purpose and objectives of that stage. Therefore, the operation process is applicable to any stage and can have a different strategy for operating the system and the enabling system applicable to that stage.

During concept and development stages of the system life cycle the operations strategy can be included in the project plan or the engineering strategy.

When the SoI is a CS of an SoS, the operation process on the SoI is possibly requested to be conducted with DevOps, such that development, operation and maintenance are performed concurrently and iteratively with minimized out-of-service periods, in order to prevent degradation of available services of the SoS. When the SoI is an SoS, the operation process on the SoI is possibly conducted with monitoring operational incidents and maintenance status of the CS and/or with continuous exploration of alternative systems to join as redundant CS, in order to prevent degradation of available services of the SoS.

6.7.5.5.4 Application of maintenance process (ISO/IEC/IEEE 15288:2023, 6.4.13)

The maintenance process should be considered even before a system is transitioned and is thereafter generally applied in parallel with the operation process. Considering maintenance throughout the life cycle improves the quality of the maintenance strategy and training, as well as the adequacy of logistics arrangements.

Like the operation process, the maintenance process is generally applied for much longer spans of time, and in different environments, than the product definition or realization processes. The long-term success of the maintenance process depends on maintaining alignment with changes in the operation of the system.

The maintenance process includes any element of logistics support including the training of maintenance personnel, in-service configuration management, operation of depots and maintenance facilities, supply management, supply functions as defined by the agreement or other directives and package, handling, storage, transportation and shipping.

Each system life cycle stage has a maintenance function to carry out the purpose and objectives of that stage. Therefore, this process is applicable to any stage and can have a different strategy for maintaining the system and the enabling system applicable to that stage. With modern software system development approach, system maintenance can occur in parallel with system development. The system needs to have an effective monitoring mechanism to collect system performance feedback or user's feedback, so that it can be provided back to the development team for just-in-time improvements. Activities conducted under the maintenance process should be closely aligned with the configuration management process to help ensure that the system configuration is updated anytime maintenance activities are performed that affect system configuration.

Appropriate records recording maintenance and logistics actions and outcomes should be maintained.

When the SoI is a CS of an SoS, the maintenance process on the SoI is possibly requested to be conducted with redundant systems (e.g. dual systems, multiple hot stand-by systems, or dual operation of the legacy system and the maintained one) in order to prevent degradation of available service of the SoS. When the SoI is an SoS, the maintenance process on the SoI is possibly conducted when CS are entering into and out of maintenance periods, and/or when interfaces of CS are going to be changed.

6.7.5.5.5 Application of disposal process (ISO/IEC/IEEE 15288:2023, 6.4.14)

The disposal process should be considered while a system is still operational and can be applied to the SoI or to select system elements. In the case of incremental development of capability, it is not uncommon to need to dispose of select system elements. The disposal strategy can become complex in such cases and the strategy needs to be identified. The disposal strategy should also include methods to help ensure that disposal of system elements happens in accordance with applicable laws, policies and procedures.

On the other hand, it is also not uncommon for only part of the disposal process to be applied. For example, an obsolete part of a system is removed from operational use, but still be left intact and able to perform, if need be, in an emergency or as a platform to test capabilities for further evolution of a system. While the disposal process needs to be developed and executed in synchronization with operation and maintenance of the system, it is particularly important in these complex cases.

The disposal process should pay close attention to archiving information related to disposal, and ensuring that all required certifications are obtained and available. This can be necessary over an extended span of time.

EXAMPLE 1 An element of the SoI or an enabling system can require a special disposal method to protect the environment.

EXAMPLE 2 A storage device can require a special disposal method to protect the data in it.

Each life cycle stage can have a disposal function to carry out the purpose and objectives of that stage. Therefore, this process can be applicable to any stage and can have a different strategy for disposing the SoI or system elements, elements of the definition, waste products, non-reparable or non-reclaimable products and undesired by-products from that stage.

The disposal process can also be applicable to any enabling systems for that stage.

6.8 Application of conformance and adaptation concepts

6.8.1 Application of conformance concepts

ISO/IEC/IEEE 15288 allows claims of either full or tailored conformance for a declared set of processes. Claims of full conformance for a declared set of processes require demonstrating that either:

a) all of the outcomes of the declared set of processes have been achieved; or

b) all of the activities and tasks of the declared set of processes have been achieved.

Tailored conformance is achieved by demonstrating that the outcomes, activities and tasks, as tailored according to ISO/IEC/IEEE 15288:2023, Annex A, have been achieved.

NOTE Both full and tailored conformance to the requirements of ISO/IEC/IEEE 15288 are discussed in ISO/IEC/IEEE 15288:2023, Clause 4.

In determining claims of conformance, the following points should be kept in mind.

— Process selection: Claims of conformance to ISO/IEC/IEEE 15288 are made for a declared set of processes. Neither an organization nor a particular project is required to use every process. They may select the processes relevant to their needs and declare that subset as the basis of conformance.

— Process substitution: Processes used in related standards, such as ISO/IEC/IEEE 12207 are described as "specialization" of processes in ISO/IEC/IEEE 15288. The system-level process can be used as a basis for conformance rather than the software-level process.

— Use of notes: ISO/IEC/IEEE 15288 uses non-normative notes or other forms of guidance for provisions that are not required for conformance. In specific situations, implementation of selected notes can be appropriate.

— Depending on the domain and discipline, conformance to other standards can be necessary. It is possible that conflicts can arise in the ability to claim conformance to a set of standards. Care should be taken to resolve these conflicts to establish a holistic approach to claiming conformance.

6.8.2 Application of adaptation concepts

6.8.2.1 Adaptation concepts for life cycle models

Life cycle models, as well as the processes from ISO/IEC/IEEE 15288, may be adapted for an individual project to reflect the variations appropriate to the organization, project and system while still being able to claim tailored conformance.

6.8.2.2 Adaptation using identification of project circumstances

ISO/IEC/IEEE 15288:2023, Annex A specifies a normative tailoring process, including an example, informational list of circumstances that influence tailoring as stated in the list below with the following elaboration:

a) stability of, and variety in, operational environments;

b) risks, commercial or performance, to the concern of stakeholders;

c) novelty, size and complexity;

d) starting date and duration of utilization;

e) integrity issues such as safety, security, privacy, usability, availability;

f) emerging technology opportunities;

g) profile of budget and organizational resources available;

h) availability of the services of enabling systems;

i) roles, responsibilities, accountabilities and authorities in the overall life cycle of the system;

j) the need to conform to other standards.

For example, if the operational environment is stable, one process set can be appropriate, but if the operational environment is unstable, an alternate process set can be more appropriate. Identifying degrees of stability instead of the binary choice can produce more options for consideration.

The presence of integrity issues driven by the domain or regulatory requirements can require additional processes and outcomes relevant to those issues.

The decision management process in ISO/IEC/IEEE 15288:2023, 6.3.3 can be used to provide a structured, analytical framework for objectively identifying, characterizing and evaluating a set of alternatives for the tailoring decision.

6.8.2.3 Adaptation using characteristics

The presence or absence of certain characteristics can be used to guide tailoring. If the system has safety-critical elements, processes and additional outcomes related to safety can be turned on. If the system does not have safety critical elements, the associated processes may be tailored out. In the context of this document, ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207, there is a continuum of human-made systems from those that use little or no software to those in which software is the primary interest. When software is the predominant system or element of interest, ISO/IEC/IEEE 12207 should be used. Both documents have the same process model share most activities and tasks, and differ primarily in descriptive notes. The determination of the applicability of ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 should be decided by the nature of the system and its enabling systems. Often, a mixed tailoring of each standard can be appropriate.

The list of characteristics can be similar to the list of circumstances listed in ISO/IEC/IEEE 15288. In both cases, the intent is to explore the context of the project to guide the tailoring process. As organizations build proficiency with tailoring, patterns can emerge upon which to speed the process for future projects. These patterns can be used to establish templates for processes to product line engineering.

6.8.2.4 Adaptation using characteristics and scaling

In addition to characteristics, scaling factors can be used to further clarify the potential implications. For example, if requirements size (quantity) is used a characteristic, a scaling factor can be beneficial. That is, the optimal process approach can differ if the number of requirements is low, medium or high. If the number of requirements is high, increased rigour can be necessary to achieve the outcomes of the system requirements definition process. If the number of requirements is considered to be medium, then rigor should be traded against adaptability/alternatives for the process. If the number of requirements is low, alternate processes and tool can achieve the outcomes more effectively and efficiently.

Other dimensions to consider include team size, geographic distribution, organizational distribution, skill availability, conformance, domain complexity and solution complexity, with scaling factors in each dimension.

6.8.2.5 Adaptation for very small entities

For the specific case of Very Small Entities (VSEs), the ISO/IEC 29110 series can be applied. For the purpose of the ISO/IEC 29110 series, a VSE is an enterprise, an organization, a department or a project having up to 25 people. A set of guides has been developed based on a set of VSE characteristics. For example, VSE often do not have separate levels of governance above the project or team level and can lack the resources within the organization to perform some processes independently of the development team. The guides are based on subsets of appropriate standards processes, activities, tasks and outcomes, referred to as profiles. The purpose of a profile is to define a subset of International Standards relevant to the VSEs' context; for example, processes, activities, tasks and outcomes of ISO/IEC/IEEE 12207 for software; processes, activities, tasks and outcomes of ISO/IEC/IEEE 15288 for systems; and information products (documentation) of ISO/IEC/IEEE 15289 for software and systems.

This series of International Standards and Technical Reports is intended to be used by VSEs that do not have experience or expertise in adapting ISO/IEC/IEEE 12207 or ISO/IEC/IEEE 15288 standards to the needs of a specific project. VSEs that have expertise in adapting/tailoring ISO/IEC/IEEE 12207 or ISO/IEC/IEEE 15288 are encouraged to use those standards instead of ISO/IEC 29110.

Annex A
(informative)

Summary of typical revised points in ISO/IEC/IEEE 15288:2023 from ISO/IEC/IEEE 15288:2015

Table A.1 summarizes what is topically revised in ISO/IEC/IEEE 15288:2023 from ISO/IEC/IEEE 15288:2015 for clause of concepts and life cycle processes.

Subclauses not mentioned are either unchanged or slightly modified. In ISO/IEC/IEEE 15288:2023, Clause 6, only significant changes to the outcomes, activities and tasks are mentioned.

Table A.1 — Typical corresponding relations of life cycle processes contributing to quality evaluation process

ISO/IEC/IEEE 15288:2023, Clause 3 Terms, definitions, and abbreviated terms
Definition of the term “system” has been changed and some of definitions and Notes have been modified. New terms: “artefact”, “interface”, “interoperating system”, “process iteration”, “process outcome”, “process recursion”, “safety”, “system of systems”, “view” and “viewpoint”. However, the definitions of the terms “architecture framework”, “architecture view” and “architecture viewpoint” have been removed but are defined in ISO/IEC/IEEE 42020. Also, the following terms are removed: “design, verb”, “facility” and “trade-off”. The abbreviated term “SoI” has been provided for the term “system-of-interest”.
ISO/IEC/IEEE 15288:2023, Clause 4 Conformance (ISO/IEC/IEEE 15288:2015, Clause 2 and thus all subclauses renumbered correspondingly)
ISO/IEC/IEEE 15288:2023, Clause 5 Key concepts and their application
ISO/IEC/IEEE 15288:2023, 5.2 System concepts
ISO/IEC/IEEE 15288:2023, 5.2.2 System structure
The relationship of SoI and its system elements may be networks and other distributed systems (e.g. SoS) in addition to hierarchical. ISO/IEC/IEEE 15288:2023, Figure 1 “System and system element relationship” has been slightly modified.
ISO/IEC/IEEE 15288:2023, 5.2.3 Interfacing, enabling and interoperating systems (ISO/IEC/IEEE 15288:2015, 5.2.3 Enabling systems)
The concepts of identify interfacing and interoperating systems are covered as well as enabling system.
ISO/IEC/IEEE 15288:2023, 5.2.4 Concepts related to the system solution context (New subclause)
An SoI can be used in multiple different solution contexts with different enabling systems. ISO/IEC/IEEE 15288:2023, Figure 3 “System solution contexts” shows this graphically by revising ISO/IEC/IEEE 15288:2015, Figure 3 “System-of-interest, its operational environment and enabling systems”.
ISO/IEC/IEEE 15288:2023, 5.2.5 Product line engineering (PLE) (New subclause)
Subclause explains when product line engineering (PLE) is used. The product line is an SoI as a whole and at other times each variation is an SoI.
ISO/IEC/IEEE 15288:2023, 5.3 Organizational concepts
ISO/IEC/IEEE 15288:2023, 5.3.3 Organization and collaborative activities (New subclause)
Subclause describes the possible employment of collaborative engineering approaches across the system life cycle to address the increasing complexities of system solutions.
ISO/IEC/IEEE 15288:2023, 5.4 System of systems concepts (New subclause)

Table A.1 *(continued)*

Subclause discusses system of systems (SoS) concepts and guidance for application life cycle processes when the SoI is a constituent system of an SoS or the SoS is treated as an SoI. There are five subclauses to this subclause. Previously, this material was in ISO/IEC/IEEE 15288:2015, Annex G (informative) "Application of system life cycle processes to a system of systems". The details about types of SoS have been moved to ISO/IEC/IEEE 21839, ISO/IEC/IEEE 21840 and ISO/IEC/IEEE 21841.
ISO/IEC/IEEE 15288:2023, 5.5 Life cycle concepts (ISO/IEC/IEEE 15288:2015, 5.4)
ISO/IEC/IEEE 15288:2023, 5.6 Process concepts (ISO/IEC/IEEE 15288:2015, 5.5)
ISO/IEC/IEEE 15288:2023, 5.7 Processes in this document (ISO/IEC/IEEE 15288:2015, 5.6)
ISO/IEC/IEEE 15288:2023, 5.7.1 General (changed from ISO/IEC/IEEE 15288:2015, 5.6.1 Introduction)
It has been modified from ISO/IEC/IEEE 15288:2015, 5.6.1.
ISO/IEC/IEEE 15288:2023, 5.7.2 Agreement processes
This subclause merges and modifies material from ISO/IEC/IEEE 15288:2015, 5.6.2 and the ISO/IEC/IEEE 15288:2015, 6.1. Adds some material about SoS.
ISO/IEC/IEEE 15288:2023, 5.7.3 Organizational project-enabling processes
This subclause merges and modifies material from ISO/IEC/IEEE 15288:2015, 5.6.3 and ISO/IEC/IEEE 15288:2015, 6.2. Adds some material about SoS.
ISO/IEC/IEEE 15288:2023, 5.7.4 Technical management processes
This subclause merges and modifies material from ISO/IEC/IEEE 15288:2015, 5.6.4 and from ISO/IEC/IEEE 15288:2015, 6.3. Adds some material about SoS.
ISO/IEC/IEEE 15288:2023, 5.7.5 Technical processes
This subclause merges and modifies material from ISO/IEC/IEEE 15288:2015, 5.6.5 and from ISO/IEC/IEEE 15288:2015, 6.4. Adds some material about SoS.
ISO/IEC/IEEE 15288:2023, 5.8 Process application (ISO/IEC/IEEE 15288:2015, 5.7)
This clause has been split into three subclauses: ISO/IEC/IEEE 15288:2023, 5.8.1 Overview, ISO/IEC/IEEE 15288:2023, 5.8.2 Process iteration, recursion, and concurrency, and ISO/IEC/IEEE 15288:2023, 5.8.3 Process views.
ISO/IEC/IEEE 15288:2023, 5.8.1 Overview (New subclause)
ISO/IEC/IEEE 15288:2023, Figure 5 "Interrelationships between processes" is added to illustrate the application of life cycle processes with process iteration, concurrency and recursion through interrelationships among the processes. Also, Model-Based Systems Engineering (MBSE) is mentioned with most of the information provided in ISO/IEC/IEEE 15288:2023, Annex D.
ISO/IEC/IEEE 15288:2023, 5.8.2 Process iteration, recursion, and concurrency (New subclause)
This subclause has been rephrased to provide better descriptions of iteration and recursion on process application.
ISO/IEC/IEEE 15288:2023, 5.8.3 Process Views (New subclause)
This subclause explains the concept of process views (ISO/IEC/IEEE 15288:2015, Annex E).
ISO/IEC/IEEE 15288:2023, 5.9 Concept and system definition (New subclause)
Emphasizes that concepts, needs and requirements evolve at various levels. That evolution is accomplished through the iterative application of the business or mission analysis, stakeholder needs and requirements definition, system requirements definition, system architecture definition and design definition processes with the support of other processes, as needed.
ISO/IEC/IEEE 15288:2023, 5.10 Assurance and quality characteristics (New subclause)
Explains approach of assurance case for quality characteristics assurance through application of life cycle processes, and encourages collaborative activities with system assurance and quality characteristics.
ISO/IEC/IEEE 15288:2023, 5.11 Process reference model (ISO/IEC/IEEE 15288:2015, 5.8)
ISO/IEC/IEEE 15288:2023, 6 System life cycle processes
ISO/IEC/IEEE 15288:2023, 6.1 Agreement processes
ISO/IEC/IEEE 15288:2023, 6.1.1 Acquisition process

Table A.1 *(continued)*

ISO/IEC/IEEE 15288:2015, 6.1.1.3 c)4) "Negotiate the agreement with the supplier" has been removed. Negotiation of an agreement between acquirer and supplier is still there in supply process as ISO/IEC/IEEE 15288:2015, 6.1.1.3 c)1) as an approach from supplier.
ISO/IEC/IEEE 15288:2023, 6.1.2 Supply process
ISO/IEC/IEEE 15288:2015, 6.1.2.3 c)4) "Negotiate the agreement with the supplier" has been removed. ISO/IEC/IEEE 15288:2015, 6.1.2.3 c) "Establish and maintain an agreement", has been simplified and subsumed into ISO/IEC/IEEE 15288:2015, 6.1.2.3 c)1) "Negotiate and approve an agreement with the acquirer that includes acceptance criteria."
ISO/IEC/IEEE 15288:2023, 6.2 Organizational project-enabling processes
ISO/IEC/IEEE 15288:2023, 6.2.1 Life cycle model management process
Purpose has minor changes. ISO/IEC/IEEE 15288:2023, 6.2.1.2 c) "Policies, life cycle processes, life cycle models and procedures for use by the organization are selected" has been added.
ISO/IEC/IEEE 15288:2023, 6.2.2 Infrastructure management process
ISO/IEC/IEEE 15288:2023,6.2.2.2 e) "Prioritised infrastructure improvements are implemented" has been added.
ISO/IEC/IEEE 15288:2023, 6.2.3 Portfolio management process
ISO/IEC/IEEE 15288:2023, 6.2.3.2 a) and ISO/IEC/IEEE 15288:2023, 6.2.3.3. a)2) has been slightly modified to replace the term "business" with "strategic". ISO/IEC/IEEE 15288:2015, 6.2.3.3b)2) has been divided into ISO/IEC/IEEE 15288:2023, 6.2.3.3 b)2) and b)3).
ISO/IEC/IEEE 15288:2023, 6.2.4 Human resource management process
Purpose has been slightly modified to replace the term "business" with "strategic". Outcome ISO/IEC/IEEE 15288:2015, 6.2.4.2 d) "Conflicts in multi-project resource demands are resolved" has been modified to ISO/IEC/IEEE 15288:2023, 6.2.4.2 d) "Personnel conflicts are resolved". ISO/IEC/IEEE 15288:2015, 6.2.4.3 c)5) "Control multi-project management interfaces to resolve personnel conflicts" has been modified to ISO/IEC/IEEE 15288:2023, 6.2.4.3c)5) "Resolve personnel conflicts across or within projects."
ISO/IEC/IEEE 15288:2023, 6.2.5 Quality management process
ISO/IEC/IEEE 15288:2023, 6.2.5.2 d) has been slightly modified.
ISO/IEC/IEEE 15288:2023, 6.2.6 Knowledge management process
ISO/IEC/IEEE 15288:2023, 6.2.6.2 d) The organizational knowledge, skills and knowledge assets are communicated across the organization" has been added. ISO/IEC/IEEE 15288:2015, 6.2.6.3 b)3) Share knowledge and skills across the organization" has been replaced with ISO/IEC/IEEE 15288:2023, 6.2.6.3 b)3) Make knowledge and skills accessible to the organization". ISO/IEC/IEEE 15288:2015, 6.2.6.3 c)3) "Share knowledge assets across the organization" has been replaced with ISO/IEC/IEEE 15288:2023, 6.2.6.3 c)3) "Make knowledge assets accessible to the organization".
ISO/IEC/IEEE 15288:2023, 6.3 Technical management processes
ISO/IEC/IEEE 15288:2023, 6.3.1 Project planning process
ISO/IEC/IEEE 15288:2023, 6.3.1.2 c) "Performance and achievement criteria are defined" has been added to point out more clearly preparation of criteria to determine performance and achievement of the project. ISO/IEC/IEEE 15288:2023, 6.3.1.3 a)4) "Establish appropriate breakdown structures" is modified to avoid specific type of breakdown structures that is "based on the evolving system architecture". ISO/IEC/IEEE 15288:2023, 6.3.1.3 b) 3) "Define project performance criteria" has been added.
ISO/IEC/IEEE 15288:2023, 6.3.2 Project assessment and control process