INTERNATIONAL STANDARD

ISO/IEC/ IEEE 24748-2

First edition
2018-12

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)

Reference number
ISO/IEC/IEEE 24748-2:2018(E)

Contents

Page

iii

Foreword

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

This first edition cancels and replaces ISO/IEC TR 24748-2:2011. The changes to this edition reflect changes in ISO/IEC/IEEE 15288:2015 from the 2008 edition, as well as the movement of concept material to ISO/IEC/IEEE 24748-1:2018.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document and its companion, ISO/IEC TR 24748-3 *Guide to the application of ISO/IEC 12207 (Software life cycle processes)* specifically support use of ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207, respectively. These two guidelines continue and make use of the alignment effort evident in the two revised International Standards. Terminology, structure and content in the guidelines are aligned consistent with that in the two International Standards. Consequently, the users of ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 will benefit from having documents complementarily addressing all aspects of services or products over their life cycle.

Besides the above, 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. This 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 is a guideline for the application of ISO/IEC/IEEE 15288:2015. It addresses system, life cycle, organizational, project, and process, concept application, principally through reference to ISO/IEC/IEEE 24748-1 and ISO/IEC/IEEE 15288:2015. It gives guidance on applying ISO/IEC/IEEE 15288:2015 from the aspects of strategy, planning, application in organizations, and application on projects. It also provides comparison of the differences between ISO/IEC/IEEE 15288:2015 and the prior versions, ISO/IEC 15288:2008.

This document is intended to be consistent with both ISO/IEC/IEEE 24748-1 and ISO/IEC/IEEE 15288:2015 in its treatment of life-cycle concepts and systems engineering processes.

NOTE   Systems engineering for defense programs is addressed in IEEE Std 15288.1, *Application of Systems Engineering on Defense Programs*.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC/IEEE 15288:2015 apply.

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

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

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

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

4 Overview of ISO/IEC/IEEE 15288:2015

4.1 General

ISO/IEC/IEEE 15288:2015 *Systems and software engineering — System life cycle processes*, establishes a common framework for system life cycle processes, with well-defined terminology, that can be referenced by any party, particularly those having any involvement or interest in the system life cycle or performance of systems engineering activities. 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.

ISO/IEC/IEEE 15288:2015 may be used stand-alone or jointly with other International Standards, such as ISO/IEC/IEEE 12207:2017, and supplies a process reference model that supports process capability assessment in accordance with ISO/IEC 33002:2015 (Process assessment).

The purpose of ISO/IEC/IEEE 15288:2015 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 15288:2015 is written for acquirers of systems and for suppliers, developers, operators, maintainers, managers, quality assurance managers, and users of systems.

4.2 Structure of ISO/IEC/IEEE 15288:2015

ISO/IEC/IEEE 15288:2015 contains requirements in two clauses:

1) Clause 6, which defines the requirements for the system life cycle processes;

2) Annex A that provides requirements for tailoring of ISO/IEC/IEEE 15288:2015.

Six informative annexes support the use of ISO/IEC/IEEE 15288:2015 or its harmonization with ISO/IEC 12207:2008:

1) Annex B provides information on possible information items that may be associated with each process in ISO/IEC/IEEE 15288:2015.

2) Annex C provides information about use of the ISO/IEC/IEEE 15288:2015 system life cycle processes as a process reference model to support process assessment.

3) Annex D provides an informative description of the process constructs used in ISO/IEC/IEEE 15288:2015.

4) Annex E provides information on the process view concept and examples of its use from two different process viewpoints.

5) Annex F provides information on the Architecture Definition and Design Definition processes in ISO/IEC/IEEE 15288:2015 as they relate to the Architectural Design process in the 2008 version of ISO/IEC/IEEE 15288.

6) Annex G provides information on application of system life cycle processes to a system of systems.

Readers of ISO/IEC/IEEE 15288:2015 are advised to consult Clause 5 of that International Standard to gain understanding of the key concepts used.

4.3 Context of ISO/IEC/IEEE 15288:2015

ISO/IEC/IEEE 15288:2015 has a focus 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. A project is assigned responsibility that encompasses one or more life cycle stages of the system-of-interest. ISO/IEC/IEEE 15288:2015 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 context of ISO/IEC/IEEE 15288:2015 is illustrated in Figure 1. As the figure indicates, a single project may involve multiple organizations working together as partners. The project for the system-of-interest may also interact with other projects, either for other systems that will interoperate with the system-of-interest, or for enabling systems. Such a project should use ISO/IEC/IEEE 15288:2015 to establish common terminology, as well as information flows and interfaces among the several organizations, to enhance communications.
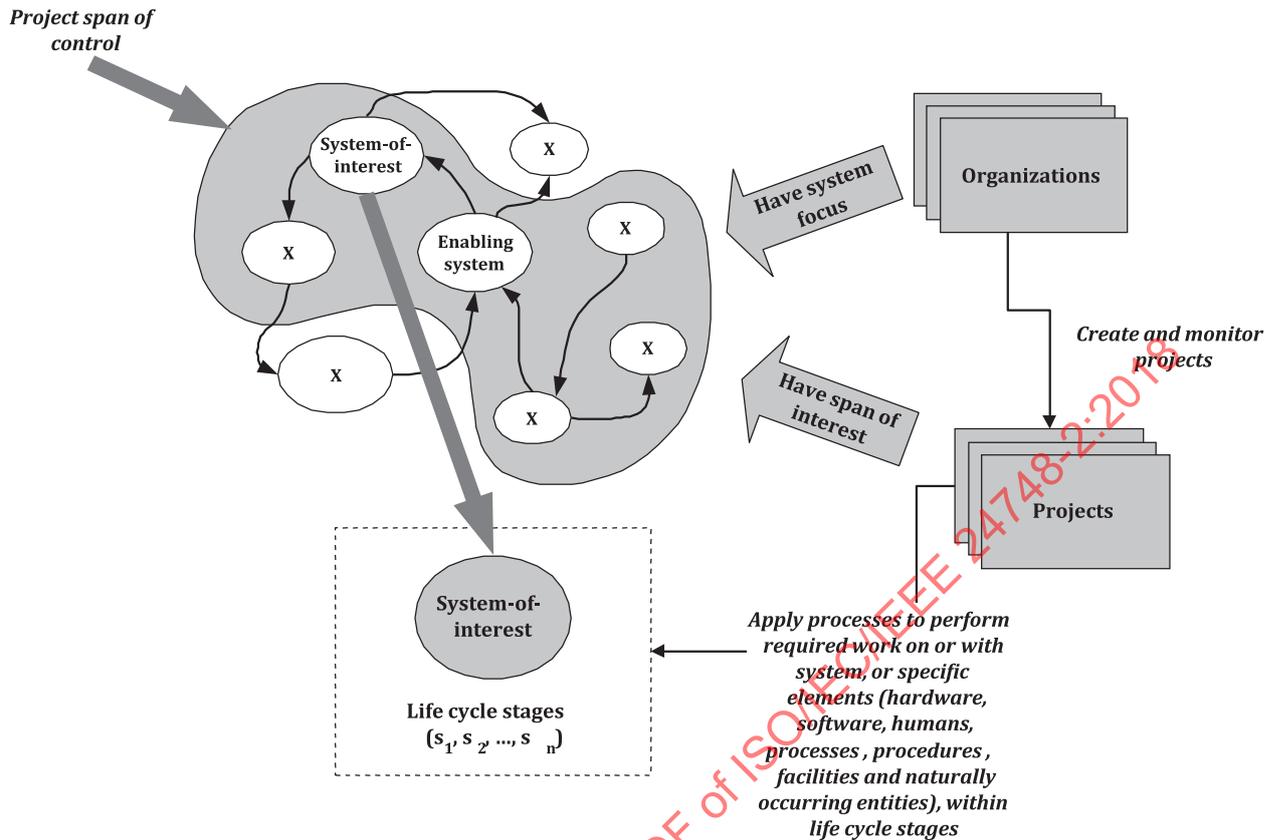
Figure 1 — Context of ISO/IEC/IEEE 15288:2015

When an organization applies ISO/IEC/IEEE 15288:2015 to a particular system that system becomes the system-of-interest. The system-of-interest has a life cycle that consists of multiple stages through which the system passes during its lifetime, denoted in the figure as s_1, s_2, ... s_n. These stages are not necessarily sequential and their execution can be completely or partially in parallel, as well as iterative or recursive. An example of typical stages is:

— s_1: concept;

— s_2: development;

— s_3: production;

— s_4: utilization;

— s_5: support; and

— s_6: retirement.

NOTE 1   Stages are described in ISO/IEC/IEEE 15288:2015, 5.4.2 and in ISO/IEC/IEEE 24748-1:2018, 4.3.2 and 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 system-of-interest with support as needed. Each life cycle stage can require one or more enabling systems. It is important to note that an enabling system has its own life cycle and that when ISO/IEC/IEEE 15288:2015 is applied to it, it then becomes a system-of-interest.

NOTE 3   The role and use of enabling systems are described in 6.3.4 and 6.7.4.6 of this document.

NOTE 4   For related material on enabling systems, see also ISO/IEC/IEEE 15288:2015, 5.2.3 and ISO/IEC/IEEE 24748-1:2018, 4.2.4.

ISO/IEC/IEEE 15288:2015 is applicable at any level of the structure associated with a system-of-interest. As a system is decomposed recursively into its system elements, the processes of ISO/IEC/IEEE 15288:2015 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 15288:2015, 5.2.2 and ISO/IEC/IEEE 24748-1:2018, 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 system-of-interest 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 24748-1:2018, 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 system-of-interest and its related enabling systems. Some enabling systems are under direct control of the project. The system-of-interest and those enabling systems make up the project span of control.

The work performed by projects is on or with the system-of-interest within one or more life cycle stages. ISO/IEC/IEEE 15288:2015 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 15288:2015 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 15288:2015 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 24748-1:2018, Clause 5 and tailoring described in ISO/IEC/IEEE 15288:2015, Annex A.

4.4   Comparison of ISO/IEC/IEEE 15288:2015 to prior versions

This clause compares the 2008 and 2015 versions of International Standard ISO/IEC/IEEE 15288. Changes have been made to the processes at the structural level (i.e., processes have been added, renamed, or combined with others, with resultant renumbering). These structural changes in the ISO/IEC/IEEE 15288 process set are summarized in Table 1 and the reasons for each structural change are given in Table 2.

Table 1 — Mapping of process sets between ISO/IEC 15288:2008 and ISO/IEC/IEEE 15288:2015

ISO/IEC 15288:2008		ISO/IEC/IEEE 15288:2015		
Clause	**Process**	**Clause**	**Process**	**Structural Changes**
6.2.3	Project Portfolio Management Process	6.2.3	Portfolio management process	Title changed
		6.2.6	Knowledge management process	Added process
6.3	Project Processes	6.3	Technical management processes	Title changed

Table 1 *(continued)*

ISO/IEC 15288:2008		ISO/IEC/IEEE 15288:2015		
Clause	**Process**	**Clause**	**Process**	**Structural Changes**
		6.3.8	Quality assurance process	Added process
		6.4.1	Business or mission analysis process	Added process
6.4.1	Stakeholder Requirements Definition Process	6.4.2	Stakeholder needs and requirements definition process	Title changed; numbering;
6.4.2	Requirements Analysis Process	6.4.3	System requirements definition process	Title changed; numbering;
6.4.3	Architectural Design Process	6.4.4	Architecture definition process	Title changed; numbering
		6.4.5	Design definition process	Added process
		6.4.6	System analysis process	Added process
6.4.4	Implementation Process	6.4.7	Implementation process	Numbering
6.4.5	Integration Process	6.4.8	Integration process	Numbering
6.4.6	Verification Process	6.4.9	Verification process	Numbering
6.4.7	Transition Process	6.4.10	Transition process	Numbering
6.4.8	Validation Process	6.4.11	Validation process	Numbering
6.4.9	Operation Process	6.4.12	Operation process	Numbering
6.4.10	Maintenance Process	6.4.13	Maintenance process	Numbering
6.4.11	Disposal Process	6.4.14	Disposal process	Numbering

Table 2 — Basis for change of process set in ISO/IEC/IEEE 15288:2015

Title change between ISO/IEC 15288:2008 and ISO/IEC/IEEE 15288:2015	Reason for change
6.2.3 Project Portfolio Management Process (2008) Changed to: 6.2.3 Portfolio management process (2015)	The purpose of the Portfolio Management process is to initiate and sustain necessary, sufficient and suitable projects in order to meet the strategic objectives of the organization. Accordingly, it is done outside the scope of any one project and further, it is inappropriate to speak of the project portfolio of a single project.
6.2.6 Knowledge management process (2015) [ADDED]	This was activity 6.2.4.3 d) under process 6.2.4 Human Resource Management Process in the 2008 version. The change to a process in ISO/IEC/IEEE 15288:2015 reflects the greater appreciation that an organizations knowledge is more than what its human resources possess and that the outcomes, activities and tasks need to be more inclusive to reflect this fact.
6.3 Project Processes (2008) Changed to 6.3 Technical Management Processes (2015)	Reflects that the processes under this heading relate to the technical management of a project, but are not the full set of processes involved in managing a project.
6.3.8 Quality assurance process (2015) [ADDED]	In the 2008 version of 15288, quality assurance was task 6.3.2.3 a) 2) under process 6.3.2, Project Assessment and Control Process. It is now recognized as having a broader contribution, under process group 6.3, Technical processes, to the successful realization of the system over its life cycle.

Table 2 *(continued)*

Title change between ISO/IEC 15288:2008 and ISO/IEC/IEEE 15288:2015	Reason for change
6.4.1 Business or mission analysis process (2015) [ADDED]	This is a critical precursor to determining needs and defining requirements. It was not explicitly addressed in ISO/IEC 15288:2008 and has now been added as a separate process in the 2015 version.
6.4.1 Stakeholder Requirements Definition Process (2008) Changed to: 6.4.2 Stakeholder needs and requirements definition process (2015)	The change clarifies that stakeholder needs must first be determined, then used as a basis for deriving stakeholder requirements. That is: a) needs and requirements are related but different b) that both must be addressed to provide a system that responds to stakeholders, c) the stakeholders' views of what they desire that the system provide them in terms of products and services drives the requirements that express the intended interaction the system will have with its operational environment, and d) the stakeholders' requirements are derived by analysis of the stakeholder needs This is consistent with ISO/IEC/IEEE 29148:2011, Systems and software engineering — Life cycle processes — Requirements engineering, Clause 5.2.3, paragraph 1, Transformation of needs into requirements.
6.4.2 Requirements Analysis Process (2008) Changed to: 6.4.3 System requirements definition process (2015)	The process title in the 2008 version of 15288 did not reflect the full scope of what must be done to define system requirements: analysis is only a part of it. In addition, the scope of the process itself is broadened in the 2015 version of 15288 to include the preparation and maintenance of system requirements, not just the initial definition itself.
6.4.3 Architectural Design Process (2008) Changed to: 6.4.4 Architecture definition process (2015)	The process in the 2015 version of 15288 gives a more encompassing view of all the activities and tasks required to architect a system, whereas the 2008 version focuses on the narrower aspect of architecture design.
6.4.5 Design definition process (2015) [ADDED]	Design was inferred in ISO/IEC 15288:2008 process 6.4.3, Architectural Design Process. However, the 2015 version treats architecting (process 6.4.4) and design (6.4.5) as two distinct sets of effort, with outcomes, activities and tasks appropriate to each.
6.4.6 System analysis process (2015) [ADDED]	System analysis was inferred in ISO/IEC 15288:2008 process 6.4.3, Architectural Design Process. In the 2015 version, it is treated explicitly. Further, the process in the 2015 version of 15288 recognizes that system analysis can be performed in conjunction with more processes than just system design.

In addition to the above, the preponderance of changes in the 2015 edition of ISO/IEC/IEEE 15288 are refinements to the purpose, outcomes, activities and tasks of the processes in the International Standard. All of these changes reflect further experience with the International Standard since publication of the 2008 edition. Table 3 illustrates the extent of these changes for one process, using the Purpose, Outcomes and the first part of the Activities and Tasks in the Acquisition Process as an example, highlighting the specific changes with an underline. It is critical that the user of 15288 conduct a detailed comparison of each process in ISO/IEC/IEEE 15288:2015 compared to ISO/IEC 15288:2008.

Table 3 — Illustration of detail level process changes from ISO/IEC 15288:2008 to ISO/IEC/ IEEE 15288:2015

Acquisition process in ISO/IEC 15288:2008	Acquisition process in ISO/IEC/IEEE 15288:2015
6.1.1.1 Purpose The purpose of the Acquisition Process is to obtain a product or service in accordance with the acquirer's requirements.	**6.1.1.1 Purpose** The purpose of the Acquisition process is to obtain a product or service in accordance with the acquirer's requirements. NOTE As part of this process, the agreement is modified when a change request is agreed to by both the acquirer and supplier.
6.1.1.2 Outcomes As a result of the successful implementation of the Acquisition Process: a) A strategy for the acquisition is established. b) One or more suppliers are selected. c) Communication with the supplier is maintained. d) An agreement to acquire a product or service according to defined acceptance criteria is established. e) A product or service complying with the agreement is accepted. f) Payment or other consideration is rendered.	**6.1.1.2 Outcomes** As a result of the successful implementation of the Acquisition process: a) A request for supply is prepared. b) One or more suppliers are selected. c) An agreement is established between the acquirer and supplier. d) A product or service complying with the agreement is accepted. e) Acquirer obligations defined in the agreement are satisfied. f) [DELETED]
6.1.1.3 Activities and tasks The acquirer shall implement the following activities and tasks in accordance with applicable organizational policies and procedures with respect to the Acquisition Process. NOTE The activities and tasks in this process can apply to one or more suppliers. a) **Prepare for the acquisition.** This activity consists of the following tasks: 1) Establish a strategy for how the acquisition will be conducted. NOTE This strategy includes reference to the life cycle model, a schedule of milestones and selection criteria if the supplier is external to the acquiring organization.	**6.1.1.3 Activities and tasks** The acquirer shall implement the following activities and tasks in accordance with applicable organization policies and procedures with respect to the Acquisition process. NOTE The activities and resulting agreement from this process often apply to suppliers in the supply chain, including subcontracted suppliers. a) **Prepare for the acquisition.** This activity consists of the following tasks: 1) Define a strategy for how the acquisition will be conducted. NOTE This strategy describes or references the life cycle model, risks and issues mitigation, a schedule of milestones, and selection criteria if the supplier is external to the acquiring organization. It also includes key drivers and characteristics of the acquisition, such as responsibilities and liabilities; specific models, methods, or processes; level of criticality; formality; and priority of relevant trade factors.

Besides thoroughly reviewing all processes in ISO/IEC/IEEE 15288:2015 versus those in the 2008 edition, it may be useful for the user to recognize that a number of the processes changes reflect a significant change in the thoroughness with which the processes for requirements identification, architecting, design, and analysis are treated. Table 4 shows the overall scope of this major change in the "front end" processes.

Table 4 — Comparison of requirements, architecting, design and analysis processes between ISO/IEC 15288:2008 and ISO/IEC/IEEE 15288:2015

Requirements, architecting, design and analysis processes in ISO/IEC 15288:2008	Requirements, architecting, design and analysis processes in ISO/IEC/IEEE 15288:2015
	6.4.1 Business or mission analysis process
6.4.1 Stakeholder Requirements Definition Process; 6.4.2 Requirements Analysis Process	6.4.2 Stakeholder needs and requirements definition process (includes analysis of stakeholder requirements); 6.4.3 System requirements definition process (includes analysis of system requirements)
6.4.3 Architectural Design Process	6.4.4 Architecture definition process;
	6.4.5 Design definition process
	6.4.6 System analysis process

5   Application concepts

5.1   Overview

This document provides guidelines for life cycle management in the field of systems. This clause highlights and explains essential concepts on which this document is based, and introduces key concepts useful in reading and applying ISO/IEC/IEEE 15288:2015.

NOTE   ISO/IEC/IEEE 24748-1 provides more information on concepts related to life cycle management in general.

5.2   System concepts

Application of ISO/IEC/IEEE 15288 presupposes an understanding of system concepts.

NOTE   System concepts for systems that are any mix of products and services are introduced in ISO/IEC/IEEE 15288:2015, 5.2. Additional discussion is in ISO/IEC/IEEE 24748-1:2018, 4.2.

5.3   Life cycle concepts

Application of ISO/IEC/IEEE 15288 presupposes an understanding of life cycle concepts.

NOTE 1   Life cycle concepts are introduced in ISO/IEC/IEEE 15288:2015, 5.4. Additional discussion is in ISO/IEC/IEEE 24748-1:2018 4.3.

NOTE 2   ISO/IEC/IEEE 24748-1 provides more information on concepts related to life cycle management in general.

5.4   Process concepts

Application of ISO/IEC/IEEE 15288 presupposes an understanding of process concepts.

NOTE   Process concepts are introduced in ISO/IEC/IEEE 15288:2015, 5.5. Additional discussion is in ISO/IEC/IEEE 24748-1:2018, Annex A.

5.5   Organizational concepts

Application of ISO/IEC/IEEE 15288 presupposes an understanding of organizational concepts.

NOTE   Organizational concepts are introduced in ISO/IEC/IEEE 15288:2015, 5.3. Additional discussion is in ISO/IEC/IEEE 24748-1:2018, Annex B.

5.6 Project concepts

Application of ISO/IEC/IEEE 15288 presupposes an understanding of organizational concepts.

NOTE   Project concepts are introduced in ISO/IEC/IEEE 15288:2015, 5.3. Additional discussion is in ISO/IEC/IEEE 24748-1:2018, Annex C.

6   Applying ISO/IEC/IEEE 15288:2015

6.1   Overview

Understanding concepts does not give the ability to immediately apply them without further thought and work. The following clauses give guidance on what should be done to bridge the gap between concept and practical use in different project, organizational and life cycle environments, starting with planning the application of ISO/IEC/IEEE 15288:2015.

Modern businesses strive to develop a robust set of life cycle processes that are applied repeatedly to the projects of the business. To accommodate that need, ISO/IEC/IEEE 15288:2015 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 procedures, practices, tools and policies. A project of the organization should typically conform to the organization's processes rather than conform directly to this document.

In some cases, projects may be executed by an organization that does not have an appropriate set of processes adopted at the organizational level. Such a project may apply the provisions of ISO/IEC/IEEE 15288:2015 directly to the project.

6.2   Application strategy

6.2.1   Overview

ISO/IEC/IEEE 15288:2015 may 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; and

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 15288:2015, a suggested application strategy consists of the following:

a)   plan the application;

b)   adapt ISO/IEC/IEEE 15288:2015, if applicable;

c)   conduct pilot project(s);

d)   formalize the approach; and

e)   institutionalize the approach.

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

Whether the existing basis for system life cycle processes is ISO/IEC 15288:2008 or some other reference point, the fundamental starting point is to identify all the changes to go from that basis to

ISO/IEC/IEEE 15288:2015. If the existing process basis is ISO/IEC 15288:2008, the amount of changes will be noticeably less than if a different process basis is in use.

Bringing all the stakeholders together 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 checklist of things that should be considered in applying ISO/IEC/IEEE 15288:2015. This may include, and possibly will not be limited to:

a) documentation changes, including flow and nomenclature;

b) staff training needs;

c) responsibility changes, including need for new agreements;

d) impacts on tools and databases; and

e) changes in the inputs required by and outputs from each process.

The initial checklist should then be used by an immediately subsequent, larger, group of all stakeholders to work through what other items need to be added and what the specific changes are for each item on the checklist. Repeated reviews of checklist drafts should be held to find the final few surprises.

Once there is a detailed listing of the changes derived in this, or equivalent, manner, the time and cost impacts of each need to be assessed and adjusted for the risks of each change and various groupings of change. Then further analysis of the sequence of implementing the changes is necessary. The group should explore phasing in changes in a way that minimizes cost, project disruption and the potential for adverse human reactions. Readiness criteria should be developed for starting each step of a phase-in, as well as checks for successful completion after each step of phasing in the changes. Quantitative metrics should be developed and used.

Throughout, a core group should be maintained to oversee the change from one basis to another, with periodic meetings of the entire group of stakeholders.

When a project or organization is already in a steady state, i.e. where the processes have been established and institutionalized, then the implementation strategy can be shortened and should probably include the following:

a) plan the application;

b) adapt ISO/IEC/IEEE 15288:2015, if applicable (for the risk level of the work); and

c) conduct the project(s).

6.2.2 Planning the application

Applying ISO/IEC/IEEE 15288:2015 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 project. Possibilities include:

  1) a single project either internal to an organization or as part of a two party contract;

  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 and can lead to a full application of ISO/IEC/IEEE 15288:2015 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 will be necessary;

  3) adoption of ISO/IEC/IEEE 15288:2015 across a range of projects with probably a staged introduction. Here the organization should probably have no or few defined processes and should be standardizing on ISO/IEC/IEEE 15288:2015;

4) adoption of ISO/IEC/IEEE 15288:2015 across all projects and within all parts of the organization. It is unlikely that any organization except a very small one should take this approach. It should be relevant though for a new subsidiary of an existing organization that has adopted ISO/IEC/IEEE 15288 into working practice previously.

b) identify the project goals and determine how they fit into the organization-wide business goals. If no obvious link is established between this 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 project team/organization, assigning a single point of responsibility for each process. In many cases, one individual or organization may be responsible for more than one process, particularly in small projects or organizations;

d) identify the resources available for the application of ISO/IEC/IEEE 15288:2015, such as time, money, people and equipment;

e) create and document the project management plan for applying ISO/IEC/IEEE 15288:2015.

6.2.3 Conduct pilot project(s)

When introducing ISO/IEC/IEEE 15288:2015 in an organization across many projects, some pilot use in key areas and for key processes will help to limit the risk exposure of the organization. A successful introduction should usually include such approaches as the following:

a) identify pilot projects that can utilize the processes selected. 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, and that can be expected to provide quick, visible results;

b) select a team of volunteers to conduct the pilot projects then publicize and reward their efforts;

c) train all involved. Awareness can be aided by regular communication of progress in the implementation process, in addition to formal training classes;

d) plan the pilot projects and identify critical success factors and measures of success;

e) for each pilot project, incorporate the selected adapted process or processes into the project management plan. Reference or include as appropriate, the necessary documentation, e.g. the adaptation decisions and rationale; and

f) execute the pilot project(s), tracking and documenting the performance against the critical success factors. 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 Formalize the approach

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

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 should be incorporated into future projects.

6.2.5 Institutionalize the approach

Institutionalization focuses on what is involved in ensuring that a process is used consistently and automatically throughout the project or organization. This also involves measuring performance of the process, and implementing process improvement again as necessary.

6.3 Application of system concepts

6.3.1 General

ISO/IEC/IEEE 15288:2015 provides a set of processes that support realizing and using a system. This clause focuses on those processes that most directly apply the system concepts stated in ISO/IEC/IEEE 15288:2015, 5.2 and in further expanded in ISO/IEC/IEEE 24748-1:2018, 4.2. To support the discussions in 6.3.2 and 6.3.3, Table 5 shows the processes being discussed, the general purpose for using them, and key points to consider.

Table 5 — ISO/IEC/IEEE 15288:2015 processes used to directly apply system concepts

24748-2 Clause	15288 Processes	Purpose	Key Points
6.3.2	6.4.1 Business or mission analysis process 6.4.2 Stakeholder needs and requirements definition process 6.4.3 System requirements definition process 6.4.6 System analysis process	Understand why there needs to be a system, its boundaries, users and other stakeholders Develop the understanding into, first a statement of needs and requirements as seen by stakeholders, then translate those into requirements for a system that should satisfy the stakeholder needs	This work does not, and should not, seek to determine architecture or design of the system It is critical to identify and meaningfully involve all who will be stakeholders over the systems life cycle
6.3.3	6.4.4 Architecture definition process 6.4.5 Design definition process 6.4.6 System analysis process	Translate the system requirements into an understanding of how an actual system can be realized, first as seen from outside the system and in its elements and their relationship (architecture) and then in terms of specifics of the insides of the system (design)	Maintaining stakeholder involvement throughout is still critical There will be a great deal of recursion and iteration when doing this work, as well as questions that may require revision of the work in 6.3.1

6.3.2 Systems

To determine how to provide products, services, or both, for the benefit of users and other stakeholders, the starting point should be to define the purpose of the system, its boundaries, and those who should be its stakeholders. At that point, neither the structure nor the composition of the system is known, nor should they be the focus of interest. For those reasons, users of ISO/IEC/IEEE 15288:2015 should start with an analysis of the business or mission of the proposed system, applying the ISO/IEC/IEEE 15288:2015, 6.4.1 process of that International Standard, then use this as a bounding framework to define stakeholder needs and requirements, applying process ISO/IEC/IEEE 15288:2015, 6.4.2. These processes may need to be applied iteratively, or recursively and may be applied to new systems, existing systems where changes are being considered, and enabling systems.

Applying a systems concept should mean that the analysis and determination mentioned above are then used to define the requirements of some collection of interacting elements that should satisfy the analysis and determination, applying process ISO/IEC/IEEE 15288:2015, 6.4.3. Note that, once again, 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 system of interest and its enabling systems.

For any of this work, process 6.4.6, Systems Analysis Process, of ISO/IEC/IEEE 15288:2015 may be useful to apply.

6.3.3   System structure

With a thorough understanding of the purpose and benefits of the system-of-interest, 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 15288:2015 should next apply this system to progressively define the structure of the system (its architecture) and the specific ways in which that architecture can be realized.

More specifically, the user of ISO/IEC/IEEE 15288:2015 should apply process 6.4.4, Architecture Definition, and then process 6.4.5, Design Definition. In applying these processes, probably iteratively and recursively, the user of ISO/IEC/IEEE 15288:2015 should understand that characteristic properties at a system's boundary arise from the interactions between subordinate 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 downward to the most detailed level. Process 6.4.6, System Analysis, may need to be applied at any step along the way.

Briefly stated, the user of ISO/IEC/IEEE 15288:2015 should work from the interfaces inward, and from the top downward (downward implying a greater level of detail, but not necessarily a hierarchical system structure). This applies to the system of interest and its enabling systems, whether new or under consideration for change. Accordingly, the application of the processes described above can be done at any stage of a system's life cycle.

For any of this work, process 6.4.6, Systems Analysis Process, of ISO/IEC/IEEE 15288:2017 may be useful to apply.

6.3.4   Structure in systems and projects

The user of ISO/IEC/IEEE 15288:2015 should determine the project scope, or the scopes of the set of projects, that best supports definition, realization and use of the system of interest and its enabling systems. To do this, the user of ISO/IEC/IEEE 15288:2015 should draw on the results of applying, directly or with adaptation the Agreement Processes (6.1), Organizational Project-Enabling Processes (6.2) and Technical Management Processes (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 system of interest and its enabling systems.

6.3.5   Enabling systems

The applications of system concepts described in the preceding clauses apply directly to enabling systems, with the following clarifications:

a)   in considering the scope and structure of the projects to support actualization of a system of interest, it is critical to also consider all enabling systems;

b)   the understanding of enabling systems follows the understanding of the system of interest, at each level of that understanding;

c)   the user of ISO/IEC/IEEE 15288:2015 should re-use, possibly with adaptation, existing enabling systems wherever possible; and

d)   the use of existing enabling systems can constrain the realization of the system of interest, therefore the user of ISO/IEC/IEEE 15288:2015 should perform the appropriate system analyses to

determine if it is more beneficial to adapt the enabling system to the system of interest, or constrain the system of interest to accommodate the existing enabling system.

6.4 Application of life cycle concepts

6.4.1 Overview

ISO/IEC/IEEE 15288:2015 requires the establishment of a life cycle model to provide a framework in which the processes of the International Standard are performed [See 6.2.1.2 c)]. It also requires the definition of purpose and outcomes for each stage in the established life cycle model. ISO/IEC/IEEE 24748-1:2018 provides (in Clause 4) 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 as a reference for two related views of the system life cycle – the organizational view and the engineering view.

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. In actuality, as described in ISO/IEC/IEEE 24748-1:2018, 4.3.1, stages can be interdependent and overlapping, can be of differing durations and can iterate or be applied recursively.

NOTE 2   There can also be a project view, and possibly other views, of the life cycle model.
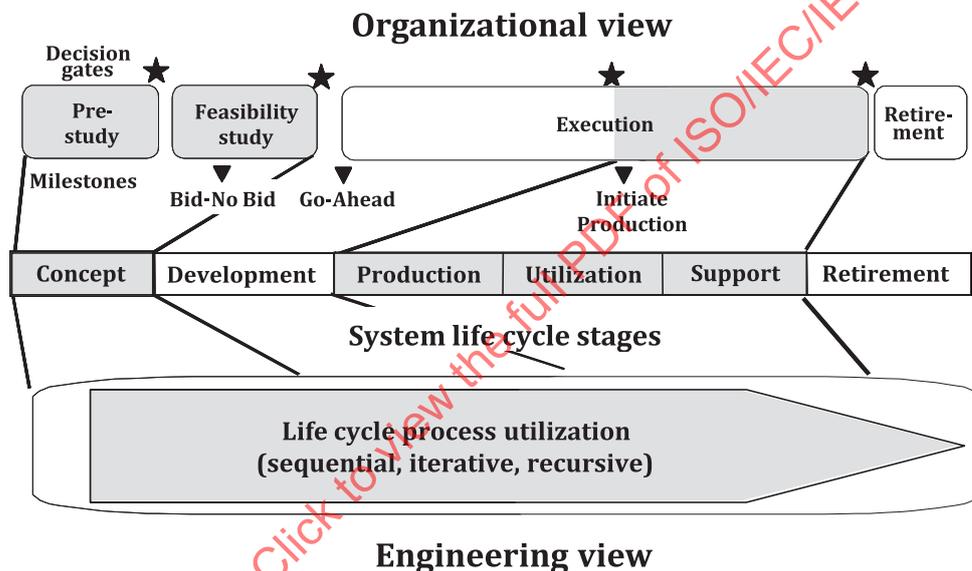
Figure 2 — Organizational and engineering views related to representative system life cycle model

The system life cycle model illustrated in Figure 2 does not imply any application precedence or sequence for the application of ISO/IEC 15288:2008 life cycle processes. The order of 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 15288:2015 is guided by the purpose and outcomes for each of the stages (see ISO/IEC/IEEE 24748-1:2018, Clause 4). 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. Both the organization and engineering views of Figure 2 can be helpful in enabling this passage.

An organization (for example an automobile company or medical equipment supplier) or a domain group of an organization (for example 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. The organizational view illustrated includes 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 be continued to the next system life cycle stage or be modified, be cancelled or retired or have the plans for the next stage revised before approval. 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 utilized.

The views of Figure 2 provide an example framework in which different approaches can be used to meet organization goals and objectives. In order to meet the exit criteria of a decision gate, the appropriate artefacts need to be produced to provide decision-making information and required deliverables. Thus, planned engineering activities need to take place during each system life cycle stage to obtain the outcomes and meet the purpose of the stage or a set of stages.

The framework and example approaches for the views of Figure 2 are described in 6.4.3 below.

6.4.2 Decision gates

The organizational view of Figure 2 can vary according to the nature, purpose, use and prevailing circumstance of the system-of-interest or the business of the organization. Nevertheless, despite a necessary and apparently limitless variety in such views, 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.

NOTE   Examples of decision options and their purpose for each stage of a life cycle are shown in, of ISO/IEC/IEEE 24748-1:2018, 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 to proceed to the next stage or select one of the other options from ISO/IEC/IEEE 24748-1:2018. The decision gates provide a framework within which organization management has high-level visibility and control of the project.

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 whether the system is ready to progress to another stage or, alternatively, hold or continue in the present stage, return to a previous point in the present stage, or return to another stage or stages.

The specific rationale for the decision may vary for each stage. For example, during later 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); and

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:

a) after a period of pre-study; and

b)   after studying the feasibility of the alternative concepts.

Prior to the first decision gate, appropriate research and development is carried out, technology challenges and opportunities are explored and potential system concepts are analysed. Those concepts that have promise for future business opportunities are presented to management for approval to continue the development of the more promising concepts. The concepts can be needed to develop a new market, to respond to a specific threat or to respond to a request for proposal.

After alternative concepts have been studied, a second decision gate can be used. Determinations such as listed below should be made before a decision is made to initiate the execute stage of the organizational view:

a)   whether a concept is feasible and is considered able to counter an identified threat or exploit an opportunity;

b)   whether a concept is sufficiently mature to warrant continued development of a new product or line of products; and

c)   whether to approve a proposal generated to respond to a request for proposal.

For organizations that are responding to a request for proposal, there is an important feasibility stage milestone. This milestone is used to determine whether or not to make a bid based on the initial results of a feasibility study.

The views illustrated in Figure 2 includes activities related to four stages of the system life cycle – development, production, utilization and support. Typically, there are two decision gates and two milestones associated with execution activities of the management view. The first milestone provides the opportunity for management to review the plans for execution before giving approval to proceed. The second milestone provides the opportunity to review progress before the decision is made to initiate production. The decision gates during execution can be used to determine whether to produce the developed system-of-interest and whether to improve it or retire it.

These views apply not only to the system-of-interest but also to its systems and system elements that make up the system structure, as well as enabling 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 system-of-interest in which they are embedded, so these individual systems or system elements can need to be replaced with improved ones during the life of the system-of-interest.

6.4.3   Application approaches

Organizations employ the execution activities of Figure 2 differently to satisfy contrasting business and risk resolution strategies. Sequential, incremental or evolutionary approaches are frequently used. These approaches are discussed in the clauses below. Alternatively, a suitable hybrid of these approaches can be developed.

NOTE   The "Vee" model is a specific example of an application approach. It is described in Annex B of this document.

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

a)   the acquisition policy of the organization;

b)   the nature and complexity of the system;

c)   the stability of system requirements;

d)   technological opportunities;

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

f)   the availability of resources.

6.4.3.1 Sequential approach

6.4.3.1.1 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 face 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 is illustrated by the organizational view of Figure 2 and has defined decision gates so that an organization can manage an orderly progression of the system from conception through retirement. For systems that rely heavily on off-the-shelf system elements, development is often directed to start in the execution phase of Figure 2 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 may 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.

6.4.3.1.2 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 realized 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 system-of-interest does need to be analysed and where conflicts are revealed, the changes to higher-level systems and the system-of-interest need to be made or the requirements for the applicable system need to be revised.

6.4.3.1.3 Risks

Because of the long duration of development using the sequential approach, several risks such as those listed below 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) Technical obsolescence can arise during a long development.

6.4.3.1.4   Opportunities

The opportunities such as listed below 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.

6.4.3.2   Incremental approach

6.4.3.2.1   General

The incremental approach can be applied to organizations that market new versions of a product. An organizational view not unlike the view of Figure 2 is used. However, milestones are established at planned intervals to introduce a planned version of the system that can be released to the market. The system realized as a result of the concept stage can be a first version.

The overall capabilities of the last version to be marketed may 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 15288:2015 life cycle processes, further described in 6.7 of this document, is performed to realize 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.

6.4.3.2.2   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.

6.4.3.2.3   Risks

The incremental approach has associated risks such as listed below 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) Expectations may not be met if customers desire the full capabilities in the first version.

e) Poor results may be realized if requirements are not as well understood as originally thought.

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) The customer may change the requirements as the development progresses.

6.4.3.2.4 Opportunities

The opportunities such as listed below 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.

6.4.3.3 Evolutionary approach

6.4.3.3.1 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.

The ISO/IEC/IEEE 15288:2015 life cycle processes, further described in 6.7 of this document, 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.

6.4.3.3.2 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.

6.4.3.3.3 Risks

The evolutionary approach has associated risks such as listed below that should be considered and resolved before adopting this approach:

a) Full capabilities can be preferred at the same time.

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) Configuration control can be a problem.

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

6.4.3.3.4 Opportunities

The opportunities such as listed below can be associated with the evolutionary approach:

a) Acquirer requirements for an early capability can be satisfied.

b) 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.

6.4.3.4 Technical reviews

Technical reviews such as listed below should be conducted for each project as appropriate to the development model used:

a) 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;

b) 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;

c) an evaluation of the established requirements baseline to confirm that the set of technical requirements are balanced with respect to cost, schedule and risk;

d) 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;

e) 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; and

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

f) a review conducted for the detailed design of each system of the system structure to demonstrate that:

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

  the design solution is consistent with the acquirer requirements;

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

g) 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; and

h) 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 15288.2, *Application of Technical Reviews and Audits on Defense Programs*, gives information on technical reviews for the defence sector.

NOTE 2   IEEE 1028:2008, *IEEE Standard for Software Reviews and Audits*, ISO/IEC/IEEE 20246:2017, *Software and systems engineering — Work product reviews* and IEC 61160:2005, *Design Review* give additional detail on reviews.

6.4.3.5   Configuration audits

Two types of configuration audits can be performed – functional audit and physical audit. These two audits are described below:

a) 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, authorized changes and "as-built" or "as-coded" records.

NOTE   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.

b) 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 realized correctly in accordance with 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; and

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

6.5   Application of organizational concepts

6.5.1   Overview

Organizations are producers and consumers of systems; that is they trade products and services. The processes in ISO/IEC/IEEE 15288:2015 are used by organizations that acquire and use or create and supply 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 may 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 15288:2015.

Additionally, a management group of a multi-organization project working on the same system can use ISO/IEC/IEEE 15288:2015 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 15288:2015 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 15288:2015 is intended to be applied internally by an organization or contractually by two or more organizations. In order to facilitate application of ISO/IEC/IEEE 15288:2015 either internally or contractually, the tasks are expressed in contractual language. When applied internally, the contractual language is interpreted as self-imposed tasks.

ISO/IEC/IEEE 15288:2015 should be harmonized 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 15288:2015 within an organization, it is therefore important to clarify the relationship between ISO/IEC/IEEE 15288:2015, the organization's own standards, and the various techniques that have been employed.

Figure 3 shows one possible example of such relationships that may be useful when applying ISO/IEC/IEEE 15288:2015 within an organization. ISO/IEC/IEEE 15288:2015 is located at the first level, standards for the discipline are located at the second level, and the third level is for procedures specific to an organization. The terms defined and used in the second and the third levels are required to conform to ISO/IEC/IEEE 15288:2015.

Level 1

Work is done according to the items
In each process

Level 2

Work is done according to procedures in
a defined sequence

Level 3

Procedures are detailed for a
specific organization

Level 4

Techniques are provided for a specific problem
Solution. Tools are provided that support the
various techniques

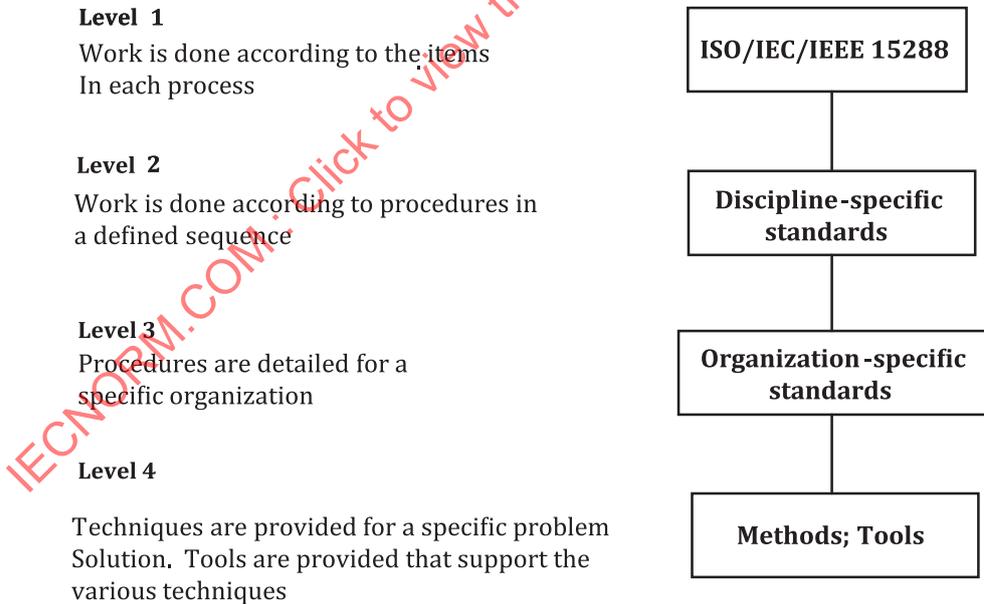| ISO/IEC/IEEE 15288 |
| :---: |
| Discipline-specific standards |
| Organization-specific standards |
| Methods; Tools |

Figure 3 — Relationship with existing documents

Resolution of any conflicts is left to the organization applying ISO/IEC/IEEE 15288:2015 and may involve developing a mapping and if necessary, filling any gaps.

6.5.2 Considerations and techniques

Organizations should generally use ISO/IEC/IEEE 15288:2015 as part of an effort to improve system-related processes. This may be through standalone use or in conjunction with available process assessment and capability determination methods.

NOTE   The application of ISO/IEC/IEEE 15288:2015 within an organization is based upon the same approaches as are used on projects. Consideration is given to the issues raised and the strategies described in 6.2 of this document that are followed by organizations when using ISO/IEC/IEEE 15288:2015.

6.5.3 Application opportunities

The reasons for applying ISO/IEC/IEEE 15288:2015 internally within an organization may include such situations as:

a) verifying the thoroughness of an existing method. This should usually be more relevant where the method was developed in-house or adopted and extensively modified;

b) adapting an existing method to cater to the risks associated with moves into new market sectors where more rigor is required because of perceived risks;

c) developing a new method to meet the needs of a new organization. This includes organizations created through mergers or business alliances. It may be necessary to maintain several process models to suit particular activities;

d) 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 15288:2015 defines criteria which can be used to benchmark the completeness of the method before and after the technology is changed;

e) evaluating an internal capability of a party to meet agreed criteria e.g. as part of a tender review process; and

f) establishing a benchmark upon which improvement programs can be developed e.g. audit against ISO/IEC/IEEE 15288:2015.

6.5.4 Management commitment

As with any program which results in changes to work practices, it is essential that the management within the affected organization is visibly committed to implementing and supporting the changes. In a two-party situation this should be initiated by a contract and then, as for general organizational use, it should be normal practice to establish policies covering the relevant parties.

6.5.5 Uses of ISO/IEC/IEEE 15288:2015 within an organization

There are four key uses of ISO/IEC/IEEE 15288:2015 within an organization. These uses are illustrated in Figure 3 and described below.

Use 1 is a direct application of ISO/IEC/IEEE 15288:2015 to organizational work. ISO/IEC/IEEE 15288:2015 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 appropriate system-of-interest during a life cycle stage to achieve the process outcomes and satisfy stage objectives and exit criteria. To successfully apply the selected processes each activity is further defined by the organization. This further definition includes identifying the tasks by which an activity will be accomplished. From these tasks and the nature of the activity, methods and tools are determined for completing the tasks efficiently and effectively.

The outcomes from performing tasks should include appropriate documentation. The extent of documentation should be based on project 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 15288:2015 in order to standardize the primary work of the organization in disciplines such as software, mechanical, chemical, electrical, and so forth, as well as domains such as aerospace, automotive, medical equipment and so forth. In this use it should be an adaptation of the scope of ISO/IEC/IEEE 15288:2015 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 should be defined in more detail by identifying necessary tasks, selecting and providing the appropriate methods and tools and performing work according to procedures and sequencing defined in these standards. Discipline and domain members should be trained in the appropriate standard and the applicable methods and tools prior to applying on a project.

Use 3 is for the purpose of creating organizational standards and guidance. In this use it should be an adaptation by the organization of the scope of ISO/IEC/IEEE 15288:2015 and possible adaptation of discipline or domain standards, or both. As in Uses 1 and 2, the activities should be defined in more detail by identifying the necessary tasks, selecting and providing the appropriate methods and tools and performing work according to procedures and sequencing defined in these standards. Organization members should be trained in the appropriate standard and the applicable methods and tools prior to applying on a project.

Use 4 is for the purpose of preparing appropriate documents describing discipline, domain and organization-wide methods, procedures and guidance for implementation of their related standards, as well as for direct application of ISO/IEC/IEEE 15288:2015. Appropriate training on the applicable documents is necessary prior to application on a project.

6.6   Application of project concepts

ISO/IEC/IEEE 15288:2015 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); and

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 15288:2015 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 15288:2015 life cycle processes are meant to be generic and applicable to the engineering of any system within the scope of ISO/IEC/IEEE 15288:2015. 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

This clause provides guidelines to consider in executing the activities and tasks of the processes stated in ISO/IEC/IEEE 15288:2015 in order to better obtain the intended outcomes of the processes and achieve their purpose.

NOTE   The relevant clause number for each process from ISO/IEC/IEEE 15288:2015 is given in parentheses following the process name in each of the following sub-clauses, e.g. (6.1) means that Agreement processes are in clause 6.1 of ISO/IEC/IEEE 15288:2015.

6.7.1 Application of Agreement processes (6.1)

The processes of ISO/IEC/IEEE 15288:2015 can be used to attain an agreement. Figure 4 illustrates the use of the agreement processes in conjunction with the other life cycle processes of ISO/IEC/IEEE 15288:2015 to attain an agreement. Agreements can be between organizations, between projects, and for work efforts within a project.
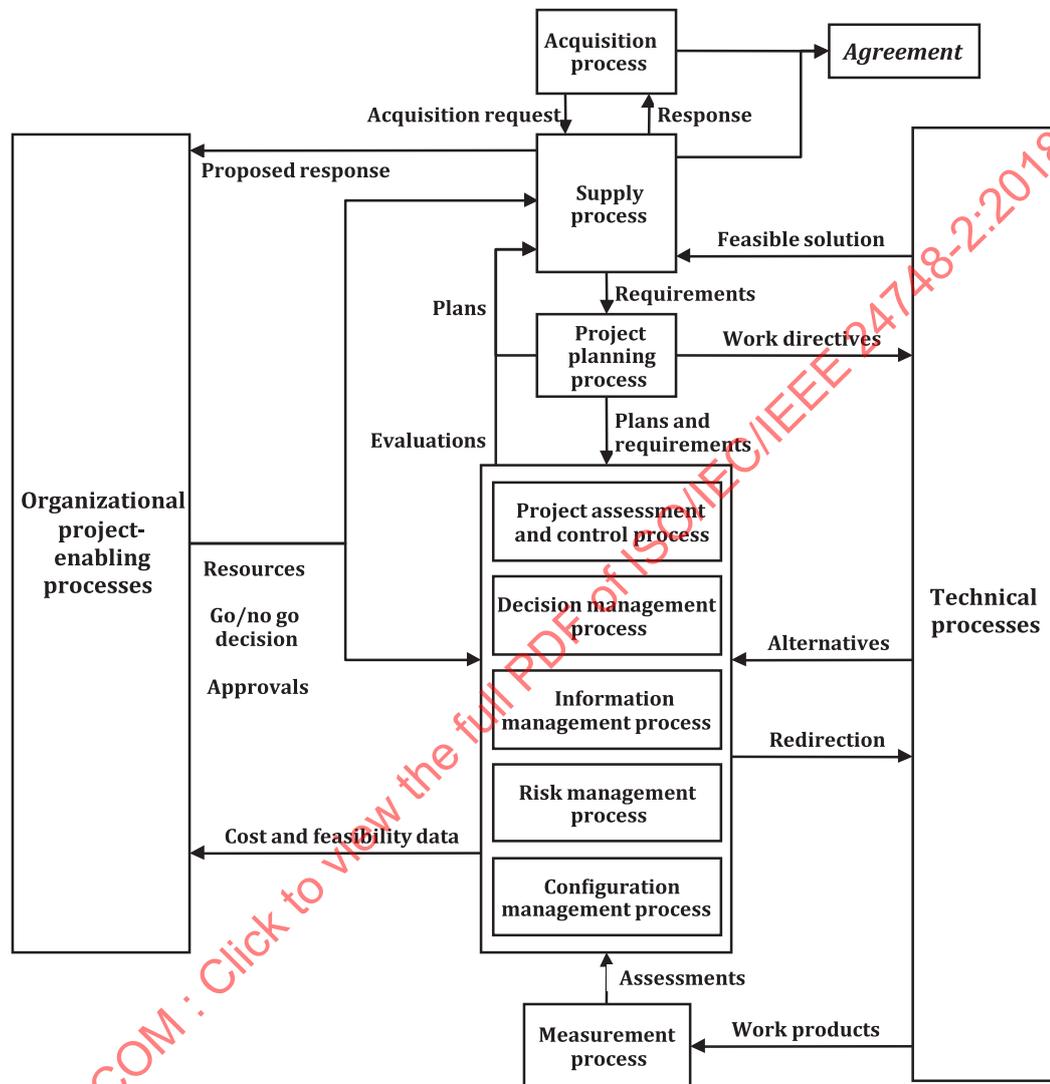
Figure 4 — Application of processes to form a formal agreement

The Figure 4 model is not meant to reflect all possible process flows to attain an agreement but to show that all processes of ISO/IEC/IEEE 15288:2015 can have a role in forming an agreement, especially formal agreements that can be legally binding. When an agreement involves a relationship between individuals of sub-projects within the same project much less formality can be expected than suggested by the Figure 4 model. The following paragraphs describe the process flow of the Figure 4 model and exceptions as appropriate.

The processes of ISO/IEC/IEEE 15288:2015 can be initiated with the receipt of an acquisition request such as a formal request for proposal or an informal internal directive for certain work to be done. This can be before a project is formed for a new engineering effort or within a project if it is for project-related work.

Appropriate to the level of formality, the following list of expectations should be used to establish a common basis for the acquirer and supplier to understand the project requirements:

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; and

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

The negotiation can be considered complete when the terms of agreement are acceptable to both the acquirer and supplier.

6.7.1.1 Application of Acquisition Process (6.1.1)

In order to properly accomplish the Acquisition Process activities and tasks, applicable Organizational Project-Enabling, Technical Management and Technical processes from ISO/IEC/IEEE 15288:2015, 6.2, 6.3 and 6.4, respectively, should be implemented, as appropriate.

An appropriate team or individual, depending on the project size and complexity, should be assigned to consider and prepare a response to the acquisition request. For smaller projects a single individual can be assigned the responsibility to prepare the response, to do the work and to create the required work products to be delivered.

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.

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 in accordance with the plan and should be assessed and controlled using the appropriate project 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:

a) aftermarket opportunities;

b) business unit policies;

c) organization environment;

d) financial resource availability;

e) human factors;

f) improvement strategy;

g) integration and interoperability;

h) logistics (supportability);

i) obsolescence;

j) operational environment (pollution, disposal);

k) producibility;

l) safety;

m) security;

n) competition;

o) stakeholder goals;

p) survivability;

q) time-to-market constraints; and

r) potential risks for acquisition and supply.

Acquisition planning is conducted using the Project Planning Process from ISO/IEC/IEEE 15288:2015, 6.3.1.

Typical solicitation documents include: acquisition request (for example request for proposal, request for bid, request for information, and request for quote), memorandum of intent, offer or directive.

Whenever possible for a formal contract situation involving outside suppliers the potential suppliers need to be involved in the definition of the acquisition request document to provide an optimum match of stakeholder needs with system requirements. Similarly, the same suppliers need to be involved in changes during maintenance of the agreement.

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 gauging acceptable execution of the agreement.

6.7.1.2 Application of Supply Process (6.1.2)

In order to properly accomplish the Supply Process activities and tasks, applicable Organizational Project-Enabling, Technical Management and Technical processes from ISO/IEC/IEEE 15288:2015, 6.2, 6.3 and 6.4, respectively, should be implemented, as appropriate.

After an agreement is established a project is formed, if not already in place, and the appropriate agreement, project and organizational project-enabling processes of ISO/IEC/IEEE 15288:2015 are used in conjunction with the technical processes of the International standard to do the work to meet agreement requirements. The model illustrated in Figure 5 provides an example of the relationship of processes used within a project for satisfying an agreement. This example is not meant to represent all possible process flows by all possible projects. It does, however, provide an approach one can consider in establishing a process flow appropriate to a particular project. Smaller projects should still do the same processes but the formalization, documentation and level of activity can be reduced in scale as appropriate to the economics of the project.
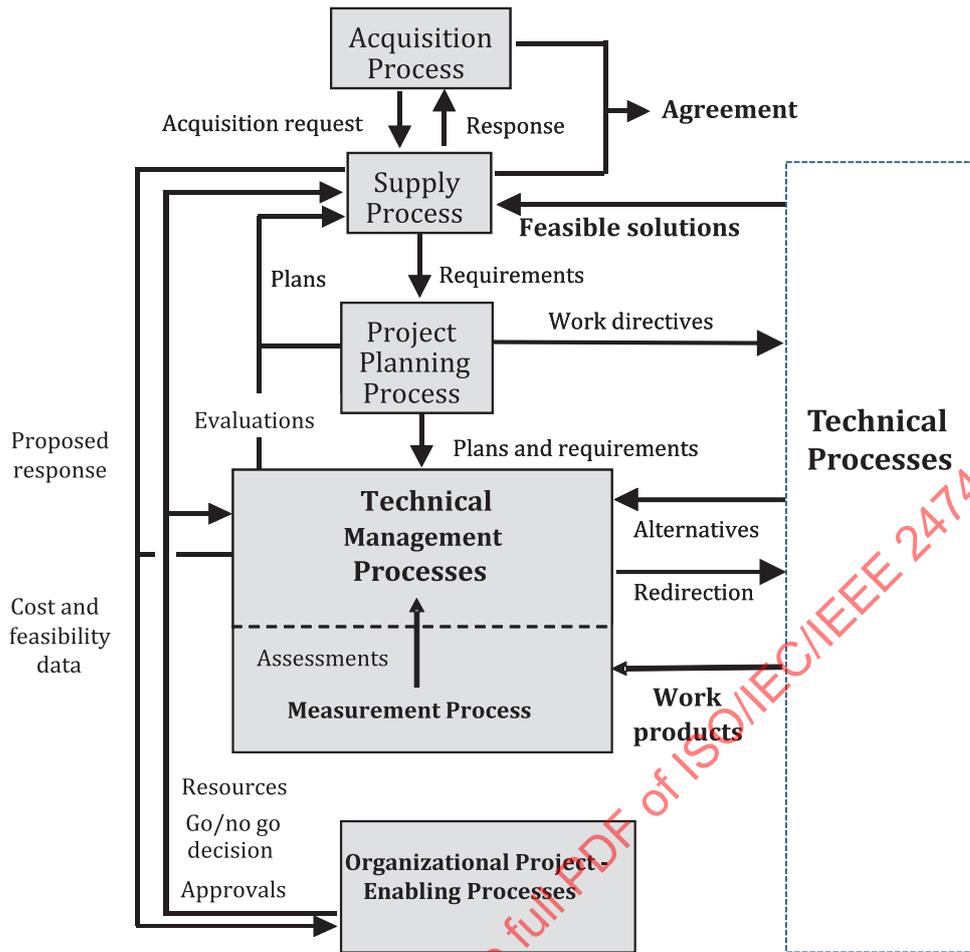
Figure 5 — Application of processes to satisfy an agreement

The project work should not be undertaken until the resources such as funds, team members, equipment and facilities needed to meet the project agreement and plans are attained.

The project exists to satisfy an agreement by providing the desired deliverables to the quality expected. The project performs the Planning Process that can consist of updating the plans used to form the response to the acquisition request or the applicable plans from the previous life cycle stage. Appropriate teams are assigned the work required to meet planned requirements. These teams do the work associated with application of the technical processes to obtain the work products required. The Project Assessment and Control Process, Decision Management Process, Risk Management Process, Configuration Management Process, Information Management Process and Quality Assurance Process should be used to monitor, control, and assess the technical process outcomes to be able to keep work within acceptable cost, schedule and risk in order to meet performance requirements for the system. The Organizational Project-enabling Processes and Technical Management Processes are implemented to provide support to the project, and to review the project, as appropriate.

The activities of the processes shown in Figure 5 can be considered as complete when the agreement is fully satisfied with the delivery of required products and services.

The actual realized form of the system-of-interest, enabling system or system element can vary from a conceptual model to a production representative product. The realized form of the deliverable is typically a function of the exit criteria of the applicable system life cycle stage and agreement requirements.

A supply strategy is defined using the Project Planning Process from ISO/IEC/IEEE 15288:2015, 6.3.1.

A solicitation is typically from an internal or external business unit (it can be internal to the project). The solicitation does not need to be formal.

Business units 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)   business unit goals;

c)   competition;

d)   organization environment and policies and procedures;

e)   resource availability; and

f)   related management, technical and resource risks.

Whenever possible for a formal contract situation involving a primary and supporting suppliers, the potential supporting suppliers need to be involved in the definition of the tender response and supply 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 supply agreement, including mutual responsibilities, frequency and mode of monitoring and ways of gauging acceptable execution of the agreement.

Establish who is authorized to accept the supplied each 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 supply agreement.

6.7.2   Application of Organizational Project-enabling Processes (6.2)

6.7.2.1   Application of Life Cycle Model Management Process (6.2.1)

In selecting processes for application within a system life cycle stage, some of the processes of ISO/IEC/IEEE 15288:2015 may not be applicable for an organization. In this case, such processes are expected to be not included in organizational standards, policies and procedures or other directive media. In cases where the organization desires that certain activities of a process be part of directive materials, these selected activities 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.

New project processes can be formed, or an activity under one of the system life cycle processes can be elevated to the process level.

Standardization of life cycle processes within a business unit can vary. However, organizations typically encourage all projects and functional business units to use common practices and standards where it is advantageous to do so.

Definition of standardized processes includes related methods and tools to be implemented in projects in accordance with organizational policies and procedures and investment decisions.

Appropriate disaster recovery procedures are typically established for all organizational project-enabling processes and databases.

6.7.2.2   Application of Infrastructure Management Process (6.2.2)

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

It is critical to establish, use and continually refine metrics 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.

6.7.2.3   Application of Portfolio Management Process (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 realize continuous improvement of organizational maturity for satisfying its strategic and tactical objectives is realized.

The integrity level for different systems produced by projects can require separate sets of policies and procedures.

Appropriate management aids are typically established to enable availability of valid information for directing and enabling projects including project status, standardized 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, metrics 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.

6.7.2.4   Application of Human Resource Management Process (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; and

g) knowledge capture, storage and re-deployment.

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

6.7.2.5   Application of Quality Management Process (6.2.5)

This process is consistent with establishment of quality management approaches that lead to conformance with ISO 9001:2015, *Quality management systems — Requirements*.

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.

6.7.2.6   Application of Knowledge Management Process (6.2.6)

It is important that knowledge management is recognized in the organization as a strategic effort and that accumulated and used knowledge is therefore appreciated as a valuable asset.

Participation in knowledge management in the organization should be widespread and participants should receive appropriate levels of training.

6.7.3   Application of Technical Management Processes (6.3)

6.7.3.1   Application of Project Planning Process (6.3.1)

The Project Planning Process defines the necessary plans to support other processes. For example, to:

a)   arrive at an investment decision;

b)   prepare a responsive response to a solicitation;

c)   determine whether to proceed or continue work to satisfy the requirements of a specific organizational model stage entry/exit criteria;

d)   guide the work required to meet the requirements of an established agreement; and

e)   re-plan the work.

Plans are constrained by organizational goals and objectives and stakeholder needs.

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.

Re-planning is typically initiated:

a)   when required by an agreement;

b)   when significant variations or anomalies are identified from other process outcomes. or;

c)   before implementation of the next engineering view or organizational view stage related to the system life cycle model selected by the organization.

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.

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 project process activities is typically established. Non-system-structure related project process activities include project planning, assessment and control, decision management, risk management, configuration management, information management, measurement and quality assurance (see ISO/IEC/IEEE 15288:2015, 6.3.2 through 6.3.8, respectively).

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.

The items listed below should be helpful for determining project schedules, staffing requirements and resources requirements:

a) key events required to meet technical requirements (for example technical review, production readiness review, verification, modification decision review);

b) primary tasks related to accomplishing entry and exit criteria of each key event (for example define stakeholder requirements, prepare engineering drawings, complete technical or management review package, conduct test);

c) support tasks that enable the staff accomplishing primary tasks to meet their objectives. For example:

   1) acquire resources, equipment and facilities;

   2) acquire appropriately skilled personnel for accomplishing the primary tasks; and;

   3) arrange travel.

d) management tasks required to direct, monitor, review and approve the primary and support tasks (for example serve as chair of a technical review, review and approve documents for transmittal to the customer, attend management review, and decide whether to do a technology refreshment, technology insertion or retire the system).

After approval by the appropriate authority the project schedules are considered a baseline subject to change control in accordance with organizational policies and procedures.

After approval by the appropriate authority the planned budget is typically considered a baseline subject to change control in accordance with business unit policies and procedures.

Plans can be individual documents in a collective document or captured in an electronic media for access by appropriate participants. A plan is an initial output of a process that enables the process to be efficiently and effectively accomplished. A plan should be made using appropriate Project Planning Process activities.

The engineering plan provides an explanation of what needs to done, how it will be done, who will do it, when it will be done and where it will be done; as well as how much of a resource is necessary to do the work for each technical process. The engineering plan explains the above within established constraints of resources and staff and in order to meet cost, schedule and performance requirements within acceptable risks.

An engineering plan is appropriate for each applicable organizational view stage and for each project (for the engineering or re-engineering of a system) using the appropriate model. See 6.4.3 of this document for discussion of some of the possible models.

The engineering plan is also known as the Systems Engineering Management Plan (SEMP) or Integrated Management Plan (IMP).

The list below should be used as a checklist for inclusion and completion of essential and applicable information in an engineering 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 influencing factors and constraints;

f)   the system concerns with respect to reliability, availability, maintainability, security, safety, information quality, health factors, survivability, electromagnetic compatibility, radio frequency management and human factors;

g)   project processes, activities, and tasks that will be accomplished;

h)   how each applicable technical process will be accomplished and how each process connects (inputs and outputs data flows and sequencing) with other technical, project, organization and agreement processes;

i)   resources, methods and tools planned to accomplish the activities and tasks of each applicable process;

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

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

l)   how the project will be staffed and managed;

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

n)   key intermediate events and how such event completion will be determined;

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

p)   the technical risks involved and how risks will be managed;

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

r)   the completion criteria for the process activities;

s)   the entry and exit criteria for re-performing each process; and

t)   how completion will be determined.

NOTE   Also relevant to the project planning process are ISO/IEC/IEEE 24748-4:2016, *Systems and software engineering — Life cycle management — Part 4: Systems engineering planning*, ISO/IEC/IEEE 24748-5:2017, *Systems and software engineering — Life cycle management — Part 5: Software development planning*, ISO/IEC/ IEEE 16326:2009, *Systems and software engineering — Life cycle processes — Project management*, and ISO/IEC/ IEEE 15289:2017, *Systems and software engineering -- Content of life-cycle information items (documentation)*.

6.7.3.2   Application of Project Assessment and Control Process (6.3.2)

Formalized methods for cost and schedule management exist. Examples include:

a)   design-to-cost (used to establish a cost requirement equivalent to other system performance requirements);

b)   event-based scheduling (used to establish events, such as milestones, significant activities and tasks related to an event, and the criteria by which completion of activities or tasks are determined); and

c)   earned value (used to define the budgeted cost of the work performed and make comparison to the budgeted cost of the work scheduled and the actual costs of work performed to determine estimates at completion and cost and schedule variances).

Appropriate analyses and assessments are conducted to determine:

a)   the continuing consistency and relevance of project plans (management and technical);

b) project technical progress using defined technical metrics based on estimated achievement and milestone completion;

c) effectiveness of the project team technical roles and structure using where possible objective measures such as technical achievement and efficiency of resource use;

d) the adequacy of team member technical competencies and skills to satisfy technical roles and accomplish technical tasks;

e) the effectiveness and value of supporting training;

f) the adequacy and availability of the technical infrastructure and services at defined intervals to confirm that intra-organizational commitments are satisfied;

g) the quality and progress of the design of system, materials used, and enabling system services;

h) technical variances with project estimates and identify variances to cost, availability and performance specifications;

i) the effectiveness of technical data gathering, processing and dissemination;

j) technical variations between expected results and assessment results to detect trends and identify root causes; and

k) the quality of technical data gathered, the value of the information derived, its timeliness, completeness, validity, confidentiality (if required) and its benefit to recipients.

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; and

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

Use of the Project Assessment Process aids management decision making by providing information that results from monitoring and analysing project work to determine:

a) progress and achievement against plans (work productivity) and against technical requirements (product quality);

b) adherence to practices and procedures;

c) readiness to proceed to the next stage of the organizational view (through decision gates or milestone reviews) or to the next level of the system structure;

d) effectiveness, risks and opportunities associated with alternatives available to decision makers; and

e) trade-off analyses results, to include recommended course of action and impacts of each on cost, schedule, performance and risk.

The planned times, and actual or estimated labour, material and service costs should be collected and evaluated and compared against baseline budgets and current forecasts.

The outcomes of a productivity assessment (progress satisfying plans) provide status information to enable efficient use of resources, evaluation of progress against plans, identification of variances of cost and schedule from planned project baselines and early identification and resolution of productivity problems.

When variations are significant or cannot be corrected by re-performing the process tasks that generated the outcome data, the project planning process is re-initiated in order to plan and implement appropriate corrective actions.

Product measures assess progress and achievement against system and other work product technical requirements. The Measurement process (6.3.7 from ISO/IEC/IEEE 15288:2015) is used so that:

a) measures are identified and used to assess the efficiency of the scheduled work. Example measures include earned value (cost/schedule measure), amount of waste, number of engineering changes, percentage of drawings completed, number of drawing errors, percentage of lines of code completed, rework percentage, idle time (for example work in progress), change rate and turnover in personnel. The criteria for process measure selection are based on how well enhancement in project performance correlates with improvement in potential customer satisfaction with respect to cost, schedule and risk.

b) measures are defined and used and the data is gathered to permit assessment of customer satisfaction.

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

Typical review objectives include determination of:

a) system maturity and how well the solution satisfies requirements;

b) traceability of requirements, the validity of assumptions and decision rationale;

c) identification of un-resolved issues and those issues not determined during project work; and

d) related risks, needed resources and adequacy of preparation for conducting the next system life-cycle stage.

System-of-interest 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.

Use of the Project Assessment and Control Process aids the capture and management of outcomes from project management and technical work including the redirection of that work to overcome obstacles, to respond to changing circumstances or to correct variances.

6.7.3.3   Application of Decision Management Process (6.3.3)

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; and

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 or time is not available for a more formal approach. Most trade-off analyses performed are of the judgmental type.

Trade-off analyses are conducted throughout implementation of project 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 logical 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.

6.7.3.4 Application of Risk Management Process (6.3.4)

Risk management should not be viewed as an extra activity, as an activity layered on assigned work, or as an activity outside a project's responsibility.

Risk management is a general procedure for resolving risks. Risks are considered resolved when the possible consequences are acceptable. Acceptable means that the project can live with the worst-case outcome.

Risk management includes:

a) risk planning that includes preparing a risk management plan, which addresses the:

    1) purpose of the risk management effort;

    2) participants, their roles and responsibilities, and their training;

    3) process, including work and review forums, and artefacts;

    4) measures for reporting risks and for determining the overall effectiveness and efficiency of the risk management effort;

b) the risk management process, that addresses:

    1) identification of risk to include sources and related issues, concerns, doubts, uncertainties and assumptions;

    2) analysis based on established criteria to include estimation of risk probability and consequences and the prioritization of risks;

    3) planning of alternative strategies for risk resolution, definition of a specific risk action plan for selected approach and establishment of triggers (or thresholds) for taking risk resolution action;

    4) resolution of risks by appropriately identifying triggers, implementing an action plan, report results and continuing planned actions till risk is acceptable;

    5) tracking, to include monitoring risk status and comparing thresholds to risk status, using triggers to provide early warning and reporting status based on risk measures; and

c) periodic reassessment of the risk management effort and measures to continually improve it.

Risk management has two dimensions of awareness — past 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 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.

Risk management tools include ones for:

a) risk identification — risk taxonomy, research, interviews, lessons learned, control charts, affinity diagrams, interrelationship diagrams and system structure or WBS interfaces;

b) risk analysis — impact models, probability models, Gantt chart, impact distribution, risk coupling, system structure or WBS interfaces, and iso-risk charts;

c) risk alternative strategy planning — iso-risk charts, lessons learned, risk leveraging, warrantees and insurance;

d)   risk tracking — technical performance measures, earned value, measures and risk watch list;

e)   risk resolution — impact model, risk watch list, risk template and risk management matrix.

There are three categories of risk to consider:

a)   project risk – organizational, operational, or contractual concerns including resource constraints, external interfaces, supplier relationships, contractual restrictions, lack of organizational support and vendor unresponsiveness;

b)   process risk — planning, staffing, tracking, quality assurance and configuration management;

c)   product risk — technical process implementation, work product characteristics, requirements stability, design performance, complexity and test requirements.

Risks can also be categorized based on the nature of their impact:

a)   cost;

b)   schedule;

c)   technical.

Risk resolution approaches may draw upon any combination of:

a)   acceptance (live with it);

b)   avoidance (eliminate);

c)   protection (redundancy);

d)   reduction (mitigation-risk management culture-do the right processes);

e)   prevention (team activity-use integrated product teams);

f)   anticipation (quantitative risk management measures, prioritize, proactive approach);

g)   opportunity (look at good outcomes, not just bad ones, everyone's responsibility, reduce costs, do better than planned);

h)   research (more information);

i)   reserves (contingency funding); and

j)   transfer (to another person or organization).

Keys to successful risk management include:

a)   right people. People communicate issues, concerns and uncertainties. It is essential to define desired participation, ability and motivation.

b)   right process. Process transforms uncertainty into acceptable risk through risk management activities including execution and definition.

c)   right infrastructure. The organizational culture determines how projects use risk management. The infrastructure is typically specified through appropriate policies and standards and includes identification and dissemination of resources (staff, schedule, budget), requirements (contractual, standards) and expected outcomes (cost, benefit).

d)   right information. It is important that the information used to evaluate risks and the status of risks is correct, reliable and timely.

e)   right implementation. It is important to plan risk management and use the appropriate methodologies to perform risk management on a specific project.

Metrics are necessary to take a periodic look at the effectiveness and efficiency of the overall risk management effort (separate from looking at the status of individual risks). This periodic assessment should be done with project management and other senior stakeholders in the project or organization.

6.7.3.5 Application of Configuration Management Process (6.3.5)

Identifying what to control and to what degree different things should be controlled should recognize the nature of the organization, its mission, customer expectations and legal and other constraints.

Assessments of risk from ISO/IEC/IEEE 15288:2015, 6.3.4, should be included in the change management part of configuration management.

Supporting tool use should be considered at an early stage in developing the approach to configuration management.

6.7.3.6 Application of Information Management Process (6.3.6)

Information management typically includes: planning information; requirements; progress status reports; review data package and other materials for or from acquirer, project management, and technical reviews; design data and schema; lessons learned; the evaluation of input and output information quality; variances and anomalies from validations and verifications and other progress assessments; data deliverables; approved changes; and work authorizations and work orders resulting from management decisions, planning, or approved changes.

6.7.3.7 Application of Measurement Process (6.3.7)

System measures (also called product measures) are used to assess stakeholder satisfaction and to deliver an ever-improving value to the acquirers of project products and services. These measures also are indicative that the design process is continuing in the direction of an acceptable solution. An example of an input system measure is the quality of materials and skills of assigned project personnel. Examples of output measures include: customer complaints, in-service failure reports and technical performance measures (TPM).

A TPM is a measure used to assess design progress, compliance 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 a design in terms of satisfying selected critical technical parameter requirements.

The TPM includes the projected performance, such as a growth curve with thresholds of acceptable variance. Performance of the system or system element is tracked through the life cycle and compared to the projected and required values. Early in the life cycle the performance values may be estimated, based on simulation and modelling. As the life cycle proceeds, actual data replaces estimates and adds to the fidelity of the information. This measurement of the design solution as it evolves allows action to be taken early in the process, rather than wait until system testing to address.

Measures should be adapted to the organization and 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 considerable measurement effort. The general recommendation is to use limited trials of a selected few measurements, then slowly expand once the reality of obtaining the information and actually using it for decisions is proven out.

Regular assessment of the utility of measurements is commonly overlooked. No measurement should be taken as above challenge.

NOTE   Refer to ISO/IEC/IEEE 15939:2017, *Measurement process*, for more specialized guidance and requirements.

6.7.3.8 Application of Quality Assurance Process (6.3.8)

The quality assurance strategy should emphasize applying quality assurance measures at the earliest possible points in each life cycle process, as well as application of quality assurance measures at significant points throughout each process, rather as use as quality assurance only at the end of each process.

The quality assurance evaluations should include use of multiple methods of assuring quality.

Tools used in performing quality assurance should be evaluated for their limitations and constraints on assuring quality. That is, it should be understood what each tool can not do, or where the tool can not provide a dependable result in all cases

The results of applying quality assurance methods should be used as a significant input to the organizations knowledge management process.

Periodic reviews should be held of all incidents during at least the period that:

a) were deemed, individually, as not important enough to act on, or;

b) did not, individually, have enough information to allow them to be addressed.

6.7.4 Application of technical processes (6.4)

6.7.4.1 General

Figure 6 provides a model for the application of the Technical processes of ISO/IEC/IEEE 15288:2015. This model includes only the technical processes that are primarily used for engineering a system-of-interest. Three of the technical processes are not explicitly shown in Figure 6: the Operation Process, Maintenance Process and Disposal Process. Those three processes are, however, discussed in 6.7.4.5. Those three processes should be used as appropriate to provide inputs to the Business or Mission Analysis Process, or the Stakeholder Needs and Requirements Definition Process, or both. The requirements can be in the form of acquirer requirements such as operability, supportability and disposability or in the form of other interested party requirements such as for enabling systems to provide related services.

In the discussions below on the technical process model for engineering a system, process application will be to a system whether it is the top-level system-of-interest or one of the systems or system elements in the system structure, or an enabling system. When a process application is relevant to just the system-of-interest or a system element in the system structure, then specific terminology will be used.

Although a system 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 may analyse the business needs and stakeholders for a new or modified system, while a second project may define the system and yet a third project should turn the design into a realized system. With that in mind, application of technical processes to a project is covered in three clauses in this document. Subclause 6.7.4.2 discusses understanding the need for a system, 6.7.4.3 covers system definition and 6.7.4.4 addresses system realization.

The Business or Mission Analysis Process, Stakeholder Needs and Requirements Definition Process and System Requirements Definition Process are used, together with the System Analysis Process, to gain understanding of the fundamental need for a system, its boundaries, and its stakeholders. The Architecture Definition Process and Design Definition Process are used, together with the System Analysis Process, to design the solution for each system in the system structure. Application of these processes can be highly iterative in order to arrive at the desired design solution.

The Implementation Process, Integration Process, Verification Process, Transition Process and Validation Process are used to realize the system design solution for each system in the system structure. Application of these processes can be highly iterative, both for the system of interest and any enabling systems.

All of the processes described above are applied recursively to the system-of-interest and then its systems from the top down until a system element can be implemented (for example built, bought, reused) using the Implementation Process. This occurs when no further systems need to be developed.

NOTE   See ISO/IEC/IEEE 24748-1:2018 Annex A for discussion of iteration and recursion.
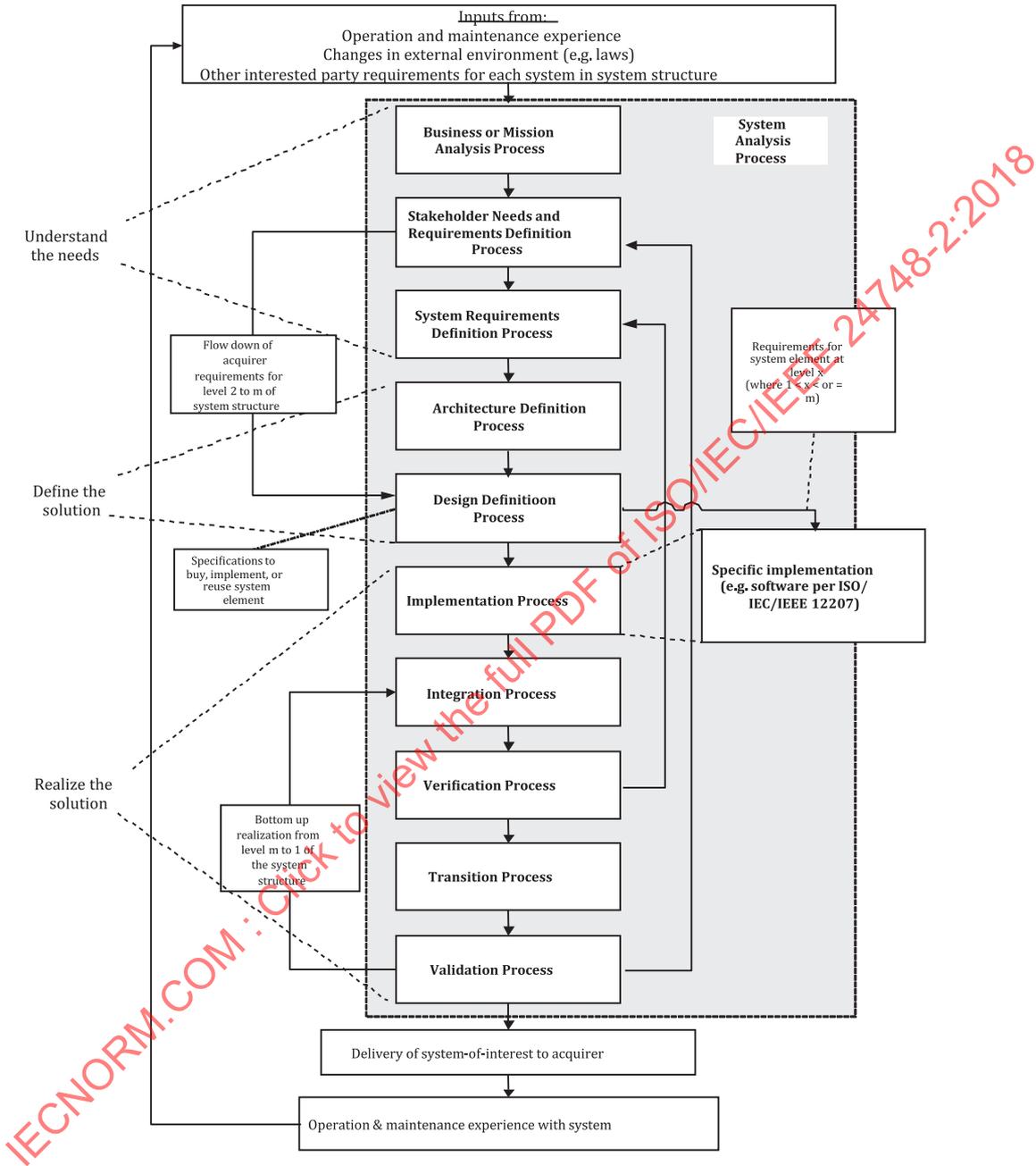
Figure 6 — Application of technical processes to engineer a system-of-interest

Each process of this model is described below with guidelines intended to help use of these processes.

6.7.4.2   Related technical processes for understanding system needs

6.7.4.2.1   General

The Business or Mission Analysis Process, Stakeholder Needs and Requirements Definition Process and System Requirements Definition Process should be used in conjunction with the System Analysis Process to create understanding of the fundamental problem to be addressed, along with its boundaries,

stakeholders, their needs and possible directions for a solution, for a system from the top-level system-of-interest down through the lowest system element level of the system structure. Processes for system definition are covered in 6.7.4.3.

6.7.4.2.2   Business or Mission Analysis Process (6.4.1)

The Business or Mission Analysis Process should first carefully define the problem to be solved for the organization, and the reasons why it is beneficial to the organization to resolve the problem, before effort is put into any selection of a specific solution. Instead, 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 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); and

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 Phase of a system's life cycle. However, as with all ISO/IEC/IEEE 15288:2015 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 system of interest 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 Business or Mission Analysis Process should be repeated on a periodic basis, and performed on an ad hoc/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 15288:2015,6.2.6, should be thorough and explicit.

6.7.4.2.3   Stakeholder Needs and Requirements Definition Process (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. The acquirer provides the initial set of needs and requirements for each system in the system structure. Other interested parties typically provide additional needs and requirements that can influence the understanding of the system and the eventual design solution. 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 factor needs such as safety, security, producibility, reliability, availability, usability and maintainability; and

c)   operator and user need, skills, competencies and working environments.

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 service related to enabling systems. To help ensure that all possible sources of stakeholder requirements have been considered, all the processes in ISO/IEC/IEEE 15288:2015 should be examined. So, 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 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 requirements,

After the set of stakeholder requirements is defined, upward and downward traceability (or completeness and consistency checks) between the stakeholder requirements and stakeholder needs 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 requirements constitute the raw inputs into establishing the problem to be solved (new system concept or modified system based on deficiencies, failures and other anomalies discovered during use).

The acquirer stakeholder can be internal to the organization (for example another project, marketing organization, parent product team, the product team itself, user, operator, executive manager, supervisor), or external to the organization (for example a procurement agency, prime contractor, another organization, customer, user, operator, owner, purchaser).

A user is a special case of the acquirer stakeholder who operates a system (for example computer) or who installs a system (for example software) to form a higher-level system (for example a computer or a microchip) in the system structure.

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:

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

b) environmental, local, national, and international regulations and laws; and

c) functional support requirements 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 may become clearer after the need has been formally stated and then questioned by others;

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

— developing stakeholder requirements from the initial stakeholder needs may 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 (noun), an action (verb), and an object (noun) of the action. For example, "The actuator (actor) opens (action) the door (object) within 10 seconds."

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

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

This process involves assuring that requirements for downstream system life cycle concerns [production, test, operations and logistics (deployment, training, maintenance, disposal)] affecting system functionality 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 these affect (or will affect) how 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 15288:2015, 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 guideline when selecting users for trials and tests.

NOTE   See ISO/IEC 25063.3:2014, *Systems and software engineering — Systems and software product Quality Requirements and Evaluation (SQuaRE) — Common Industry Format (CIF) for usability: Context of use description*, for more information on defining and analysing context of use.

It is usually not possible to meet all stakeholder (acquirer and other interested party) requirements for a particular system since various stakeholders can have conflicting requirements relative to one another. These conflicts should be identified and resolved during the performance of this process, or as soon as a conflict is identified during activities or 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/customer viewpoint, are the customer'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.

Requirements traceability is initiated at this point for tracking requirements and changes to requirements from the stakeholder initial inputs through architecture design.

6.7.4.2.4   System Requirements Definition Process (6.4.3)

Stakeholder requirements are stated from the point of view of the various stakeholders, and are not stated 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 system design. 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 non-functional (e.g. thermal, reliability, finish, etc.) requirements and the constraints on them.

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 compound requirements containing multiple parts, which should then be decomposed into individual requirements.

The System Requirements Definition Process should be applied to some extent during the Concept Phase of a system's life cycle, once the Business or Mission Analysis Process and Stakeholder Needs and Requirements Process have set some basis for doing so. The most intensive application of this process is generally during the Development Stage. However, as with all ISO/IEC/IEEE 15288:2015 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 System Requirements Definition Process applies to both the system of interest and any enabling systems.

The functional boundary applies to systems that provide services as well as those consisting of products.

The functional boundaries of any enabling system should also be established.

Requirements management is done in parallel with cost, schedule, quality, configuration, interface, risk and change management activities that track compliance of project agreement and technical requirements.

6.7.4.2.5   System Analysis Process (6.4.6)

The System Analysis Process is used throughout the application of the Business or Mission Analysis Process, Stakeholder Needs and Requirements Definition Process and System Requirements Definition Process for understanding system needs. However, since it is equally used for the definition of the system solution, described in the next subclause, discussion of the System Analysis Process is deferred to 6.7.3.4.

6.7.4.3   Related Technical processes for defining the system solution

6.7.4.3.1   General

The Architecture Definition Process and the Design Definition Process should be used in conjunction with the System Analysis Process to define specific, realizable solutions for a system from the top-level system-of-interest down through the lowest system element level of the system structure. Processes for system realization are covered in 6.7.2.4.

6.7.4.3.2   Architecture Definition Process (6.4.4)

The Architecture Definition Process is used to take the first step in translating a set of requirements into an actual response, i.e. a realized system. While it does not design the response in detail, it provides various views and models of what the response should look like to satisfy the requirements. 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 architecture can demonstrate how various requirements can be met, though it does not show in detail how the requirements can be met. That is, it is not a detailed design. The design arises through the application of the Design Definition Process. In practice, the Design Definition Process and Architecture Definition Process interact with each other iteratively: it may be necessary to develop design detail from a specific viewpoint to assure that an assumed architecture does indeed respond to a particular stakeholder's requirements.

The Stakeholder Needs and Requirements Definition Process and System Requirements Definition Process can be applied again, as necessary, to refine the requirements for the architecture definition. Factors that can cause this iteration include identification of a need for new stakeholder requirements during architecture definition or the failure to satisfy an upward and downward requirements traceability check.

Two of the possible outcomes from architecture definition are, either the requirements for the next lower level systems or system elements, or the requirements for enabling systems, or both. The systems or system elements at the next lower level of the system structure should then be integrated into the overall architecture and set of system and stakeholders requirements through one or more iterations of the processes listed previously in this subclause.

Existing system elements, or the introduction of new technology, should be considered in establishing the system architecture. The use of existing systems helps reduce developmental time and cost but may increase complexity. Use of new technologies can provide a competitive edge but can also increase risk. In such considerations, new interfaces may be introduced and should be included in the set of system requirements through iteration of the System Requirements Definition Process.

Since the Architecture Definition Process follows the processes that build understanding of the system and precedes the processes that define and implement, it is in a key position to build on what has been done before and provide a basis for what is to happen next. Based on experience with the prior version of ISO/IEC/IEEE 15288, it has received additional emphasis in the 2015 version of ISO/IEC/IEEE 15288 by being identified as a separate process, no longer merged into design. Consequently, users of the new version of ISO/IEC/IEEE 15288 should take particular steps to obtain the resources and expertise to implement this process thoroughly.

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.

Logical 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.

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 model depends on the applicable organizational view stage, its purpose or agreement requirements.

During architecture definition, it can be necessary to repeat the Stakeholder Needs & Requirements Definition Process and System Requirements 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 is made with the following considerations:

a) physical 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;

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

c) technological needs necessary to make 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 modes, effects and criticality of failure analyses have an unacceptable or high criticality rating;

g) degree to which the performance of the derived technical requirements are 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 system-of-interest 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 standardized system elements, protocols, interfaces and so forth;

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 less need for cognitive skills; and

   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 or the system-of-interest higher in the system structure than the one being engineered or re-engineered.

The baseline description of the selected architecture is used for configuration management of the system-of-interest or system element.

The results of the Architecture Definition Process may be captured in an architecture description as defined by ISO/IEC 42010:2011, *Systems and software engineering — Architecture description*. In this case "Stakeholders and concerns" as defined by ISO/IEC 42010 are likely to be produced during the Stakeholder Needs & Requirements Definition Process and System Requirements Definition Process. The representation of an architecture solution as described here should probably be represented as a "Design view" or "Functional view" associated with a Functional viewpoint that is consistent with the

requirements of ISO/IEC/IEEE 15288:2015. The using organization may establish other architectural views: ISO/IEC/IEEE 15288:2015 should not be interpreted as mandating a single architectural viewpoint and view.

6.7.4.3.3 Design Definition Process (6.4.5)

The Design Definition Process transforms the set of stakeholder's requirements that have been translated into system requirements and 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.

The Design Definition Process continues until the implementable level of detail is achieved for the system of interest 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 process will occur as needed. Throughout, the System Analysis Process should be used to support the Design Definition Process.

Examples of the results of applying the Design Definition Process are:

a) a functional flow block diagram reflecting the decomposition of major functions into their sub-functions;

b) a data flow diagram that decomposes functions while explicitly showing the data needed for each function;

c) a data structure with corresponding functions and processing flows related to the data and associated with assigned technical requirements;

d) interface definition documents with logical, physical and functional attributes of system element and system to external system boundaries delineated;

e) a behavioural diagram that describes input stimuli and outputs by function and includes operating order, as appropriate to input or output criteria;

f) a control diagram that indicates the controlling factors of a function and the resulting behaviour;

g) the states and modes of the system;

h) a timeline that allocates a time requirement to a set of functions;

i) a functional failure modes and effects table that indicate the possible effects of a function failure mode, such as not doing what it is designed to do or doing a function for which it not expected to perform. Possible resolutions for each failure mode should be generated;

j) objects that encapsulate a partition and mapping of technical requirements and that are characterized by services (behaviours, functions and operations) provided by encapsulated attributes (values, characteristics and data);

k) a set of algorithms derived from contextual diagrams; and

l) an IDEF0 (Integration Definition 0) diagram. IDEF0 modelling is designed to represent the decisions, actions, and activities of an existing or prospective organization or system.

NOTE   See IEEE Std. 1320.1, IEEE Standard for functional modelling language — Syntax and semantics for IDEF0 for more information.

The features incorporated in the system design should be checked for upward and downward traceability with respect to the set of system requirements generated by the System Requirements Definition Process. Each feature should in turn be traceable to one or more stakeholder requirements.

Design features that are not specifically supported by documented and previously agreed requirements should be eliminated from the system.

The recursive application of the Stakeholder Needs and Requirements Definition Process, System Requirements Definition Process and Architecture Definition Process is shown in Figure 7 as the loop identified as the flow down of acquirer requirements for each level of the system structure. For each system or system element of the system structure that has to be developed the Stakeholder Needs and Requirements Definition Process, System Requirements Definition Process and Architecture Definition Process should be applied. Other interested party requirements should also be determined in order to form the input set of stakeholder requirements for each system or system element at the next level of the system structure.

The recursive loop of Figure 7 is continued until all system elements of the system structure have been defined and no additional systems or system elements need to be developed. System elements can occur at any level x of the system structure. At each level x, when no further development is needed for a system in the system structure, the next set of processes for system realization should be performed. This is an example of the recursive application of technical processes to enhance the top-level system-of-interest definition by defining its lower level systems and system elements. The top level for one organization can be the system that will be purchased by a consumer in a commercial market, such as an automobile. The top level for another organization can be a system within the system structure such as a motor that will be assembled into the 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. This is illustrated in Figure 7 for software using ISO/IEC/IEEE 12207.

The recursive application of the first three processes of Figure 7 is repeated within the system structure until the Implementation Process can be applied to every system element, down to the lowest level, for the system of interest and any enabling systems. At this point the system is fully designed.

The requirements for enabling systems come from:

a) user or customer or assigned requirements and other stakeholder needs for the system and;

b) derived technical requirements for systems and generated applying the Architecture Definition Process. Thus, initiation of enabling system development or procurement (a function of the project's system boundary) is dependent on the completion of the architecture definition solution for the system being engineered or re-engineered and also the applicable system life cycle stage and related engineering view activity or organizational view stage.

The Stakeholder Needs & Requirements Definition Process, System Requirements Definition Process and Architecture Definition Process are also used for developing enabling system solutions after the requirements for such development are identified and defined as a result of defining the system-of-interest or system element being developed. Enabling system development or procurement of enabling systems is applicable for each system -of-interest and system element in the system structure.

The defined system requirements are appropriately allocated to the generated logical architecture definition representations. From the various representations, a set of derived requirements is generated that is used for design definition. There can be unassigned requirements after this allocation is completed. These are assigned directly to alternative design solutions.

In allocating logical representation requirements and derived system requirements the following are considered as to whether they provide requirements that can best be done:

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

b) manually or by facilities, material or data; and

c) by hardware, software and firmware physical element (new or existing).

The Stakeholder Needs & Requirements Definition Process, System Requirements Definition Process and Architecture Definition Process are repeated for each successive lower level in the system structure until specified requirements for all system elements have been defined or until the defined system element can be built, reused or purchased. If further development is required for a system element, the development can be undertaken using an appropriate system element development standard such as ISO/IEC/IEEE 12207 for software.

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 specification (specified requirements) generated by architecture definition can establish a specific level of required system performance without saying how that performance is to be achieved. This is termed a performance specification (although performance-focused should be a more accurate term). If the result of the architecture definition goes into more detail, including specific ways in which the performance should be achieved, this is termed a detailed design. Which kind is generated is generally dependent on the next step in development or how they will be used. If the next step is development of a lower level system and it is desired that the supplier 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:

a)   the required results without stating the method for achieving the required results;

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

c)   the environment in which the system-of-interest or system element should perform these functions;

d)   the interface and inter-changeability characteristics; and

e)   the means for verifying compliance.

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

a)   material to be used;

b)   how a requirement should be achieved; and

c)   how a system should be fabricated or constructed.

The initial or "design to" specifications provide the input acquirer requirements for initiating development of the systems. These initial specifications are finalized after the Stakeholder Needs & Requirements Definition Process, System Requirements Definition Process and Architecture Definition Process are progressively and iteratively applied to each level system elements. Specifications describe the required characteristics of systems in the system structure and include the functional and performance requirements, interface requirements, the environments in which the systems are required to perform their functions, physical characteristics and attributes, the basis for evaluating verification and validation test systems, the methods for verifying compliance, intended uses and enabling system requirements.

6.7.4.3.4   System Analysis Process (6.4.6)

The System Analysis Process is used throughout the application of the ISO/IEC/IEEE 15288 processes described in 6.7.4.2 for understanding system needs and is similarly applied throughout the use of the processes described in 6.7.4.3. The user, and indeed all stakeholders in the system of interest, should assure 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 may 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; and

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

Resulting sets of architecture definition solutions and related derived requirements should be evaluated to show as applicable that each set of derived requirement statements for the solution has acceptable quality to include:

a)   confirmation that intended functions of the system and related services (expressed by the derived requirements and requirements allocated directly to the candidate architecture solution) are correctly implemented;

b)   system and related services constraints, including interfaces, are satisfied;

c)   resolution of identified voids, variances, and conflicts including:

   1)   re-write of derived requirements to be of acceptable quality;

   2)   confirmation that appropriate action has been taken when the specified requirements are not upward traceable to the set of derived requirements driving the candidate architecture solution and the requirements allocated directly to solution physical entities;

   3)   determination whether non-sourced (orphaned) specified requirements were introduced, whether they were intended to be included and whether they are desired by appropriate stakeholders;

   4)   omitted derived requirements have been added to the candidate architecture solution when derived requirements were determined to be inadequately reflected in the selected candidate architecture solution;

   5)   identification and recording of actions taken to eliminate non-sourced specified requirements, to establish the correct set of derived requirements or to revise the set of validated requirements;

   6)   proof that re-verification of the specified requirements has been done when a change is needed to the set of validated requirements and that the appropriate activities and tasks of the requirements analysis process and architecture definition process were re-performed, as appropriate; and

   7)   proof that re-verification tests were repeated when test outcome variations and anomalies were traced to poor verification conduct or to inadequate verification environment.

Each requirement statement should be validated for the following quality attributes:

a)   ability to preserve competitiveness — permits preservation of a competitive stance and is only as constraining on competitive stance as is justified by benefits delivered by requirement;

b)   clarity — requirement statement is readily understandable without analysis of meaning of words or terms used;

c)   correctness — requirement statement does not contain an error of fact;

d) feasibility — requirement can be satisfied within:

1) natural physical constraints;

2) state of the art as it applies to the project and;

3) all other absolute constraints applying to the project;

e) focus — requirement is expressed in terms of 'what' and 'why' or form, fit and function, not in terms of how to develop the products or the materials to be used — detailed requirements that are required to guide detailed design of a product are an exception to this;

f) implementability — requirement statement contains information necessary to enable requirement to be implemented;

g) modifiability — necessary changes to a requirement can be made completely and consistently;

h) removal of ambiguity — allows only one interpretation for meaning of the requirement, for example not defined by words or terms such as 'excessive,' 'sufficient' and 'resistant' that cannot be measured;

i) singularity — requirement statement cannot be sensibly expressed as two or more requirements having different agents, actions, objects or instruments;

j) testability — existence of finite and objective process with which to verify that the requirement has been satisfied;

k) verifiability — can be verified at the level of system structure at which it is stated;

l) abstraction — the correct level of abstraction for the organizational view stage and maturity of the system.

Requirement statements in pairs and sets should be validated for the following quality attributes:

1) absence of redundancy — each requirement is specified only one time;

2) connectivity — all terms within a requirement are adequately linked to other requirements and to word and term definitions so that individual requirements relate properly to other requirements as a set;

3) removal of conflicts — requirement is not in conflict with other requirements or within itself.

To help ensure achievability of requirements the supplier should consider:

a) existing system elements such as commercial-off-the-shelf, known as COTS, that can help reduce development time and cost but may increase complexity;

b) introduction of new technology that can provide a competitive edge;

c) possible physical solutions; and

d) new interfaces that can be introduced.

The resulting set of requirements is validated as being necessary and sufficient for designing the system-of-interest architecture design solution. This includes as appropriate:

a) downward traceability of the validated set of stakeholder requirements to the set of defined technical requirements;

b) upward traceability of the individual technical requirement statements, from the set of defined technical requirements, to the validated sets of stakeholder requirements;

c) confirmation that assumptions and derived requirements are valid and consistent with the system and related services being engineered or re-engineered;

d) resolution of identified voids, variances, and conflicts including:

1) confirmation that appropriate action has been taken when the set of defined technical requirements is not upward traceable to the validated set of stakeholder needs;

2) determination whether non-sourced (orphaned) requirements or constraints were introduced and whether they are desired by appropriate stakeholders;

3) omitted requirements are added to the set of defined technical requirements, as appropriate, when stakeholder needs are not adequately reflected in the set of defined technical requirements; and

4) proof that re-validation of the set of technical requirements has been done when a change is needed to one of the validated sets of stakeholder needs and that the appropriate activities and tasks of the stakeholder needs definition process and requirements analysis process were performed again, as appropriate.

6.7.4.4 Related Technical processes for system realization

6.7.4.4.1 General

Technical processes for system understanding and definition are covered in 6.7.4.2 and 6.7.4.3. The Implementation Process, Integration Process, Verification Process, Transition Process and Validation Process should be used to realize the architecture design solution for each system in the system structure from the bottom system element to the top-level system-of-interest of the system structure.

After all system elements of the system structure are appropriately implemented, the definition of the system structure is complete. Then the bottom up, recursive application of the Integration Process, Verification Process and Transition Process should be performed from the lowest level of the system structure to the highest for each system and for the system-of-interest. Each implemented and integrated system element should be verified using the Verification Process before integration is performed at the next higher level of the system structure. Commonly, a final validation is done after transition and on a system basis. However, each system implementation should be evaluated for an appropriate validation strategy.

6.7.4.4.2 Implementation Process (6.4.7)

The Implementation Process can be used when further development of a system element is not needed. At this point the system element defined as part of an architecture design solution can be implemented. 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 its position in the system structure 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 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; and

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

Any system element can be modelled based on the maturity of its definition as well as the applicable organizational view stage, milestone or decision gate and associated exit criteria.

The system element is either a single product (for example component or part) or composite of products (for example subassembly, line replaceable unit) depending on its level in the system structure and its ability to be built, purchased or implemented using a standard such as ISO/IEC/IEEE 12207.

System elements consisting solely of hardware items can be:

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

b) fabricated in-house; or

c) from in-house, off-the-shelf supply.

System elements consisting solely of software items can be:

a) purchased from a supplier or vendor;

b) coded in-house; or

c) reused.

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 (e.g. 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 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 requirements.

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

6.7.4.4.3 Integration Process (6.4.8)

The Integration Process can be used after the lower level system elements have been implemented and delivered to the integrator responsible for integration into a system at the next level above. Integration of the system elements may be performed by the same party that performed the implementation or by the acquirer. The implemented system elements are assembled and integrated into a higher-level system in accordance with the configuration descriptions developed during the top down definition and design of that system. This newly integrated system is verified using the Verification Process, transitioned to the acquirer at the next level above using the Transition Process and validated using the Validation Process. This bottom-up integration of systems is continued until the top-level system-of-interest is realized using these same processes.

The integration strategy should address all possible elements of the system. So, specific consideration should be given to all services and products that are elements of the system and which can be composed of a 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 measures to assess all interfaces after each stage of integration to check for and address possible changes.