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Systems and software engineering — Life cycle management —

Part 1: Guidelines for life cycle management

Ingénierie des systèmes et du logiciel — Gestion du cycle de vie — Partie 1: Lignes directrices pour la gestion du cycle de vie

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the rules given in the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

This first edition of ISO/IEC/IEEE 24748-1 cancels and replaces ISO/IEC TS 24748-1:2016, which has been technically revised to include movement of material from the new edition of ISO/IEC/IEEE 24748-2.

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

The purpose of this document is to facilitate the joint usage of the process content of the latest revisions of both ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207, by providing unified and consolidated guidance on life cycle management of systems and software. This is to help ensure consistency in system concepts and life cycle concepts, models, stages, processes, process application, key points of view, adaptation and use in various domains as the two International Standards are used in combination. That will in turn help a project team design a life cycle model for managing the progress of their project. Hence, ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 are the documents that apply the concepts found in this document to specific processes.

NOTE ISO/IEC/IEEE 16326 also applies the concepts found in this document, in the process context for project management.

This document will also aid in identifying and planning use of life cycle processes described in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 that will enable the project to be completed successfully, meeting its objectives/requirements for each stage and for the overall project.

Besides the above, there is also increasing recognition of the importance of helping to ensure that all life cycle stages and all aspects within each stage are supported with thorough guidance to enable alignment with any process documents that might subsequently be created that focus on areas besides systems and software, including hardware, humans, data, processes (e.g. review process), procedures (e.g. operator instructions), facilities and naturally occurring entities (e.g. water, organisms, minerals).

By addressing these needs specifically in this document, the users of the process-focused ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 will not only benefit from having one document complementarily addressing the aspect of product or service life cycle: they will also benefit from a framework that links life cycle management aspects to more than just the systems or software aspects of products or services.

ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 also have published guidelines (ISO/IEC/IEEE 24748-2 and ISO/IEC TR 24748-3), respectively, to support use of the two revised International Standards individually.

Systems and software engineering — Life cycle management —

Part 1: Guidelines for life cycle management

1 Scope

This document provides guidelines for the life cycle management of systems and software, complementing the processes described in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207. This document:

- addresses systems concepts and life cycle concepts, models, stages, processes, process application, key points of view, adaptation and use in various domains and by various disciplines;
- establishes a common framework for describing life cycles, including their individual stages, for the management of projects to provide, or acquire either products or services;
- defines the concept and terminology of a life cycle;
- supports the use of the life cycle processes within an organization or a project. Organizations and projects can use these life cycle concepts when acquiring and supplying either products or services;
- provides guidance on adapting a life cycle model and the content associated with a life cycle or a part of a life cycle;
- describes the relationship between life cycles and their use in applying the processes in ISO/IEC/IEEE 15288 (systems aspects) and ISO/IEC/IEEE 12207 (software aspects);
- shows the relationships of life cycle concepts to the hardware, human, services, process, procedure, facility and naturally occurring entity aspects of projects; and
- describes how its concepts relate to detailed process standards, for example, in the areas of measurement, project management and risk management.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 https://www.iso.org/obp
- IEEE Standards Dictionary Online: available at http://ieeexplore.ieee.org/xpls/dictionary.jsp

3.1
acquirer
stakeholder that acquires or procures a product or service from a supplier

Note 1 to entry: Other terms commonly used for an acquirer are buyer, customer, owner, purchaser, or internal/organizational sponsor.

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

3.2
acquisition
process of obtaining a system, product or service

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

3.3
activity
set of cohesive tasks of a process

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

3.4
agile development
software development approach based on iterative development, frequent inspection and adaptation, and incremental deliveries, in which requirements and solutions evolve through collaboration in cross-functional teams and through continual stakeholder feedback

[SOURCE: ISO/IEC/IEEE 26515:—]

3.5
agreement
mutual acknowledgement of terms and conditions under which a working relationship is conducted

EXAMPLE Contract, memorandum of agreement.

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

3.6
architecture
<system> fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution

Note 1 to entry: ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 use the word "elements" instead of "components" and this document follows that usage.

[SOURCE: ISO/IEC/IEEE 42010:2011, modified — Note 1 to entry has been added.]

3.7
architecture framework
conventions, principles and practices for the description of architectures established within a specific domain of application and/or community of stakeholders

EXAMPLE 1 *Generalized Enterprise Reference Architecture and Methodologies (GERAM)* (ISO 15704) is an architecture framework.

EXAMPLE 2 *Reference Model of Open Distributed Processing (RM-ODP)* (ISO/IEC 10746) is an architecture framework.

[SOURCE: ISO/IEC/IEEE 42010:2011]

3.8
architecture view
work product expressing the architecture of a system from the perspective of specific system concerns

[SOURCE: ISO/IEC/IEEE 42010:2011]

3.9
architecture viewpoint
work product establishing the conventions for the construction, interpretation and use of architecture views to frame specific system concerns

[SOURCE: ISO/IEC/IEEE 42010:2011]

3.10
audit
independent examination of a work product or set of work products to assess compliance with specifications, standards, contractual agreements, or other criteria

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

3.11
baseline
approved version of a configuration item, regardless of media, formally designated and fixed at a specific time during the configuration item's life cycle

[SOURCE: IEEE 828:2012]

3.12
concept of operations
verbal and/or graphic statement, in broad outline, of an organization's assumptions or intent in regard to an operation or series of operations

Note 1 to entry: The concept of operations frequently is embodied in long-range strategic plans and annual operational plans. In the latter case, the concept of operations in the plan covers a series of connected operations to be carried out simultaneously or in succession. The concept is designed to give an overall picture of the organization operations. See also *operational concept* (3.26).

Note 2 to entry: It provides the basis for bounding the operating space, system capabilities, interfaces and operating environment.

[SOURCE: ANSI/AIAA G-043A-2012e]

3.13
concern
<system> interest in a system relevant to one or more of its stakeholders

Note 1 to entry: A concern pertains to any influence on a system in its environment, including developmental, technological, business, operational, organizational, political, economic, legal, regulatory, ecological and social influences.

[SOURCE: ISO/IEC/IEEE 42010:2011]

3.14
configuration item
item or aggregation of hardware, software, or both, that is designated for configuration management and treated as a single entity in the configuration management process

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

3.15
customer
organization or person that receives a product or service

EXAMPLE Consumer, client, user, acquirer, buyer, or purchaser.

Note 1 to entry: A customer can be internal or external to the organization.

[SOURCE: ISO 9000:2015, modified — added “service”.]

3.16
design, verb
<process> to define the architecture, system elements, interfaces, and other characteristics of a system or system element

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

3.17
design, noun
result of the process in 3.16

Note 1 to entry: Information, including specification of system elements and their relationships, that is sufficiently complete to support a compliant implementation of the architecture.

Note 2 to entry: Design provides the detailed implementation-level physical structure, behaviour, temporal relationships and other attributes of system elements.

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

3.18
design characteristic
design attributes or distinguishing features that pertain to a measurable description of a product or service

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

3.19
enabling system
system that supports a system-of-interest during its life cycle stages but does not necessarily contribute directly to its function during operation

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

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

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

3.20
environment
<system> context determining the setting and circumstances of all influences upon a system

[SOURCE: ISO/IEC/IEEE 42010:2011]

3.21
facility
physical means or equipment for facilitating the performance of an action, e.g. buildings, instruments, tools

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

3.22
incident
anomalous or unexpected event, set of events, condition, or situation at any time during the life cycle of a project, product, service, or system

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

3.23
information item
separately identifiable body of information that is produced, stored, and delivered for human use

[SOURCE: ISO/IEC/IEEE 15289:—]

3.24
life cycle
evolution of a system, product, service, project or other human-made entity from conception through retirement

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

3.25
life cycle model
framework of processes and activities concerned with the life cycle that may be organized into stages, which also acts as a common reference for communication and understanding

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

3.26
operational concept
verbal and graphic statement of an organization's assumptions or intent in regard to an operation or series of operations of a system or a related set of systems

Note 1 to entry: The operational concept is designed to give an overall picture of the operations using one or more specific systems, or set of related systems, in the organization's operational environment from the users' and operators' perspective. See also *concept of operations* (3.12).

[SOURCE: ANSI/AIAA G-043A-2012e]

3.27
operator
individual or organization that performs the operations of a system

Note 1 to entry: The role of operator and the role of user may be vested, simultaneously, or sequentially, in the same individual or organization.

Note 2 to entry: An individual operator combined with knowledge, skills and procedures may be considered as an element of the system.

Note 3 to entry: An operator may perform operations on a system that is operated, or of a system that is operated, depending on whether or not operating instructions are placed within the system boundary.

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

3.28
organization
group of people and facilities with an arrangement of responsibilities, authorities and relationships

EXAMPLE Company, corporation, firm, enterprise, institution, charity, sole trader, association, or parts or combination thereof.

Note 1 to entry: An identified part of an organization (even as small as a single individual) or an identified group of organizations can be regarded as an organization if it has responsibilities, authorities and relationships. A body of persons organized for some specific purpose, such as a club, union, corporation, or society, is an organization.

[SOURCE: ISO 9000:2015, modified — Note 1 to entry has been added.]

3.29
party
organization entering into an agreement

Note 1 to entry: In this document, the agreeing parties are called the acquirer and the supplier.

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

3.30
problem
difficulty, uncertainty, or otherwise realized and undesirable event, set of events, condition, or situation that requires investigation and corrective action

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

3.31
process
set of interrelated or interacting activities that transforms inputs into outputs

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

3.32
process outcome
observable result of the successful achievement of the process purpose

[SOURCE: ISO/IEC/IEEE 12207:2017]

3.33
process purpose
high level objective of performing the process and the likely outcomes of effective implementation of the process

Note 1 to entry: The purpose of implementing the process is to provide benefits to the stakeholders.

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

3.34
product
result of a process

Note 1 to entry: There are four agreed generic product categories: hardware (e.g. engine mechanical part), software (e.g. computer program), services (e.g. transport), and processed materials (e.g. lubricant). Hardware and processed materials are generally tangible products, while software or services are generally intangible.

[SOURCE: ISO 9000:2015]

3.35
project
endeavour with defined start and finish criteria undertaken to create a product or service in accordance with specified resources and requirements

Note 1 to entry: A project is sometimes viewed as a unique process comprising co-coordinated and controlled activities and composed of activities from the Project Processes and Technical Processes defined in the referenced International Standards.

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

3.36
qualification
process of demonstrating whether an entity is capable of fulfilling specified requirements

[SOURCE: ISO/IEC/IEEE 12207:2017]

3.37
quality assurance
part of quality management focused on providing confidence that quality requirements will be fulfilled

[SOURCE: ISO 9000:2015]

3.38
quality characteristic
inherent characteristic of an object related to a requirement

[SOURCE: ISO 9000:2015]

3.39
quality management
coordinated activities to direct and control an organization with regard to quality

[SOURCE: ISO 9000:2015]

3.41
requirement
statement that translates or expresses a need and its associated constraints and conditions

[SOURCE: ISO/IEC/IEEE 29148:—]

3.42
resource
asset that is utilized or consumed during the execution of a process

Note 1 to entry: Includes diverse entities, such as funding, personnel, facilities, capital equipment, tools and utilities, such as power, water, fuel and communication infrastructures.

Note 2 to entry: Resources include those that are reusable, renewable, or consumable.

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

3.43
retirement
withdrawal of active support by the operation and maintenance organization, partial or total replacement by a new system, or installation of an upgraded system

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

3.44
risk
effect of uncertainty on objectives

Note 1 to entry: An effect is a deviation from the expected, positive or negative. A positive effect is also known as an opportunity.

Note 2 to entry: Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process).

Note 3 to entry: Risk is often characterized by reference to potential events and consequences, or a combination of these.

Note 4 to entry: Risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence.

Note 5 to entry: Uncertainty is the state, even partial, of deficiency of information related to understanding or knowledge of an event, its consequence, or likelihood.

[SOURCE: ISO Guide 73:2009, 1.1]

3.45
security
protection against intentional subversion or forced failure, containing a composite of four attributes: confidentiality, integrity, availability and accountability, plus aspects of a fifth, usability, all of which have the related issue of their assurance

[SOURCE: NATO AEP-67]

3.46
service
performance of activities, work, or duties

Note 1 to entry: A service is self-contained, coherent, discrete and can be composed of other services.

Note 2 to entry: A service is generally an intangible product.

[SOURCE: ISO/IEC/IEEE 12207:2017]

3.47
software item
source code, object code, control code, control data, or a collection of these items

Note 1 to entry: A software item can be viewed as a system element of the referenced International Standard and of ISO/IEC/IEEE 15288:2015.

[SOURCE: ISO/IEC/IEEE 12207:2017]

3.48
software product
set of computer programs, procedures, and possibly associated documentation and data

[SOURCE: ISO/IEC/IEEE 12207:2017]

3.49
software unit
atomic level software component of the software architecture that can be subjected to stand-alone testing

[SOURCE: ISO 26262-1:2018]

3.50
stage
period within the life cycle of an entity that relates to the state of its description or realization

Note 1 to entry: As used in this document, stages relate to major progress and achievement milestones of the entity through its life cycle.

Note 2 to entry: Stages often overlap.

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

3.51
stakeholder
individual or organization having a right, share, claim, or interest in a system or in its possession of characteristics that meet their needs and expectations

EXAMPLE End users, end user organizations, supporters, developers, producers, trainers, maintainers, disposers, acquirers, supplier organizations and regulatory bodies.

Note 1 to entry: Some stakeholders can have interests that oppose each other or oppose the system.

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

3.52
supplier
organization or an individual that enters into an agreement with the acquirer for the supply of a product or service

Note 1 to entry: Other terms commonly used for supplier are contractor, producer, seller, or vendor.

Note 2 to entry: The acquirer and the supplier sometimes are part of the same organization.

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

3.53
system
combination of interacting elements organized to achieve one or more stated purposes

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

Note 2 to entry: In practice, the interpretation of its meaning is frequently clarified by the use of an associative noun, e.g. aircraft system. Alternatively, the word "system" is substituted simply by a context-dependent synonym, e.g. aircraft, though this potentially obscures a system principles perspective.

Note 3 to entry: A complete system includes all of the associated equipment, facilities, material, computer programs, firmware, technical documentation, services and personnel required for operations and support to the degree necessary for self-sufficient use in its intended environment.

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

3.54
system element
member of a set of elements that constitutes a system

EXAMPLE Hardware, software, data, humans, processes (e.g. processes for providing service to users), procedures (e.g. operator instructions), facilities, materials and naturally occurring entities, or any combination.

Note 1 to entry: A system element is a discrete part of a system that can be implemented to fulfil specified requirements.

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

3.55
system-of-interest
system whose life cycle is under consideration in the context of this document

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

3.56
system-of-systems (SoS)
set of systems that integrate or interoperate to provide a unique capability that none of the constituent systems can accomplish on its own

Note 1 to entry: Each constituent system is a useful system by itself, having its own management, goals, and resources, but coordinates within the SoS to provide the unique capability of the SoS.

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

3.57
systems engineering
interdisciplinary approach governing the total technical and managerial effort required to transform a set of stakeholder needs, expectations, and constraints into a solution and to support that solution throughout its life

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

3.58
task
required, recommended, or permissible action, intended to contribute to the achievement of one or more outcomes of a process

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

3.59
technical management
application of technical and administrative resources to plan, organize and control engineering functions

[SOURCE: ISO/IEC/IEEE 12207:2017]

3.60
trade-off
decision-making actions that select from various requirements and alternative solutions on the basis of net benefit to the stakeholders

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

3.61
user
individual or group that interacts with a system or benefits from a system during its utilization

Note 1 to entry: The role of user and the role of operator are sometimes vested, simultaneously or sequentially, in the same individual or organization.

[SOURCE: ISO/IEC 25010:2011]

3.62
validation
confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled

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

Note 2 to entry: In a life cycle context, validation involves the set of activities for gaining confidence that a system is able to accomplish its intended use, goals and objectives in an environment like the operational environment.

[SOURCE: ISO 9000:2015, modified — Note 1 to entry and Note 2 to entry have been added.]

3.63
verification
confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

Note 1 to entry: Verification is a set of activities that compares a system or system element against the required characteristics. This includes, but is not limited to, specified requirements, design description and the system itself. The system was built right.

[SOURCE: ISO 9000:2015 modified — Note 1 to entry has been added.]

4 Life cycle-related concepts

4.1 General

This Clause addresses system and life cycle concepts. For completeness, process, organizational and project concepts are covered in Annexes A, B and C, respectively.

4.2 System concepts

4.2.1 General

This sub clause is included to highlight and explain essential concepts on which this document is based. These concepts are directly applicable to software, as addressed in ISO/IEC/IEEE 12207, systems, as addressed in ISO/IEC/IEEE 15288, and to hardware, facilities, services, humans, processes and procedures, data and naturally occurring entities.

4.2.2 Systems

The systems considered in this document are man-made and utilized to provide services in defined environments for the benefit of users and other stakeholders. These systems may be configured with one or more of the following: hardware, software, services, humans, data, processes (e.g. processes for providing services to users), procedures (e.g. operator instructions), facilities and naturally occurring entities (e.g. water, organisms, minerals).

The perception and definition of a particular system, its architecture and its system elements depend on an observer's interests and responsibilities. One person's system-of-interest can be viewed as a system element in another person's system-of-interest. Conversely, it can be viewed as being part of the environment of operation for yet another person's system-of-interest.

Figure 1 exemplifies the multitude of perceivable systems-of-interest in an aircraft and its environment of operation. First, Figure 1 in its entirety comprises a transportation system with air, ground and water elements, which can be a system-of-interest. Next, any one element of the transportation system can be viewed as a system-of-interest, such as the Air Transport System. The example can be continued through the levels so that, for example, the display can be an element of the navigation system, which is in turn an element of the aircraft system within the air transport system. However, from an equally valid perspective, such as that of display manufacturers, the display will be their system-of-interest and they will then determine the elements within their display system. On a deeper level, Figure 1 also illustrates the following:

— the importance of defined boundaries that encapsulate meaningful needs and practical solutions;

— the perception of system structure (in this case, the physical structure, hierarchical in this instance);

— that an entity at any level in a system structure can be viewed as a system;

— that a system is comprised of a fully integrated, defined set of subordinate systems;

— that characteristic properties at a system's boundary arise from the interactions between subordinate systems;

— that humans can be viewed as users external to a system (e.g. air crew and navigation system) and as system elements within a system (e.g. air crew and aircraft);

— that a system can be viewed as an isolated entity (that is, a product), or as an ordered collection of functions capable of interacting with its surrounding environment, (i.e. a set of services);

— that a system can be viewed as part of a larger system of systems and that a system of systems can be viewed as a system.

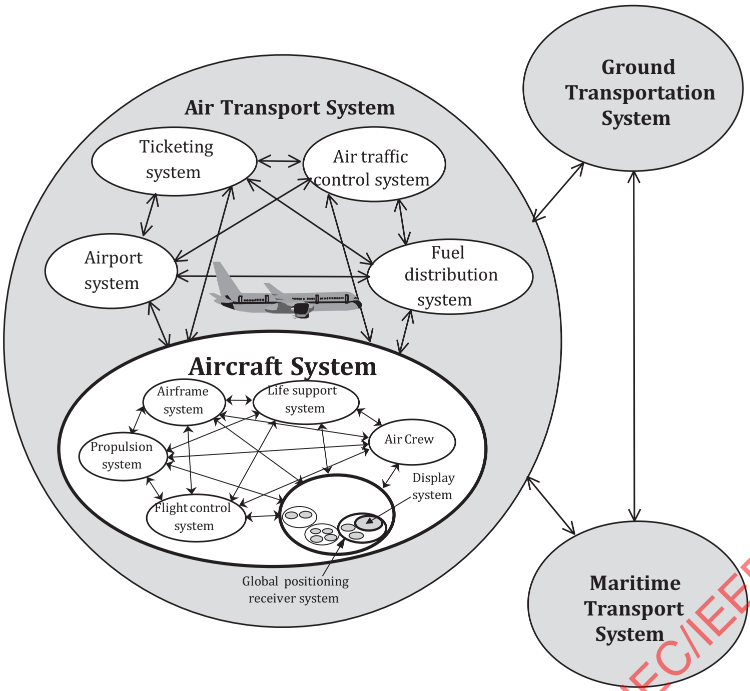

Figure 1 — Typical system view of an aircraft in its environment of use

Whatever the boundaries chosen to define the system, the concepts and models in this document are generic and permit a practitioner to correlate or adapt individual instances of life cycles to its system concepts and principles.

In this document, humans are considered both as users and as elements of a system. In the first case, the human user is a beneficiary of the operation of the system. In the second case, the human is an operator carrying out specified system functions, such as those involved in providing a service. An individual can be, simultaneously or sequentially, a user and an element of a system, for example, the pilot of a private aircraft in the civil aviation system.

Humans contribute to the performance and characteristics of many systems for numerous reasons, e.g. their special skills, the need for flexibility and for legal reasons. Whether they are users or operators, humans are highly complex, with behaviour that is frequently difficult to predict, and they need protection from harm. This requires that the system life cycle processes address human element factors in the areas of: human factors engineering, system safety, health hazard assessment, manpower, personnel and training. These issues are addressed by particular activities and iterations in the life cycle, and are described in more detail in ISO 9241-210:2010 and ISO/TR 18529:2000.

NOTE ISO/TR 18529 is being superseded by ISO/IEC 9241-220 which is under development.

4.2.3 System structure

The system life cycle processes in this document are described in relation to a system that is composed of a set of interacting physical, logical and/or other system elements, depicted in Figure 2, each of which can be implemented to fulfil its respective specified requirements. Responsibility for the implementation of any system element may therefore be delegated to another party through an agreement.

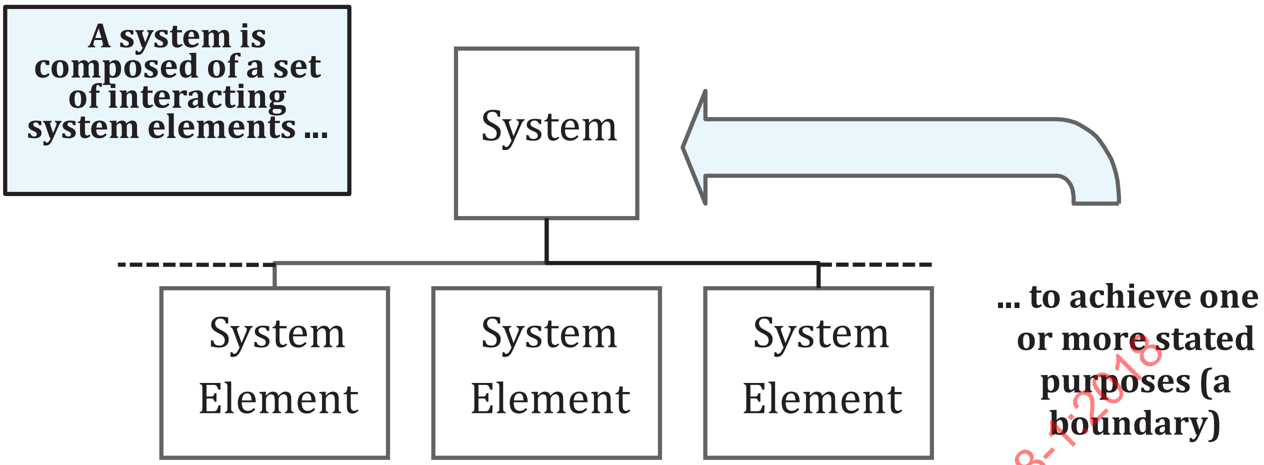

Figure 2 — System and system element relationship

The relationship between the system and its complete set of system elements can typically be resolved in a single step only for the simplest of systems-of-interest. For more complex systems-of-interest, a prospective system element may itself need to be considered as a system (that in turn can be comprised of system elements) before a complete set of system elements can be defined with confidence, as indicated by Figure 3. In this manner, the system life cycle processes are applied recursively to a system-of-interest to resolve its structure to the point where understandable and manageable system elements can be implemented or reused, or acquired from another party. While Figures 2 and 3 imply a hierarchical relationship, in reality there are an increasing number of systems that, from one or more aspects, are not hierarchical, such as networks and other distributed systems. So, recursion is not necessarily linearly downward in all cases.

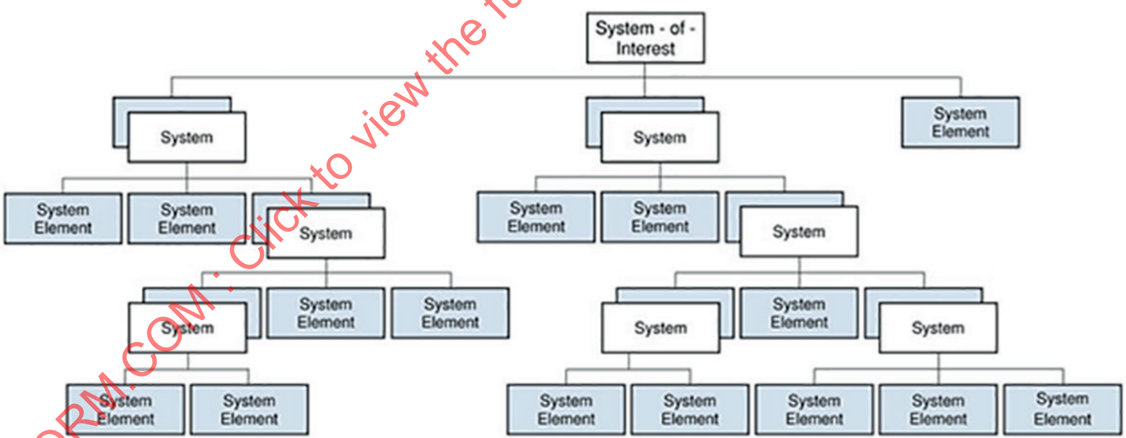

Figure 3 — System-of-interest structure

4.2.4 Enabling systems

Throughout the life cycle of a system-of-interest, essential services are required from systems that are not directly a part of the operational environment of the system-of-interest, e.g. mass-production system, training system, maintenance system. Each of these systems enables a part, for example, a stage, or stages, of the life cycle of the system-of-interest to be conducted. Termed "enabling systems", they facilitate progression of the system-of-interest through its life cycle. The relationship between the services delivered to the operational environment by the system-of-interest and the services delivered by the enabling systems to the system-of-interest are shown in Figure 4. Enabling systems can be seen to contribute indirectly to the services provided by the system-of-interest. The interrelationships between the system-of-interest and the enabling systems can be bi-directional or a one-way relationship at each stage in which the system-of-interest and specific enabling systems interrelate. In addition to interacting with enabling systems, the system-of-interest may also interact with other systems in the operating environment, shown as Systems A, B, and C. Requirements for interfaces with enabling systems and other systems in the operational environment will need to be included in the requirements for the system-of-interest.

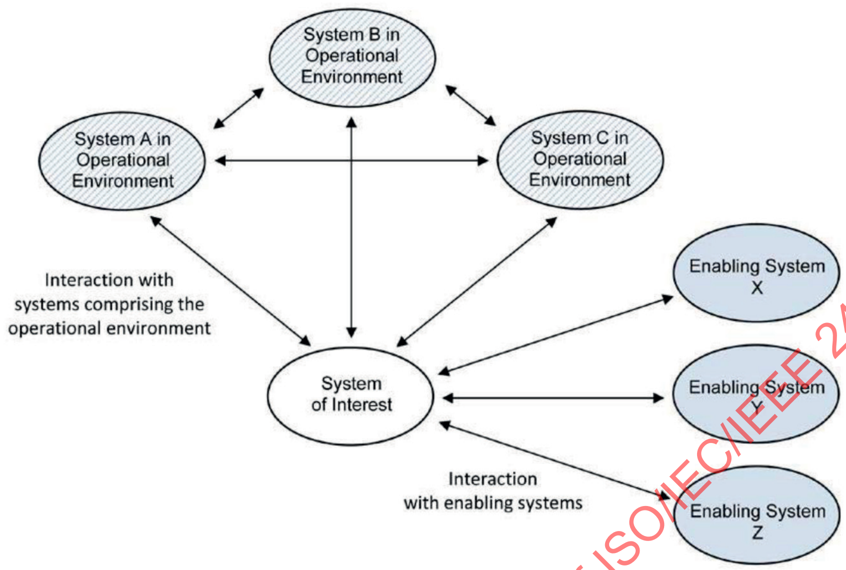

Figure 4 — System-of-interest, its operational environment and enabling systems

During each stage in the system life cycle, the relevant enabling systems and the system-of-interest are considered together. Since they are interdependent, they can also be viewed as a system. When a suitable enabling system does not already exist, the project that is responsible for the system-of-interest can also be directly responsible for creating and using the enabling system. Creating the enabling systems can be viewed as a separate project and subsequently another system-of-interest. Note that a given enabling system could be used more than once (i.e. several times during a given stage, or in multiple stages, or both) during a system's life cycle, and that such use can have discontinuities. The enabling system may also be used concurrently in multiple life cycle stages. Thus, it is necessary to consider the full life cycle and concurrency requirements for the enabling systems. For example, a specific fixture might be used for development retirement, for which there could be a significant time delay. Or the fixture could be needed for development, operations and maintenance, and have activities requiring the fixture concurrently. As another example, a training aid could be developed as part of the Concept Stage, then refined and reused in development, operation and maintenance stages.

4.3 Life cycle concepts

4.3.1 System life cycle model

Every system, whatever the kind or size, inherently evolves, from its initial conceptualization through its eventual retirement, as defined in 3.43. It is generally useful to build a model of this progression, showing each stage in the evolution, to help manage the evolution of the system. Models built for this purpose are termed life cycle models. Movement from one stage to another represents a decision point with specific criteria to be satisfied before movement to the next stage is allowed. These criteria usually are directly based either on the completion of specific tasks and demonstration of successful outcomes, or readiness to start specific tasks in order to achieve required outcomes, from sets of processes, such as are in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207. A life cycle model, then, is a decision-linked conceptual segmentation of the definition of the need for the system, its realization as a product or service, or some mix of both, and its utilization, evolution and disposal. Note that the actual progression of a system through the parts of the model, however done, is the system's life cycle.

NOTE Life cycle, life cycle model and stage are 3.24, 3.25 and 3.50, respectively.

A system life cycle model is segmented by stages because it facilitates planning, provisioning, operating and supporting the system-of-interest. This segmentation by stages provides an orderly progression of a system through established decision-making gates to reduce risk and to enable satisfactory progress. As stated before, it is the need to make a decision to specific criteria, usually process outcome-based, before a system can progress to subsequent stages that is the most important reason for using a life cycle model. Note that it may be useful to develop one or more specific process views from the viewpoint of stage transition decision making, following the information given in ISO/IEC/IEEE 15288:2015, Annex E and ISO/IEC/IEEE 12207:2017, Annex E.

A secondary aspect of using a life cycle model is that it can help an organization think of its work and its processes within a larger framework, which may have useful business overtones. See, for example, the discussion of a services life cycle model in 6.3.4.1.

Several factors make system life cycle planning, provisioning and operation difficult to manage. Economics and market forces, as well as novelty, complexity and operational stability affect the length of a system's life cycle. Some systems have life cycles that are decades long (for example, aircraft, satellites, ships) and some are very short (for example, instruments and consumer electronics).

A typical system, however, progresses through a common series of stages where it is conceptualized, developed, produced as a product or service (or a mix of both), utilized, supported and retired. The life cycle model is the framework that helps ensure that the system is able to meet its required functionality throughout its life. Thus, to define system requirements and develop system solutions during the Concept and Development Stages, experts in the activities of other stages (for example, production, utilization, support, retirement) are needed to perform trade-off analyses and to help make design decisions and arrive at a balanced solution. This helps ensure that a system has the necessary attributes designed in as early as possible. Also, it is essential to have the necessary enabling systems available to perform required stage functions.

A representative system life cycle model, shown in Figure 5, illustrates this progression. The interfaces between stages are the decision points for determining that the system is ready to progress to subsequent stages in its evolution.

Concept	**Development**	**Production**	**Utilization**	**Support**	**Retirement**

Figure 5 — Representative life cycle model

The stages in Figure 5, although drawn as discrete, are in practice interdependent and overlapping. Further, the figure implicitly conveys a uniformity and single linearity of time progression that is not inherently part of a life cycle model: stages do not necessarily occur one after another in time sequence. So, one actuality of the "progression" of a system through its life cycle could be as represented in Figure 6. When, in this document, reference is made to the next, subsequent, or later stage, this type of model should be kept in mind to avoid confusion by inferring linear time sequencing. Further, although each stage is represented in Figure 6, as if it were approximately the same time duration as the other stages, in actuality, the durations of different stages can be and usually are quite different. For example, for a given system, the Concept Stage might last only weeks, the development might take months, the utilization could continue for years and retirement might be accomplished in days.

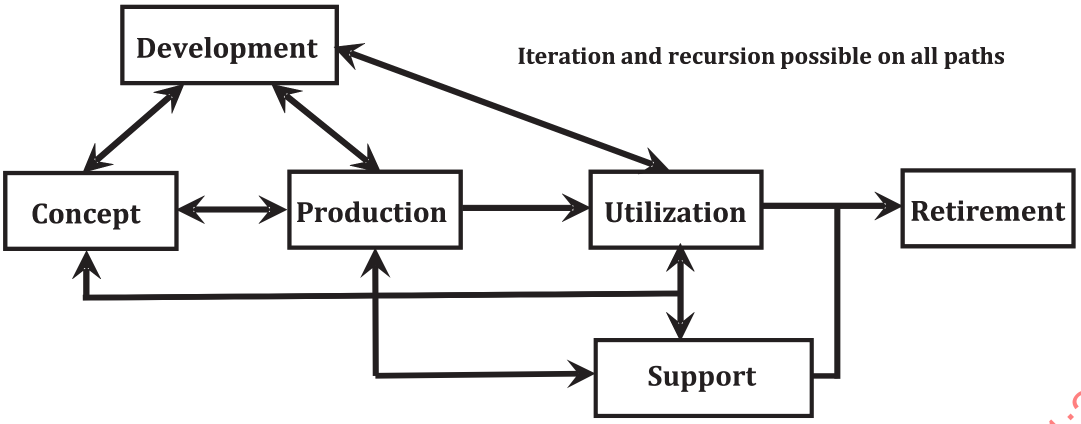

Figure 6 — Life cycle model with some of the possible progressions

A system progresses through its life cycle as the result of actions, performed and managed by people in organizations, using processes for their performance. The detail in the life cycle model is expressed in terms of these processes, their outcomes, relationships and occurrence. A key aspect of life cycle management is that each stage requires entry criteria to be met before effort from that stage is allowed. Further, each stage requires exit criteria before effort on that stage meets are criteria for satisfactory completion. Since stages can have complex relationships as illustrated in Figure 6, definition of both entry and exit criteria for a specific stage are needed. For example, if one stage should be started before a "preceding" stage is completed, the stage being started should have its own entrance criteria separate from the exit criteria of the "preceding" stage. Thus, the use of stages corresponds to satisfying decision criteria before allowing further progress, providing a strong project control feature, whatever the sequence of stages within a given system's life cycle model.

Five common principles associated with a life cycle model are the following:

1) a system progresses through specific stages during its life;

2) enabling systems should be available for each stage in order to achieve the outcomes of the stage;

3) at specific life cycle stages, attributes, such as producibility, usability, supportability and disposability should be specified and designed into a system;

4) progression to another stage requires satisfaction of exit criteria of the current stage and possibly entrance criteria for the following stage or stages;

5) exit criteria are usually based on satisfactory outcomes of the stage being completed and may include demonstrable readiness to execute the processes in the subsequent stage or stages.

4.3.2 System life cycle stages

Life cycles vary according to the nature, purpose, use and prevailing circumstances of the system. Nevertheless, despite an apparently limitless variety in system life cycles, there is an underlying, essential set of characteristic life cycle stages that exists in the complete life cycle of any system. Each stage has a distinct purpose and contribution to the whole life cycle and should be considered when planning and executing the system life cycle.

The stages represent the major life cycle periods associated with a system and they relate to the state of the system description or realization of the system's set of products or services. The stages describe the major progress and achievement milestones of the system through its life cycle. They give rise to the primary decision gates of the life cycle. These decision gates are used by organizations to contain the inherent uncertainties and risks associated with costs, schedule and functionality when creating or utilizing a system. The stages thus provide organizations with a framework within which management has high-level visibility and control of project and technical processes.

Table 1 shows a commonly encountered example of life cycle stages. Also shown are the principal purposes of each of these stages and the possible decision options used to manage the achievement and risk associated with progression through the life cycle.

Table 1 — Example of stages, their purposes and major decision gates

Life cycle stages	Purpose	Decision options
Concept	Identify stakeholders' needs Explore concepts Propose viable solutions	— Begin subsequent stage or stages — Continue this stage — Go to or restart a preceding stage — Hold project activity — Terminate project
Development	Refine system requirements Create solution description Build system Verify and validate system	
Production	Produce systems Inspect and test	
Utilization	Operate system to satisfy users' needs	
Support	Provide sustained system capability	
Retirement	Store, archive or dispose of system	

Organizations employ stages differently to satisfy contrasting business and risk mitigation strategies. Using stages concurrently and, in a few cases, even in different orders, can lead to life cycle forms with distinctly different characteristics. Sequential, incremental or evolutionary life cycle forms are frequently used. Alternatively, a suitable hybrid of these can be developed. The selection and development of such life cycle forms by an organization depend on several factors, including the business context, the nature and complexity of the system, the stability of requirements, the technology opportunities, the need for different system capabilities at different times and the availability of budget and resources. In addition, major decision gates, often called milestones and reviews to focus on making the decisions may be incorporated by an organization on an incremental basis within a stage, as well as at the end of a stage, to further manage risks.

Just as all the system elements of a system contribute to the system as a whole, so each stage of the life cycle needs to be considered during any other stage of the life cycle. As a consequence, the contributing parties need to coordinate and cooperate with each other throughout the life cycle. This synergism of the life cycle stages and the functional contributors is necessary for successful project actions. Close communication with project team members from the different functions and organizations responsible for other life cycle stages leads to consistency in the life cycle.

4.3.3 Stages in a system-of-interest and its enabling systems

As with any system, each enabling system also has its own life cycle. Each life cycle is linked and synchronized to that of the system-of-interest. For example, if an enabling system does not already exist, its requirement is defined during the Concept Stage of the system-of-interest (or later if lead times permit), before the enabling system is utilized as shown in Figure 7 to provide its particular service to the system-of-interest.

An enabling system may pre-exist the system-of-interest, i.e. be an existing part of the infrastructure of the organization responsible for the system-of-interest or be in a service supplier's organization. Pre-existing enabling systems can introduce additional constraints on the system-of-interest.

Each enabling system can itself be considered as a system-of-interest, having in turn its own enabling systems. Therefore, the concepts in this document can also be applied to enabling systems.

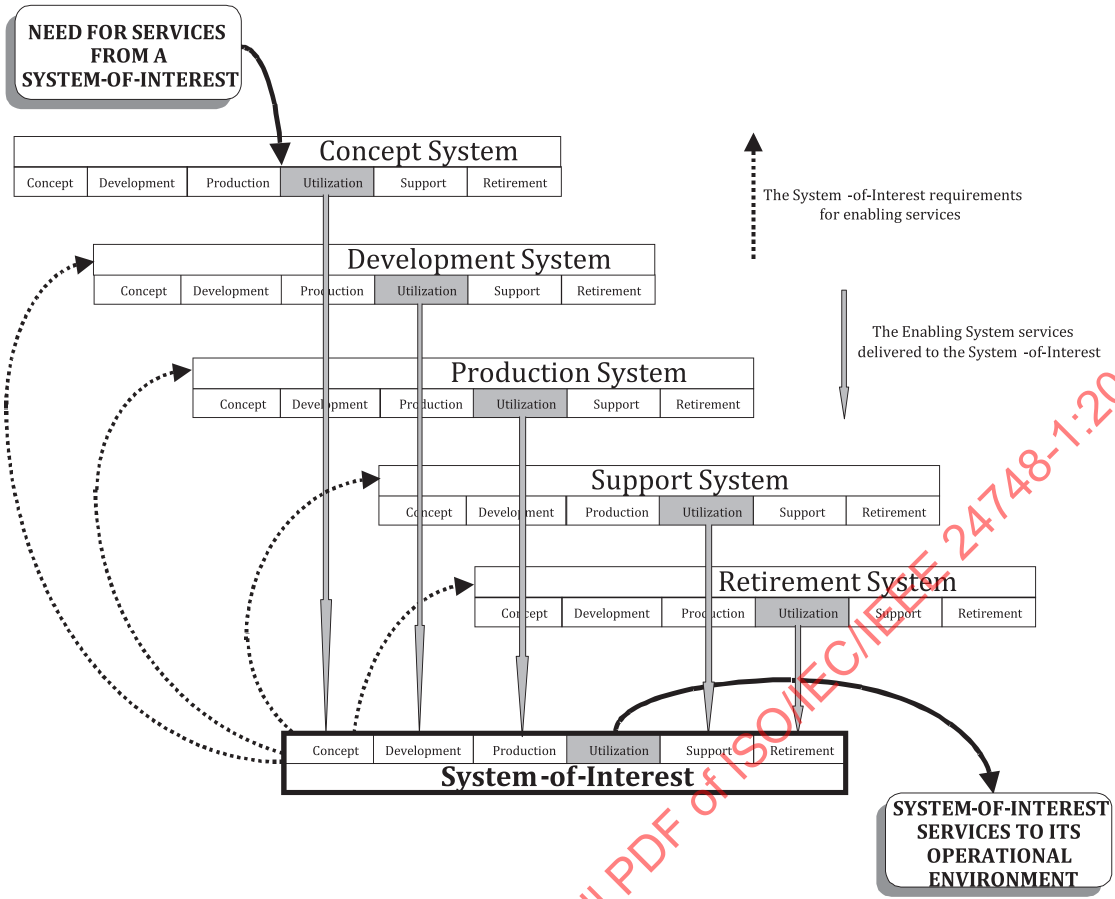

Figure 7 — System interaction with typical enabling systems

5 Life cycle stages

5.1 General

Life cycle stages are the specific framework within which system life cycle processes are applied to life cycle models. The value of stages is that entry into and exit from each stage represents a decision point. Therefore, progress is explicitly gated and the criteria for each step of progress, moving to the next stage is also explicit. These criteria determine when a stage can be exited and when the next appropriate stage can be commenced. For stages that follow each other in linear fashion, the exit and entrance criteria are the same. However, more complex stage relationships may necessitate separate exit and entrance criteria.

Each life cycle process of ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 can be invoked at any point throughout the life cycle, as was noted in 4.2.1. The order and sequence in which processes are invoked, and when they are invoked, is driven by the project requirements and context: there is no unique definitive order or time sequence for their use within a stage or across several stages. Note that, for a given process, the outcome or outcomes for one stage may not be the same as for other stages. It is necessary to consider the outcome or outcomes for each process invoked during a given stage to support the exit criteria for that stage and the entrance criteria for any ensuing stages.

So, system, software, service (or other) life cycle processes can be invoked concurrently, iteratively, recursively and time dependently in whatever stages of an individual system, software, service, or other life cycle model applicable to a given project. The scale and rigour of process application in the listed stages and the duration of these stages will be determined by the varying business and technical needs of the projects defining and using the life cycle model.

The processes invoked are generally performed by systems other than the system-of-interest, e.g. by enabling systems.

This document describes the following six stages as examples:

a) Concept Stage;

b) Development Stage;

c) Production Stage;

d) Utilization Stage;

e) Support Stage;

f) Retirement Stage.

In the following subclauses, for each example stage, an overview description is given, followed by descriptions of the example stages purpose and outcomes.

5.2 Concept Stage

5.2.1 Overview

The Concept Stage begins with initial recognition of a need or a requirement for a new system-of-interest or for the modification to an existing system-of-interest. This is an initial exploration, fact finding and planning period when economic technical, strategic and market bases are assessed through acquirer/market survey, business or mission analysis, solution space identification and feasibility analysis and trade-off studies. Acquirer/user feedback to the concept is obtained.

One or more alternative concepts to meet the identified need or requirement are developed through analysis, feasibility evaluations, estimations (such as cost, schedule, market intelligence and logistics), trade-off studies, and experimental or prototype development and demonstration. The need for one or more enabling systems for development, production, utilization, support and retirement of the system-of-interest is identified and candidate solutions are included in the evaluation of alternatives in order to arrive at a balanced, life cycle solution. Typical outputs are stakeholder requirements, concepts of operation, assessment of feasibility, preliminary system requirements, outline architecture and design solutions in the form of drawings, models, prototypes, etc., and concept plans for enabling systems, including whole life cost and human resource requirements estimates and preliminary project schedules. Decisions are made whether to continue with the implementation of a solution in the Development Stage or to cancel further work.

It is presumed that the organization has available enabling systems for the Concept Stage that consist of the methods, techniques, tools and competent human resources to undertake market/economic analysis and forecasting or mission analysis, feasibility analysis, trade-off analysis, technical analysis, whole life cost estimation, modelling, simulation, and prototyping.

5.2.2 Purpose

The Concept Stage is executed to assess new business opportunities or mission assignments and to develop preliminary system requirements and a feasible architecture and design solution.

5.2.3 Outcomes

The outcomes of the Concept Stage are listed below.

a) Plans and exit criteria for the Concept Stage.

b) The identification of new concepts that offer such things as new capabilities, enhanced overall performance, or reduced stakeholders' total ownership costs over the system life cycle.

c) An assessment of feasible system-of-interest concepts, with initial architectural and other solutions, including enabling systems throughout the life cycle, for closure against both technical and business or mission stakeholder objectives.

d) The preparation and baselining of stakeholder requirements and preliminary system requirements (technical specifications for the selected system-of-interest and usability specifications for the envisaged human-machine interaction).

e) Refinement of the outcomes and cost estimates for stages of the system life cycle model.

f) Risk identification, assessment and mitigation plans for this and subsequent stages of system life cycle model.

g) Identification and initial specification of the services needed from enabling systems throughout the life of the system.

h) Concepts for execution of all succeeding stages.

i) Definition of the enabling system services required in subsequent life cycle stages.

j) Project budget and schedule baselines and life cycle ownership cost estimates.

k) Satisfaction of stage exit criteria.

l) Approval to proceed to the appropriate stage or stages, based on the specific life cycle model in use by the project.

5.3 Development Stage

5.3.1 Overview

The Development Stage begins with sufficiently detailed technical refinement of the system requirements, system architecture, and the design solution and transforms these into one or more feasible products that enable one or more services during the Utilization Stage. The system-of-interest may be a prototype in this stage. The hardware, software, operator, process and facility interfaces are specified, analysed, designed, fabricated, integrated, tested and evaluated, as applicable and the requirements for production, training and support facilities, and transitions, are defined. This stage also involves considering and incorporating into the design the applicable constraints of other stages (production, utilization, support, and retirement) and their enabling systems' requirements and capabilities. Feedback is obtained from stakeholders and those who will produce, operate, use, support and retire the system-of-interest through such means as a series of technical or other reviews. Outputs are a system-of-interest or a prototype of the final system-of-interest, refined requirements for enabling systems or the enabling systems themselves and all documentation and cost estimates of future stages.

Planning for this stage includes preparing to establish an infrastructure of development enabling systems consisting of facilities, processes, procedures, methods, techniques, tools and competent human resources to undertake analysis, modelling and simulation, prototyping, design, integration, test, transition and documentation. These items are developed or acquired to be available when needed to support development.

5.3.2 Purpose

The Development Stage is executed to develop a system-of-interest that meets stakeholder requirements and can be produced, tested, evaluated, operated, supported and retired.

5.3.3 Outcomes

The outcomes of the Development Stage are listed below.

a) Plans and exit criteria for the Development Stage.

b) Architectural and design artefacts for the system of interest.

c) A system-of-interest structure comprised of, for example, hardware elements, software elements, human elements, process elements, facility elements and the interfaces (internal and external) of all such elements.

d) Verification and validation documentation.

e) Transition planning documentation.

f) Evidence supporting a decision, with all risks and benefits considered, that the system-of-interest meets all specified requirements and is producible, operable, supportable and capable of retirement and is cost-effective for stakeholders.

g) Refined and baselined requirements for the enabling systems, along with methods and tools for establishing and maintaining traceability between requirements and the developed system.

h) A prototype or final system-of-interest.

i) Refined outcomes and cost estimates for the Production, Utilization, Support and Retirement Stages.

j) Identification of current risks and determination of their treatment.

k) Satisfaction of stage exit criteria.

l) Approval to proceed to the appropriate stage or stages, based on the specific life cycle model in use by the project.

5.4 Production Stage

5.4.1 Overview

The Production Stage begins with the approval to produce the system-of-interest. The system-of-interest may be individually produced, assembled, integrated and tested, as appropriate, or may be mass-produced. Planning for this stage begins in the preceding stage. Production may continue throughout the remainder of the system life cycle. During this stage, the system may undergo enhancements or redesigns, the enabling systems may need to be reconfigured and production staff re-trained in order to continue evolving a cost-effective service from the stakeholder view.

It is presumed that the organization has available the budget and enabling systems that consist of production equipment, facilities, tools, processes, procedures and competent human resources. These items are developed or acquired in order to be available when needed to enable production.

5.4.2 Purpose

The Production Stage is executed to produce or manufacture the system-of-interest, test it and produce related enabling systems as needed.

5.4.3 Outcomes

The outcomes of the Production Stage are listed below.

a) Plans and exit criteria for the Production Stage.

b) Qualification of the production capability.

c) Acquisition of resources, material, services and system elements to support the target production quantity goals.

d) The system produced according to approved and qualified production information.

e) Packaged product transfer to distribution channels or acquirer.

f) Updated concepts for execution of all succeeding stages.

g) Current risks and mitigating actions identified.

h) Quality assured systems-of-interest accepted by the acquirer.

i) Satisfaction of stage exit criteria.

j) Approval to proceed to the appropriate stage or stages, based on the specific life cycle model in use by the project.

5.5 Utilization Stage

5.5.1 Overview

The Utilization Stage begins after installation and transition to use of the system. The Utilization Stage is executed to operate the product at the intended operational sites to deliver the required services with continuing operational and cost-effectiveness. This stage ends when the system-of-interest is taken out of service.

Planning for this stage begins in the preceding stages. This stage includes those processes related to use of the system to provide services, as well as monitoring performance and identifying, classifying and reporting of anomalies, deficiencies, and failures. The response to identified problems includes taking no action; maintenance and minor (low cost/temporary) modification; major (permanent) modification and system-of-interest life extensions, and end-of-life retirement.

During this stage, the product or services can evolve giving rise to different configurations. Enabling systems may likewise evolve. The operator operates the different configurations and the responsible product supplier manages the status and descriptions of the various versions and configurations of the product or services in use.

It is presumed that the organization has available the Utilization Stage enabling system which could include elements such as facilities, hardware and software, processes, procedures, trained personnel, documentation and data. These items are developed or acquired in order to be available when needed to support utilization.

5.5.2 Purpose

The Utilization Stage is executed to operate the product, to deliver services within intended environments and to help achieve continuing operational effectiveness.

5.5.3 Outcomes

The outcomes of the Utilization Stage are listed below.

a) Plans and exit criteria for the Utilization Stage.

b) Experienced personnel with the competence to be operators in the system-of-interest and provide operational services.

c) An installed system-of-interest that is capable of being operated and of providing sustainable operational services.

d) Performance and cost monitoring and assessment to confirm conformance to service objectives.

e) New opportunities for system-of-interest enhancement through stakeholder feedback.

f) Current risks and mitigation actions identified.

g) Satisfaction of stage exit criteria.

h) Approval to proceed to the appropriate stage or stages, based on the specific life cycle model in use by the project.

5.6 Support Stage

5.6.1 Overview

The Support Stage begins with the provision of maintenance, logistics and other support for the system-of-interest's operation and use. Planning for this stage begins in the preceding stages. The Support Stage is completed with the retirement of the system-of-interest and termination of support services.

This stage includes those processes related to providing services that support utilization of the system-of-interest. This stage also includes processes to use and monitor the support system itself and its services, including the identification, classification, and reporting of anomalies, deficiencies and failures of the support system and services. Actions to be taken as a result of identified problems with the support system include maintenance and minor modification of the support system and services, major modification of the support system or services, and end-of-life retirement of the support system and services.

During this stage, the support system and services can evolve under different versions or configurations. The support organization operates the different versions or configurations and the responsible product organization manages the status and descriptions of the various versions and configurations of the support system and services in use.

It is presumed that the supporting organization has available the enabling systems, which consist of facilities, equipment, tools, processes, procedures, trained support personnel and maintenance manuals. The items making up the support enabling system are developed and acquired in order to be ready when needed to support the system-of-interest.

5.6.2 Purpose

The support stage is executed to provide logistics, maintenance, and support services that enable continuing system-of-interest operation and a sustainable service.

5.6.3 Outcomes

The outcomes of the Support Stage are listed below.

a) Plans and exit criteria for the Support Stage.

b) Trained personnel who will maintain the system and provide the support services.

c) Organizational and enabling system interfaces for problem resolution and corrective actions.

d) Maintained product and services and the provision of all related support services, including logistics, to the operational sites.

e) Identification of problems or deficiencies, informing appropriate parties (user, development, production, or support) of the need for corrective action.

f) Product and service maintenance and corrected design deficiencies.

g) All required logistics support provided, including a spare parts inventory sufficient to satisfy operational availability goals.

h) Current risks and mitigating actions identified.

i) Satisfaction of stage exit criteria.

j) Approval to proceed to the appropriate stage or stages, based on the specific life cycle model in use by the project. Ordinarily, this would be the Retirement Stage.

5.7 Retirement Stage

5.7.1 Overview

The Retirement Stage provides for the removal of a system-of-interest and related operational and support services, including appropriate disposal of specified system elements. Planning for the Retirement Stage begins in the preceding stages. This stage begins when a system-of-interest is taken out of service.

This stage includes those processes related to operating the system that enables retirement of the system-of-interest (the retirement enabling system), including appropriate disposal of specified enabling system elements, and also includes monitoring performance of that enabling system and the identification, classification, and reporting of anomalies, deficiencies, and failures of the retirement enabling system. Actions to be taken as a result of identified problems include maintenance and minor modification of the retirement enabling system, major modification of the retirement enabling system, and end-of-life retirement of the retirement enabling system itself.

It is presumed that the organization has access to an enabling system, which consists of facilities, tools, processes, procedures, equipment, trained personnel and, as appropriate, access to recycling, disposal or containment facilities. The items making up the retirement enabling system are developed and acquired in order to be ready when needed to perform retirement functions.

This stage is applicable whenever a system-of-interest reaches its end-of-service life. Such end-of-service life can be the result of replacement by a new system, irreparable wear, catastrophic failure, no further use to the user (e.g. through change in mission or business direction), or when it is no longer cost-effective to continue operating and supporting the system-of-interest.

5.7.2 Purpose

The Retirement Stage is executed to provide for the removal of a system-of-interest and related operational and support services, and to operate and support the retirement system itself.

5.7.3 Outcomes

The outcomes of the Retirement Stage are listed below.

a) Plans and exit criteria for the Retirement Stage.

b) Disposal constraints are provided as inputs to requirements, architecture, design, and implementation.

c) Any enabling systems or services needed for disposal are available.

d) Agreement to terminate support services.

e) Residual risks and mitigating actions identified.

f) The system elements or waste products are destroyed, stored, reclaimed or recycled in accordance with safety and security requirements.

g) The environment is returned to its original or an agreed state.

h) Records of disposal actions and analysis are available.

i) Satisfaction of stage exit criteria.

6 Life cycle adaptation

6.1 General

No two projects are the same. Each organization is driven by the nature of its mission or business, its social responsibilities and its forward strategy. These provide constraints on available opportunities that the organization and its projects can exploit. To help exploit opportunities, the organization establishes policies and procedures to guide the performance of projects. Variations in organizational policies and procedures, acquisition methods and strategies, project size and complexity, system requirements and development methods, among other things, influence how a system is acquired, developed, operated, or maintained.

To help establish these policies and procedures and to determine the resources needed by the organization, International Standards, such as ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 can be used to provide specific standardized processes for use within one or more life cycle models. However, in the interest of cost reduction and quality improvement, the processes from the International Standards, as well as life cycle models, may be adapted, in the dictionary sense of the word, for an individual project to reflect the variations appropriate to the organization, project and system. The framework for adapting processes is given ISO/IEC/IEEE 15288:2015, Clause 2, 5.5.4 and Annex A and ISO/IEC/IEEE 12207:2017, Clause 4, 5.5.4 and Annex A. The following Clauses of this document give guidance for adapting the life cycle model itself.

6.2 Adaptation sequence

6.2.1 General

Figure 8 gives an illustrative sequence of steps that can be followed to adapt the life cycle model to a particular need. First, the adaptations reflecting the project environment are addressed, and then inputs on possible changes are solicited from potentially affected parties. After that, the specific life cycle model is selected.

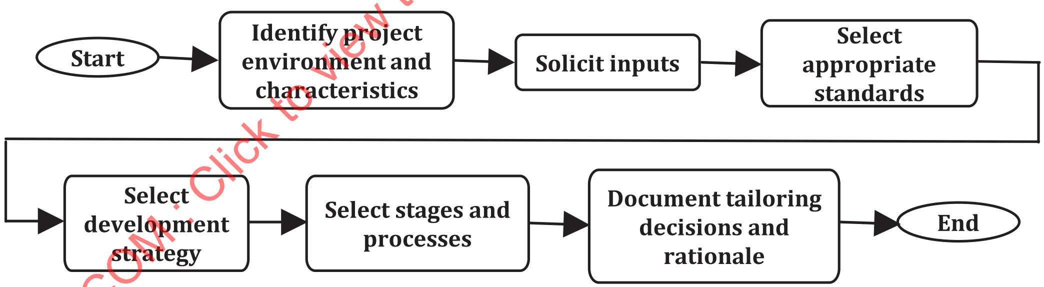

Figure 8 — Adaptation sequence

6.2.2 Identify the project environment and characteristics

Organizational characteristics may be determined by considering such issues as organizational policies and procedures. Identify the relevant policies and procedures of the organizations involved, particularly of the acquirer and supplier, with which the project needs to comply. Examples include policies and procedures related to: security, safety, privacy, risk management, use of an independent verification and validation agent, use of a specific computer programming language and, hardware resourcing. Pertinent laws and regulations that may impact the project, including those related to environment, public safety and privacy, should be identified and subsequently monitored for compliance.

6.2.3 Solicit inputs

The requirements derived from the relevant business or mission and contractual needs are major drivers in adapting the life cycle model to support using the processes from an International Standard.

Affected parties should be involved in the adaptation decisions. These parties can help ensure that the resulting adapted life cycle model is feasible and useful. Where possible, include feedback from previous projects. For example, the life cycle model for a project using ISO/IEC/IEEE 12207 could be adapted according to the contract between a supplier and the purchaser of a software product. A customer may only require the design of software to be carried out and not full development of a software system, which would be reflected in one or more stages and their relationships in the life cycle model. In another instance, if the customer requirements are for safety critical software instead of consumer software, it might be appropriate for the acquirer to require the execution of activities and tasks beyond those provided in ISO/IEC/IEEE 12207, which could, for example, affect the exit criteria of a specific life cycle stage or stages.

6.2.4 Select the appropriate standards

ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 provide an interoperable suite of processes suitable for the life cycles of both system and software products. Projects may vary in their relative emphasis upon system and software aspects. This variation may inform the choice of standards appropriate to the project.

— For system projects that have only minor software content, the use of the processes of ISO/IEC/IEEE 15288 may be sufficient. In this case, ISO/IEC/IEEE 12207 need not be applied.

— For software projects that have only minor system-level content, the use of the processes of ISO/IEC/IEEE 12207 may be sufficient. In this case, ISO/IEC/IEEE 15288 need not be applied.

— For projects that have both extensive hardware and software content in their system of interest, the use of both standards may be merited. While the process purposes and outcomes are identical in ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288:2015, the activities and tasks are adapted to suit the respective domain needs. One criterion for selecting the source of the process may depend on the acquisition strategy. For example, if the system-level prime contractor is performing all system transition (deployment of systems with embedded software), the prime may not be concerned with the details of software configuration management performed while the software is under development by a subcontractor. Such choices can affect the characteristics of the life cycle model that will best support execution of the processes in the International Standards that are used.

6.2.5 Select development strategy

Determine which development strategy is most relevant and applicable for the system, such as waterfall, evolutionary, incremental, pre-planned product improvement, or spiral. Each such strategy prescribes certain processes and activities that may be performed sequentially, repeated, and combined; in these strategies, the life cycle processes in the relevant International Standards should be mapped to the selected strategy and, in turn, mapped to the specifics of the life cycle model used for the project. For evolutionary, incremental, and pre-planned product improvement models, the outputs of one project activity feed into the next. In these cases, the documentation should be complete at the end of an activity or a task and the exit criteria of the life cycle model should reflect that fact. (Annex E of this document provides guidance on development strategies and build planning.)

Note that the determination of development strategy must be performed for the system and for each system element that is itself developmental and similarly for all enabling systems.

6.2.6 Select stages and processes

Identify the relevant life cycle model stages that need to be distinguished for the project, as well as their entry and exit criteria and their relationship (serial, parallel, wholly or partly combined). Define the outcomes that determine successful completion of each of the stages and the milestones or decision gates that distinguish them. Also, select and prioritize the processes of the appropriate International Standards that will be implemented to achieve the outcomes of the stages.

NOTE In implementing a suite of processes intended to be applied uniformly throughout an organization, it is usually preferable to start with those processes that will achieve the most significant returns, rather than attempting to implement all of the International Standard at once.

International Standards, such as ISO/IEC/IEEE 15288 or ISO/IEC/IEEE 12207 do not define the sequencing of processes and activities and they do not prescribe any particular life cycle model. Mapping the organization's current processes, practices and/or methods to the processes, activities and tasks of the applicable International Standard is useful at this stage. The mapping may be used to verify the completeness of the approach; that is, to identify where gaps exist between the current situation and the target situation where processes from the International Standard are used.

6.2.7 Document the adaptation decisions and rationale

When applying International Standards, such as ISO/IEC/IEEE 12207 or ISO/IEC/IEEE 15288, a mapping of the defined processes and activities onto the selected life cycle model should be documented, together with the determined relationships and the reasons for adopting this approach. The verification of this work is to demonstrate that the outcomes of each stage will be achieved by the processes selected to implement the stage. This documentation should be incorporated into the project management plan for implementing the applicable International Standard as it provides a reference framework for evaluating the success or otherwise of the approach taken.

Specific guidance and examples of adaptation can be found in ISO/IEC/IEEE 24748-2 and ISO/IEC TR 24748-3, the application guidelines for International Standards ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207, respectively.

6.3 Life cycle model adaptation guidance

6.3.1 General

ISO/IEC TR 24748-3:2011, Clause 5, and ISO/IEC/IEEE 24748-2:—, 5.8 provide general guidance on adapting applications of International Standards ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288. This sub clause provides guidance on life cycle model scope and stage adaptation, as well as adaptation for specific domains, disciplines and specialities.

Whatever life cycle model is used in dealing with problems arising during the execution of life cycle processes, it is useful to maintain a unified problem reporting capability. By its nature, a unified capability may deal with large numbers of problems. It is therefore useful to categorize the problems in various ways. Annex G describes two classifications: by category and by priority. Others may be applicable in particular situations.

Additional adaptation considerations can be found in the conformance requirements of the International Standard.

6.3.2 Scope adaptation

As an example, if an organization does development only and is not involved in the utilization, support, or retirement life cycle stages that organization could adapt the scope of the applicable International Standard accordingly by selecting only the appropriate processes. The policies and procedures called for in the non-applicable parts of the International Standard would not be included in the organization's policies and procedures. Additionally, inputs such as those listed below can help shape the policies and procedures of an organization are the following:

a) life cycle model and related entry or exit criteria used by the organization for decision making, as well as for establishing milestone reviews of a project. Select one or more appropriate life cycle models for the project, since hardware, software, humans and other aspects of the system may have their own life cycles. Determine whether the hardware, software, or other life cycle model is a sub-part of the life cycle model of the system of interest, or enabling system, or is the complete life cycle model;

b) resource availability and the resources the organization is willing to commit;

c) expertise and skills available to the organization to provide the organization's products and services;

d) technology available for the organization's products and services.

6.3.3 Stage adaptation

Depending on the specific system-of-interest and the environment in which a project is established to realize it, stages may be combined, eliminated, or added to the generic model. For example, an organization may buy a concept, establish a project to design and produce a system, then turn the result over to another organization for marketing to consumers, or operation and maintenance. In another case, there could be repeated iterations between concept and development stages or lengthy evolution after fielding of a system. Each stage in these cases would have different criteria for entry and exit, as well as possibly drawing on different processes. Accordingly, each stage in the life cycle, as well as the juxtaposition of each stage with those before and after it, requires specific consideration for the project and system to be realized.

6.3.4 Life cycle model adaptation for domains, disciplines and specialties

6.3.4.1 Adaptation for domains

The life cycle model that is appropriate at the system level may need adaptation if the system-of-interest falls largely or entirely within one domain, such as software. Further, the life cycle model that best reflects events in one domain (such as software) may not be equally suitable for others (such as hardware, humans, processes, procedures, facilities and naturally occurring entities), as is illustrated by the examples shown in Figure 9. Note that, for simplicity of illustration, these are drawn as if the stages are linearly sequential. However, as discussed in 4.3.1, the relations between stages are usually more complex.

The life cycle stages shown are illustrative only; this is not an exhaustive list of possible life cycle models. For example, using life cycle models is just as relevant to services as it is to hardware, software, or other products. A life cycle model for service management could include stages of: Service Strategy; Service Design; Service Transition; Service Operation and; Continual Service Improvement, as shown in Figure 9. The advantage to a service organization of using a life cycle model approach is that it gives them a unifying framework for examining what processes they need to have do their work. If a service management organization viewed itself as doing nothing but service operations, not thinking in terms of a life cycle model, it could, for example, fail to consider continual service improvement or not occasionally re-examine its service strategy. That could make the organization less desirable to a customer compared to a service management organization that uses a life cycle model framework to keep its competitive view, as wide as possible.

Note that, for all models, the length of any one stage or of the entire model, does not represent any uniform time scale or coincident start or stop timing.

The basic point is that each domain should be considered as an entity that can have a series of stages through which it goes, forming a life cycle model for that domain. As a result, when a system has elements that span multiple domains,

a) every domain's life cycle model should be thought through, and

b) the life cycle models and their stages should be considered as a whole and care taken that they work in concert.

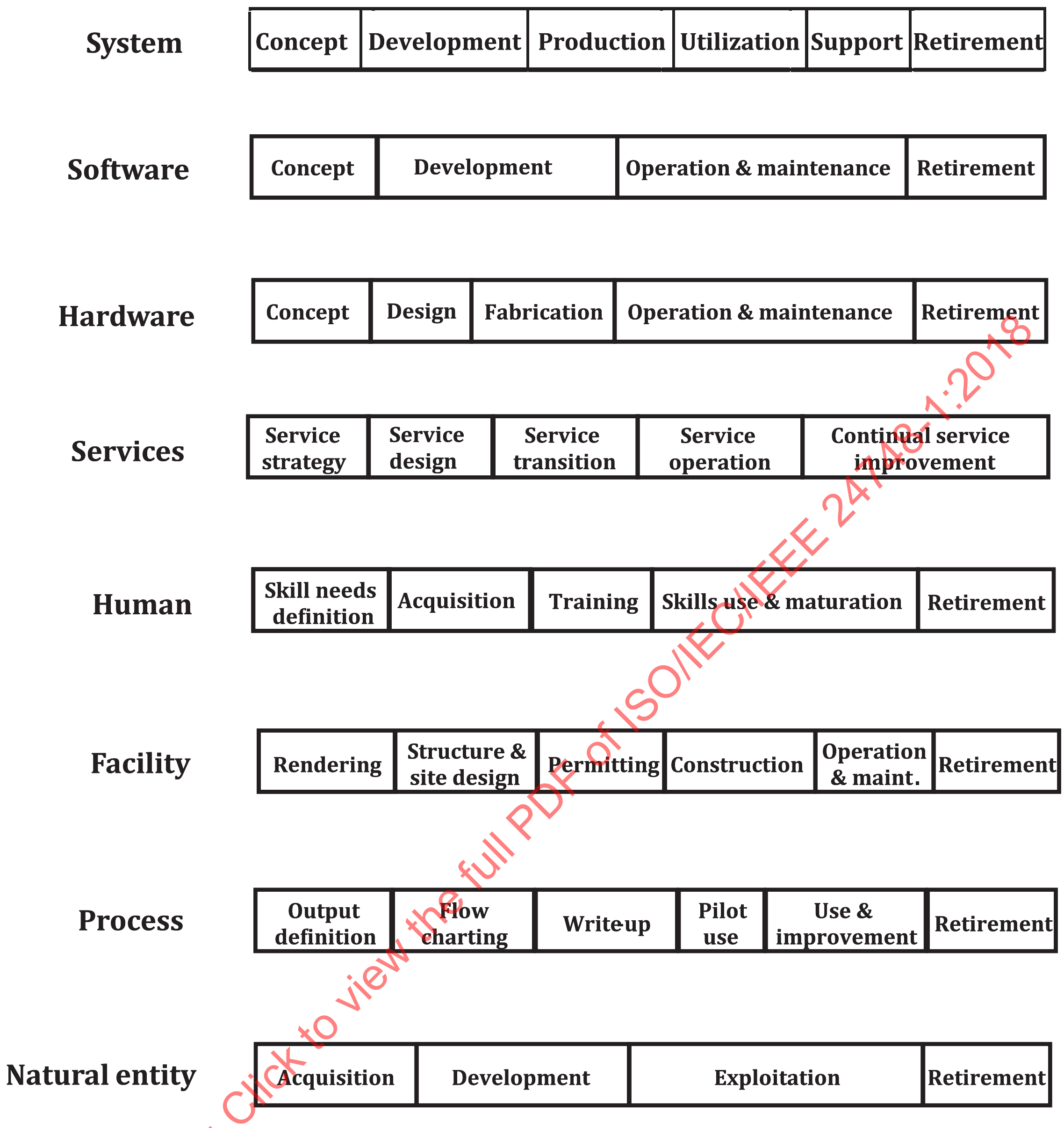

Figure 9 — Illustrative examples of domain life cycle models

6.3.4.2 Adaptation for disciplines

In general, life cycle models would not need to be developed or adapted for a specific discipline (such as mechanical engineering, electrical engineering, civil engineering, quality, system administration). Instead, the processes associated with the life cycle model(s) in which that discipline is used would be adapted to reflect the overall considerations discussed in 6.1 of this document, possibly with additional adaptation for the discipline itself. For example, the agreement processes associated with a facility could be adapted to the specific facility project. In addition, some details might be adapted to reflect civil engineering concepts, practices, or terminology.

6.3.4.3 Adaptation for specialties

6.3.4.3.1 General

The focus of International Standards for systems and software is on the engineering, operation, maintenance and disposal of complex man-made products. Each product can have critical qualities that should be considered, with possible adaptation of specific processes, so that the product can be successful. The list of these critical qualities is long and not well agreed on and could include, but not be limited, to such areas as: human factors, health and safety, reliability, maintainability, availability, supportability/usability, security, environmental impacts (including disposability), electromagnetic compatibility, mass properties, interoperability. These critical qualities, although requiring special knowledge and expertise in one area, generally cannot be evaluated in isolation from each other. For example, assessments of safety, human factors, and environmental compatibility may need to be done as one integrated effort and that assessment could link to yet others. Some, though obviously not all, of the critical qualities are discussed below to illustrate adaptation for specialities.

6.3.4.3.2 Human

Human interaction with products and services associated with a system should be looked at from the perspective of impacts on operators, users and the general public. Impacts should be analysed to determine adverse impacts that should be avoided or mitigated through product related design requirements that could mitigate the adverse impacts identified.

6.3.4.3.3 Health

Planned usage rates and environments, operational concepts and other requirements can present health risks with respect to potential damage to human life including operators and others (both people and animals) that come in contact with the product or exist within its operational environment. Use cases, human-machine interfaces, operating environments, electromagnetic radiation, heat and noise emissions and waste materials should be analysed to determine such risks. Outcomes from such analyses should include specific health concerns and recommendations as to health-related design requirements that could prevent the health hazards identified.

NOTE Health issues can persist after the product is retired.

6.3.4.3.4 Safety

Operational concepts and other product requirements can present safety risks with respect to potential damage to human life, property and the environment. Use cases, human-machine interfaces, operating environments, electromagnetic radiation, heat and noise emissions, waste materials and failure modes should be analysed to determine such risks. Outcomes from such analyses should include specific safety concerns and recommendations as to safety related design requirements that could prevent the safety hazards identified.

6.3.4.3.5 Security

Operational concepts, usage environments and other product requirements can present security risks with respect to the product and its users. Risks include 1) access and damage to personnel, properties and information, 2) corruption, theft or compromise of sensitive information, 3) denial of approved access to property and information, 4) unauthorized system access and 5) loss of life or property. Applicable areas of security should be analysed to include physical security, communications security, computer security and electronic emissions security. Outcomes from such analyses should include specific security concerns and recommendations as to security related requirements that could mitigate the security risks identified.

6.3.4.3.6 Interoperability

Data flows are essential within a product and possibly between products so that operational functions can be successfully performed over the product's life. The potential failure causes of data (or information) to flow properly should be analysed to include use of appropriate communication connectivity protocols with external systems or internal systems within a system structure. Outcomes from such analyses should include specific interoperability concerns and recommendations as to related design requirements that could improve interoperability.

6.3.4.3.7 Usability

The operational effectiveness and hence the acceptance of many products depends on a user's ability to realize the intended capability of the product. Systems that include human elements depend on operators of the product performing tasks within specified times and required accuracies and with efficient and effective resource utilization. Use cases, human-machine interfaces, operating environments and training and operating procedures should be defined based on targets for usability such as understandability, learnability, operability and attractiveness, and evaluated against quality of use criteria, such as effectiveness, productivity, safety and satisfaction.

6.3.4.3.8 Dependability

The failure potential of any part of the product will determine whether the product will be available when and as long as it is needed during any operational use and at any given (random) time. Factors that affect dependability include mean-time-between-failures, mean-time-to-repair and administrative down time. Such factors should be analysed to determine their impact over the product life. Outcomes from such analyses should include specific dependability concerns and recommendations as to related requirements that could help make the product more dependable.

6.3.4.3.9 Environmental impacts

The impacts on the environment from short and long-term use of a product, and disposing of hazardous materials related to its use or retirement, can present risks to all life forms. Risks include loss of life, illness and lowering of the standard of living. Environmental impacts as a result of use or disposal of waste products from product use or from disposal of the product or one of its elements that have reached end-of-life, should be analysed. Outcomes from such analyses should include specific environmental impact concerns and recommendations as to related requirements that could reduce risks related to product use and eventual disposal.

6.4 Adapting evaluation-related activities

Persons who are involved in any activity of the life cycle of a project or a process may conduct evaluations either on their own or other's products and activities. This document groups these evaluations into five categories, which are listed below. The first four evaluation categories are at the project level; the last one is at the organizational level. These evaluations should be selected and adapted proportional to the scope, magnitude, complexity, and criticality of the project or of the organization. The problem, non-conformance, and improvement reports from these evaluations feed back into one or more of the life cycle processes shown in Figure 9.

a) Process-internal evaluations are conducted by personnel performing the assigned tasks within the process during their day-to-day activities.

b) Verification and Validation are conducted by the acquirer, the supplier, or an independent party, to verify and validate the products in varying depth depending on the project. These evaluations do not duplicate or replace other evaluations, but supplement them.

c) Joint reviews and audits are conducted in a joint forum by the reviewing and reviewed parties to evaluate status and compliance of products and activities on a pre-agreed to schedule. Additional guidance on joint reviews is given in Annex F.

d) Quality management is conducted by personnel independent of the personnel directly responsible for developing the product or executing the process. The goal is to *independently assure* conformance of the products and processes with the contract requirements and adherence to the established plans. This process may use the results from a, b, and c above as inputs. This process may coordinate its activities with those of a), b), and c).

e) Improvement is conducted by an organization for efficient management and self-improvement of its process. This is conducted regardless of project or contract requirements.

7 Relationship with detailed process standards

This document gives overall guidance on life cycles and adaptation that can be applied across the International Standards (the conformance documents) that could be applied to a particular situation. Further guidance on the application of the processes of each applicable International Standards would come from other International Standards and documents. These relationships are illustrated in Figure 10.

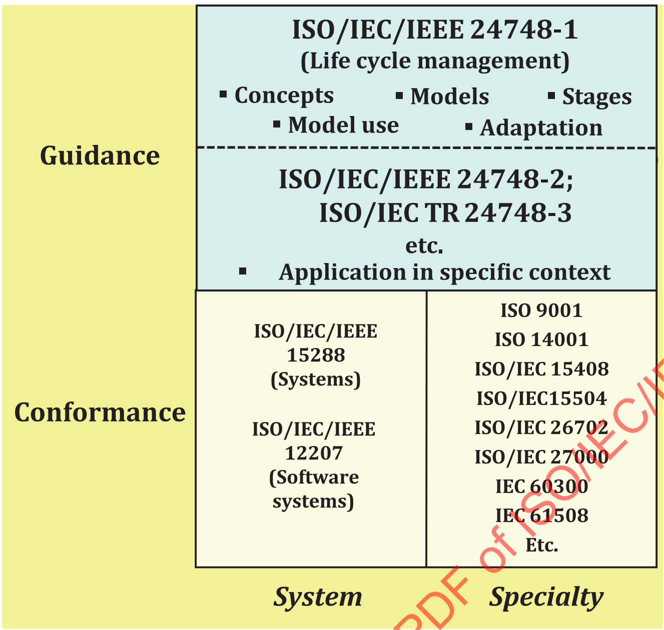

Figure 10 — ISO/IEC/IEEE 24748 relationship to detailed process standards

ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 define a generic, top-level framework based upon a set of processes that can be combined into various suitable life cycle models. These documents do not, and are not intended to, define in detail systems engineering, software engineering, or the engineering of systems. However, the documents are expected to strengthen the relationships among systems engineering, software engineering and other affected engineering disciplines. They are intended to do this through promotion of consistent and uniform terminology among the various domains and engineering disciplines. They are also intended to establish interactions and improved communication between the various engineering disciplines needed to create systems.

The other International Standards address either domains (e.g. aircraft, cloud services) in detail, or treat specific disciplines or specialties. The International Standards are used as the basis for building applicable sets of life cycle processes that provide activities to achieve a stated goal. The processes defined by the International Standards are likely to be invoked during the whole life cycle of the system. The International Standards are, in turn, supported by application guidelines, such as ISO/IEC/IEEE 24748-2 for systems and ISO/IEC TR 24748-3 for software. This document thus provides spanning guidance in two key areas of interest across domains and disciplines, complemented by the specific conformance and guidance documents for each area. A more detailed view of the emphasis given each area (e.g. process definitions) by each of the International Standards and the related documents is shown in Table 2.

Table 2 — Overview of coverage and emphasis among International Standards and Guidance Documents

Area	ISO/IEC/IEEE 15288	ISO/IEC/IEEE 12207	ISO/IEC/IEEE 24748-1	ISO/IEC/IEEE 24748-2	ISO/IEC TR 24748-3
Process definitions	Systems engineering and common	Software engineering	General overview: what a process is and pointer to standards	n/a	n/a
Life cycle concepts	Summary		Detail	n/a	n/a
Life cycle stages	Summary		Detail	n/a	n/a
Life cycle tailoring	Process requirements		General guidance	Specific detail for systems engineering	Specific detail for software engineering
Life cycle application/usage	n/a		General guidance	Domain-specific guidance	Domain-specific guidance
Life cycle model examples/ illustrations	n/a		General guidance	Domain-specific examples	Domain-specific examples
Terminology	Systems engineering	Software engineering	Life cycle and pointer to standards	As needed	As needed
System process key concepts	Summary	n/a	n/a	Detail in systems context	n/a
Software process key concepts	n/a	Summary	n/a	n/a	Detail in software context
Organization/ project application	Summary		Summary in life cycle context	Detail in systems context	Detail in software context
Process application	Summary		Summary in life cycle context	Detail in systems context	Detail in software context
Process tailoring	Normative requirements		Summary in life cycle context	Example for systems	Example for software
Process reference model	Detail		General description and pointer to standards	n/a	n/a
Specialty applications	Summary		Summary in life cycle context	Detail in systems context	Detail in software context
Conformance	Included		n/a	n/a	n/a

Annex A
(informative)

Process concepts

A.1 General

Application of ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 presupposes an understanding of process concepts.

NOTE 1 Process concepts are introduced in ISO/IEC/IEEE 12207:2017, 5.5, and ISO/IEC/IEEE 15288:2015, 5.5.

NOTE 2 ISO/IEC TR 24774 provides guidance on process descriptions, which have been applied to the process descriptions used ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207.

The focus of ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 is on the processes that are applied within a life cycle. The processes can be used by organizations (for example functional organizations and projects) that play the role of acquirer, supplier (for example main contractor, subcontractor, or service provider) or management to fulfil responsibilities pertaining to the system of interest. Additionally, the processes in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 can be used as a reference model for assessments under the ISO/IEC 33000 family of standards.

A process is an integrated set of activities that transform inputs (for example a set of data such as requirements) into desired outputs (for example a set of data describing a desired solution). Controls and enabling mechanisms are associated with processes. These relationships are illustrated in Figure A.1 and described in A.1.1 through A.1.4.

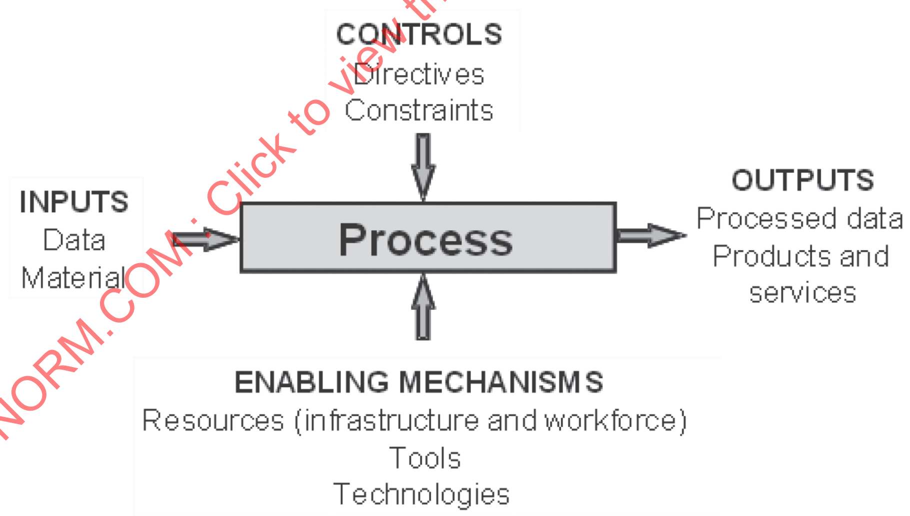

Figure A.1 — Example process inputs and outputs

An activity is a set of cohesive tasks. A task is a requirement, recommendation, or permissible action, intended to contribute to the achievement of one or more outcomes of a process.

A task is expressed in the form of a requirement, self-declaration, recommendation, or permissible action. For this purpose, ISO/IEC/IEEE 12207:2017, 4.1, NOTE 5 and ISO/IEC/IEEE 15288:2015, 2.1, NOTE 5 carefully employ certain auxiliary verbs to differentiate between the forms of tasks:

a) “Shall” is used to express a requirement of ISO/IEC/IEEE 15288:2015 or ISO/IEC/IEEE 12207;

b) “Should” to express a recommendation;

c) “May” to indicate permission.

Within a life cycle stage, processes are performed as required to achieve stated objectives. The progression of a system through its life is the result of actions managed and performed by people in one or more organizations using the processes selected for a life cycle stage.

A.1.1 Inputs

Inputs can come from outside an organization or project, or from other processes that precede or accompany the process being examined. Examples of inputs to a process include:

a) information, such as requirements, interface or architecture definitions;

b) data, such as measurements and test reports;

c) material that either ends up in the output or is consumed in producing the output;

d) services that are part of a chain of services, such as setting up a computer prior to, or coincident with establishing an account.

A.1.2 Outputs

Outputs can go to other processes or back to the same process (recursive processing) inside the organization, project (or both), or they can go outside the project or organization, or both. Examples of outputs parallels the examples given for inputs in A.1.1. However, the outputs are often (but not necessarily) transformed in some way by the process being examined.

A.1.3 Controls

Processes can be controlled by organizational or organization management directives and constraints and by governmental regulations and laws. Examples of such controls on a process include:

a) the project agreement;

b) the interfaces with processes used on other systems for which the project is responsible (see Clause 5.6.3 of this document);

c) the applicable system life cycle stage or stages;

d) internal standard practices of the organization, or the part of the organization, that has project responsibility.

A.1.4 Enabling mechanisms

Each process can have a set of process enabling mechanisms such as listed below:

a) the workforce that performs the tasks related to the process;

b) other resources required by the process such as facilities, equipment and funds;

c) tools (for example software and hardware, automated, manual) required for performing the process activities;

d) technologies required by persons performing the activities including methods, procedures and techniques.

The processes defined in ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 can be used by any organization when acquiring and using, as well as when creating and supplying, software or a system. They can be applied at any level in software’s or a system's structure and at any stage in the life cycle.

The life cycle processes are based on principles of ownership (a process is associated with a responsibility, discussed further in A.6) and modularity. That is, the processes are the following:

a) strongly cohesive, meaning that all the parts of a process are strongly related;

b) loosely coupled, meaning that the number of interfaces among the processes is kept to a minimum.

The processes described in ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 are not intended to preclude or discourage the use of additional processes that organizations find useful.

Organizations, when considering a new project, should select a life cycle model, such as shown in Figure 9 and the necessary life cycle processes to satisfy applicable life cycle stage entry or exit criteria. Decisions as to which processes to select should be based on cost-benefit or risk reduction. Within a life cycle stage, processes are performed as required to achieve stated objectives. The progression of a system through its life is the result of actions managed and performed by people in one or more organizations using the processes selected for a life cycle stage.

ISO/IEC/IEEE 15288:2015 and ISO/IEC/IEEE 12207:2017 provide a specific example of four groups of system life cycle processes: Agreement, Organizational Project-enabling, Technical Management and Technical. Each process has a specific purpose, a set of expected outcomes and a set of activities and tasks. Each group of processes is described in Clause 6 of each referenced International Standard and summarized below.

NOTE The process groups in ISO/IEC/IEEE 15288:2015 and ISO/IEC/IEEE 12207:2017 are identical. There are differences between the two standards at lower levels within a given group (i.e. purpose, outcomes, activities and tasks). Those differences do not affect the discussion of project groups in this sub clause.

A.2 Process application

Each system life cycle process in Figure A.2 can be invoked, as required, at any point, and at multiple points, throughout the life cycle and there is no definitive order or time sequence in their use. The detailed purpose and timing of use of these processes throughout the life cycle are influenced by multiple factors, including social, trading, organizational and technical considerations, each of which can vary during the life of a system. An individual system life cycle is thus a complex system of processes that will normally possess concurrent, iterative, recursive and time dependent characteristics. These statements are true for both a system-of-interest and any enabling systems.

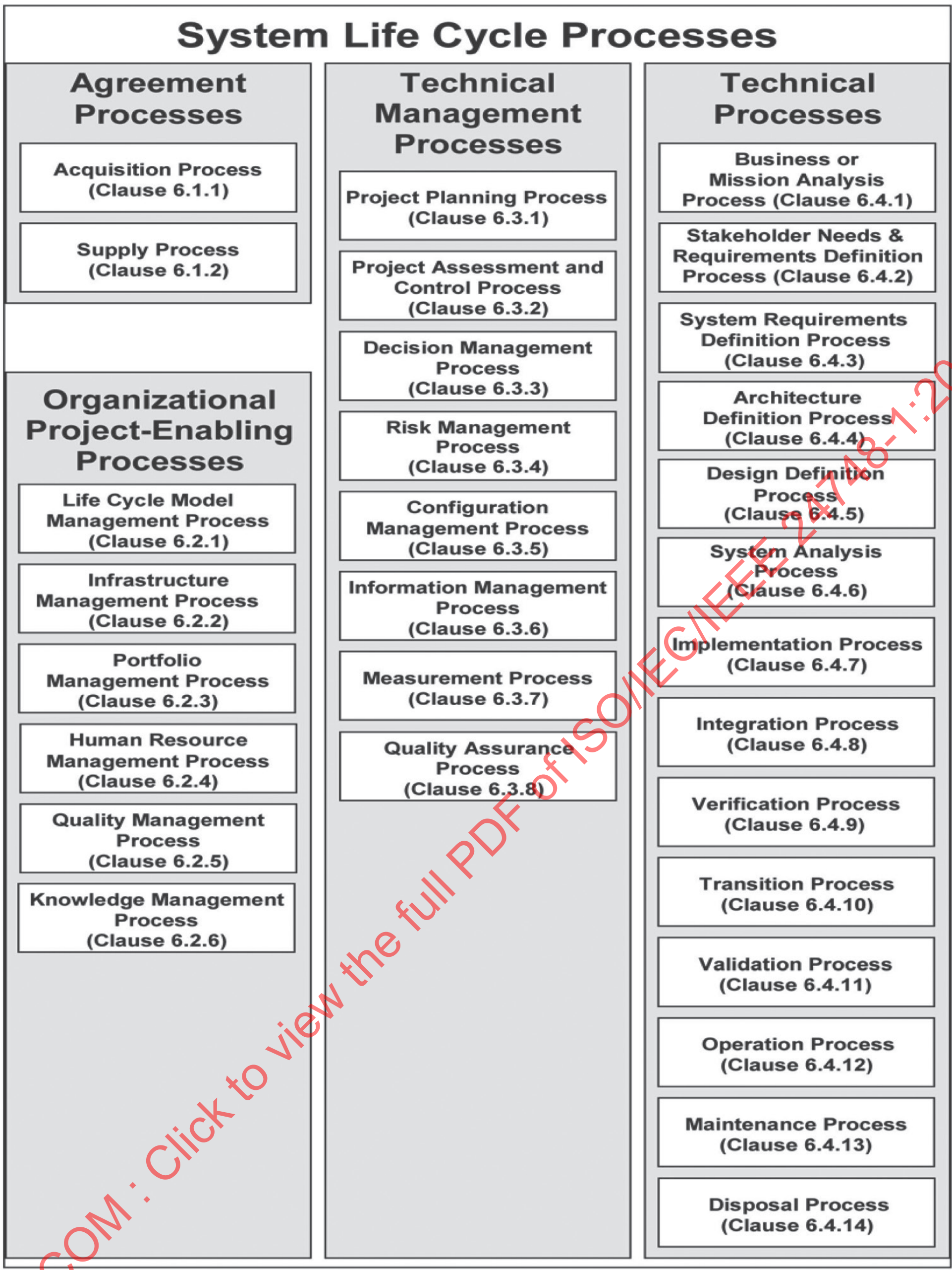

Figure A.2 — System life cycle processes

NOTE 1 In Figure A.2, the sub clause numbers refer to the sub clauses in ISO/IEC/IEEE 15288:2015 and ISO/IEC/IEEE 12207:2017 where the processes are described, not to the clauses in this document.

NOTE 2 In ISO/IEC/IEEE 12207:2017, the heading for the figure in that standard is Software Life Cycle Processes and the process in ISO/IEC/IEEE 12207:2017, 6.4.3 is titled System/Software Requirements Definition Process.

Concurrent use of processes can exist within a project, e.g. when design actions and preparatory actions for building a system are performed at the same time, as well as between projects, e.g. when different system elements are designed at the same time under different project responsibility.

The changing nature and complexity of the influences on the system (e.g. operational environment changes, new opportunities for system element implementation, modified structure and responsibilities in organizations) requires continual review of the selection and timing of process use. Process use in the life cycle is thus dynamic, responding to the many external influences on the system.

The life cycle stages assist the planning, execution and management of life cycle processes in the face of this complexity in life cycles by providing comprehensible and recognizable high-level purpose and structure. Precedence, particularly in similar market and product sectors can assist the selection of stages and the application of life cycle processes to build an appropriate and effective life cycle model for any system.

A.3 Process groups of ISO/IEC/IEEE 15288:2015 and ISO/IEC/IEEE 12207:2017

The four process groups of ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288:2015, as well as the primary relationships between the groups, are portrayed in Figure A.3. The role of the Organizational Project-enabling and Technical Management groups of processes is to achieve the project goals within applicable life cycle stages to satisfy an agreement. Organizational Project-Enabling processes provide enabling resources and infrastructure that are used to create, support, and monitor projects and to assess project effectiveness. The Technical Management processes provide requirements so that adequate planning, assessment, and control activities are performed to manage processes and life cycle stages.

Appropriate processes are selected from the Technical Processes and used to populate projects in order for the project to perform life cycle related work.

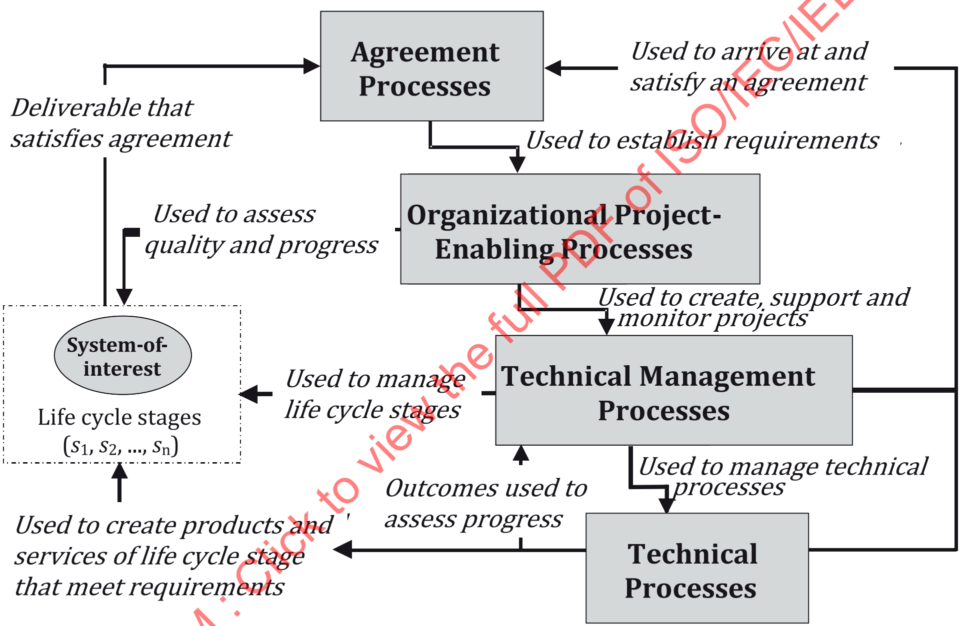

Figure A.3 — Role of the ISO/IEC/IEEE 15288:2015 and ISO/IEC/IEEE 12207:2017 processes

Projects may need to establish relationships with other projects within the organization, as well as those in other organizations. Such relationships are established through the agreement processes of acquisition and supply as shown in Figure A.4. The degree of formality of the agreement is adapted to the internal or external business relationships between projects.

NOTE An example and discussion of the use of the agreement processes is provided in ISO/IEC/IEEE 24748-2:—, 6.7.1.

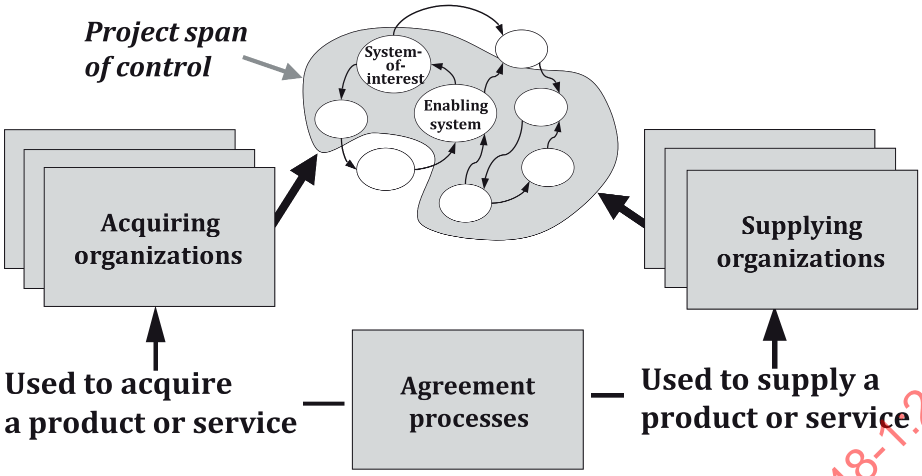

Figure A.4 — Use of agreement processes

A.4 Agreement processes

The agreement processes are applicable for establishing the relationship and requirements between an acquirer and supplier. The agreement processes provide the basis for initiation of other project processes to enable arriving at an agreement to conceive, develop, produce, utilize, support, or retire a system and to acquire or supply related services.

The agreement processes can be used for several purposes, such as listed below, to

a) form and specify completion of an agreement between an acquirer and a supplier for work on a system at any level of the system structure,

b) establish and carry out agreements to acquire a system or related enabling system services,

c) obtain work efforts by consultants, subcontractors, organizations, projects or individuals or teams within a project, and

d) provide the basis for closing an agreement after the system has been delivered or work has been completed and payment made.

A.5 Organizational project-enabling processes

Organizational project-enabling processes are for that part of the general management that is responsible for establishing and implementing projects related to the products and services of an organization. Thus, the organization through these distinct processes provides the services that both constrain and enable the projects, directly or indirectly, to meet their requirements.

The Organizational Project-enabling Processes included in International Standards, such as ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 are not necessarily the only processes used by an organization for governance of its business. For example, organizations also have processes for managing accounts receivable, accounts payable, payroll processing and marketing. These business-related processes are not directly within the scope of the mentioned standards and thus are not discussed further in this document. The Organizational Project-enabling Processes of ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 are constrained in their scope to the aspects of those processes that are required to bound and guide the project, even though there are implicit relationships that the organization should address elsewhere, for example, in the Human Resource Management Process.

For multiple projects involved in or interfacing with an organization or for a teaming arrangement among external organizations, other organizational project-enabling processes can be appropriately tailored.

To perform these processes, it is not intended that a new organizational unit or discipline within an organization be created. Identified and defined roles, responsibilities and authorities may be assigned to individuals or established organizational units. When necessary, however, a new organizational unit can be formed.

The organizational project-enabling processes have specific objectives to fulfil, such as listed below are the following:

a) provide the proper environment so that projects within the organization can accomplish their purpose and objectives;

b) establish an orderly approach to starting, stopping and redirecting projects;

c) define organizational policies and procedures are defined that set forth the relevant life-cycle processes of the International Standards cited above and that are applicable to projects within the organization and its constituent parts;

d) select and provide appropriate models, methods and tools are selected and provided to projects so that they can complete process activities efficiently and effectively;

e) provide adequate resources for the project to meet budget, schedule and performance requirements within acceptable risks and train human resources for completing their responsibilities;

f) deliver project work products of a suitable quality for delivery to customers;

g) retain knowledge acquired during the execution of a project is retained in a form that is accessible for future needs.

A.6 Technical management processes

The technical management processes are used to manage technical process activities and to assure satisfaction of an agreement. Technical management processes are performed to establish and update plans, to assess progress against plans and system requirements, to measure and control work efforts, to make required decisions, to manage risks and configurations and to capture, store, and disseminate information. Outcomes from performing the technical management processes help in the accomplishment of the technical processes.

The technical management processes apply to technology exploration projects that are most often part of larger projects. When that is the case, the appropriate technical management processes are performed at each level of the system structure. These processes also apply when performing organizational project-enabling processes or carrying out the activities related to a life cycle stage, including utilization, support and retirement.

When several projects co-exist within one organization, technical management processes should be defined to allow for the management of the resources and performance of the multiple projects.

A.7 Technical processes

The technical processes are applicable across all life cycle stages. For example, the following Technical Processes from ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288:2015 should be performed to engineer a system.

a) Business or Mission Analysis Process

b) Stakeholder Needs and Requirements Definition Process

c) System Requirements Definition Process

d) Architecture Definition Process

e) Design Definition Process

f) System Analysis Process

g) Implementation Process

h) Integration Process

i) Verification Process

j) Transition Process

k) Validation Process

l) Operation Process

m) Maintenance Process

n) Disposal Process

NOTE The titles of these processes are identical to those in ISO/IEC/IEEE 12207:2017 except for c), which is System/Software requirements definition process in that document.

These processes should be performed to satisfy the entry or exit criteria of a system life cycle stage or set of stages. For example, they may be used during early system life cycle stages to create a feasible system concept, determine technology needs and establish future developmental costs, schedules and risks. During ensuing life cycle stages the technical processes may be used to define, realize and make use of a new system. During later system life cycle stages, they may be used on legacy systems to make technology refreshments or technology insertions, as well as to correct variations from expected performance during production, utilization, support or retirement. These processes apply to both a system-of-interest and its enabling systems.

The last three Technical Processes listed (Operations Process, Maintenance Process and Disposal Process) can be used during any system life cycle to accomplish the objectives of a life cycle stage and support the technical processes used for engineering a system. The Operations Process and the Maintenance Process can be performed, as applicable, to support a particular version of a system. The Disposal Process can be performed to deactivate legacy systems, to dispose of legacy systems and to safely dispose of by-products from system use.

There may be additional technical processes used for a specific technical domain within a system, such as software, hardware, humans, or facilities, which would be discussed in the appropriate International Standard for that technical domain.

A.8 Processes under key views

ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 contain processes that are applicable throughout a life cycle. However, these processes may be used in different ways by different organizations and parties with different views and objectives. This sub clause presents processes and their relationships under key views.

Figure A.5 depicts illustrative examples of the life cycle processes and their relationships under different views of the usage of either document. The basic views shown are: contract, management, technical management, engineering, operating, support and project. Further discussion of views, their creation and use, is given in Annex D.

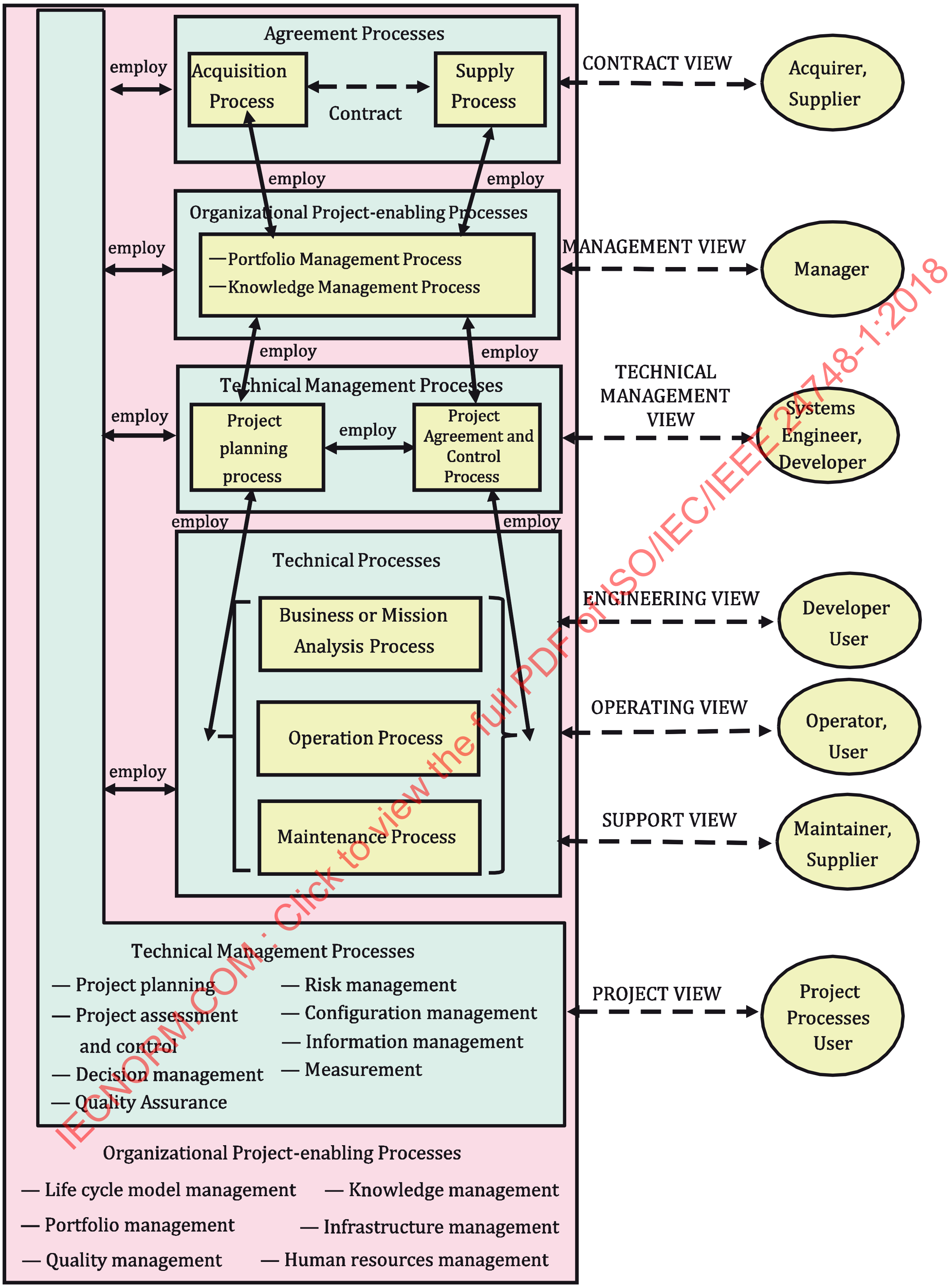

Figure A.5 — Life cycle processes roles and relationships

Under the contract view, acquirer and supplier parties negotiate and enter into a contract or other agreement and employ the Acquisition Process and Supply Process respectively. Under the management view, the organization establishes, uses and maintains a process framework that services multiple projects and complements their technical effort. Under the technical management view, the organization initiates, supports and controls projects. Under the engineering view, the developer or maintainer conducts its respective engineering tasks to produce or modify products or services. Under the operating view, the operator provides operation service for the users. Under the support view, the maintainers and suppliers apply parts and services to sustain and improve the operation of the system. Under the project view, parties (such as configuration management or information management) provide supporting services to others in fulfilling specific, unique tasks. Also shown (see the bottom box) are some of the organizational project-enabling processes provided by the organization to support multiple projects; these are employed by an organization at a higher, e.g. corporate, level to establish and implement an underlying structure made up of associated life cycle processes and personnel and their continuous improvement.

The processes and parties (or stakeholders) are only related functionally. They do not dictate a structure for a party.

An organization or a party gets its name from the process it performs, for example, it is called an acquirer when it performs the Acquisition Process.

An organization may perform one process or more than one process; a process may be performed by one organization or more than one organization. Under one contract or application of this document, a given party may perform both the Acquisition Process and the Supply Process.

In the documents themselves, the relationships between the processes are only static. The more important dynamic, real-life relationships between the processes, between the parties, and between the processes and the parties are established when the appropriate document is applied on projects in a manner specific to that project. Each process (and the party performing it) contributes to the project in its own unique way. The Acquisition Process (and the acquirer) contributes by defining the product or service (or both) to be obtained. The Supply Process (and the supplier) contributes by providing the product or service. The Integration Process (and the integrator) contributes by "looking" to the system for correct derivation and definition of software, hardware and other products, as well as services, by supporting proper integration of products and services back into an overall system. The Operation Process (and the operator) contributes by operating the products or providing the services in the system's environment for the benefit of the users, the business, and the mission. The Maintenance Process (and the maintainer) contributes by maintaining and sustaining the products and services for operational fitness and by providing support and advice to the user community. Each process contributes by providing unique, specialized functions to other processes as needed.

Where processes are applied to system elements of a specific nature, the relevant processes from the standard that applies to that kind of element will be invoked, as well as appropriate system processes. This holds true for elements of all types. Thus, there is a complementary duality of process interplay as the particulars of a system are instantiated. As a specific example, the validation process for software will be invoked as part of the overall process of validating the system, to ensure that the software is validated as part of the system.

All of the above statements apply to enabling systems, as well as the system-of-interest.

NOTE Process concepts are introduced in ISO/IEC/IEEE 15288:2015, 5.5.

The focus of ISO/IEC/IEEE 15288:2015 is on the processes that are applied within a life cycle. The processes can be used by organizations (for example functional organizations and projects) that play the role of acquirer, supplier (for example main contractor, subcontractor, or service provider) or management to fulfil responsibilities pertaining to the system-of-interest. Additionally, the processes in ISO/IEC/IEEE 15288:2015 can be used as a reference model for assessments under the ISO/IEC 33000 family of standards.

A.9 Iterative and recursive application of processes

A.9.1 General

Two forms of process application—iterative and recursive—are essential and useful for executing the requirements of ISO/IEC/IEEE 12207 or ISO/IEC/IEEE 15288. The iterative use of processes, i.e. the repeated application of a process or set of processes at the same hierarchical level of structural detail, is important for the progressive refinement of process outputs, e.g. the interaction between successive verification actions and integration actions can incrementally build confidence in the conformance of the product. The recursive use of processes, i.e. the repeated application of the same process or set of processes applied to successive levels of detail in a system's hierarchical structure is a key aspect of the application of ISO/IEC/IEEE 15288 or ISO/IEC/IEEE 12207. The outputs of processes at any level, whether information, artefacts or services are inputs to the same processes used at the level above or level below. This results in a response, information, artefacts, or service, which can then modify the original output. In this way, the outputs across all levels of the system can be resolved and consistency achieved, e.g. system element descriptions that conform to an architecture.

A.9.2 Iterative application of processes

When the application of the same process or set of processes is repeated on the same system, at the same level, the application is referred to as iterative. The iterative application of processes is illustrated in Figure A.6.

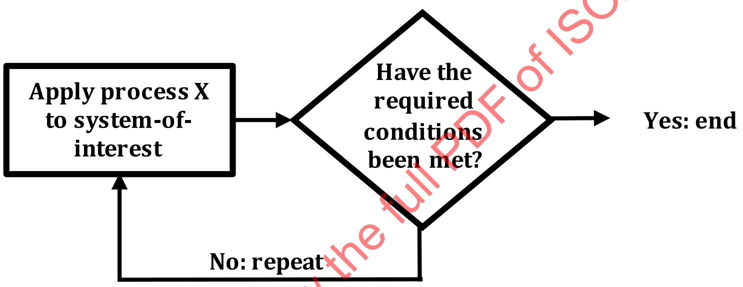

Figure A.6 — Iterative application of process(es)

Iteration is not only appropriate but also expected. New information is created by the application of a process or set of processes. Typically, this information takes the form of questions with respect to requirements, analysed risks or opportunities. Such questions should be resolved before completing the activities of a process or set of processes. When re-application of activities or processes can resolve the questions, then it is useful to do so. Processes should be repeated until an acceptable quality of results is obtained prior to applying the next process or set of activities to a system-of-interest. In this case iteration adds value to the system to which the processes are being used.

A.9.3 Recursive application of processes

When the same set of processes or the same set of process activities are applied to successive levels of system elements within the system structure until some condition is satisfied, the application form is referred to as recursive. Figure A.7 illustrates the recursive application of processes to systems. The most common applications of recursion are in computer programs, mathematics, and language.

The following describes how X is applied recursively to a system element, where:

- **S is the system-of-interest, which is also considered as a system element of itself, and**
- **E and E′ vary in system elements**

Apply X to S considered as a system element of itself.
  <u>where</u>
    Apply X to E, where E is a system element defined by {
      ... Apply some activities of X to E; ...
      <u>if</u> (E is not small enough [or low level enough] {
        Apply X to E′ that is smaller (or at a lower level than E
    }
      ...Apply the rest of activities of X to E; ...
    }

Psuedocode example for a factorial function:

function factorial is:
input: integer *n* such that *n* >= 0
output: [*n* × (*n*-1) × (*n*-2) × ... × 1]
1. if *n* is 0, **return** 1 2. otherwise, **return** [*n* × factorial(*n*-1)]
end factorial

Figure A.7 — Recursive application of processes

A.10 Methods and tools

In practice, there are many situations where system size and complexity, project duration and the number of contributing organizations require process execution to be supported by methods and tools.

The selection of methods and tools depend on many factors including stage in the life cycle, level in the system's hierarchy and application domain. As a result, neither ISO/IEC/IEEE 12207, ISO/IEC/IEEE 15288, nor this document includes discussions of specific methods and tools. Nevertheless, there are some issues that the user of ISO/IEC/IEEE 12207 or ISO/IEC/IEEE 15288:2015 should bear in mind when selecting and using methods and tools to accomplish life cycle process activities or related tasks. Four such issues are listed below:

a) A method or tool should not dictate the process to be followed, but should support the set of activities of a selected process. Methods should be selected to fit the system life cycle stage;

b) Selection of tools should be based on connectivity to other tools that provide inputs or use outputs of the tool being considered for use. The engineering data produced should be in an appropriate form to enable the data to be captured, stored and available as long as it is needed. Those members of organizations, projects and other stakeholders who have the need should be given access authority to the data;

c) The training requirements for application of the method or tool should be considered. The initial, as well as subsequent training time after a user has not used the tool for a period of time, should be included in the consideration;

d) Enabling systems as well as tool administration should be considered.

Annex B
(informative)

Organizational concepts

B.1 General

An organization is a body of entities organized for some specific purpose and may be as diverse as a corporation, agency, society, union, or club. An organization may be part of a parent organization (e.g. a society being parent to clubs that are a part of it). When an organization enters into an agreement, it is a party. Parties may have the same parent organization, although it is equally possible that they have different parent organizations (e.g. two clubs from the same society making an agreement or two clubs from two different societies making an agreement).

For the purpose of ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288, any project is assumed to be conducted within the context of an organization. This is important because a system project is dependent upon various outcomes produced by the business processes of the organization, e.g., employees to staff the project and facilities to house the project. For this purpose, ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 12207 provide a set of Organizational Project-Enabling Processes. It is important to note that the Organizational Project-Enabling Processes are not assumed to be adequate to operate a business, nor are the Technical Management Processes assumed to be adequate to operate a project. Instead, the processes, considered as a collection, are intended to state the minimum set of dependencies that the project places upon the organization.

ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 describe the set of processes that comprise the life cycle of any human-made system. Therefore, ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 are designed so that they can be tailored for a project of any type, size and complexity, whether focused on tangible products, services, or a mix of both.

The sequence of the processes, activities, and tasks in ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 does not dictate the sequence of their application in a life cycle model. It is intended that the project select, order, tailor and iterate the processes, activities, and tasks as applicable or appropriate.

On the same project, ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 may be separately applied more than once. For example, in a given system implementation project, an acquirer may request a supplier to perform system implementation, with the acquirer and the supplier executing one application of ISO/IEC/IEEE 12207 or ISO/IEC/IEEE 15288. The supplier may then request its sub-contractor to perform all or part of the system development, e.g. develop the software. The supplier (now in an acquisition mode) and its sub-contractor (in supplier mode) execute a separate application of ISO/IEC/IEEE 12207 or ISO/IEC/IEEE 15288. In both situations, it is necessary to adapt ISO/IEC/IEEE 12207 or ISO/IEC/IEEE 15288 to reflect the arrangements.

NOTE 1 Sub clause 4.2.3 of this document provides more detail on structure in systems and projects.

NOTE 2 Sub clause 4.2.4 of this document provides more detail on enabling systems.

NOTE 3 ISO/IEC/IEEE 16326 provides more information on projects and project management.

B.2 Process responsibility

Typically, organizations distinguish different areas of managerial responsibility and action through agreements, as indicated in Figure B.1. Different organizations (or parts thereof) as parties, and different areas of responsibility within an organization, mutually establish their working relationships and acknowledge their respective responsibilities through such agreements. These agreements unify and coordinate the contributions made by different parties in order that they can meet a common business purpose.

Together, these agreements contribute to the organization's overall capability to trade. This document employs a process model based on three primary organizational areas (or levels) of responsibility: organization, project and technical. Within each organization, a coordinated set of organizational project-enabling, technical management and technical processes contribute to the effective creation and use of systems, and therefore to achieving the organization's goals.

Each process is considered to be the responsibility of a party. An organization may perform one or more processes. A process may be performed by one organization or more than one organization, with one of the organizations being identified as the responsible party. A party executing a process has the responsibility for that entire process even though the execution of individual tasks may be by different parties. The responsibility aspect of the life cycle architecture facilitates adaptation and application of International Standards, such as ISO/IEC/IEEE 15288 or ISO/IEC/IEEE 12207 on a project, in which many parties may be legitimately involved.

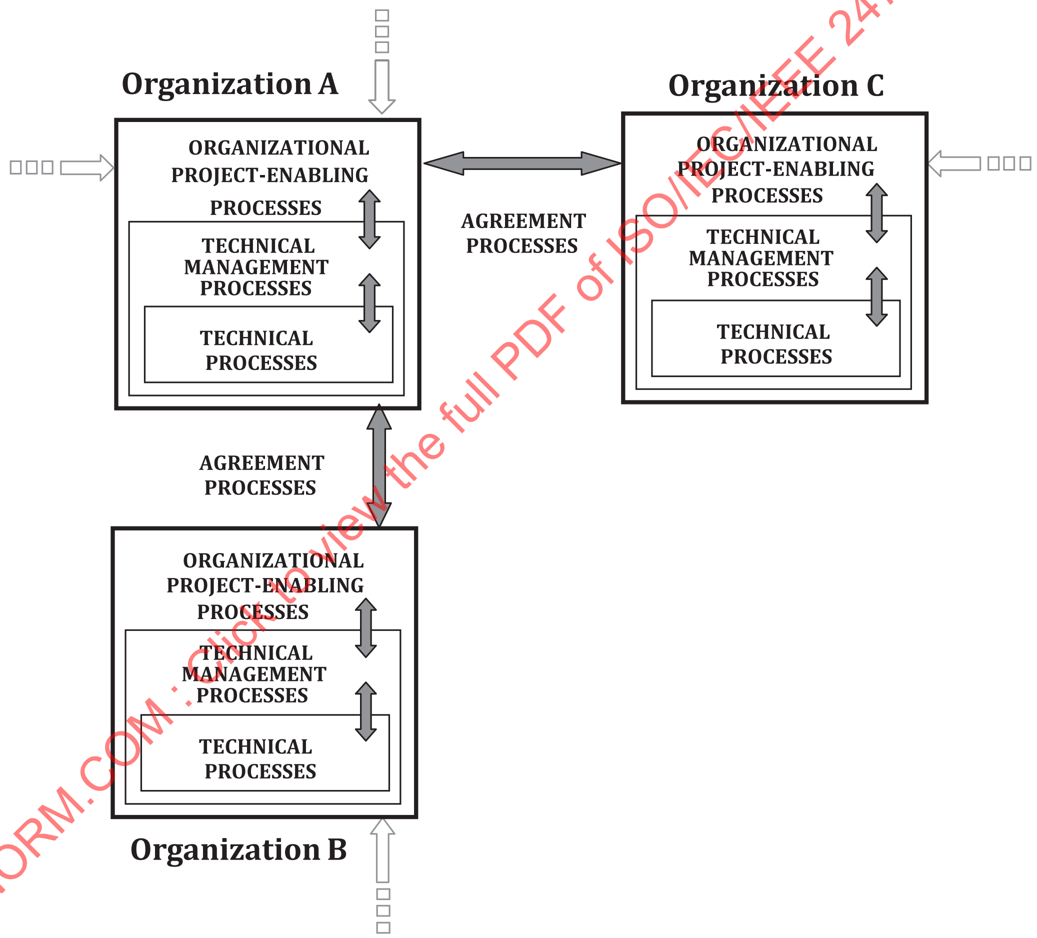

Figure B.1 — Agreements on responsibilities for organizational project-enabling, technical management and technical processes among cooperating organizations

Annex C
(informative)

Project concepts

C.1 Structure in systems and projects

The scope of responsibility that an organization assigns to its projects is related to a number of factors:

a) complexity of the system or software engineering effort;

b) typical span of control and staffing levels compared to the norm for the organization;

c) expected duration of the effort;

d) participation and direct support from organizational process-enabling groups.

In sort, the complexity of the system design is one factor among many determining the number and types of projects associated with the system engineering effort. Accordingly, each system in the structure illustrated in Figure 2 (or Figure 3) of 4.2.3 of this document could be the responsibility of a separate project. This can be true whether the system is hierarchical, as used for the illustration, or other system structure, such as a network, or a mix of structures. The point is that there can be (and typically is) a strong correlation between levels of detail in the system structure and levels of responsibility in a set of projects. Each project characteristically has responsibility for acquiring and using system elements subordinate to it and creating and supplying to the level superior to it, as would be the case for hierarchical, non-hierarchical, or mixed, system structures.

Any particular project normally views its system as the system-of-interest and whilst it can influence higher system levels, it does not have responsibility for them. However, even though it may not have responsibility for each system element considered by itself, it does have responsibility for all system elements that constitute its system-of-interest and consequently for the output of projects at all levels subordinate to it, as shown in Figure C.1.

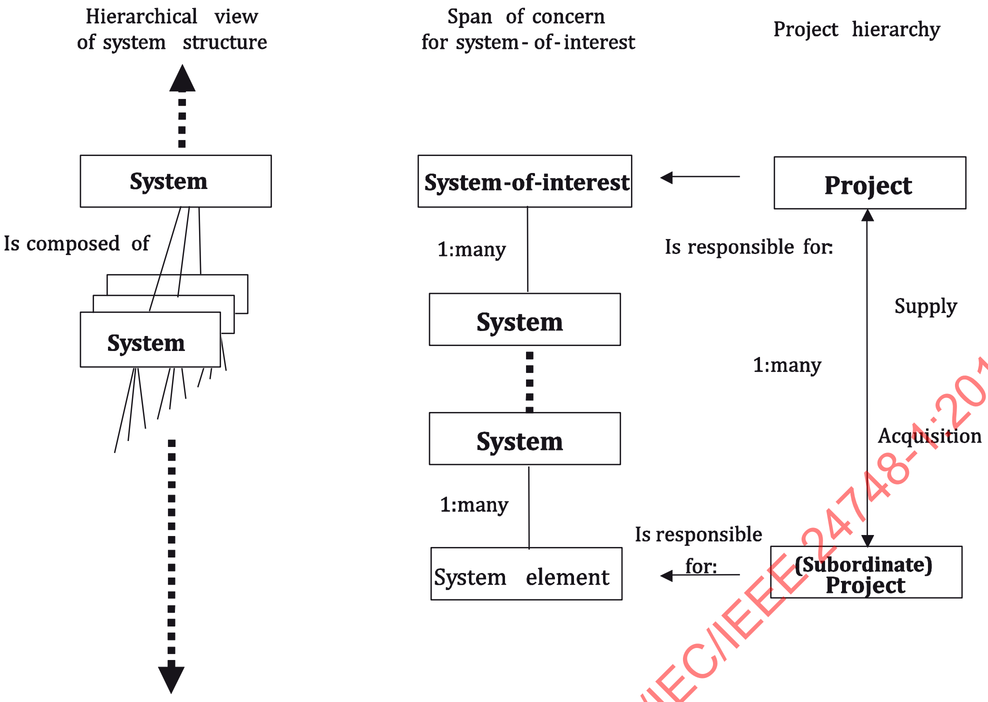

Figure C.1 — System and project hierarchies

In practice, the risks associated with implementing systems that fulfil specified requirements typically diminish with descending level of detail in the system-of-interest's structure and eventually are no longer of direct attention or concern to the particular project. At this level (not necessarily the same level down different paths of system-of-interest decomposition), a system element can be acquired with acceptable risk and the detail of its composition can remain hidden below some level. For example, if the system-of-interest for the project were a radar, in normal practice, the formulation and cure of the slurry mix for the resistive part of a composition resistor on a printed circuit board in a subassembly in a system element of the system-of-interest would not be addressed directly. Rather, the requirements at the system-of-interest and possibly the system element level would drive choices that would force a particular selection of this material in order to meet all the requirements for the higher-level elements. From the system-of-interest view, the system elements may appear to be where specialist disciplines or particular implementation technology practices are present.

C.2 Project relationships

A relationship can exist between a project and other projects, and subprojects. A subproject as used here and in Figure C.2 is a set of resources and tasks organized to undertake a portion of a project. A subproject may be considered a project by those assigned the work. Figure C.2 illustrates typical relationships between projects, which may be within a single organizational entity, or across entities.

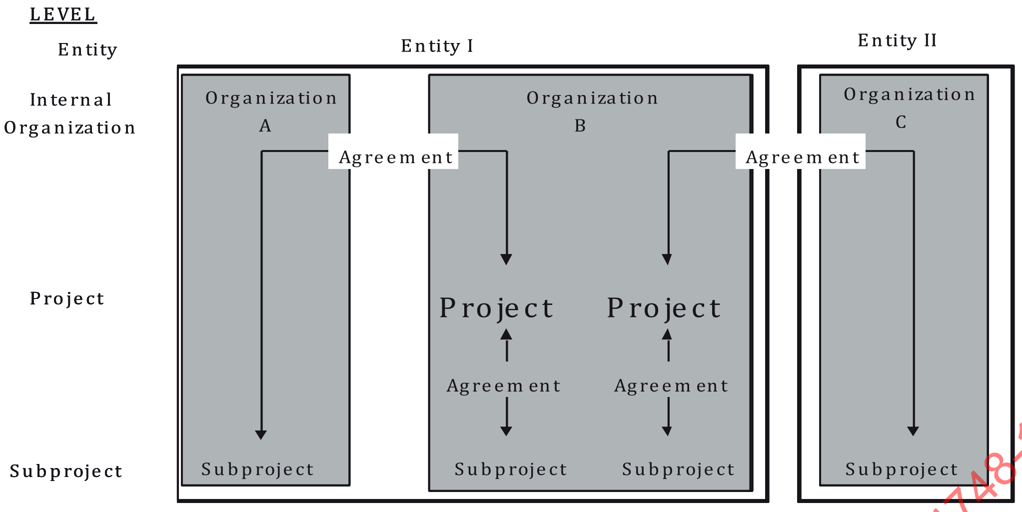

Figure C.2 — Relationships between projects

Project relationships are established, maintained and changed through formal or informal agreements in accordance with organizational policies and procedures, as appropriate. Depending on the type of project relationship involved, agreements may exist within a single organization, or may span organizational boundaries. Relationships, and therefore the establishing agreements, may be between a project and a specific organizational element or elements, among multiple projects, or among a project and its subprojects. Agreements provide a mutual understanding of the problem to be solved, work to be done, established constraints, deliverables and clearly defined responsibilities and accountability.

Another kind of relationship, and agreement, not shown in Figure C.2, would be applicable when two or more organizations cooperate on a single project. In this case, it is important to define each organization's authorities, responsibilities and rights, including the sharing of proprietary information applicable to the project in then agreement.

Regardless of the kind of relationship, with its corresponding agreement, there is some basic information needed to do the work required in ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288. Each agreement, whether formal or informal, should carefully consider, and address as appropriate, the activities and tasks of the Agreement Processes. Additional guidelines to consider include:

a) responsibilities for the work expected to be done could be in the form of work statements or internal charters, but in any event, should be defined for all entities that will be involved;

b) products, services and data, created within the project may need to be formalized as deliverables either to another part of the organization or to external entities. In such cases, the means of delivering and accepting these deliverables should be made explicit;

c) technical or management reviews may be required within the project, or other parts of the organization, to support the reviews formalized in the agreement. Such reviews need to be driven by specific criteria for their initiation, completion and documentation.

NOTE A model is provided in ISO/IEC/IEEE 24748-2:—, 5.7.1 for the application of ISO/IEC/IEEE 15288:2015 processes to reach an agreement.

C.3 Enabling system relationships

Another relationship among projects is one that involves enabling systems. The project is responsible for ensuring that required enabling systems are available when needed to fulfil the functions of the system-of-interest or enable the system-of-interest to be realized. Some or possibly all enabling systems could be outside the direct responsibility (boundary) of the project. Some or all of the enabling systems could already exist within the project's organization. Other enabling systems could be easily made available, for example by rental or purchase. However, one or several enabling systems may not exist and should be created and be made available in time to provide required services.

It is within the project's span of interest that not only the system-of-interest should appropriately be made available but also all enabling systems that are needed for the project. Potentially, some or all of these enabling systems could be needed for subsequent projects and stages and possibly throughout the system life cycle. Thus, the project should determine needed enabling systems and take appropriate actions to ensure their availability for use.

Agreements should be established between the project and the internal or external organization or organizations, as applicable, to ensure that specified enabling system services are provided when needed. A project span of interest is illustrated in Figure C.3.

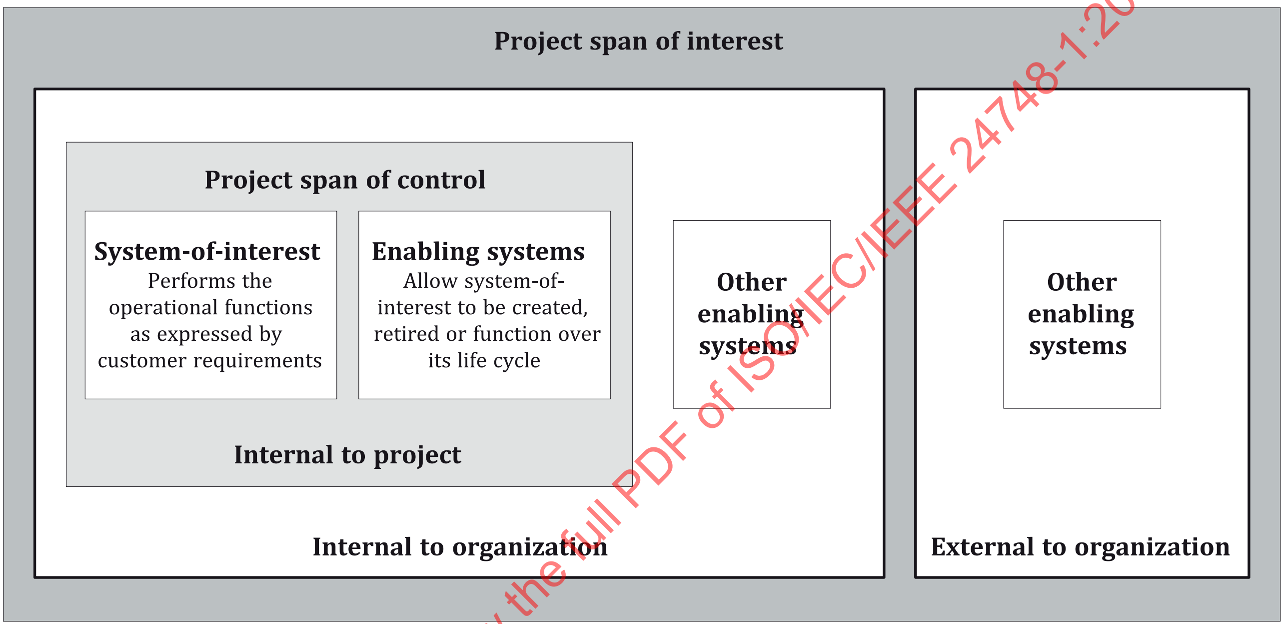

Figure C.3 — Project span of interest

C.4 Hierarchy of projects

The system that the project is responsible for is considered a system-of-interest. Each subordinate or sub-project is considered as a project itself. A resultant hierarchy of projects can then be formed. The basic relationship of Figure C.3, which illustrates the project span of interest, can be combined with the hierarchical view of a system structure as is portrayed in more detail in Figure C.4.

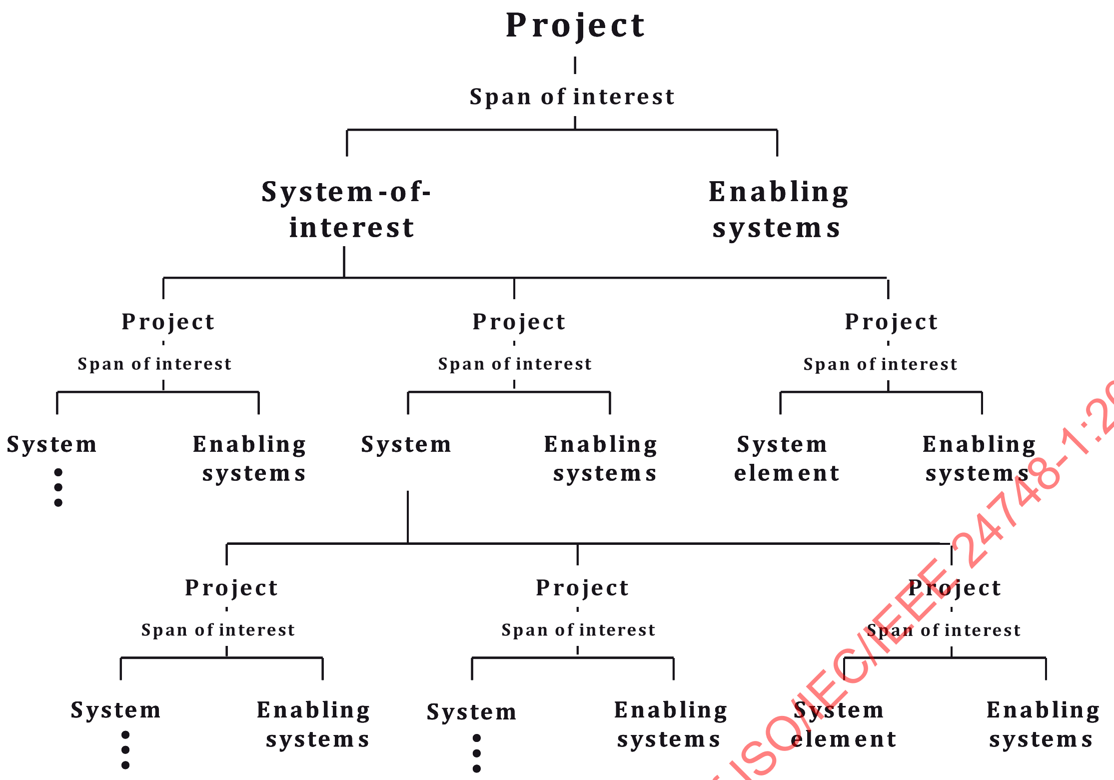

Figure C.4 — Hierarchy of projects

Figure C.4 shows only the lower level of projects of one system. Each system, however, should be decomposed into lower level projects until each consists of only a system element and its enabling systems. Two such projects in Figure C.4 end with a system element. Each project should be carried out using applicable system life cycle processes to the extent required by requirements and to satisfy applicable life cycle stage entry or exit criteria.

As explained in Figure C.3, the enabling systems of Figure C.4 may be under project control or, if external to the project, under the control of other organizations. However, the project should work with these other organizations through agreements to ensure that the required enabling systems are available when needed to support the system-of-interest during its life cycle.

Annex D
(informative)

Process views

D.1 General

There are instances where those representing a particular engineering interest would like to see gathered in a single place the set of process activities that directly and succinctly address their concern. For such interests, a process view can be developed to organize processes, activities, and tasks selected from ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 to provide a focus to their particular concern in a manner that cuts across all or parts of the life cycle. This Annex provides a process viewpoint that may be used to define process views in these instances and gives examples from the viewpoints of the following:

a) specialty engineering;

b) interface management;

c) security.

D.2 The process view concept

There may be cases where a unified focus is needed for activities and tasks that are selected from disparate processes to provide visibility to a significant concept or thread that cuts across the processes employed across the life cycle. It is useful to advise users of the standards on how to identify and define these activities for their use, even though they cannot locate a single process that addresses their specific concern.

For this purpose, the concept of a process view has been formulated. Like a process, the description of a process view includes a statement of purpose and outcomes. Unlike a process, the description of a process view does not include activities and tasks. Instead, the description includes guidance explaining how the outcomes can be achieved by employing the activities and tasks of the various processes in ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288. Process views can be constructed using the process viewpoint template found in D.3.

D.3 Process viewpoint

A process view conforms to a process viewpoint. The process viewpoint provided here can be used to create process views.

The Process viewpoint is defined by:

a) its stakeholders: users of the standard;

b) the concerns it frames: the processes needed to reflect a particular engineering interest.

The contents of resulting process views should include the following:

a) process view name;

b) process view purpose;

c) process view outcomes;

d) identification and description of the processes, activities and tasks that implement the process view, and references to the sources for these processes, activities and tasks in other standards.

NOTE The requirements for documenting viewpoints are found in ISO/IEC/IEEE 42010:2011, 5.4. This description is consistent with those requirements.

D.4 Process view for specialty engineering

This sub clause provides an example of applying the process viewpoint to yield a process view for specialty engineering to illustrate how a project can assemble processes, activities and tasks of ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288 to provide focused attention to the achievement of product characteristics that have been selected as being of special interest.

This example treats the cluster of interests, generally called specialty engineering, which includes but is not limited to such areas as availability, maintainability, reliability, safety, human factors, and usability. Within ISO/IEC/IEEE 12207 and ISO/IEC/IEEE 15288, these “ilities” requirements are referred to as “critical quality characteristics”. These characteristics determine how well the product meets its specified requirements in a specific area selected for focus.

NOTE 1 This is a generalized instance of a process view that covers a broad set of functional and non-functional characteristics related to specialty engineering. It provides a broad view across the processes. If a specific critical quality characteristic has a high priority relative to other characteristics, a specific process view could be created for that characteristic, including more detailed information and requirements.

Name: Specialty Engineering Process View

Purpose: The purpose of the Specialty Engineering Process View is to provide objective evidence that the system achieves satisfactory levels of certain critical quality characteristics selected for special attention.

Outcomes:

a) Product critical quality characteristics are selected for special attention.

b) Requirements for the achievement of the critical quality characteristics are defined.

c) Measures for the requirements are selected and related to the desired critical quality characteristics.

d) Approaches for achieving the desired critical quality characteristics are defined and implemented.

e) The extent of achievement of the requirements is continually monitored.

f) The extent of achievement of the critical quality characteristics are specified and developed.

NOTE 2 The outcomes permit the possibility that the desired critical quality characteristics cannot be directly measured but instead might be argued and inferred based on other product or process characteristics that can be measured.

Processes, Activities and Tasks:

This process view can be implemented using the following processes, activities, and tasks from ISO/IEC/IEEE 12207:2017 and ISO/IEC/IEEE 15288:2015:

NOTE 3 ISO/IEC 25030 could be useful in specifying software product quality requirements.

NOTE 4 INCOSE Systems Engineering Handbook contains descriptions and elaboration about many of the specialty engineering areas and the associated critical quality characteristics.

a) The Agreement Processes (6.1) provide for the establishment of expectations and responsibilities related to each specialty engineering area, including legal agreements and licensing requirements. Generally, this is done in the context of establishing and maintaining agreement processes for all aspects of the system. In this case, or even when separate Agreement Process application is required for a specialty engineering area, all parts of both the Acquisition Process (6.1.1) and Supply Process (6.1.2) may be applicable.

b) The Organizational Project-Enabling Processes (6.2) help ensure the organization's capability to acquire and supply products or services through the initiation, support and control of projects. These processes provide resources and infrastructure necessary to support projects and help ensure the satisfaction of organizational objectives and established agreements. Generally, this is done in the context of applicability of the processes from all viewpoints to one or more systems across multiple projects. However, specialty engineering stakeholders should review all parts of the six Organizational Project-Enabling Processes to assure that their interests are adequately addressed.

c) The Project Assessment and Control Process (6.3.2) provides for monitoring the extent of achievement of the requirements and critical quality characteristics and communicating the results to stakeholders and managers. Relevant activities and tasks include (b) (6), (b) (7), (b) (9) and (b) (10).

d) The Decision Management Process (6.3.3) provides assessment of alternative requirements, architecture characteristics and design characteristics against the decision criteria, including the critical quality characteristics. Results of these comparisons are ranked via a suitable selection model and are then used to decide on an optimal solution. Relevant activities and tasks include (b) all tasks; and (c) (1).

e) The Risk Management Process (6.3.4), in its entirety, provides for identifying, evaluating, and handling risks of the system, including those related to meeting the critical quality characteristics.

f) The Configuration Management Process (6.3.5) manages and controls system elements and configurations over the life cycle. Relevant activities and tasks include (a) (1), (d) (1), and (f) (2) for each discipline to be addressed under specialty engineering.

g) The Information Management Process (6.3.6), in its entirety, provides for the specification, development and maintenance of information items for documenting and communicating the extent of achievement. It should be noted that information items used for the purpose of critical quality characteristics are sometimes specialized in nature. Sources for the description of these information items include industry associations, regulators, and specific standards.

h) The Measurement Process (6.3.7), in its entirety, provides for defining an approach that relates measures to the required critical quality characteristics.

i) The Quality Assurance Process (6.3.8) addresses identified anomalies (incident and problems) that relate to the achievement of critical quality characteristics.

j) The Business or Mission Analysis Process (6.4.1) provides for the definition of the problem space and characterization of the solution space, including the relevant trade-space factors and preliminary life cycle concepts. This includes developing an understanding of the context and any key parameters, such as the critical quality characteristics (e.g., safety hazards, human interfaces, operational characteristics, and system assurance context). Relevant activities and tasks include (b) (1) and (b) (2); (c) (1); and (d) (1).

k) The Stakeholder Needs and Requirements Definition Process (6.4.2) provides for the selection and definition of characteristics, including critical quality characteristics, and associated information items. The activities and the documentation are useful in identifying, prioritizing, defining, and recording requirements for the critical quality characteristics. Relevant activities and tasks include (a) (1) and (a) (2); (b) (2), (b) (3) and (b) (4); (c) (1) and (c) (2); (d) all tasks; and (e) (2).

l) The System Requirements Definition Process (6.4.3) provides for the specification of parameters for the critical quality characteristics and the selection of measures for tracking the achievement of these requirements with respect to the specific system to be developed. Relevant activities and tasks include (a) (1); (b) all tasks; and (c) (2).

NOTE The title of process 6.4.3 is Software Requirements Definition Process in ISO/IEC/IEEE 12207:2017 and System Requirements Definition Process in ISO/IEC/IEEE 15288:2015

m) The Architecture Definition Process (6.4.4) provides for the identification of stakeholder concerns from an architecture perspective. These concerns often translate into expectations or constraints across the life cycle stages that relate to the critical quality characteristics, such as utilization (e.g., availability, security, effectiveness, usability), support (e.g., reparability, obsolescence management), evolution of the system and of the environment (e.g., adaptability, scalability, survivability), production (e.g. manufacturability, testability), retirement (e.g. environmental impact, transportability), etc. This process further addresses those critical quality characteristic requirements that drive the architecture decisions, including the assessment of the architecture with respect to the concerns and associated characteristics. Relevant activities and tasks include (a) (2) and (a) (4); (b) (1); (c) (2), (c) (3), (c) (4), and (c) (5); (d) (1); and (e) (2).

n) The Design Definition Process (6.4.5) provides for the determination of necessary design characteristics, which includes the critical quality characteristics, such as security of design criteria for the specialty characteristics and the evaluation of alternative designs with respect to those criteria. Relevant activities and tasks include (a) (2); (b) (1), (b) (2), (b) (3), (b) (4) and (b) (6); and (c) (2).

o) The System Analysis Process (6.4.6) provides for the level of analysis needed to understand the trade space with respect to the critical quality characteristics through the conduct of mathematical analysis, modeling, simulation, experimentation, and other techniques. The analysis results are input to trades made through the Decision Management Process in support of other Technical Processes. Relevant activities and tasks include (a) all tasks; and (b) all tasks.

p) The Implementation Process (6.4.7) provides for recording the evidence that critical quality requirements have been met. Relevant activities and tasks include (b) (3).

q) The Integration Process (6.4.8) provides for planning the integration, including the considerations for critical quality characteristics, and the assurance that the achievement of the characteristics is determined and recorded. Relevant activities and tasks include (a) (1); (b) (3); and (c) (1).

r) The Verification process (6.4.9), provides for the planning and execution of a strategy to perform verification, including the critical quality characteristics. The selected verification strategy may introduce design constraints that could affect the achievement of the characteristics. Relevant activities and tasks include (a) (1) and (3); (b) (1), (b) (2); and (c) (1) and (c) (2).

s) The Transition Process (6.4.10) provides for installing the system in its operational environment. Because some specialty properties involve a trade-off between design constraints and operational constraints, attention to installation is often important. Relevant activities and tasks include (a) (4); and (b) (4), (b) (6), and (b) (7).

t) The Validation Process (6.4.11) provides evidence that the services provided by the system meet the stakeholders' needs, including the critical quality characteristics. Relevant activities and tasks include (a) (1) and (a) (3); (b) (1) and (b) (2); (c) (1) and (c) 2).

u) The Operation Process (6.4.12) provides for usage of the system. Assuring that critical quality characteristics are appropriately achieved involves monitoring the operation of the system. Relevant activities and task include (b) (3) and (b) (4); (c) (1) and (c) (2); and (d) (1) and (d) (2).

v) The Maintenance process (6.4.13) sustains the capabilities of the system, helping to ensure its ongoing availability to provide its functions, including its critical quality characteristics. This includes failure analysis, maintenance tasks, and logistics tasks needed to assure continued operation of the system. Relevant activities and tasks include (b) all tasks; (c) all tasks; and (d) (1) and (d) (2).

w) The Disposal Process (6.4.14) ends the existence of a system. The inherent need to anticipate disposal may place constraints on development. In fact, these constraints may themselves be critical quality characteristics. Relevant activities and tasks include (a) (2); (b) (1) and (b) (2); and (c) (3).

D.5 Process view for interface management

This sub clause provides an example of applying the process viewpoint to yield a process view for interface management, intended to illustrate how a project can assemble processes, activities and tasks of ISO/IEC/IEEE 15288:2015 to provide focused attention to the achievement of product characteristics that have been selected as being of special interest.

This example treats a specific instance of a process view, called interface management, which includes but is not limited to interface definition, design, and change management. Within ISO/IEC/IEEE 15288:2015, the tasks that comprise interface management are fully contained within the existing processes.

Name: Interface Management Process View

Purpose: The purpose of the Interface Management Process View is to facilitate of the identification, definition, design and management of interfaces of the system.

Outcomes:

a) Business or mission needs related to interfaces are identified.

b) Stakeholder needs related to interfaces are identified.

c) Requirements for the interfaces are defined.

d) Interfaces between system elements, as well as interfaces between the system and external systems are identified and defined.

e) Approaches for achieving the desired interface characteristics are defined and implemented.

f) The extent of realization of the interface requirements is continually monitored.

g) The extent of achievement of the interface requirements are specified and developed.

Processes, Activities and Tasks:

This process view can be implemented using the following processes, activities, and tasks from ISO/IEC/IEEE 15288:2015:

NOTE INCOSE Systems Engineering Handbook contains descriptions and elaboration about interface management.

a) The Agreement Processes (6.1) provide for the establishment of expectations and responsibilities related to interface management, including legal agreements and licensing requirements. Generally, this is done in the context of establishing and maintaining agreement processes for all aspects of the system. In this case, or even when separate Agreement Process application is required, such as for a specific interface, all parts of both the Acquisition Process (6.1.1) and Supply Process (6.1.2) may be applicable.

b) The Organizational Project-Enabling Processes (6.2) help ensure the organization's capability to acquire and supply products or services through the initiation, support and control of projects. These processes provide resources and infrastructure necessary to support projects and help ensure the satisfaction of organizational objectives and established agreements. Generally, this is done in the context of applicability of the processes from all viewpoints to one or more systems across multiple projects. However, interface management stakeholders should review all parts of the six Organizational Project-Enabling Processes to assure that their interests are adequately addressed.

c) The Project Assessment and Control Process (6.3.2) provides for monitoring the extent of achievement of the requirements, including interfaces, and communicating the results to stakeholders and decision makers. Relevant activities and tasks include (b) (6), (b) (7), (b) (9) and (b) (10).

d) The Decision Management Process (6.3.3) provides assessing alternative requirements, architecture characteristics and design characteristics against the decision criteria, including the interfaces. Results of these comparisons are ranked, via a suitable selection model and are then used to decide on an optimal solution. Relevant activities and tasks include (b) all tasks; and (c) (1).

e) The Risk Management Process (6.3.4), in its entirety, provides for identifying, evaluating, and handling risks of the system, including those related to interfaces.

f) The Configuration Management Process (6.3.5) manages and controls system elements and configurations over the life cycle. All activities and tasks in this process are particularly relevant to interface management.

g) The Information Management Process (6.3.6), in its entirety, provides for the specification, development and maintenance of information items for documenting and communicating the extent of achievement.

h) The Measurement Process (6.3.7), in its entirety, provides for defining an approach that relates measures to the required interface information needs, and then generating and using those measures to address the identified interface information needs.

i) The Quality Assurance Process (6.3.8) addresses identified anomalies (incident and problems) that relate to the achievement of interface requirements. The Business or Mission Analysis Process (6.4.1) provides for the definition of the problem space and characterization of the solution space, including the description of the environment and context, as well as preliminary operational concepts. It often identifies external systems that must interface with the system-of-interest. Relevant activities and tasks include (b) (1) and (b) (2); and (c) (1).

j) The Business or Mission Analysis Process (6.4.1) provides for the definition of the problem space and characterization of the solution space, including the relevant trade-space factors and preliminary life cycle concepts. This includes developing an understanding of the context and any key parameters, such as the critical interfaces within the system-of-interest, as well as those to external systems, and similarly for all enabling systems. Relevant activities and tasks include (b) (1) and (b) (2); (c) (1); and (d) (1).

k) The Stakeholder Needs and Requirements Definition Process (6.4.2) provides for the definition of operational concepts and the interactions of the system with users and the intended environment (including other systems). It often identifies external systems that must interface with the system-of-interest. Relevant activities and tasks include (c) (1) and (c) (2); and (d) (1) and (d) (3).

l) The System Requirements Definition Process (6.4.3) provides for the definition of the interface requirements. Relevant activities and tasks include (a) (1); (b) all tasks; (c) all tasks; and (d) all tasks.

m) The Architecture Definition Process (6.4.4) provides for the identification of interfaces from an architecture perspective as the architecture models evolve. This process further describes and defines the interfaces to the extent needed for the architecture description. Relevant activities and tasks include (a) (2) and (a) (4); (c) (1) through (c) (4); (d) all tasks; and (f) (3) through (f) (6).

n) The Design Definition Process (6.4.5) provides for the refinement and full definition of the interfaces and the creation of the necessary information items. Relevant activities and tasks include (b) (5) and (b) (6); and (d) (1) through (d) (3).

o) The System Analysis Process (6.4.6) provides for the level of analysis needed to understand the trade space with respect to the interface requirements and definition through the conduct of mathematical analysis, modeling, simulation, experimentation, and other techniques. The analysis results are input to trades made through the Decision Management Process in support of other Technical Processes. Relevant activities and tasks include (a) all activities; and (b) all tasks.

p) The Implementation Process (6.4.7) provides for development of the interfaces and recording the evidence that interface requirements for an implemented system element have been met. Relevant activities and tasks include (b) (3).

q) The Integration Process (6.4.8) provides for planning the integration, including the considerations for interfaces between system elements. It also includes the integration of systems or system elements and interfaces. Relevant activities and tasks include (a) (1); (b) all tasks; and (c) (1).

r) The Verification Process (6.4.9), provides evidence that the services provided by the system meet the system requirements, including the interface requirement. The process provides for the planning and execution of a strategy to perform verification, including the interface requirements. The selected verification strategy may introduce interface constraints that could affect their achievement. Relevant activities and tasks include (a) (1) and (a) (3); (b) (1), (2); and (c) (1).

s) The Transition Process (6.4.10) provides for installing the system in its operational environment. This includes identifying constraints, and checking the installation and operational state of the interfaces. Relevant activities and tasks include (a) (4); and (b) (3), (b) (4), (b) (6), and (b) (7).

t) The Validation Process (6.4.11) provides evidence that the services provided by the system meet the stakeholders' needs, including the interface requirements. The selected validation strategy may introduce interface constraints that could affect their achievement. Relevant activities and tasks include (a) (1), (a) (2), and (a) (3); (b) (1) and (b) (2); (c) (1) and (c) (2).

u) The Operation Process (6.4.12) provides for usage of the system. There also may be constraints to the interfaces for operations. Assuring that the interface requirements are appropriately achieved involves monitoring the operation of the system. Relevant activities and task include (a) (2), (b) (3) and (b) (4); and (c) (1) and (c) (2).

v) The Maintenance Process (6.4.13) sustains the capabilities of the system, helping to ensure its ongoing availability to provide its functions, including its interfaces. This includes failure analysis, maintenance tasks, and logistics tasks needed to assure continued operation of the system. There also may be constraints to the interfaces for maintenance. Relevant activities and tasks include (a) (2); (b) all tasks; and (d) (1) and (d) (2).

w) The Disposal Process (6.4.14) ends the existence of a system. It may require activities to disengage interfaces. The inherent need to anticipate disposal may place constraints on the interfaces. Relevant activities and tasks include (a) (2) and (b) (1) and (b) (2).

D.6 Process view for security

This sub clause provides an example of applying the process viewpoint to yield a process view for security, intended to illustrate how a project can assemble processes, activities and tasks of ISO/IEC/IEEE 15288:2015 to provide focused attention to the achievement of system characteristics that have been selected as being of special interest.

This example is focused on protection against intentional subversion or forced failure due to the architecture, design, implementation, operation, support, or disposition of any of the types of elements (hardware, software, data, facilities, etc.) that may comprise a system, including enabling systems, delivering any mix of services and products.

Name: Security Process View

Purpose: The purpose of the Security Process View is to provide objective evidence that the system is capable of achieving satisfactory levels of certainty, that sufficient protection is achieved against intentional subversion or forced failure due to the architecture, design, implementation, operation, support, or disposition of any of the types of elements (hardware, software, data, facilities, etc.) that may comprise a system, including enabling systems, delivering any mix of services and products..

Outcomes:

a) Product and service security characteristics are selected for special attention.

b) Requirements for the achievement of the security characteristics are defined.

c) Measures for the requirements are selected and related to the desired security characteristics.