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Systems engineering — A guide for the application of ISO/IEC 15288 (System life cycle processes)

Ingénierie systèmes — Un guide pour l'application de l'ISO/CEI 15288 (processus de cycle de vie des systèmes)

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

In exceptional circumstances, the joint technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when the joint technical committee has collected data of a different kind from that which is normally published as an International Standard (“state of the art”, for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC TR 19760, which is a Technical Report of type 3, was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 7, *Software and system engineering*.

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Systems engineering — A guide for the application of ISO/IEC 15288 (System life cycle processes)

1 Scope

1.1 Purpose

This Technical Report provides guidance for the application of ISO/IEC 15288 *Systems engineering — System life cycle processes* (referred to as the International Standard) to systems and projects of various size and type. This Technical Report can be used as a companion document to the International Standard.

This Technical Report elaborates on factors that should be considered when applying the International Standard. It does this in the context of the various illustrative ways in which the International Standard may be applied. Also, lists within this Technical Report are not meant to be exhaustive but to provide the user with examples to consider.

The guidance contained in this Technical Report may be tailored as appropriate to the system and project using guidance in Annex A of the International Standard and 4.4 of this Technical Report.

This Technical Report is intended to provide appropriate links to other ISO documents for supporting application of the International Standard and to aid in assessing the effectiveness of the application of the International Standard.

Not all areas of the International Standard are meant to have equal treatment in this Technical Report. More specific information is provided where providing such information will help in the application of the International Standard. This Technical Report is not meant to provide how-to guidance for each area of the International Standard.

1.2 Audience

This Technical Report is applicable to audiences such as identified below:

a) those who apply the International Standard;

b) those who use the International Standard for a specific system;

c) those who prepare organizational and specific domain standards based on the International Standard.

1.3 Prerequisites

The list below provides prerequisites for users of this Technical Report:

a) availability of ISO/IEC 15288;

b) familiarity with ISO/IEC 15288;

c) familiarity with relevant organizational and project policies;

d) general knowledge of project management, systems engineering and system life cycle models.

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2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 15288, *Systems engineering — System life cycle processes*

ISO/IEC 12207, *Information technology — Software life cycle processes*

ISO/IEC TR 15271, *Information technology — Guide for ISO/IEC 12207 (Software life cycle processes)*

ISO/IEC 15504 (all parts), *Information technology — Software process assessment*

ISO 9001:2000, *Quality management systems — Requirements*

3 Context of this Technical Report

3.1 Overview

This clause has two objectives. The first objective is to provide an overview of the dynamic utilization of the International Standard with respect to key concepts and processes. Illustrated in this clause are the relationships between types of systems, system life cycles and the application of agreement, enterprise, project and technical processes. The second objective is to give pointers to the various clauses of this Technical Report that provide guidance to a user for applying the International Standard concepts and processes.

3.2 Context of the International Standard

Organizations need to be able to conduct commerce in systems (including their associated products and services). The International Standard facilitates commerce by providing the common framework for establishing and executing agreements between system acquirers and suppliers with respect to developing, using, and managing a system within the defined life cycle of that system. The International Standard is applicable to organizations, enterprises and projects whether they act as the acquirer or the supplier of a system.

The context of the International Standard is illustrated in Figure 1.

A single project may involve multiple organizations working together as partners. Such a project should use the International Standard to establish common terminology, information flows and interfaces among the several organizations to enhance communications.

When an organization applies the International Standard to a particular system, that system becomes the system-of-interest. The system-of-interest has a life cycle that consists of multiple stages through which the system passes during its lifetime, denoted s1, s2, … sn. Typical stages, as described in Annex B of the International Standard, are concept, development, production, utilization, support and retirement. The management of the progression from one stage to another and the engineering activities associated with providing appropriate work products and decision-making information is described in Clause 6 of this Technical Report.

A number of enabling systems are deployed throughout the system life cycle to provide the system-of-interest with support as needed. Each life cycle stage prior to system use (concept stage, development stage, and production stage) can require an enabling system. Enabling systems that cooperate with the system-of-interest during its utilization, support and retirement stages can be needed, as well. It is important to note that an enabling system has its own life cycle and that when the International Standard is applied to it, it then becomes a system-of-interest. The role and use of enabling systems are described in 5.2.3, 5.3.1.4, and 6.2.5 of this Technical Report.

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The International Standard is applicable at any level of the structure associated with a system-of-interest. As a system is decomposed recursively into its system elements, the processes of the International Standard may be used for each system and system element in the system structure. Each system and system element has a life cycle of its own and its own set of enabling systems. This system structure is described in 5.2.1 of this Technical Report.

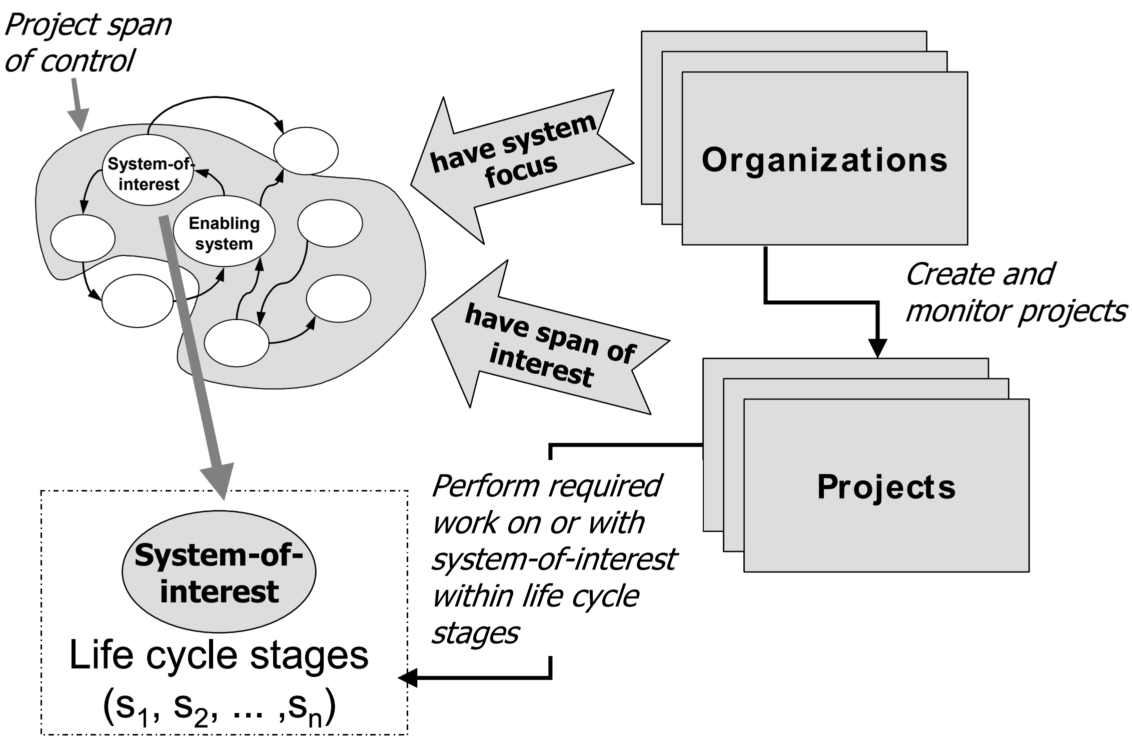

Figure 1 — Context of the International Standard

In order to perform needed operations and transformations upon systems during their life cycles, the organization creates and monitors projects. Projects have defined scope, resources (including time) and focus. The scope can involve managing all of the stages of the life cycle, a subset of the stages, one or more defined processes or one or more process activities. The time scale can be of varying duration, for example one hour or tens of years. The focus of the project is related to the system-of-interest and its systems and system elements in some form of system structure or stage partitioning. Related project concepts are described in 5.3 of this Technical Report and system life cycle concepts are described in 5.4.

Organizations focus on systems that are created by projects within the organization or in conjunction with other organizations. Projects have a span of interest that includes the system-of-interest and its related enabling systems. Some enabling systems are under direct control of the project. The system-of-interest and those enabling systems make up the project span of control. The span of interest is described in 5.3.1.4.

The work performed by projects is on or with the system-of-interest within one or more system life cycle stages. The scope of the International Standard includes the definition of an appropriate life cycle for a system, the selection of processes to be applied throughout the life cycle and the application of these processes to fulfil agreements and achieve customer satisfaction.

The International Standard can be applied to all types of systems and system elements consisting of one or more of the following: hardware, software, humans, processes, procedures, facilities, and naturally occurring entities. The use of the International Standard for systems within this broad scope is one of its main advantages.

The use of the International Standard may be adapted to accommodate the varying project requirements in treating system life cycles. This may be performed by adjusting the scope as described in 4.2 and tailoring described in 4.4 of this Technical Report and Annex A of the International Standard.

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3.3 Process categories of the International Standard

The four process groups of the International Standard as well as the primary relationships between the groups are portrayed in Figure 2. The role of the Enterprise and Project group processes is to achieve the project goals within applicable life cycle stages to satisfy an agreement. Enterprise processes provide enabling resources and infrastructure that are used to create, support, and monitor projects and to assess project effectiveness. The project processes ensure 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.

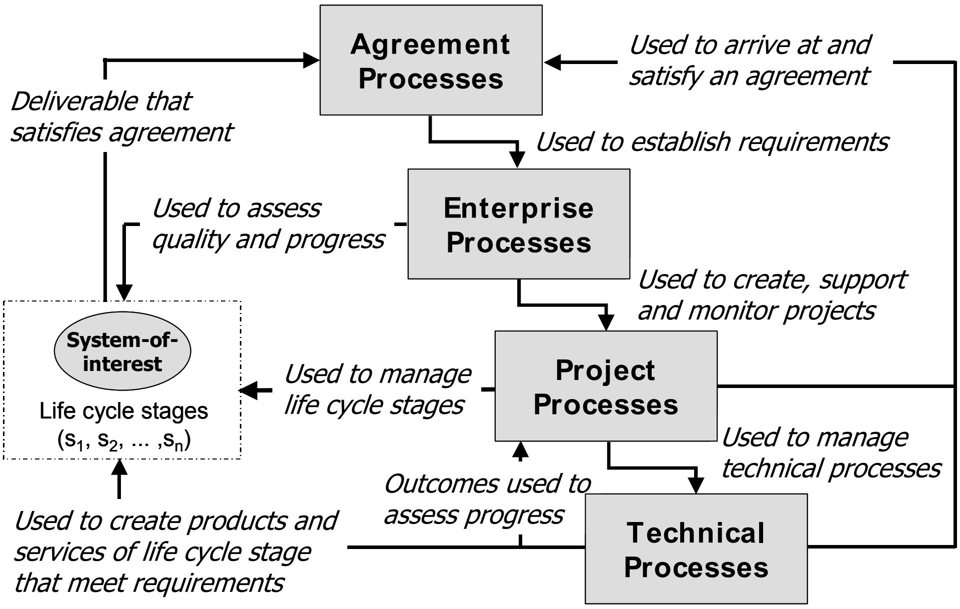

Figure 2 — Role of International Standard processes

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 3. The degree of formality of the agreement is adapted to the internal or external business relationships between projects. An example and discussion of the use of the agreement processes is provided in 5.3.1.3 of this Technical Report.

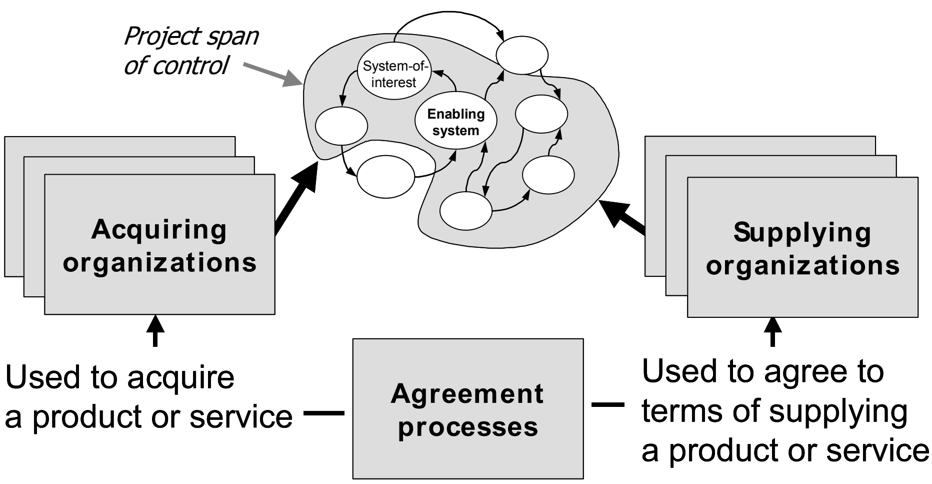

Figure 3 — Use of agreement processes

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4 Use of the International Standard

4.1 Overview

The International Standard can be used for one or more of the following reasons.

a) A specific project can use the International Standard for engineering, utilizing, supporting or retiring a system-of-interest.

b) An organization can use the International Standard for supporting and controlling the operation of one or more of the system life cycle stages.

c) A domain organization or other organization can use the International Standard for developing domain-specific or organization-specific standards. These can address the engineering of systems, the management of engineering activities or the operation of one of the system life cycle stages.

d) Multiple organizations can use the International Standard as a basis for joint projects.

4.2 Concept of use

4.2.1 General

Each organization is driven by the nature of its business, its social responsibilities, and its business strategy. These provide constraints on available business opportunities that the organization and its enterprises can exploit. To help exploit opportunities the enterprise establishes policies and procedures to guide the performance of projects. To help establish these policies and procedures, and to determine the resources needed by the enterprise, the International Standard can be used to provide specific standardized processes for use within one or more life cycle models.

A suggested use concept is illustrated in Figure 4. This figure provided the basis for tailoring the scope of the International Standard for one of the specific uses of 4.1.

4.2.2 Scope tailoring

For example, if an enterprise that does development only and is not involved in the utilization, support, or retirement life cycle stages, that enterprise could tailor the scope of the International Standard accordingly. 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 enterprise:

a) life cycle model and related entry or exit criteria used by the enterprise for decision making as well as for establishing milestone reviews of a project;

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

c) expertise and skills available to the enterprise to provide enterprise products and services;

d) technology available for enterprise products and services.

4.2.3 Process tailoring

When a project is established to satisfy a set of stakeholder requirements or acquirer specifications, processes included in the enterprise policies and procedures or in the International Standard itself can be tailored according to the scope, size and funding of the work to be done. Planning the work of the project can be dependent on factors such as the following:

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a) the team structure required by enterprise policy and procedures or by the acquirer and the enterprise culture in which teams exist and perform;

b) requirements and schedules established in the agreement with the acquirer;

c) the specific life cycle model to be used for performing the processes of the life cycle;

d) the resources made available to the project by the enterprise.

Figure 4 illustrates application of tailored technical and management processes from the International Standard within a project context. The enterprise processes of the International Standard can also be selected for application at the enterprise level.

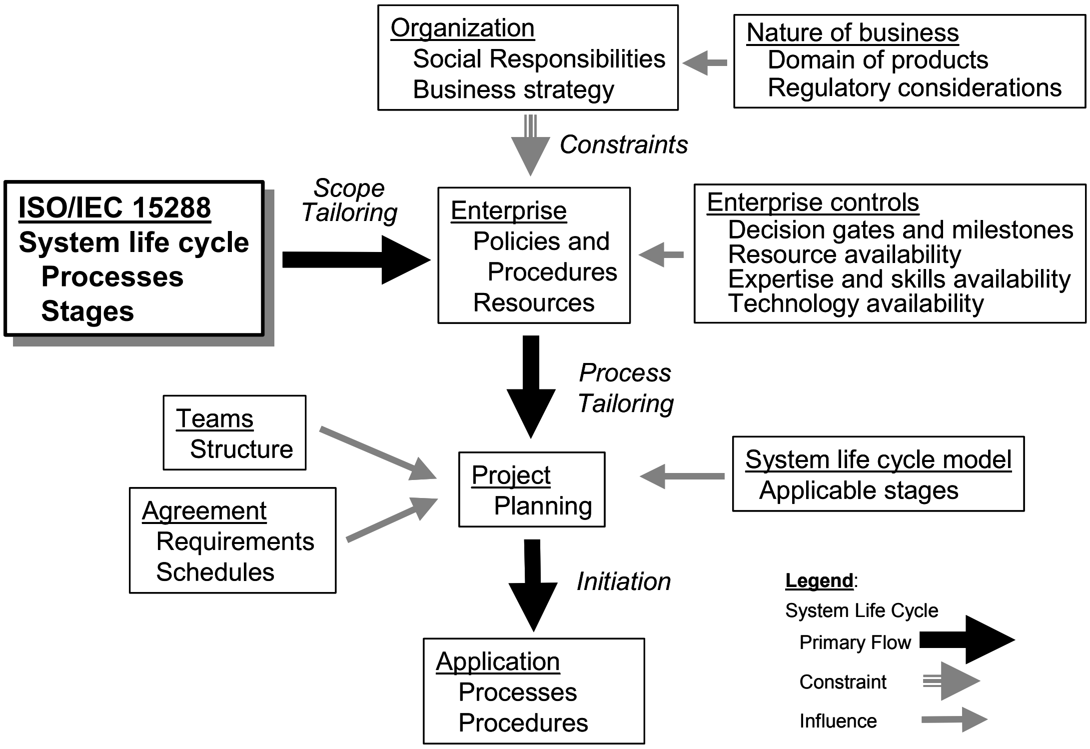

Figure 4 — Concept of use

4.3 Planning for use

The International Standard can be considered for a specific project with a set duration or for a continuous work effort conducted by an organization.

The following are examples of items to consider while planning use of the International Standard.

a) The scope of the work effort such as:

1) a single project either internal to the organization or an enterprise within the organization, or as part of a multi-party agreement;

2) concentration on some key processes or a single process where there is expected to be some gain for the organization or enterprise;

3) concentration on a single life cycle stage to carry out the operation of that stage.

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b) Identification and listing of stakeholders such as:

   1) intended users or customers of the work products, applicable systems or services;

   2) providers of enabling systems;

   3) other interested parties who have an interest or stake in the products or services;

   4) sources of requirements (including constraints).

c) Desired outcomes such as:

   1) work products (for example system-of-interest, paper report, digital data, hardware or software configuration item, waste material or procedure document);

   2) services or capabilities to be delivered or demonstrated at the end of the project and at specific milestones.

d) Special considerations such as:

   1) systems technologies that focus on software, hardware, humans, processes or procedures;

   2) system utilization including single use, repeated use and continuous use;

   3) system fabrication, for example one-of-a-kind, replicated or mass-produced;

   4) system topologies such as networks (for example a corporate global network), system of systems (for example a command and control or telecommunication system) and long-lived systems (for example those that never reach an end of use life such as electric power service);

   5) methods and tools that enable implementation of the processes throughout the life cycle.

e) Goals and objectives of the project such as:

   1) specific objectives identified by milestones;

   2) long-term utilization goals related to the work and work products, especially with respect to the use of a system.

f) Project strategy such as:

   1) how the project will be carried out, including any agreement considerations;

   2) how work packages will be planned, assessed and controlled;

   3) how work products will be planned, evaluated and controlled;

   4) how work and changes will be authorized;

   5) major milestone decision or event points (for example management reviews, meetings, pilot tests, deployments and deliveries) with milestone entry or exit criteria.

g) Requirements and constraints such as:

   1) specific functional and performance requirements for capabilities of or data from a system, including special attributes and usability expectations or concerns;

   2) policies, priorities and constraints that will affect meeting the cost, schedule and quality requirements and objectives of the project;

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3) core organizational technologies that will affect system requirements or other work product requirements and constraints; applicable organizational processes, standards and specifications (including source and availability); product implementation risks; and how information of required quality (including different product versions) will be captured, stored and controlled;

4) applicable system life cycle stage activities (for example development, pilot testing, full production, retirement) and expected outputs (for example. deliverables, work products and management reviews);

5) relevant stage entry or exit criteria, including expected level of system maturity, level of acceptable risks and management review concerns;

6) project start-up and end dates, including milestone dates associated with approval and progress reviews and pilot tests, as applicable;

7) management structure, including participants and their roles;

8) exclusions of organizations or persons (if applicable), including when the exclusion is or is not valid;

9) level of security classification and other security considerations, if applicable;

10) expected deliverables at milestones, at end of project and during project performance;

11) environment, recycling and reuse issues.

The information from a) through g) above should be appropriately documented. Based on the above documented information, appropriate detailed action planning should be performed to generate appropriate plans that can guide application of the International Standard.

4.4 Tailoring

4.4.1 General

When the International Standard is used by an enterprise to form a set of policies and procedures governing project work, then tailoring may be used to appropriately reduce or extend the scope of the International Standard as necessary for the business strategy and kind of business for which the policies and procedures are framed.

When the International Standard is used by a project, then tailoring may be used to appropriately consider the peculiar characteristics of the project, life cycle stage or agreement. Since each project has to consider and demonstrate the benefits of what it does to satisfy stakeholder requirements, there is a need to concentrate on the relevant processes and activities and the expected outcomes, including specific output documentation.

Tailoring takes the form of deletion, alteration or addition. Careful consideration should be given to dropping factors of the International Standard that do not add value to the process, system-of-interest or system element.

When tailoring is done, it may be important to ensure that applicable conformance requirements of the International Standard are met (see Clause 2 of the International Standard).

4.4.2 Tailoring considerations

The objectives and requirements of an agreement should define the context of application of the International Standard. To assist in defining the level of detail and effort required for execution of some processes, the following should be considered in tailoring:

a) the life cycle stage and the applicable exit criteria;

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b) the mission profiles, operational scenarios and operational concepts for each major functional requirement of the system-of-interest;

c) the set of measures of effectiveness, with relative importance, by which the acquirer typically determines satisfaction of the requirements;

d) empirical data that describes the constraints and risks that could affect the project and enterprise, including budget, resources, competition and schedule;

e) the technology base and any limitations on the use of technologies.

Additional tailoring considerations can be found in the conformance requirements of Clause 2 and Annex A of the International Standard.

4.4.3 Tailoring guidance

Either the organizational unit responsible for forming policies and procedures, or the project team or individual assigned to plan the project can be responsible for completing appropriate tailoring. To aid tailoring the following factors affecting the project effort should be helpful.

a) Project requirements such as the required work, schedule, funding and technical requirements (for example functional requirements, performance requirements and interface requirements) can drive stage timing and the definition of the system under consideration. These can also drive the criticality of the system and its enabling systems.

b) The applicable processes of the International Standard that apply to the domain, business of the organization and type of enterprise (for example supplier, user, acquirer, or other stakeholder) should be included in project plans. Other processes that are not in the International Standard can be required by an agreement, or they can be required by the nature of the project, the applicable system or the type of organization. These processes may be added, complete with their purpose, outcomes and activities.

c) Activities for each applicable process and the expected outcomes of each activity should be selected. Depending on the size and scope of the project, the type of enterprise and whether an unprecedented system is the object of the project, one or more of the International Standard activities for a process could possibly not apply. Likewise, outcomes and activities may be added to a process when needed to meet agreement requirements or to meet unique requirements for a system. See Annex A of this Technical Report for sources of such additional activity detail.

d) Tasks, methods and tools required for activity completion should be determined. The applicable tasks, methods and available tools are not included in the International Standard. These may be added by the project or organization during planning for an adopted process. See Annex A of this Technical Report for sources of additional task detail.

e) Reporting and technical review requirements applicable to the life cycle stage or stipulated in the governing agreement or in organizational policies and procedures should be considered.

f) Project measurement requirement provisions should be included for the collection and reporting of key measures by which project progress will be evaluated.

g) Requirements related to activities and tasks involving specialty engineering and functional disciplines may be integrated in appropriate processes. These processes include requirements (special requirements or critical project and system requirements) and life cycle stage entry or exit criteria (for example safety, security, human factor engineering, design, software development, production, test and logistics). Specialty and functional plans that are needed to ensure completion of project work may be included in work definition.

h) Applicable standards, policies and procedures, regulations and laws can be the source of additional process and activity requirements to add to the work definition, even though not included in the

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International Standard process requirements. Some reference standards for special factors that should be designed into architectural solutions are provided in Annex B of this Technical Report.

4.4.4 Tailoring documentation

According to the International Standard tailoring is required to be documented for the benefit of all who execute or assess the resulting set of processes. Tailoring records should be established and maintained. Some suggestions to follow in documenting tailoring are given below.

a) Explicit process, activity and task descriptions and output document descriptions should be documented in the project management plan, engineering plan, operation plan or similar high-level plan.

b) Where tailoring does not need to be formally documented, an annotated copy of the standard showing additions and deletions can be used.

c) Templates or worksheets for each International Standard process and life cycle stage can be developed to prescribe the depth of detail required for particular project documentation.

d) A matrix can be developed to show the level of conformance (full, tailored, none or not applicable), a description of tailoring and the rationale for deletions and traceability of the organization, enterprise or project documentation to the requirements of the International Standard.

5 Application concepts

5.1 Overview

This clause extends Annex D of the International Standard to provide the basis for application of the system life-cycle processes to a system within the constraints of system boundaries and applicable life cycle models.

5.2 System related concepts

5.2.1 System structure

Figure D.4 of the International Standard identifies three views of a system structure. The view on the left provides a hierarchical view of a system structure with a system composed of multiple systems. In this view, at some lower level of the hierarchy a system can be realized by being built, bought or reused. All systems in the hierarchy above this level are integrated composites of lower level systems.

The view in the middle of Figure D.4 is where the top system in the system structure is called a system-of-interest and consists of lower level systems. At the lowest level of the system structure are system elements.

Identification and understanding of the system structure is important in that in order to engineer a system-of-interest, each subordinate system and system element has to be engineered. The unique difference between the two system structures is that each system element has to be implemented whereas all other systems and the system-of-interest are integrated composites of lower level system elements and systems. The appropriate processes of the International Standard are applied individually to the system-of-interest, each system, and each system element in the system structure to define its requirements, develop its architectural design solution and realize its physical products and services.

A third view in Figure D.4 (the view on the right) provides a project hierarchy and assigns the responsibility for the system-of-interest to a project. Thus a project has the responsibility for the application of the International Standard life cycle processes to a system-of-interest.

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5.2.2 Kinds of systems

The International Standard considers two specific kinds of systems – systems-of-interest and enabling systems. There is a relationship between these two kinds of systems. Each system-of-interest has its associated set of enabling systems needed for the system-of-interest to be created, utilized and retired from use during its life cycle.

A system-of-interest provides operational capabilities as well as operational functions required or expected by a stakeholder such as a customer or user. Examples of a system-of-interest are an aircraft, automobile, payroll processing system, satellite, ship, telecommunications network or x-ray machine. Subordinate systems of these example systems-of-interest are also considered as a system-of-interest when engineered by a project using the International Standard life cycle processes.

One or more enabling systems are associated with each system-of-interest. Essential services are required from other systems throughout the life of a system-of-interest. Such systems may be needed to perform the responsibilities associated with a life cycle stage, for example a concept system, development system, production system, utilization system, support system or retirement system. In addition there may be infrastructure systems such as water and electricity supply systems and systems for test, delivery, maintenance and training. Enabling systems related to a system-of-interest could exist already or need to be developed specifically to support the system-of-interest.

Figure D.1 in the International Standard provides an example of an aircraft system with several of its related systems (airframe, propulsion, aircrew, flight control and life support and navigation – with several of its related systems such as the display system and global positioning receiver system). Figure 5 of this Technical Report shows five example enabling systems for the aircraft system-of-interest. These include development, production, utilization, support, and retirement systems that enable an aircraft to be realized and perform its functions over its life cycle. Each enabling system has a set of products and services to enable performance of its functions. For example in Figure 5 aircraft enabling systems include training simulators for utilization, facilities for production and refuelling equipment for support. Figure D.5 in the International Standard indicates this interacting relationship between a system-of-interest and its enabling systems.

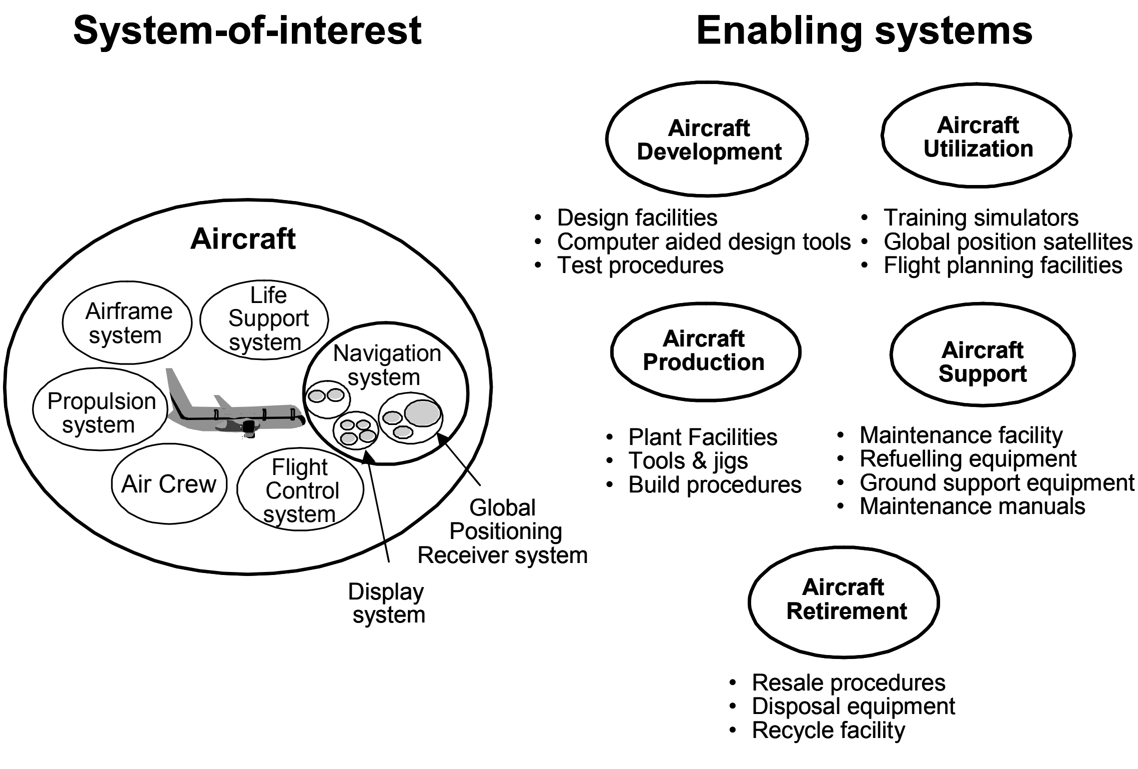

Figure 5 — Example aircraft system-of-interest and its enabling systems

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Figure 5 together with Figure D.5 in the International Standard illustrate several important relations with respect to a system-of-interest and its enabling systems. These are provided below:

a) enumeration of required enabling systems to provide life cycle support to a system-of-interest;

b) interacting relationships between a system-of-interest and its enabling systems that give rise to functional and physical interface requirements;

c) definition of system boundaries that establish interfaces requiring management;

d) a system-of-interest can impact or be impacted by its enabling systems.

5.2.3 System boundary

The relationships among a system-of-interest and its enabling systems are defined by boundaries. Such a system boundary establishes which systems are or are not under direct control of a project. Systems inside a boundary are under direct project control. While the project cannot control those systems external to the boundary it could need to influence those systems in order to reduce the impact on the system-of-interest or to make them fit system-of-interest requirements. When systems external to the boundary cannot be influenced, they become design or other life cycle process constraints with respect to the systems inside the boundary.

Enabling systems can be either inside or outside the boundary for which a project is responsible. Whether a particular enabling system is inside or outside the boundary, the enabling system is within the span of interest of a project because of interface and scheduling constraints. Figure 1 in Clause 3 illustrates a boundary for a system-of-interest with some enabling systems inside and others outside the span of control of the project but all within the span of interest.

System boundaries also establish interfaces where requirements have to be defined for environmental, physical, functional or data connectivity between those systems inside the boundary and those systems external to the boundary.

5.3 Project related concepts

5.3.1 Project focus

5.3.1.1 General

The International Standard has a project focus that defines relationships with the enterprise, other projects and enabling systems. A project is assigned responsibility for one or more life cycle stages of the system-of-interest or system element.

5.3.1.2 Enterprise relationships

The first relationship is the one that a project has with the enterprise, the business structure in which the project resides. The project places certain demands on the enterprise and the enterprise places demands on the project. The project requires physical infrastructure, financial and human resource support to carry out project work. The enterprise both constrains and supports a project. Examples of such enterprise constraints and supports are given below:

a) sets standards, policies, and procedures by which projects are carried out within the enterprise;

b) initiates, redirects or terminates projects according to business opportunities and strategies;

c) provides requested resources including physical and human within availability and financial constraints;

d) provides infrastructure support;

e) manages the overall quality of systems produced by a project for external customers.

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A project plan is often used as a basis of an agreement between projects and the enterprise.

5.3.1.3 Project relationships

The second relationship is one that can exist between a project and organizations, enterprises, other projects, and subprojects. A subproject as used here and in Figure 6 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 6 illustrates typical roles of agreements that establish project relationships internal and external to the project.

Project relationships are managed through formal or informal agreements in accordance with organizational or enterprise policies and procedures, as appropriate. Depending on the type of project relationship involved, agreements may exist within a single enterprise, or may span enterprise or organizational boundaries. Within the enterprise the agreements may be between a project and the enterprise, between multiple projects or between 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.

A fifth kind, not shown in Figure 6, 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 an agreement.

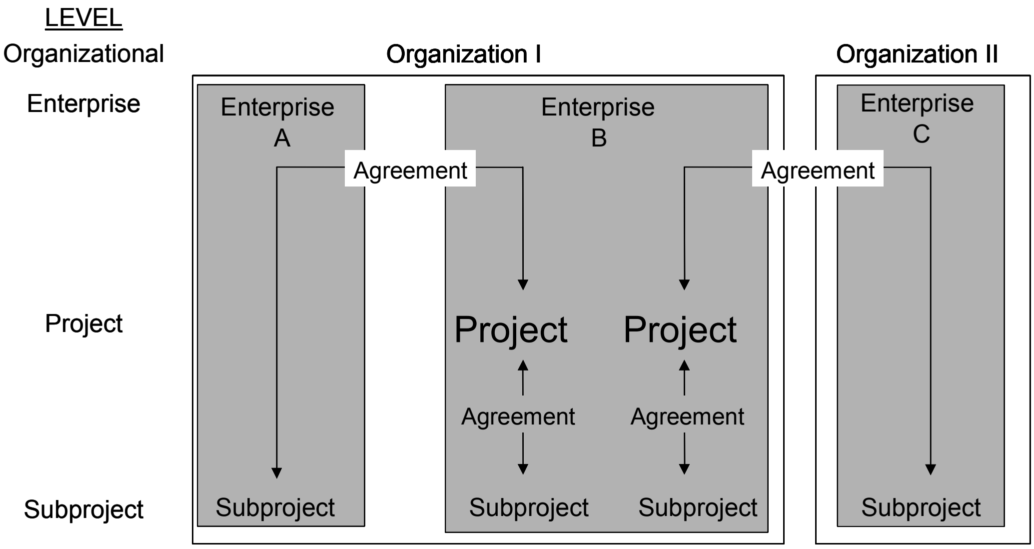

Figure 6 — Roles of agreements

Regardless of the kind of agreement, there is some basic information needed to do the work required in the International Standard. Each agreement, whether formal or informal, should include the following information to the appropriate level of detail:

a) responsibilities for the work expected to be done, for example in the form of work statements;

b) known functional and performance requirements, attributes and characteristics that clearly assign what the system and its related services are expected to do, be like or contain, including interfaces with other systems, humans and environments. These can be in the form of a set of formal requirement statements or a specification;

c) deliverables, for example products, services and data;

d) the stage or stages of the applicable life cycle model, including the related stage entry or exit decision criteria. Criteria provide the basis for determining whether the project is ready to progress to the next applicable life cycle stage;

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e) required technical reviews to track the fulfilment of the agreement and assess the maturity of the system;

f) other appropriate information such as:

1) cost and schedule constraints,

2) development delivery milestones,

3) payment schedules,

4) planning documents including applicable work breakdown or system structure, related configuration documents and acquirer supplied engineering plans,

5) verification and validation responsibilities,

6) acceptance conditions and transition instructions (for example for packaging, handling, delivery and installation),

7) rights and restrictions associated with technical data (for example for copyright, intellectual property and patents).

A model is provided in Clause 3 of this Technical Report for the application of the International Standard processes to reach an agreement.

5.3.1.4 Enabling system relationships

The third relationship 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 have to 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 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 enterprise, as applicable, to ensure that specified enabling system services are provided when needed. A project span of interest is illustrated in Figure 7.

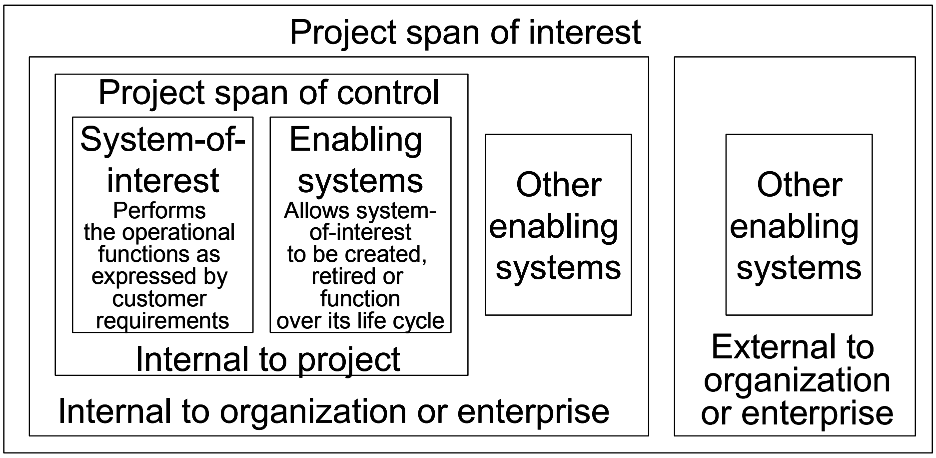

Figure 7 — Project span of interest

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5.3.2 Hierarchy of projects

The basic relationship of Figure 7, which illustrates the project span of interest, can be combined with the hierarchical view of a system structure illustrated in Figures D.4 and the system-of-interest structure in Figure D.3 of the International Standard to give a hierarchal view of a project. 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. This hierarchy is illustrated in Figure 8.

Figure 8 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 8 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 7, the enabling systems of Figure 8 may be under project control or, if external to the project, under the control of other organizations or enterprises. However, the project should work with these other organizations and enterprises through agreements to ensure that the required enabling systems are available when needed to support the system-of-interest during its life cycle.

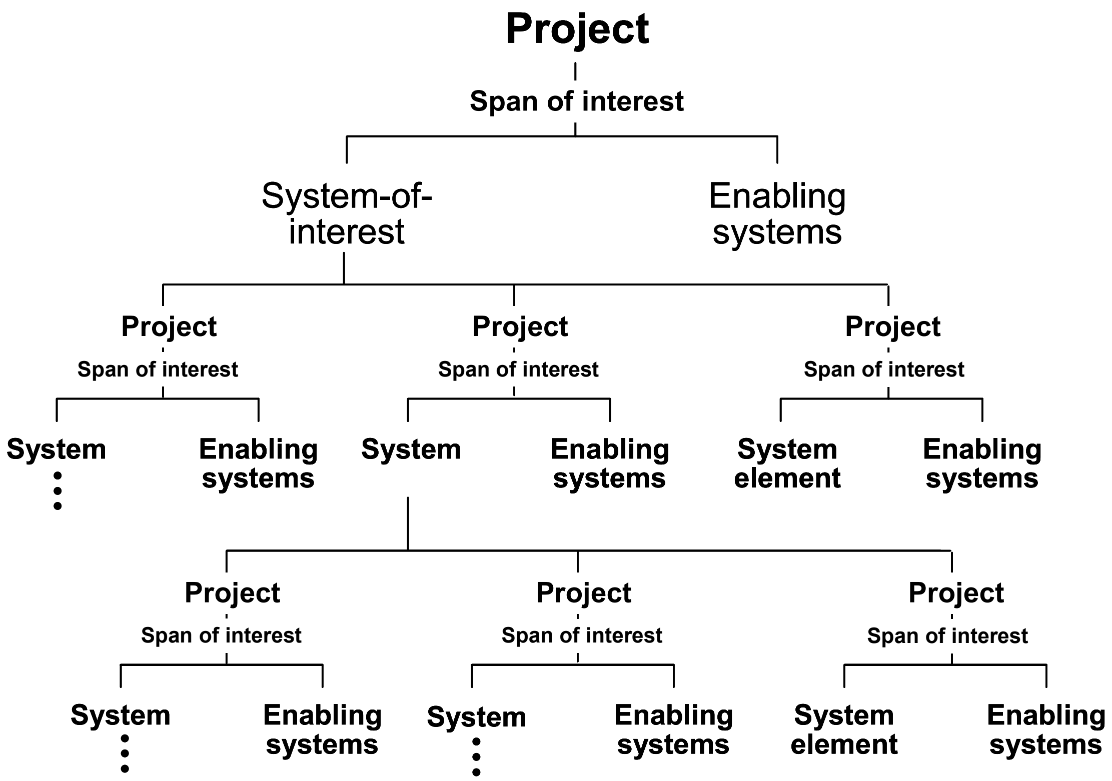

Figure 8 — Hierarchy of projects

5.3.3 Project organizational structure

The application of the International Standard does not require a specific organizational structure for projects. However, an appropriate organizational structure is essential. It is of particular importance that the appropriate teams or groups be assembled, structured and given the appropriate responsibility and authority for doing the work required to meet the project requirements, for example the activities and tasks of a process.

Team or group members assigned responsibility for a system-of-interest need to be available and competent. In the context of complex systems this could require that the structure of the teams or groups be multidisciplinary and include skills necessary to do required tasks.

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As a rule of thumb, project teams consist of seven plus or minus two members to develop the teamwork necessary for maximizing efficiency and effectiveness. Typically the team needs to rely on the individual specialist or functional groups of the organization to do such tasks as assessments on security, safety, survivability, reliability and effectiveness as well as trade-off studies, risk analyses and design work. In this context the team then becomes the integrated decision-making structure for process activities performed in a system life cycle stage. It is, however, important that individual teams share knowledge and communicate with other teams working on enabling systems for the same system and other adjoining systems. Such communications should be established so that the resultant system-of-interest is properly integrated from the lowest level up. It is also important so that each system and system element in the system structure is appropriately supported over its life.

5.4 System life cycle concept

Every system-of-interest, whatever the kind or size, follows a life cycle from its initial conceptualization through its eventual retirement. A system life cycle is typically segmented by stages to facilitate planning, provisioning, operating and supporting the system-of-interest. These segments provide an orderly progression of a system through established decision-making gates to reduce risk and to ensure satisfactory progress.

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 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, utilized, supported and retired. The representative system life cycle model shown in Figure 9 illustrates this passage. This model is based on the six stages described in Annex B of the International Standard and Clause 7 of this Technical Report.

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

Figure 9 — Representative system life cycle model

This life cycle model is a framework that helps ensure that the system is able to meet its required functionality throughout its life. The stages in Figure 9, although drawn as discrete, are in practice interdependent and overlapping. Thus, while defining system requirements and developing system solutions during the concept and development stages, functional experts from stages later in the life cycle (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.

Three common principles associated with a life cycle model are listed below:

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

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

c) specific life cycle stage attributes such as producibility, usability, supportability and disposability should be specified and designed into a system.

The system life cycle model that is presented in Figure 9 is discussed in Clause 7 from an enterprise view and an engineering view. The enterprise view illustrates sequential, incremental, and evolutionary approaches.

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5.5 Process application concepts

5.5.1 Process use

5.5.1.1 General

The focus of the International Standard 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, service provider) or management to fulfil responsibilities pertaining to the system-of-interest. Additionally, the processes in the International Standard can be used as a reference model for assessments under ISO/IEC 15504.

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).

Figure 10 illustrates example inputs and outputs of a process for engineering a system. The inputs can be either converted to desired outputs or can enable or control the conversion. Each set of these process inputs and outputs needs to be defined and managed.

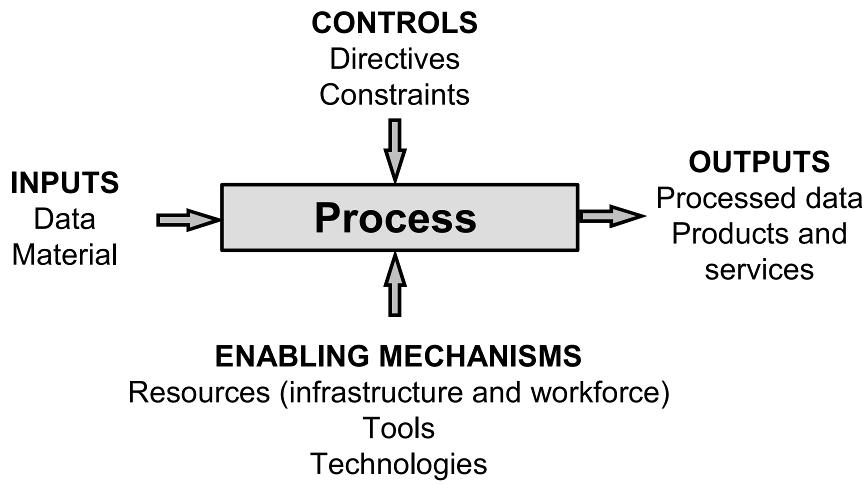

Figure 10 — Example process inputs and outputs

5.5.1.2 Controls

Processes can be controlled by organizational or enterprise 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 other systems for which the project is responsible (see Figure 8 of this Technical Report);

c) the applicable system life cycle stage or stages;

d) the organization or enterprise that has project responsibility.

5.5.1.3 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;

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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.

5.5.2 Life cycle processes

5.5.2.1 General

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 enterprises using the processes selected for a life cycle stage.

The International Standard describes four groups of system life cycle processes – agreement, enterprise, project and technical. Each process has a specific purpose, a set of expected outcomes and a set of activities. Each group of processes is described in Annex D of the International Standard and summarized in the following clauses of this Technical Report. Guidance for the application of the International Standard life cycle processes is provided in Clauses 6, 7 and 8 of this Technical Report.

Small organizations when considering a new project should select a life cycle model such as shown in Figure 9 and the necessary International Standard 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. The process groups are described below.

5.5.2.2 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 engineer, 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:

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

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

c) to obtain work efforts by consultants, subcontractors, functional organizations, projects or individuals or teams within a project. See Figure 6 of this Technical Report for examples;

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

5.5.2.3 Enterprise processes

Enterprise 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 enterprise through these distinct processes provides the services that both constrain and enable the projects, directly or indirectly, to meet their requirements.

The enterprise processes included in the International Standard are not necessarily the only processes used by an enterprise for governance of its business. For example enterprises also have processes for managing accounts receivable, accounts payable, payroll processing and marketing. These processes are not directly within the scope of the International Standard and thus are not discussed further in this Technical Report.

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For multiple projects involved in or interfacing with an enterprise, or for a teaming arrangement among external organizations, other enterprise processes can be appropriately established or the processes of the International Standard can be appropriately tailored.

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

The International Standard enterprise processes have specific objectives to fulfil such as listed below.

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

b) Ensure that there is an orderly approach to starting, stopping and redirecting projects.

c) Ensure that organizational policies and procedures are defined that set forth the processes of the International Standard and that are applicable to projects within the enterprise.

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

e) Ensure that projects have adequate resources for the project to meet budget, schedule and performance requirements within acceptable risks and that human resources are appropriately trained for completing their responsibilities.

f) Ensure that project work products for delivery to customers are of a suitable quality.

5.5.2.4 Project processes

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

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

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

5.5.2.5 Technical processes

The technical processes are applicable across all life cycle stages. The following technical processes should be performed to engineer a system:

a) Stakeholder Requirements Definition Process;

b) Requirements Analysis Process;

c) Architectural Design Process;

d) Implementation Process;

e) Integration Process;

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f) Verification Process;

g) Transition Process;

h) Validation Process.

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 mid-system life cycle stages the technical processes may be used to define and realize 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.

The other three technical processes (Operations Process, Maintenance Process, 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 unwanted by-products from system use.

5.5.3 Recursive/iterative application of processes

5.5.3.1 General

Two forms of process application – recursive and iterative – are essential and useful for executing the requirements of the International Standard.

5.5.3.2 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, the application form is referred to as recursive. The outcomes from one application are used as inputs to the next lower (or higher) system in the system structure to arrive at a more detailed or mature set of outcomes. Such an approach adds value to successive systems in the system structure. Figure 11 illustrates the recursive application of processes to systems from the top down.

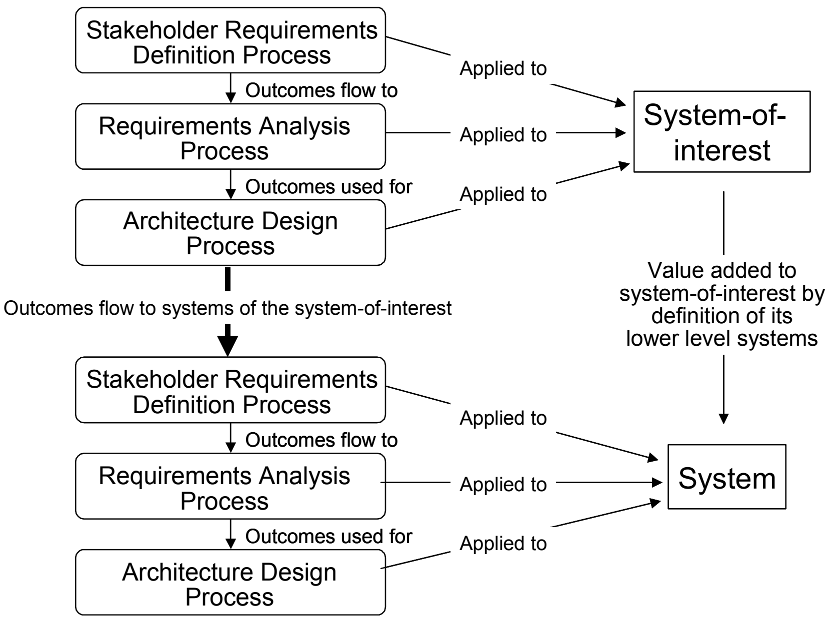

Figure 11 — Recursive application of processes

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5.5.3.3 Iterative application of processes

When the application of the same process or set of processes is repeated on the same system, the application is referred to as iterative. 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. Iteration can be required to ensure that information with admissible quality is used 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. The iterative application of processes is illustrated in Figure 12.

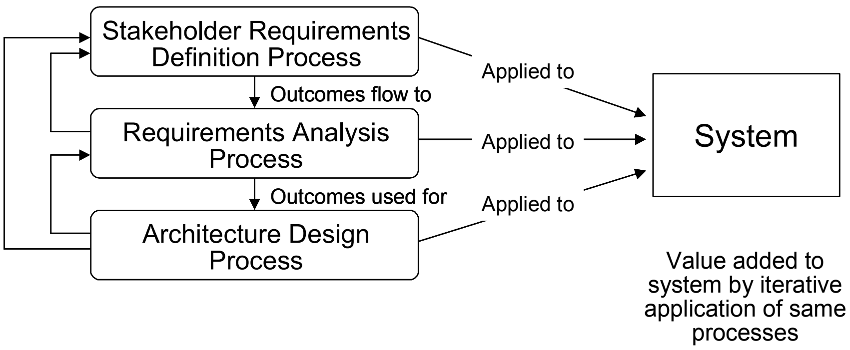

Figure 12 — Iterative application of processes

5.5.4 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 the International Standard nor this Technical Report includes discussions of specific methods and tools. Nevertheless, there are some issues that the user of the International Standard 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 does not pre-empt 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 as well as the type of system being engineered, utilized or supported.

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, enterprises, 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.

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6 Application of the International Standard life cycle processes

6.1 Overview

The International Standard life cycle processes can be used for at least four purposes:

a) to engineer or re-engineer a system;

b) to form an agreement;

c) to satisfy an agreement;

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

This clause provides guidance on the application of the International Standard life cycle processes to help satisfy the first three purposes above. The order of these three in the list reflects the sequence of the sub-clauses in this clause. As to the fourth purpose listed above, Clause 7 provides guidance on the application of processes within the system life cycle stages.

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

6.2 Application of the technical processes to engineer a system

6.2.1 General

Figure 13 provides a model for the application of the technical processes of the International Standard. This model includes only the technical processes that are primarily used for engineering a system-of-interest. Three of the technical processes are not shown in Figure 13 – the Operation Process, Support Process and Disposal Process. These three processes should be used as appropriate to provide inputs to the Stakeholder Requirements Definition Process. The requirements could be in the form of acquirer requirements such as operability, supportability and disposability or in the form of other interested party requirements such as for enabling systems to provide related services. In the discussions below on the technical process model for engineering a system, process application will be to a system whether it is the top-level system-of-interest or one of the systems or system elements in the system structure. When a process application is relevant to just the system-of-interest or a system element in the system structure, then specific terminology will be used.

The Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process are used to design the solution for each system in the system structure. Application of these processes can be highly iterative in order to arrive at the desired design solution (see 5.5.3.3 of this Technical Report). The Implementation Process, Integration Process, Transition Process and Validation Process are used to realize the architectural design solution for each system in the system structure. Likewise, application of these processes can be highly iterative.

The first three processes are applied recursively to the system-of-interest and then its systems from the top down until a system element can be implemented (for example built, bought, reused) using the Implementation Process. This occurs when no further systems need to be developed. After all system elements of the system structure are implemented, then the Integration Process, Verification Process, Transition Process and Validation Process are performed recursively on each system from the bottom up to include the top level system-of-interest.

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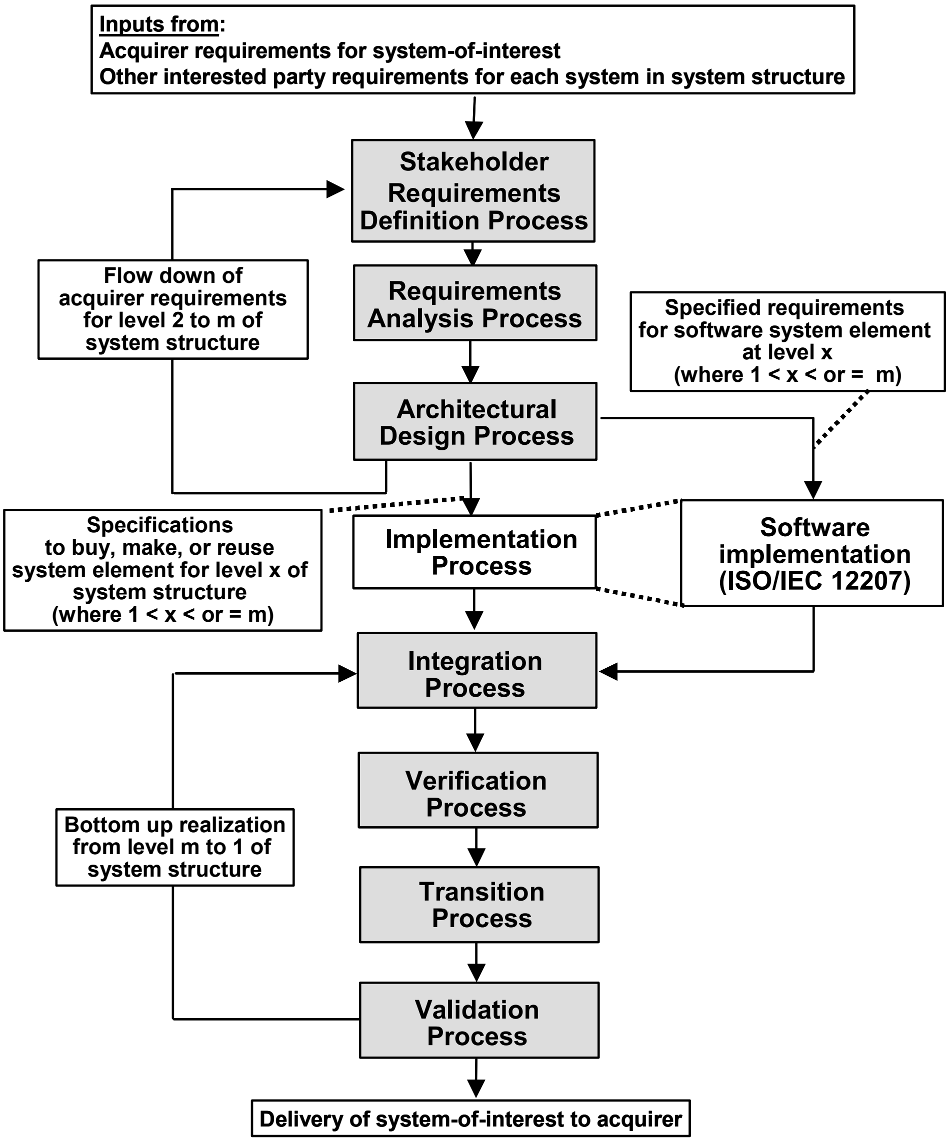

Figure 13 — Application of technical processes to engineer a system-of-interest

Each process of this model is described below. Additional notes intended to help use these processes are found in Annex C of this Technical Report.

6.2.2 Related technical processes for system definition

6.2.2.1 General

The Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process should be used to create design solutions for a system from the top-level system-of-interest down through the lowest system element level of the system structure.

6.2.2.2 Stakeholder Requirements Definition Process

The Stakeholder Requirements Definition Process can be used to identify, collect and appropriately define stakeholder requirements. The acquirer and other interested parties together form the stakeholders related to the system being engineered. The acquirer provides the initial set of requirements for each system in the system structure. Other interested parties typically provide additional requirements that can influence the design solution. Examples are given in the list below:

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

b) critical factor needs such as safety, security, producibility, reliability, availability and maintainability;

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

In performing the Stakeholder Requirements Definition Process, the appropriate activities of the Implementation Process, Integration Process, Verification Process, Transition Process and Validation Process should be used to generate requirements that will influence the system being engineered. Appropriate activities of the Operation Process, Maintenance Process and Disposal Process should also be used to generate applicable requirements.

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

The resulting set of stakeholder requirements represents a collection of requirements placed on the engineering of a system. These stakeholder requirements include the functions that are required to be performed, how well they should be performed, the environment in which they are to be performed, any required characteristics of the system and any service related to enabling systems. These requirements should be used when performing the Validation Process after the system has been implemented or integrated and verified.

6.2.2.3 Requirements Analysis Process

The Requirements Analysis Process can be used to perform an analysis of the stakeholder requirements and transform the stakeholder requirements into a set of usable technical requirements. Stakeholder requirements are not always stated in technical terms and may not be readily usable for architectural design. This includes the identification and analysis of external interface requirements, functional requirements and constraints as well as the quantitative and qualitative measures related to these requirements.

The resulting set of technical requirements should be checked for upward and downward traceability to ensure that no stakeholder requirement has been omitted and all defined technical requirements have a parent stakeholder requirement.

6.2.2.4 Architectural Design Process

6.2.2.4.1 General

The Architectural Design Process can be used to transform the defined set of technical requirements into an acceptable architectural design solution that fulfils the technical requirements for the system being engineered. The architectural design solution should be documented in a technical data package or database that includes a set of architectural design solution specifications and other configuration descriptions.

6.2.2.4.2 Logical architectural design

The first step should be to transform the set of technical requirements to a more detailed set of derived technical requirements that have been derived from a set of logical architectural design models [see 5.5.4.3 a) of the International Standard]. This can be accomplished by performing the logical architecture design activity of the Architectural Design Process. Logical architectural design models can take one or more forms such as described below:

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

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

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

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

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

f) the states and modes of the system;

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

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

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

j) a set of algorithms derived from contextual diagrams.

Each logical architectural design model should be evaluated to determine the impact of the model on system quality.

The performance requirements from the set of technical requirements can be allocated to logical architectural design models to form a set of derived technical requirements taking into consideration the operational environment. These derived technical requirements can be used as the basis for physical architectural design.

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

The set of derived technical requirements should be checked for upward and downward traceability with respect to the set of technical requirements generated by the Requirements Analysis Process.

6.2.2.4.3 Physical architectural design

6.2.2.4.3.1 General

After logical architectural design is completed, physical architecture design is performed. In performing physical architecture design, the logical architectural design models, the derived technical requirements and those technical requirements not allocated to logical architectural design models can be used to form alternative physical design solutions [see 5.5.4.3 b) through h) of the International Standard]. The analysis that should be performed to evaluate each alternative physical design solution is described in Table C.16 of this Technical Report. After each alternative physical design is evaluated, the preferred architectural design solution should be selected using an appropriate analysis of cost effectiveness, operational effectiveness and risk.

6.2.2.4.3.2 Physical architectural design outputs

The architectural design solution selected should then be fully defined to provide the outputs listed below.

a) A configuration description including the system specifications of the system that was defined by the Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process (see 6.2.2). This configuration description should be used when the Verification Process is performed after the system has been implemented or integrated.

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b) The requirements that will be flowed down to the next lower level systems or system elements (see 6.2.3). These requirements should be used as the acquirer initial specifications (or requirements) for the development of lower-level systems or system elements, unless the architectural design solution is for a system element that will have no lower-level systems to develop.

c) The requirements for enabling systems needed to provide life cycle support to the designed system (see 6.2.5). These requirements should be used to acquirer required enabling systems.

Configuration descriptions can be in the form of specifications, baselines, sketches, drawings, parts lists and other appropriate design descriptions. The specific configuration descriptions will depend on the life cycle stage in which the Architectural Design Process is being used and the information needed to satisfy the exit criteria of the life cycle stage and the entry criteria for the next stage.

6.2.2.4.3.3 Traceability of physical architectural design outputs

The requirements expressed in the configuration description outputs above should be checked by an appropriate means to ensure that they are upward and downward traceable. Traceability should be checked against three sources of requirements:

a) the derived technical requirements from logical architectural design;

b) the derived technical requirements that resulted from analyses of the alternative physical design solutions;

c) the output requirements from the Requirements Analysis Process that were not allocated to a logical architectural design model. This could happen when a technical requirement from requirements analysis cannot be allocated to a logical architectural design model (see last paragraph of 6.2.2.4.2).

The Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process can be performed again, as necessary, to refine the requirements for the physical architectural design solution and the related output configuration descriptions (see the discussion on the iteration concept, 5.5.3.3 of this Technical Report). Factors that can cause this iteration include identification of a need for new stakeholder requirements during architectural design or the failure to satisfy the upward and downward traceability check.

6.2.3 System structure definition

One of the possible outcomes from physical architecture design includes the requirements for the next lower level systems or system elements. These output requirements are the acquirer requirements for the recursive application of the Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process to a lower-level system in the system structure. The systems or system elements at the next lower level of the system structure will later be integrated into the system from which the requirements were assigned.

The recursive application of the Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process described in 6.2.2 is shown in Figure 13 as the loop identified as the flow down of acquirer requirements for level 2 to m of the system structure. For each system of the system structure that has to be developed the Stakeholder Requirements Definition Process, Requirements Analysis Process and Architecture Design Process should be applied. Other interested party requirements should also be determined in order to form the input set of stakeholder requirements for each system or system element at the next level of the system structure. (See the discussion on the recursion concept, 5.5.3.2 of this Technical Report.)

The recursive loop of Figure 13 is continued until all system elements of the system structure have been defined and no additional systems or system elements need to be developed. System elements can occur at any level x of the system structure as shown in Figure D.3 of the International Standard. At each level x, when no further development is needed for a system in the system structure, the next set of processes for system realization should be performed (see 6.2.4 and Figure 13). This is an example of the recursive application of technical processes to enhance the top-level system-of-interest definition by defining its lower level systems

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and system elements. The top level for one enterprise can be the system that will be purchased by a consumer in a commercial market, such as an automobile. The top level for another enterprise can be a system within the system structure such as a motor that will be assembled into the automobile by another enterprise.

Also, at any level x, a system element can be identified as having a unique standard that may be used for implementation of that system. This is illustrated in Figure 13 for software using ISO/IEC 12207.

The recursive application of the first three processes of Figure 13 is repeated within the system structure until the implementation process is applicable for a system element and until all system elements have been implemented. At this point the system structure is fully defined.

6.2.4 Related technical processes for system realization

6.2.4.1 General

The Implementation Process, Integration Process, Verification Process, Transition Process and Validation Process should be used to realize the architectural design solution for each system in the system structure from the bottom system element to the top-level system-of-interest of the system structure.

Each implemented system element should be verified using the Verification Process and validated using the Validation Process before integration is performed at the next higher level of the system structure.

After all system elements of the system structure are appropriately implemented, the definition of the system structure is complete. Then the bottom up, recursive application of the Integration Process, Verification Process, Transition Process and Validation Process should be performed from level m to 1 of the system structure for each system and for the system-of-interest.

6.2.4.2 Implementation Process

The Implementation Process can be used when further development of a system element is not needed. At this point the system element defined as part of an architectural design solution can be implemented. The Implementation Process should be used to transform such system element definitions into products or services appropriate to the applicable life cycle stage. The implemented system element can be either a single product (for example a component or part) or a composite product (for example a subassembly) depending on its position in the system structure and its ability to be appropriately modelled, built, bought or reused.

6.2.4.3 Integration Process

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

6.2.4.4 Verification Process

The Verification Process can be used to establish correspondence between the performance and characteristics of the system and its configuration descriptions according to which the system was implemented or integrated. This process ensures that each system element, system and the system-of-interest of the system structure has been implemented or integrated correctly.

This verification should be performed in accordance with a verification plan. The approach to verification can be dependent on the form of the system used to satisfy life cycle stage entry or exit criteria. Example approaches are listed below:

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a) inspection (for example inspection of drawings);

b) analysis (for example using mathematical modelling, simulation or a virtual reality prototype);

c) demonstration (for example using mock-ups or physical models);

d) similarity (for example using already performed verifications of similar systems with similar configuration descriptions or systems that have already been certified to a standard);

e) operation (for example for verification of configuration descriptions that apply to life cycle costs or system attributes such as MTBF);

f) test (for example using physical products, prototypes, breadboards or brassboards).

The system implemented or integrated should be used for performing verification. During early stages of a system life cycle, inspection, analysis, demonstration or similarity could be used for verification. For later stages, operation or testing could be used. For non-critical requirements, however, use of simulations during any life cycle stage for verification can be useful to save cost.

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

Verification failure can result from poor conduct of the verification or improper implementation or integration of the system. Anomalies that are discovered during verification of the system (or system element or system-of-interest) need to be appropriately resolved prior to the transition of the system to the acquirer and before performing validation.

6.2.4.5 Transition Process

The Transition Process can be used to deliver to the acquirer a fully integrated and verified system. The delivered system can also be validated if the agreement requires validation to be accomplished by the supplier before transition. Appropriate transition should be performed for each system element, system and the system-of-interest from the bottom of the system structure to the top.

Considerations for transition should include, as appropriate, packaging and handling, storage, transportation, installation and ensuring that each site is properly prepared for the installation or receipt of the system. Transition activities will be dependent on the life cycle stage and the position of the system within the system structure.

6.2.4.6 Validation Process

The Validation Process can be used to establish correspondence between the performance and characteristics of the system with respect to stakeholder requirements and other agreement requirements. Validation should ensure that the “right” system has been implemented or integrated to fulfil stakeholder requirements or expectations. The set of stakeholder requirements used for validation can be the output of the Stakeholder Requirements Definition Process. Or, they can be the acquirer requirements and applicable interested party requirements received from the acquirer in an agreement that were the inputs into the Stakeholder Requirements Definition Process. The system implemented or integrated should be used for performing validation in either its actual operational environment (considering other interfacing system elements or systems-of-interest) or its simulated operational environment. The environment of validation is dependent on the position of the system in the system structure. The form of the system will be dependent on the life cycle stage in which validation is performed.

Validation should be conducted to demonstrate that the “right” system has been implemented or integrated after the same system has been verified using the Verification Process. The system should be verified that it was implemented or integrated correctly before showing that it is the “right” system.

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

Validation can be completed either prior to transition to the acquirer or after transition as specified in the agreement. If validation of the system (“as modelled”, “as-built” or “as-integrated” and “as-verified”) is performed before transition, then the supplier normally does this. Otherwise, the acquirer validates the “as-delivered” system prior to the integration with other acquired lower level systems and system elements applicable to the system being integrated. The Validation Process can be performed using a mathematical or simulation model when cost of validation is a factor or where operational environments are not readily accessible.

There are several approaches such as listed below for performing the Validation Process:

a) validation against acquirer and applicable interested party requirements using simulation or mathematical modelling, inspection, analysis or test;

b) certification tests against established requirements;

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

d) as specified in the agreement.

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

Validation failure can result from poor conduct of the validation or improperly transforming the stakeholder requirements into the preferred architectural design solution. Anomalies discovered during validation should be appropriately resolved prior to transition of the system (or system element or system-of-interest) to the acquirer (if validation is done by the supplier) or prior to integration with other systems or system elements into a higher-level system (if validation is done by the acquirer after receiving it from the supplier).

6.2.5 Enabling system definition and realization

For each architectural design solution in the system structure the enabling system requirements related to the system should be identified. The enabling system requirements should be satisfied either by engineering the enabling systems that need to be developed or by acquisition or scheduling the existing and available enabling systems. These actions should be carried out to assure that required enabling system services are available when needed to support the applicable system in the system structure during the applicable life cycle stage. Figure 14 illustrates the relationship of enabling systems with the processes of Figure 13.

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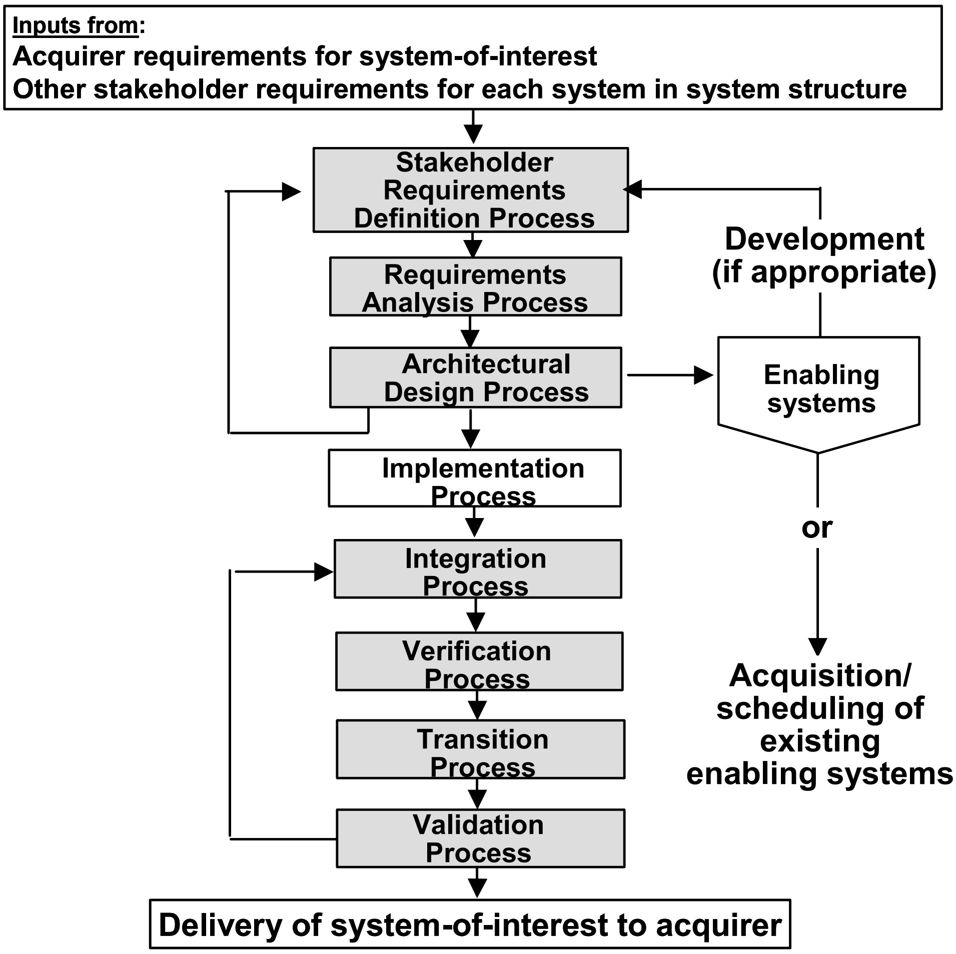

Figure 14 — Enabling systems realization

The following discusses an example of the application of Figure 14 to the availability of equipment and tools needed for implementation of a system element or for integration of lower-level system elements or systems. If such equipment and tools already exist, the processes of Figure 13 do not need to be used. Instead the existing enabling systems should be acquired or scheduled as appropriate. If, however, the equipment or tools need to be developed, then the process of Figure 13 should be used in the way described in 6.2.2 through 6.2.4. The acquirer requirements for each enabling system come from the requirements identified during the application of the Stakeholder Requirements Definition Process, Requirements Analysis Process and Architecture Design Process to the system that is to be implemented. Such requirements would include allowable tolerances, types of materials and material processing such as cutting, milling and stamping. Additionally, the concept of operations (or strategy) for implementation should be available as well as any implementation constraints to include special techniques to be used. Figure 14 suggests that an enabling system defined as a system-of-interest and realized using the processes of Figure 13 should also have their own set of enabling systems to provide appropriate life cycle support.

6.3 Application of life cycle processes to form an agreement

The processes of the International Standard can be used to attain an agreement. Figure 15 illustrates the use of the agreement processes in conjunction with the other life cycle processes of the International Standard to attain an agreement. Agreements can be between organizations, between enterprises, between projects, and for work efforts within a project. Such cases are illustrated in Figure 6.

The Figure 15 model is not meant to reflect all possible process flows to attain an agreement but to show that all processes of the International Standard can have a role in forming an agreement, especially formal agreements that can be legally binding. When an agreement involves a relationship between individuals of sub-projects within the same project much less formality can be expected than suggested by the Figure 15

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model. The following paragraphs describe the process flow of the Figure 15 model and exceptions as appropriate.

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

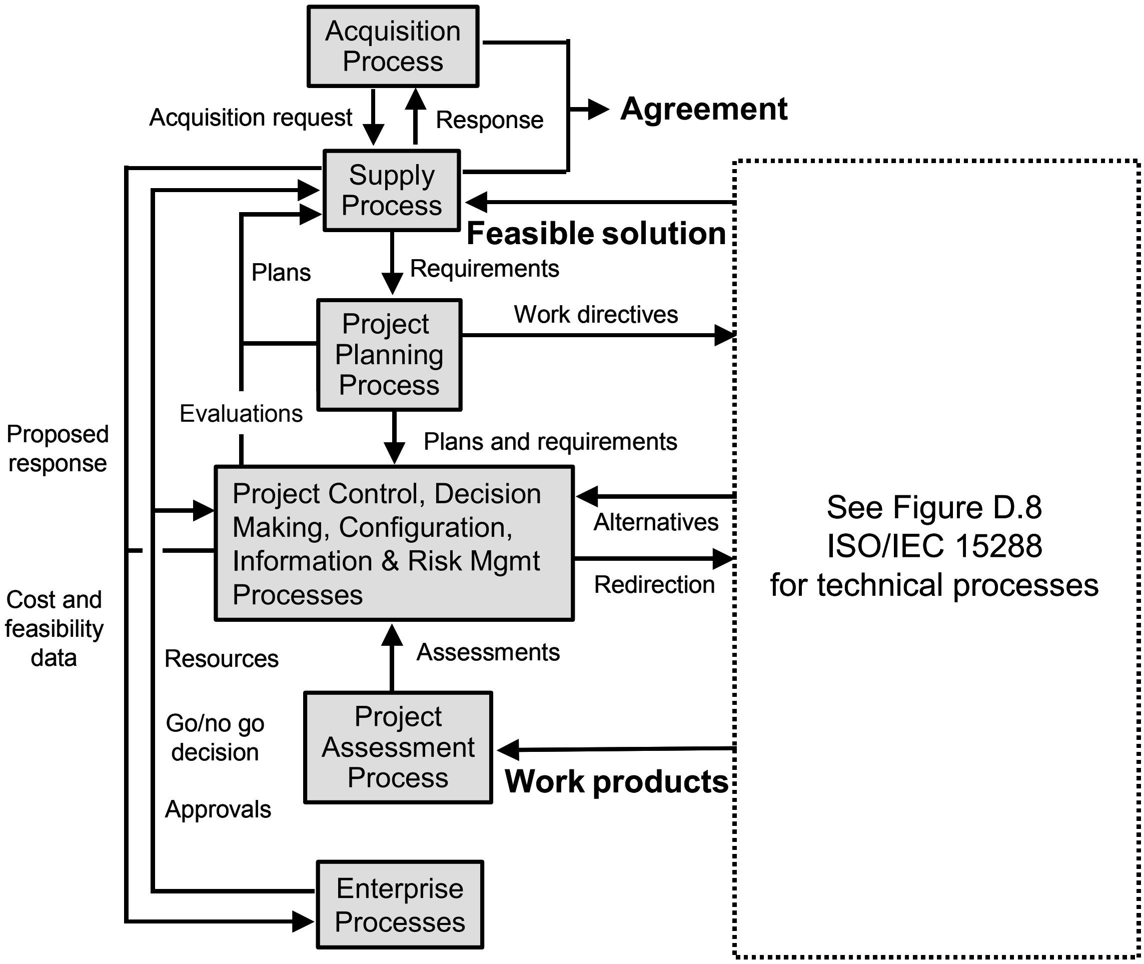

Figure 15 — Application of processes to form a formal agreement

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

The assigned team or individual should perform the activities of the supply process appropriate to establishing an agreement. First the team or individual should do the necessary planning to scope a strategy for the response preparation effort and to understand the capabilities required to do the requested work. The plan should include a schedule of milestones and decision criteria for submitting a response and consider the goals of the organization or enterprise as well as applicable investment decision criteria.

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

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

a) system and service requirements;

b) expected deliverables;

c) development and delivery schedule milestones;

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

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

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

6.4 Application of life cycle processes to satisfy an agreement

After an agreement is established a project is formed, if not already in place, and the appropriate agreement, project and enterprise processes of the International Standard are used in conjunction with the technical processes of the International Standard to do the work to meet agreement requirements. The model illustrated in Figure 16 provides an example of the relationship of processes used within a project for satisfying an agreement. This example is not meant to represent all possible process flows by all possible projects. It does, however, provide an approach one can consider in establishing a process flow appropriate to a particular project. Smaller projects would still do the same processes but the formalization, documentation and level of activity could be reduced in scale as appropriate to the economics of the project.

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

The project exists to satisfy an agreement by providing the desired deliverables to the quality expected. The project performs the Planning Process that could consist of updating the plans used to form the response to the acquisition request or the applicable plans from the previous life cycle stage. Appropriate teams are assigned the work required to meet planned requirements. These teams do the work associated with application of the technical processes to obtain the work products required. The Assessment Process, Control Process, Decision Making Process, Risk Management Process, Configuration Management Process and Information Management Process should be used to monitor, control, and assess the technical process outcomes to be able to keep work within acceptable cost, schedule and risk in order to meet performance requirements for the system. The enterprise processes are implemented as appropriate to provide support to the project, and to review the project, as appropriate. See 5.5.2.3 for the objectives of the enterprise processes.

The activities of the processes shown in Figure 16 can be considered as complete when the agreement is fully satisfied with the delivery of required products and services.

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

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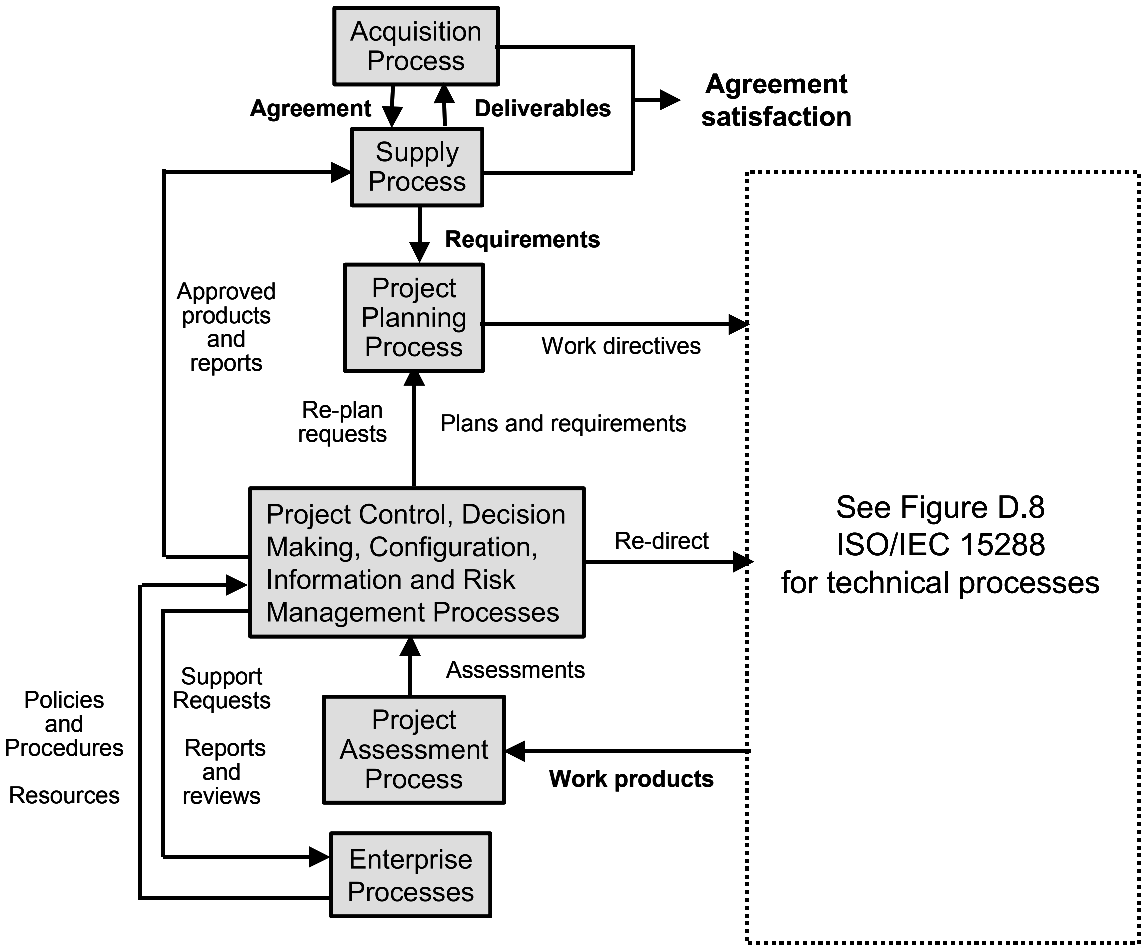

Figure 16 — Application of processes to satisfy an agreement

7 Application of International Standard processes using the system life cycle

7.1 Overview

The International Standard requires the establishment of a life cycle model to provide a framework in which the processes of the International Standard are performed. It also requires the definition of purpose and outcomes for each stage in the established life cycle model. The International Standard provides in Annex B a description, including the purpose and outcomes, of a set of six life cycle stages. Figure 9 in 5.4 of this Technical Report provides a model reflecting the six stages. This model is included in Figure 17 as a reference for two related views of the system life cycle – the enterprise view and the engineering view.

The system life cycle model illustrated in Figure 17 does not imply any application precedence or sequence for the application of the International Standard life cycle processes. The order of use of the life cycle processes is influenced by multiple factors such as social responsibilities, world trade laws, organizational cultures and technical considerations. Each of these factors can vary during the life of a system. A manager of a system life cycle stage typically selects the appropriate set of life cycle processes to meet the exit criteria and other stage objectives. For example, during any of the later life cycle stages a manager can use the Operation Process, Maintenance Process and Disposal Process to manage the system while it performs its required functions or is serviced to meet system requirements. During earlier life cycle stages the same processes can be used to help manage the development of the system as well as affect the disposal of waste products or work products that are no longer needed.

To determine which processes to select and apply during a system life cycle stage, a manager is guided by the purpose and outcomes for each of the stages (see Annex B of the International Standard). The selection

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of the appropriate processes enables the system's progression through its life cycle to be managed. The system life cycle model of Figure 17 can be considered as an illustration of an orderly passage associated with a system going from one stage of life to another. Both the enterprise and engineering views of Figure 17 can be helpful in enabling this passage.

An enterprise (for example an automobile company or medical equipment supplier) or a domain group of an organization (for example a government defence agency or industry group) often has a unique view of the system life cycle to control the passage from one system life cycle stage to the next. The enterprise view illustrated includes management-focused activities that are used to form both milestones and decision gates. The enterprise uses these milestones and gates as decision points where investment decisions can be made as to whether a system should be continued to the next system life cycle stage or be modified, be cancelled or retired or have the plans for the next stage revised before approval. These milestones and decision gates can be used by enterprises to contain the inherent uncertainties and risks associated with costs, schedule and functionality when a system is created or utilized.

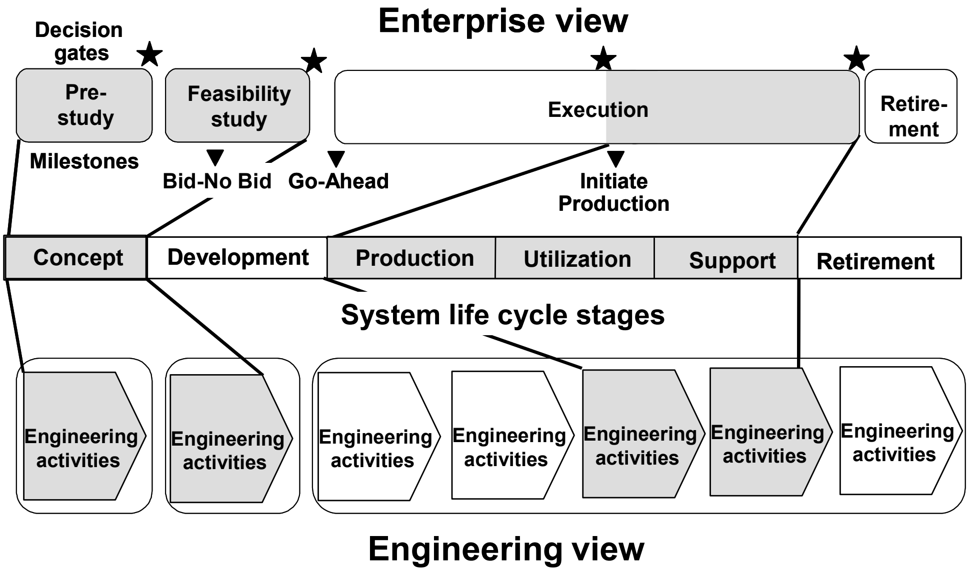

Figure 17 — Enterprise and engineering views related to representative system life cycle model

The enterprise view of Figure 17 provides an example framework in which different approaches can be used to meet enterprise goals and objectives. The framework and example approaches for the enterprise view are described in 7.2 below.

In order to meet the exit criteria of a decision gate, a system has to be appropriately engineered and the appropriate work products need to be produced to provide decision-making information and required deliverables. Thus planned engineering activities need to take place during each system life cycle stage to obtain the outcomes and meet the purpose of the stage or a set of stages. The engineering view of Figure 17 provides an example framework of engineering activities required to meet the criteria of management decision gates and related system life cycle model milestones. This engineering view is described in 7.3 of this Technical Report.

7.2 Enterprise view

7.2.1 Approaches

The enterprise view of Figure 17 can vary according to the nature, purpose, use and prevailing circumstance of the system-of-interest or the business of the enterprise. Nevertheless, despite a necessary and apparently limitless variety in such views, there is an underlying notional set of characteristic milestone and decision gates that exists. Each milestone and decision gate has a distinct purpose and contribution to the system life cycle. These milestones and decision gates should be considered when planning and executing the system

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life cycle. Milestones provide an interim opportunity for management to review progress between or before decision gates. Examples of milestones are provided in the paragraphs below. The decision gates provide a framework within which enterprise management has high-level visibility and control of the project.

During early system life cycle stages, management can use established decision gates to determine whether the objectives (financial as well as technical) of the system life stages were satisfactorily completed and whether the system is ready to progress to the next stage. During later life cycle stages while the system is being used (utilization and support), the decision gate is typically used to make three kinds of decision as listed below:

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

b) whether new system technology should be inserted (change to system performance);

c) whether the system should be appropriately retired.

The concept stage of a system life cycle model has two major decision gates. The first decision gate is after a period of pre-study. Prior to this decision gate appropriate research and development is carried out, technology challenges and opportunities are explored and potential system concepts are analysed. Those concepts that have promise for future business opportunities are presented to management for approval to continue the development of the more promising concepts. The concepts can be needed to develop a new market, to respond to a specific threat or to respond to a request for proposal.

After studying the feasibility of the alternative concepts a second decision gate is used. Determinations such as listed below should be made before a decision is made to initiate the execute stage of the enterprise view:

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

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

— whether to approve a proposal generated to respond to a request for proposal.

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

Execution of the enterprise view illustrated in Figure 17 includes activities related to four stages of the system life cycle – development, production, utilization and support. Typically there are two decision gates and two milestones associated with execution activities of the management view. The first milestone provides the opportunity for management to review the plans for execution before giving the go-ahead. The second milestone provides the opportunity to review progress before the decision is made to initiate production. The decision gates during execution can be used to determine whether to produce the developed system-of-interest and whether to improve it or retire it.

This enterprise view applies not only to the system-of-interest but also to its systems and system elements that make up the system structure. Different enterprises can be responsible for different systems of the system structure. And, the systems and system elements can have a shorter life than the system-of-interest in which they are embedded and during the life of the system-of-interest. These can need to be replaced with improved systems or system elements.

Enterprises employ the execution activities of the enterprise view of Figure 17 differently to satisfy contrasting business and risk resolution strategies. Sequential, incremental or evolutionary approaches are frequently used. These approaches are discussed in the clauses below. Alternatively, a suitable hybrid of these approaches can be developed.

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

— the acquisition policy of the organization;

— the nature and complexity of the system;

— the stability of system requirements;

— technological opportunities;

— the need for different system capabilities at different times;

— the availability of resources.

7.2.2 Sequential approach

7.2.2.1 General

For systems that have development cycles of 5 or more years before delivery of the first system, a sequential approach can be appropriate. Many systems, such as produced by the automotive industry, use a similar approach with development taking up to 3 years before a new automobile model is introduced.

The sequential approach is illustrated by the enterprise view of Figure 17 and has defined decision gates so that an enterprise can manage an orderly progression of the system from conception through retirement.

For systems that rely heavily on off-the-shelf system elements, development is often directed to start in the execution phase of Figure 17 without doing concept studies. In this case, the project needs to be aware of the risks of starting development without doing the risk reduction engineering of earlier studies. Use of off-the-shelf system elements does not alleviate doing the engineering required to ensure system feasibility or doing the risk reduction analyses and effectiveness assessments needed to ensure that interfaces are compatible and that the system elements are expected to be compatible and interoperable so as to meet functional requirements. What this off-the-shelf approach does is to reduce the need to go through earlier decision gates, not eliminate the analysis necessary to reduce risks of this approach.

The sequential approach is useful for engineering unprecedented systems or systems that use state of the art technologies to provide a competitive edge. Projects using this approach face many challenges including cost control, funding changes, technology changes, workforce retention, requirement changes and final customer or acquirer requirements satisfaction. These challenges are created because of the long period from establishing the initial requirements for the system to the deploying of the system in the marketplace.

7.2.2.2 Applicable systems

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

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

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7.2.2.3 Risks

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

a) Expectations and requirements related to the system could change over the years of development.

b) Knowledgeable workers on teams could turn over.

c) Decision making personnel in the organization could change.

d) Customer personnel in the acquirer’s organization could change.

e) Suppliers of system elements and related services could go out of business or change technologies.

f) Technical risks could be present.

g) Technical obsolescence could arise during a long development.

7.2.2.4 Opportunities

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

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

b) All system capabilities are delivered at the same time.

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

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

7.2.3 Incremental approach

7.2.3.1 General

The incremental approach applies to organizations that market new versions of a product at regular or pre-planned intervals. An enterprise view not unlike the view of Figure 17 is used. However, milestones are established at planned intervals to introduce a planned version of the system that can be released to the market. The system realized as a result of the concept stage can be a first version.

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

The application of the International Standard life cycle processes as illustrated in Figure 13, Figure 15 and Figure 16 is performed to realize each version. The operation and support of each version is done in parallel with the development, utilization and support of successive versions. Early versions of the system and support for those versions can be phased out as newer versions are bought and used by the customer base or a block modification to earlier versions could be made to incorporate the new capabilities of a later version.

7.2.3.2 Applicable systems

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

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7.2.3.3 Risks

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

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

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

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

d) Expectations may not be met if customers desire the full capabilities in the first version.

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

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

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

7.2.3.4 Opportunities

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

a) Acquirer requirements for early capabilities could be satisfied.

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

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

7.2.4 Evolutionary approach

7.2.4.1 General

The evolutionary approach also applies to enterprises that market new versions of a product at regular or pre-planned intervals. The major difference of this approach with the incremental approach is that the full capabilities of the last version of the system are not known when an evolutionary development is undertaken. Initially the requirements for the system are partially defined and then refined with each successive version of the system as lessons learned from the use of an early version are translated into new desired capabilities.

The International Standard life cycle processes as illustrated in Figure 13, Figure 15 and Figure 16 are applied to realize each version. In this case, development of new versions could be done serially or in parallel with partial overlapping. As with versions developed using the incremental approach, different versions can be operated and supported in parallel. Particular care should be taken, however, to maintain configuration control of each version so that operation, training and support procedures are appropriate to the version being used. Often, a new version with enhanced capabilities could replace an earlier version, or a block modification can be made to the earlier version to incorporate the new capabilities of a later version.

7.2.4.2 Applicable systems

This approach applies mainly to complex systems for which requirements are not well understood even though the need for the system is understood and approved. These are typically one of a kind or low quantity production systems. Example systems can include custom information technology systems, military information technology systems and specific information technology security systems. This approach is also useful for systems that have to achieve quality in use.

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7.2.4.3 Risks

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

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

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

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

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

e) Configuration control could be a problem.

f) Inappropriate early use of a product prototype in production.

7.2.4.4 Opportunities

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

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

b) Customer feedback could be used to enhance the capabilities of a future version of the system.

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

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

e) Take advantage of emerging technologies.

7.3 Engineering view

7.3.1 General

Engineering is involved with a system in the early life cycle stages (concept and development) when it is being studied, defined and created. Re-engineering is involved in later stages (production, utilization, support, retirement) when unwanted and unexpected variations come about due to design errors or failures or new requirements are provided because of technology or competition changes.

To engineer a feasible system solution during the concept stage, a system structure needs to be sufficiently defined and evaluated. This should be done to assure that system requirements are met and that the costs and risks are understood for the feasible system concept selected. When a parts list is an exit criterion (for example required as part of a proposal or in order to prepare a creditable cost proposal), sufficiently detailed engineering should be done to ensure that the parts list is complete and that the costs and risks are understood.

To engineer a system solution during the development stage a system needs to be designed with appropriate detail from the system-of-interest level down through successive system levels until a system element can be made, bought, reused or implemented by software. Each system should be verified that it meets its specification requirements included in configuration descriptions from architectural design, and validated that it meets the acquirer and other interested party requirements. Each system element needs to be transitioned to the acquirer where it can be assembled and integrated into a higher-level system that is verified, transitioned and validated. This action continues through successive levels upward to realize the desired system-of-interest.

This approach whether applied to the concept stage or the development stage is typically called top down and bottom up engineering and describes one block of the engineering activities illustrated in the engineering view

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of Figure 17. The top down, bottom up approach is illustrated in Figure 18 and is identified in technical literature as the “Vee” diagram or model. This figure reflects the work products and actions expected from the recursive application of the processes in Figure 13 to define and realize the system structure.

Although the engineering “Vee” model of Figure 18 only shows four levels, the Stakeholder Requirements Definition Process, Requirements Analysis Process and Architecture Design Process should be applied to the system-of-interest, systems and system elements of a system structure, and the example work products (specifications and verification and validation plans) should be developed for levels 1 through m of the system structure as illustrated in Figure 13.

The box at the bottom of the “Vee” in Figure 18 represents application of the Implementation Process at some level x of the system structure where $1 < x \leqslant m$. The result is an implemented system element that can be a mathematical model or physical prototype or the physical product to be transitioned to the acquirer. The actual product is dependent on the system life cycle stage and enterprise view exit criteria for a decision gate or milestone.

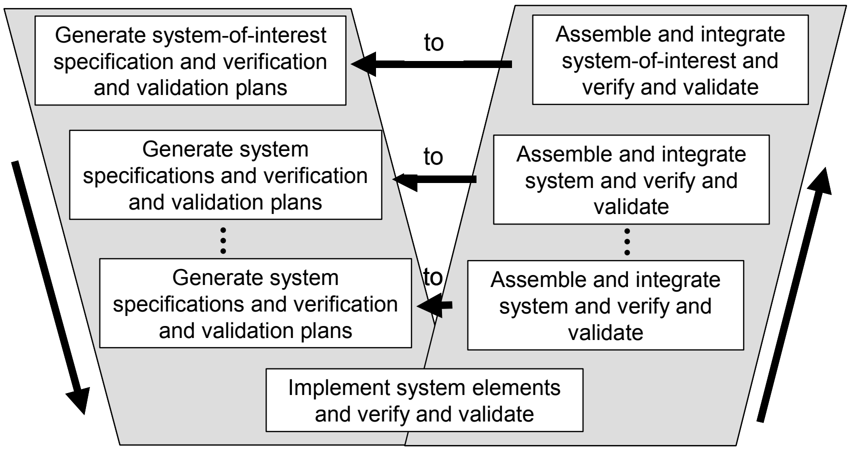

Figure 18 — The engineering “Vee” model

The right side of the “Vee” in Figure 18 illustrates the application of the Integration Process, Verification Process, Transition Process and Validation Process to form higher-level systems. These processes are applied recursively from level m to 1 to each system element, each system and finally the system-of-interest. This illustrates that each system, including the system-of-interest, in the system structure should be integrated and verified and validated against the configuration descriptions and other descriptive documents of the corresponding system on the left.

Re-engineering efforts to correct variations or failures and to meet changed requirements are typically initiated at a system level within the system structure and below the level of the system-of-interest. The same general engineering approach using the “Vee” model is appropriate. In this case, however, the system affected is the place in the system structure where the re-engineering effort begins. The requirements for the change are analyzed as to how they could affect interfacing and interacting systems and the performance of the system-of-interest. Then the Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process are used downward through successive levels of system structure to define architectural solutions. After the system elements are implemented using the Implementation Process, the Integration Process, Verification Process, Transition Process and Validation Process can be used upward through successive levels to the system-of-interest. This approach is often called middle-out engineering.

The engineering “Vee” model is used in each system life cycle stages as appropriate to meet stage entry or exit criteria or to meet the enterprise view milestone or decision gate requirements. Such use is illustrated in Figure 19 by replacing the “engineering activities” identified blocks shown in Figure 17 with the engineering “Vee” model of Figure 18.

Representative outputs are provided for each application of the “Vee.” These products are used to satisfy the requirements for the applicable milestone or decision gate of the enterprise view (see Figure 17).

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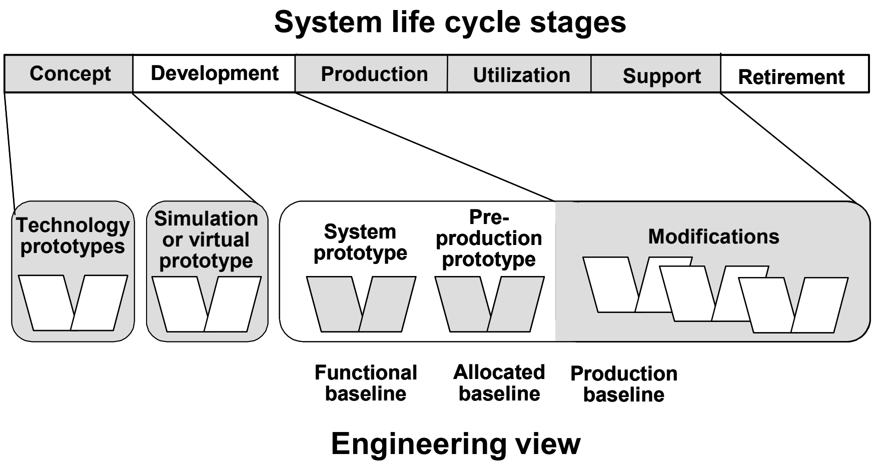

Figure 19 — Engineering view with engineering "Vee" models

7.3.2 Technical reviews

Technical reviews such as listed below should be conducted for each project as appropriate to the engineering view used.

a) A review held prior to performing the Requirements Analysis Process to ensure that the stakeholder requirements are complete, consistent with the acquirer's intent, understood by the supplier and have been validated. This review can prevent proceeding with a less than acceptable set of requirements.

b) A review conducted to consider all concepts looked at and to determine whether the preferred concept has the potential of satisfying defined stakeholder requirements and is based on a set of viable, traceable technical requirements that are balanced with respect to cost, schedule and risk.

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

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

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

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

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

   4) approaches planned for developing designs for pre-production prototypes are appropriately planned;

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

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

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

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

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

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

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

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

7.3.3 Configuration audits

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

a) A functional audit is used to demonstrate that system verification or qualification test results compare favourably with the specifications against which testing was performed and that planned test procedures were followed. This audit is also used to confirm that verification results compare favourably against configuration documentation such as drawings, authorized changes and “as-built” or “as-coded” records. Additionally, the functional audit is used to confirm that the “as-built” or “as-coded” configuration is favourably examined against its configuration documentation such as drawings, bill of materials, specifications, code lists, manuals, compliance test and compliance data. A pre-production prototype or the first system produced is typically used for verification or qualification testing. This audit should be typically completed before release of the system for initial production.

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

    1) to confirm that the system has been realized correctly in accordance with its drawings or specifications;

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

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

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

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

8 Application by organizations

8.1 Overview

Organizations are producers and consumers of systems; that is they trade products and services. The processes in the International Standard are used by organizations that acquire and use or create and supply a system. The processes apply at any level in a system structure during any applicable stage of the system life cycle and to any organization assigned responsibility for a system. The outputs of one level, whether information, products or services, are an input to the level below and result in a corresponding response

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including information, products or services. The use (recursively) of the same underlying set of processes to describe an organization's business, project and technical actions at each level of detail in a system structure is a key aspect of the application of the International Standard.

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

8.2 Uses of the International Standard within an organization

There are three key uses of the International Standard within an organization. These uses are illustrated in Figure 20 and described below.

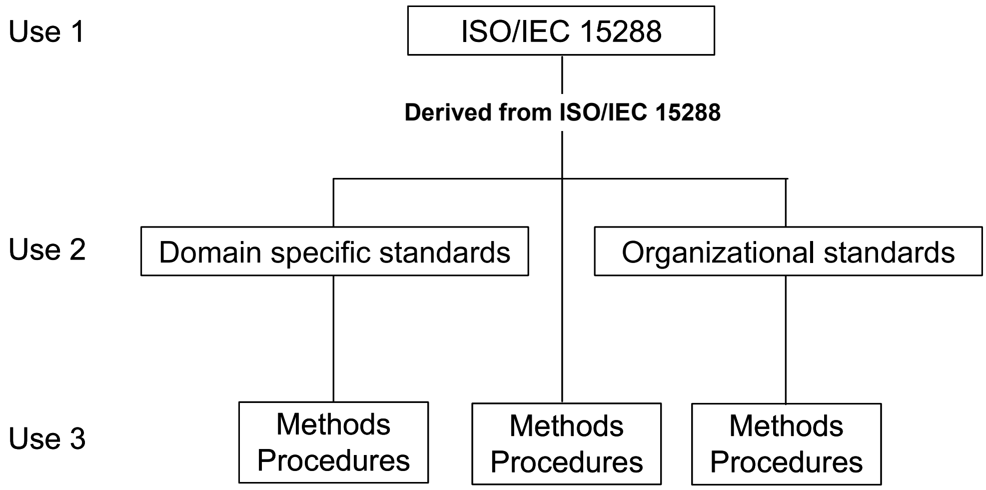

Figure 20 — Three uses of the International Standard

Use 1 is a direct application of the International Standard to organizational work. The International Standard describes the life cycle processes in terms of process name, purpose, outcomes and activities. Thus, direct application is the application of a set of selected life cycle processes to the appropriate system-of-interest during a life cycle stage to achieve the process outcomes and satisfy stage objectives and exit criteria. To successfully apply the selected processes each activity is further defined by the organization. This further definition includes identifying the tasks by which an activity will be accomplished. From these tasks and the nature of the activity, methods and tools are determined for completing the tasks efficiently and effectively. The outcomes from performing tasks should include appropriate documentation. The extent of documentation should be based on project size, life cycle stage exit criteria, agreement deliverables, resources available and any other influencing factors identified.

For successful application of the International Standard within an organization the methods and tools for completion of activities and tasks should be selected and made available to projects. The team members involved with applying the processes should be trained on the concepts and requirements of the International Standard as well as the selected methods and tools.

Use 2 is for the purpose of creating appropriate organizational standards and organizational domain standards. These standards can be derived from the applicable concepts and requirements of the International Standard in order to standardize the primary work of the organization and domains such as aerospace, automotive, medical equipment and so forth. Figure 4 illustrates this adoption as a tailoring of the scope of the International Standard to the organization. In this use it would be a tailoring of the scope of the International Standard to the applicable domain. Use 2 type standards should be more focused to the business of the various organizational units and domains. As in Use 1, the activities should be defined in more detail by identifying necessary tasks, selecting and providing the appropriate methods and tools and performing work according to procedures and sequencing defined in these standards. Organizational and domain team members should be trained in the appropriate standard and the applicable methods and tools prior to applying on a project.

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Use 3 is for the purpose of preparing appropriate documents describing organizational and domain-wide methods, procedures and guidance for implementation of organizational and domain standards as well as for direct application of the International Standard. Appropriate training on the applicable document is necessary prior to application on a project.

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Annex A
(informative)

Relationship between ISO/IEC 15288 and other more detailed standards

This annex is included to help the reader understand how other engineering related standards and ISO/IEC 15288 can be used together.

The International Standard defines a generic, top-level framework based upon a set of processes that can be combined into various suitable life cycle models. It does not, and is not intended to, define in detail systems engineering or the engineering of systems. However, the International Standard is expected to strengthen the relationships between systems engineering, software engineering and other affected engineering disciplines. It is intended to do this through promotion of consistent and uniform terminology among the various engineering disciplines. It is also intended to establish interactions and improved communication between the various engineering disciplines needed to create systems.

There are various other standards that cover engineering disciplines in detail. This Annex draws upon the content of such standards to illustrate the framework without attempting to provide specific mappings. Standards such as the following can be considered.

a) ISO 13407, *Human-centred design process for interactive systems*

b) IEC 61508, *Functional safety of electrical/electronic/programmable electronic safety-related systems*

c) ISO/IEC 15026, *Information technology — System and software integrity levels*

d) ANSI/EIA 632, *Processes for Engineering a System*

e) IEEE 1220, *Application and Management of the Systems Engineering Process*

f) ISO/IEC 12207, *Information technology — Software life cycle processes*

g) ISO/IEC TR15271, *Information technology — Guide to ISO/IEC 12207 (Software life cycle processes)*

h) ISO/IEC 15939, *Software engineering — Software measurement process*

i) ISO/IEC 9126 (all parts), *Software engineering — Product quality*

j) ISO/IEC 14598 (all parts), *Software engineering — Product evaluation*

The International Standard is 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 Standard are likely to be invoked during the whole life cycle of the system.

In addition, processes can be invoked from more than one of the stages described in the International Standard. For example the Requirements Analysis Process is not only invoked prior to initial design during the concept and development stages, but also for all subsequent evolutions during the support stage. This varied use typically requires that differences be incorporated to take account of the point of invocation from within the life cycle.

Figure A.1 illustrates notional interaction of different standards with the International Standard. In this example, four kinds of standards can be used to provide activity and task level detail for the International Standard life cycle processes. From this perspective the International Standard life provides high-level requirements for processes. A user can select the appropriate processes to manage the life cycle of the system based on their responsibilities and stage exit criteria. Figure A.1 illustrates that a second tier of standards can provides similar or alternative activities for implementing selected processes. Different second tier standards can be used for later life cycle

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stages than used earlier. A third tier of standards can provide task detail that is required to implement the activities of first and second tier standards. The use of multiple sources for defining the activities and tasks of the International Standard life cycle processes provides an effective means to construct sets of system life cycle processes that can be applied to a given system during various system life cycle stages to satisfy enterprise view exit criteria for milestones and decision gates.

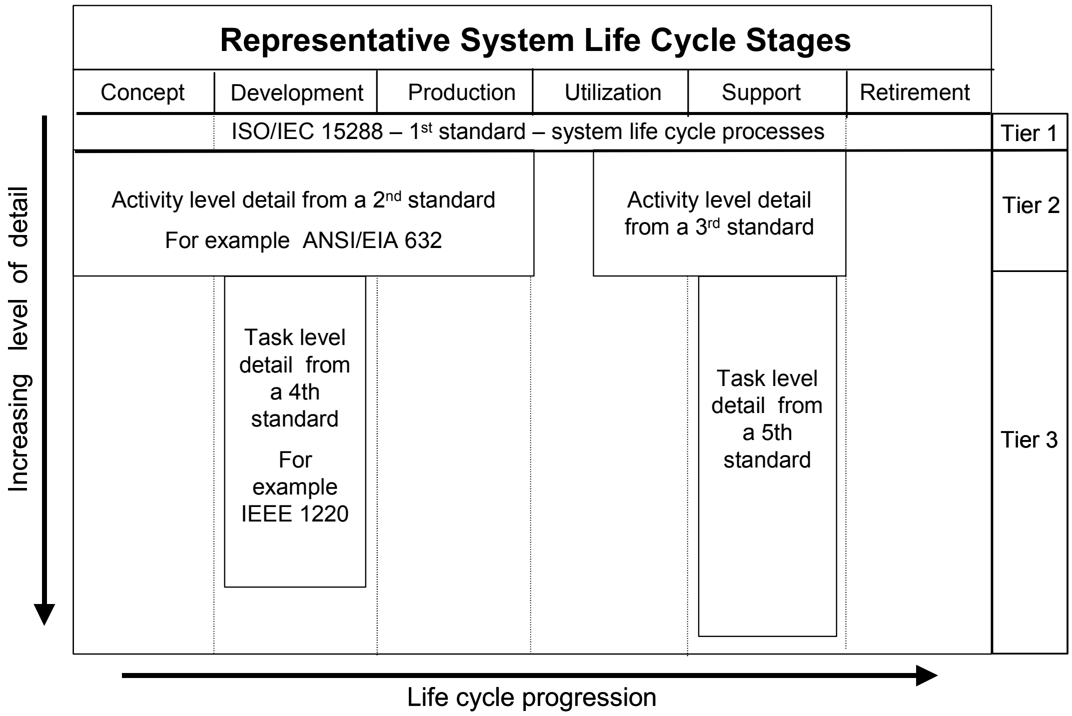

Figure A.1 — ISO/IEC 15288 and other engineering standards

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Annex B
(informative)

References for design related special factors

B.1 General

This annex provides a discussion of selected special factors that can affect system design and a list of references for guidance on the application of these special factors with respect to International Standard requirements.

B.2 Example special factors

B.2.1 General

The focus of the International Standard is on the engineering, operation, maintenance and disposal of a complex man-made system. Each system can have essential special factors such as listed below that should be designed into an architecture design solution so that a system can be successful:

a) health, safety and welfare concerns for operators, users and the general public;

b) interoperability, safety, security, reliability and disposability concerns with respect to the system.

B.2.2 Health

Planned usage rates and environments, operational concepts and other system requirements can present health risks with respect to potential damage to human life including operators and others (both people and animals) who come in contact with the system 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 that health issues may persist after the system is retired.

B.2.3 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 system design. Outcomes from analysis should include human concerns and recommendations as to related design requirements that could mitigate the adverse impacts identified.

B.2.4 Interoperability

Data flows are essential within a system and between systems so that operational functions can be successfully performed over the system life. The potential failure causes of data (or information) to properly flow 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.

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B.2.5 Safety

Operational concepts and other system 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.

B.2.6 Security

Operational concepts, usage environments and other system requirements can present security risks with respect to the system 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.

B.2.7 Usability

The operational effectiveness and hence the acceptance of many systems depends on a user's ability to realize the intended capability of the system. Systems that include human elements depend on operators of the system 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.

B.2.8 Dependability

The failure potential of any part of the system will determine whether the system 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 system life. Outcomes from such analyses should include specific dependability concerns and recommendations as to related requirements that could help make the system more dependable.

B.2.9 Disposability

The impacts on the environment from the disposing of hazardous materials 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 disposal of waste products from system-of-interest use or from disposal of the system-of-interest or one of its system 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 system disposal.

B.3 Connection between specific special factors and design

Table 1 illustrates the connection of example specific factors from Clause B.2 with example kinds of system elements that make up a system-of-interest and that is the subject of architecture design work. The intersection of a specific factor and system element of Table 1 indicates that the specific factor should be considered in the architecture design of a system when that factor will create an impact on that system. Other specific factors and system elements for user domains can use this approach to analyse important relationships applicable to design.

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Table B.1 — Connection between kinds of system elements and specific factors for design

Example specific factors	Example kinds of system elements			
	Hardware	Software	Humans	Other
Interoperability	•	•	•	
Security	•	•	•	•
Safety	•	•	•	•
Dependability	•	•	•	•
Disposability	•	•	•	•
Other		•	•	•
Other	•	•		•

The purposes of this analysis are given below:

a) to ensure that specific factor requirements are included in system development;

b) to ensure that appropriate specific factor experts participate in system architectural design work;

c) to ensure that specific factors are appropriately designed in to the architecture design solution of the system from the perspective of the impact on systems and system elements making up the system structure.

B.4 Special factor references

Table B.2 — Special factor references

Specialty	Reference	Description
Human	ISO 6385	Provides guidance on the design of systems of work, in particular task and job design.
	ISO 9241	A 19 part standard that provides recommendations for tasks, workspace, physical and software ergonomics for systems that include software.
	ISO 9241-2	Extends the guidance in ISO 6385 to include use of computer-based systems.
	ISO 9241-11	Provides guidance on the preparation and analysis of a statement of context of use, and specifies usability as a summative performance measure for a system. "Quality in use" is the equivalent term used in ISO/IEC 9126.
	ISO 10075	Provides guidance on the measurement and management of mental workload.
	ISO 13407	Describes the principles of human-centred system development and the processes in an iterative life cycle involving end users. It is written in the form of guidance for project managers. It includes criteria for assessing when human centred design is required.
	ISO TR 18529	Provides human-centred life cycle process descriptions in the format used in ISO/IEC 15288.

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Table B.2 *(continued)*

Specialty	Reference	Description
Quality	ISO 9000 ISO 9001:2000	Provides requirements for quality management and quality management systems, in particular in relationship with certification.
	ISO/IEC 9126-1	Provides quality model for software products in information technology.
	ISO/IEC 14598	Part 1 – Provides a general overview for software product evaluation in information technology. This is a framework for evaluating the quality of all types of software products and a statement of the requirements for methods of measurement and evaluation of software products. Part 2 – Provides planning and management in information technology. The details about the planning and management requirements which are associated with software product evaluation are provided herein. It also aims to clarify the requirements which should be provided by the organization in order to ensure the success of the evaluation. Part 3 – Provides a process for developers of software product evaluation in information technology. The guidelines for clarifying quality requirement and for implementing and analysing software quality measures. This applies to all software in all phases of the development lifecycle. Part 4 – Provides a process for acquirers of software product evaluation in information technology. The requirements, recommendations and guidelines for the systematic measurement, assessment and evaluation of software product quality during acquisition of “off-the-shelf” software products, custom software products, or modifications to existing software products.
Safety	IEC 61508	Provides guidance on safety engineering using electric and electronic process control systems.
Security	ISO/IEC 15408-1 ISO/IEC 15408-2 ISO/IEC 15408-3	Provides basis for evaluation of security properties of information technology products and systems.
	ISO/IEC 7498-2	Provides open systems interconnection and basic reference model for security architecture.
Usability	ISO/IEC 9126	Provides information on the definition and assessment of usability.
Dependability	IEC 60300-1	Provides non-quantitative product characteristics that encompass all aspects of availability performance and its factors of reliability performance, maintainability performance, and maintenance support processes.
Disposability (Environment)	ISO 14000 ISO 14001	Provides information on the management of systems in order to satisfy environmental needs.

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Annex C
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Notes for application of ISO/IEC 15288 processes

C.1 General

This annex provides users of the International Standard with additional help for selection and use of selected International Standard processes. This help is based on notes that could affect process selection and application.

Two essential elements of each process in the International Standard are the purpose and set of outcomes. The purpose statement provides the overall rationale for the use of the process. The outcomes are the expected observable results from carrying out the activities of a process. The outcomes provided for each process in the International Standard provide a benefit that motivates selection and execution of that process. The notes below are intended to help in the application of process activities to realize the outcomes. Cross-reference with one or more clauses from the International Standard are provided to aid use.

The NOTES embedded within the clauses of ISO/IEC 15288 are informative guidance material only and do not constitute requirements of the International Standard. The NOTES in ISO/IEC 15288 are intended to clarify the intent of the activity to which they are associated and have the same status as those included in this annex.

C.2 Agreement processes notes

Table C.1 — Acquisition Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. In order to properly accomplish the Acquisition Process activities, applicable project, technical and enterprise processes should be implemented, as appropriate.	5.2.2.3 5.3, 5.4, 5.5
2. Typically in any acquisition situation there are several approaches or ways of doing something. An approach or way that best achieves the overall acquisition goals and constraints is desired. Considerations to include are: a) after market opportunities; b) business unit policies; c) enterprise environment; d) financial resource availability; e) human factors; f) improvement strategy; g) integration and interoperability; h) logistics (supportability); i) obsolescence; j) operational environment (pollution, disposal);	5.2.2.3 a)

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Table C.1 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
k) producibility; l) safety; m) security; n) competition; o) stakeholder goals; p) survivability; q) time-to-market constraints; r) potential risks for acquisition and supply.	
3. An acquisition plan is prepared using the Project Planning Process.	5.2.2.3 a) 5.4.2
4. Typical solicitation documents include: acquisition request (for example request for proposal, request for bid, request for information, request for quote), memorandum of intent, offer or directive.	5.2.2.3 b)
5. Whenever possible for a formal contract situation involving outside suppliers the potential suppliers need to be involved in the definition of the acquisition request document to provide an optimum match of capabilities with system requirements.	5.2.2.3 c)

Table C.2 — Supply Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. In order to properly accomplish the Supply Process activities, applicable business unit, project management and technical processes are implemented, as necessary, to provide needed work product, financial and planning information.	5.2.3.3 a) 5.3, 5.4, 5.5
2. A solicitation is typically from an internal or external business unit (it can be internal to the project). The solicitation does not need to be formal.	5.2.3.3 a)
3. Alternatively, business units conduct market research in order to establish the opportunities available within a particular business sector.	5.2.3.3 a)
4. A supply plan is prepared using the Project Planning Process.	5.4.2.2
5. Typically in any supply situation there are several approaches or ways of doing something. An approach or way that best achieves the overall organizational and supply goals and constraints is desired. Considerations to include are: a) applicable legislation and regulations that apply to the supplier; b) business unit goals; c) competition; d) enterprise environment and policies and procedures; e) resource availability; f) related management, technical and resource risks; g) subcontracting options.	5.2.3.3 b)

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C.3 Enterprise processes notes

Table C.3 — Enterprise Environment Management Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. The Enterprise Environment Management Process sets the environments for business units in which multiple on going projects are accomplished to include applicable strategic and tactical business plans, system life cycle models, and policies, procedures and standards. In addition it establishes constraints for technologies, product lines, and project management aids and provides communication paths with which projects interact with each other and the enterprise.	5.3.2.1
2. Policies and procedures that support and direct projects that perform the services and produce the business unit products should be evaluated on a regular basis. Changes to policies and procedures are evaluated to ensure that continuous improvement of business unit maturity for satisfying its strategic and tactical objectives is realized.	5.3.2.3 b)
3. The integrity level for different systems produced by projects can require separate sets of policies and procedures.	5.3.2.3 b)
4. Appropriate management aids are typically established to enable availability of valid information for directing and enabling projects including project status, standardized automated tools, organizational products available for reuse, and the status of emerging technologies and related market opportunities and threats and the information databases in which captured data and documents are warehoused.	5.3.2.3 c) 5.3.2.3 d) 5.3.2.3 e) 5.3.4.3 c)
5. An essential work product of this process is the establishment and maintenance of appropriate life cycle models such as the enterprise view illustrated in Figure 17. The model selected is used to monitor the progress of projects over their life span and enable decisions regarding project initiation, redirection, or termination.	5.3.2.3 d) 5.3.2.3 e)

Table C.4 — Investment Management Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Typically evaluation criteria for establishing new business opportunities are based on: business unit strategic plan, business unit capability, business unit policies, payoff goals, market segment, market position, investment resources, risk levels, value to the customer, technology and competitive advantage.	5.3.3.3 a)
2. Market research includes: 1) contacts with potential user groups in order to identify forthcoming needs for systems, system elements and their related services and to identify expected context of use of future systems, system elements, and services, 2) collect feedback from users and stakeholders (interested parties) on systems, system elements and services already in use and 3) analysing trends in user skills, work loads, and work environments.	5.3.3.3 a)

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Table C.5 — System Life Cycle Processes Management Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. In selecting processes for application within a system life cycle stage some of the processes of the International Standard can be found to be non-applicable to a business unit. In this case, such processes are expected not to be included in business unit standards, policies and procedures or other directive media. In cases where the business unit desires that certain activities of a process be part of directive materials, these selected activities are included as part of the definition of other processes or an entire process could be subordinated to an activity level under another process.	5.3.4.3 a) 5.3.4.3 b)
2. New project processes can be formed or an activity under one of the system life cycle processes can be elevated to the process level.	5.3.4.3 a) 5.3.4.3 b)
3. Standardization of life cycle processes within a business unit can vary. However, business units typically encourage all projects and functional business units to use common practices and standards where it is advantageous to do so.	5.3.4.3 b)
4. Definition of standardized processes includes related methods and tools to be implemented in projects in accordance with business unit policies and procedures and investment decisions.	5.3.4.3 b) 5.3.4.3 c)
6. Appropriate disaster recovery procedures are typically established for all enterprise processes and databases.	5.3.4.3 e)

Table C.6 — Resource Management Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. This enterprise process includes establishment of both human and non-human resource services that enable business units to achieve their goals and objectives within constraints and agreement requirements.	5.3.5.3 a) 5.3.5.3 b)
2. Non-human resource services include, but should not be limited to: a) classified material and project facility security; b) communication systems; c) computing and information technology and services; d) contract management; e) equipment and facility maintenance; f) fabrication and manufacturing; g) field support; h) financial management; i) infrastructure support such as janitorial, mailroom and publication reproduction; j) market research and marketing; k) packaging, handling, shipping, receiving and storage services; l) research and development support; m) tools and technology; n) work, training, and test facilities and equipment.	5.3.5.3 b)
3. The infrastructure and skill mix of personnel in the project ought to be reviewed for consistency with business unit strategic and tactical objectives.	5.3.5.3 a) 5.3.5.3 c)

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Table C.7 — Quality Management Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. This enterprise process is consistent with establishment of quality management approaches that lead to conformance with ISO 9001.	5.3.6
2. This process provides a sufficient level of confidence that system and service quality attributes for each project are adequately defined and activities are effectively and efficiently managed so that customer requirements are met and other parties interested in enterprise business are satisfied.	5.3.6.3 b) 5.3.6.3 d)

C.4 Project processes notes

Table C.8 — Project Planning Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. The Project Planning Process defines the necessary plans to support other processes. For example, to 1) arrive at an investment decision, 2) prepare a responsive response to a solicitation, 3) determine whether to proceed or continue work to satisfy the requirements of a specific organizational model stage entry/exit criteria, 4) guide the work required to meet the requirements of an established agreement or 5) re-plan the work.	1) 5.3.3.3 a) 2) 5.2.3.3 c) and 5.4.2.3 l) 3) 5.3.3.3 h) to j) 4) 5.4.2.3 j) 5) 5.4.2.3 b) to j)
2. Plans are constrained by business goals and objectives and stakeholder needs.	5.4.2.3 a)
3. Re-planning is typically initiated 1) when required by an agreement, 2) when significant variations or anomalies are identified from other process outcomes or 3) before implementation of the next engineering view or enterprise view stage related to the system life cycle model selected by the enterprise (see Figure 17).	5.4.2.3 a)
4. Contingency options are used in a plan when there are known risks or opportunities (for example significant changes in budget, schedule, requirements or technology, or resource availability) that can cause the project or work effort to be redirected.	5.4.2.3 a)
5. Plans should be tailored as to the level and formality to suit project or work complexity, uncertainty and resources including funding.	5.4.2.3 b)
6. Plans include the scope, tasks, methods, tools, measures, risks and resources for applicable system or system element implementation, integration, verification, transition and validation processes, so that each contingency option can be efficiently and effectively used.	5.4.2.3 b) to l)
7. The items a) through d) below should be helpful for determining project schedules, staffing requirements and resources requirements.	5.4.2.3 b)
a) Key events required to meet technical requirements (for example technical review, production readiness review, acceptance test, modification decision review).	5.4.2.3 d)
b) Primary tasks related to accomplishing entry and exit criteria of each key event (for example define stakeholder requirements, prepare engineering drawings, complete technical or management review package, conduct test).	5.4.2.3 d)
c) Support tasks that enable the staff accomplishing primary tasks to meet their objectives [for example 1) acquire resources, equipment and facilities, 2) acquire appropriately skilled personnel for accomplishing the primary tasks, and 3) arrange travel].	5.4.2.3 g) 5.4.2.3 h)

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Table C.8 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
d) Management tasks required to direct, monitor, review and approve the primary and support tasks (for example serve as chair of a technical review, review and approve documents for transmittal to the customer, attend management review, and decide whether to do a technology refreshment, technology insertion or retire the system).	5.4.2.3 g)
8. A work breakdown structure (WBS) of the system structure and applicable non-system-structure-specific related project process activities is typically established. Non-system-structure related project process activities include project planning, assessment and control, risk management, decision-making, information management and configuration management.	5.4.2.3 c)
9. The initial WBS should be based on the system structure and the system life cycle processes. A WBS typically evolves to identify tasks and work packages associated with the specific system in parallel with the technical definition of the structure in which the system exists.	5.4.2.3 c)
10. After approval by the appropriate authority the project schedules are considered a baseline subject to change control in accordance with organizational policies and procedures.	5.4.2.3 d) 5.4.2.3 e)
11. After approval by the appropriate authority the planned budget is typically considered a baseline subject to change control in accordance with business unit policies and procedures.	5.4.2.3 f)
12. Plans can be individual documents in a collective document or captured in an electronic media for access by appropriate participants. A plan is an initial output of a process that enables the process to be efficiently and effectively accomplished. A plan should be made using appropriate project planning process activities.	5.4.2.3 j)
13. The engineering plan provides an explanation of what needs to done, how it will be done, who will do it, when it will be done and where it will be done; as well as how much of a resource is necessary to do the work for each technical process (see Figure 13). The engineering plan explains the above within established constraints of resources and staff and in order to meet cost, schedule and performance requirements within acceptable risks.	5.4.2.3 j)
14. An engineering plan is appropriate for each applicable enterprise view stage (see Figure 17) and for each project (for the engineering or re-engineering of a system) using the engineering “Vee” model.	5.4.2.3 j)
15. The engineering plan is also known as the Systems Engineering Management Plan (SEMP) or Integrated Management Plan (IMP).	5.4.2.3 j)

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Table C.8 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
16. The list below should be used as a checklist to ensure inclusion and completion of essential and applicable information in an engineering plan. a) The general problem to be solved. b) The benefit to the acquirer (business unit perspective). c) The application context of the general problem to be solved. d) The boundary of the general problem to be solved, denoting what can be controlled by the developer (inside) and what influences the development and is influenced by the development but not controlled by the developer (outside). e) The required inputs and outputs including dependencies on enabling systems. f) The influencing factors and constraints. g) The system concerns with respect to reliability, availability, maintainability, security, safety, information quality, health factors, survivability, electromagnetic compatibility, radio frequency management and human factors. h) Project processes, activities, and tasks that will be accomplished. i) How each applicable technical process will be accomplished and how each process connects (inputs and outputs data flows and sequencing) with other technical, project, enterprise and agreement processes. j) Resources, methods and tools planned to accomplish the activities and tasks of each applicable process. k) How required resources and tools will be acquired and used. l) The organizing structure to be used to ensure efficient and effective teamwork. m) How the project will be staffed and managed. n) Key measures for product quality and how satisfaction will be determined. o) Key intermediate events and how such event completion will be determined. p) When, where and by whom activities and events will be completed. q) The technical risks involved and how risks will be managed. r) Potential opportunities and how the opportunities will be identified and tracked. s) The completion criteria for the process activities. t) The entry and exit criteria for re-performing each process. u) How completion will be determined.	5.4.2.3 j)

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Table C.9 — Project Assessment Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Formalized methods for cost and schedule management exist. Examples include: a) design-to-cost (used to establish a cost requirement equivalent to other system performance requirements); b) event-based scheduling [used to establish events (for example milestones), significant activities and tasks related to an event, and the criteria by which completion of activities or tasks are determined]; c) earned value (used to define the budgeted cost of the work performed and make comparison to the budgeted cost of the work scheduled and the actual costs of work performed to determine estimates at completion and cost and schedule variances).	5.4.3.3 a)
2. Appropriate analyses and assessments are conducted to: a) determine the continuing consistency and relevance of project plans (management and technical); b) determine project technical progress using defined technical metrics based on estimated achievement and milestone completion; c) determine effectiveness of the project team technical roles and structure using where possible objective measures such as technical achievement and efficiency of resource use; d) determine the adequacy of team member technical competencies and skills to satisfy technical roles and accomplish technical tasks; e) determine the effectiveness and value of supporting training; f) determine the adequacy and availability of the technical infrastructure and services at defined intervals to confirm that intra-organizational commitments are satisfied; g) determine the quality and progress of the design of system, materials used, and enabling system services; h) determine technical variances with project estimates and identify variances to cost, availability and performance specifications; i) evaluate the effectiveness of technical data gathering, processing and dissemination; j) determine technical variations between expected results and assessment results to detect trends and identify root causes; k) determine the quality of technical data gathered, the value of the information derived, its timeliness, completeness, validity, confidentiality (if required) and its benefit to recipients.	5.4.3.3 a) to f)
3. The Project Assessment Process should be used to select, assess and collect system and process measures to provide information for support of project management. Specifically it includes determining: a) progress of the project; b) information for risk resolution; c) meaningful financial and non-financial performance; d) effectiveness and risk information for doing trade-off analyses and providing recommendations on actions to take and resulting impacts.	5.4.3.3 a) to l)

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Table C.9 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
4. Use of the Project Assessment Process aids management decision making by providing information that results from monitoring and analysing project work to determine: a) progress and achievement against plans (work productivity) and against technical requirements (product quality); b) adherence to practices and procedures; c) readiness to proceed to the next stage of the enterprise view (through decision gates or milestone reviews) or to the next level of the system structure; d) effectiveness, risks and opportunities associated with alternatives available to decision makers; e) trade-off analyses results to include recommended course of action and impacts of each on cost, schedule, performance and risk.	5.4.3.3 a) to f)
5. Product measures assess progress and achievement against system and other work product technical requirements.	5.4.3.3 a) 5.4.3.3 d) 5.4.3.3 f)
6. System measures (also called product measures) are used to assess stakeholder satisfaction and to deliver an ever-improving value to the acquirers of project products and services. These measures also are indicative that the design process is continuing in the direction of an acceptable solution. An example of an input system measure is the quality of materials and skills of assigned project personnel. Examples of output measures include: customer complaints, in-service failure reports and technical performance measures (TPM). A TPM is a measure used to assess design progress, compliance to performance requirements, and technical risks for critical performance parameters. TPMs are derived from the MOPs (see Annex C.18 Note 4) focusing on the critical technical parameters of specific architectural elements of the system as it is designed and implemented. Selection of TPMs should be limited to critical technical thresholds or parameters that, if not met, put the project at cost, schedule, or performance risk. A TPM provides an early warning of the adequacy of a design in terms of satisfying selected critical technical parameter requirements. The TPM includes the projected performance, such as a growth curve with thresholds of acceptable variance. Performance of the system or system element is tracked through the life cycle and compared to the projected and required values. Early in the life cycle the performance values may be estimated, based on simulation and modelling. As the life cycle proceeds, actual data replaces estimates and adds to the fidelity of the information. This measurement of the design solution as it evolves allows action to be taken early in the process, rather than wait until system testing to address.	5.4.3.3 a)
7. The planned times, and actual or estimated labour, material and service costs should be collected and evaluated and compared against baseline budgets and current forecasts.	5.4.3.3 a) 5.4.3.3 h)
8. The outcomes of a productivity assessment (progress satisfying plans) provide status information to enable efficient use of resources, evaluation of progress against plans, identification of variances of cost and schedule from planned project baselines and early identification and resolution of productivity problems.	5.4.3.3 b) 5.4.3.3 h)
9. When variations are significant or cannot be corrected by re-performing the process tasks that generated the outcome data, the project planning process is re-initiated in order to plan and implement appropriate corrective actions.	5.4.3.3 d) 5.4.3.3 e) 5.4.3.3 f)

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Table C.9 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
10. Measures are identified and used to assess the efficiency of the scheduled work. Example measures include earned value (cost/schedule measure), amount of waste, number of engineering changes, percentage of drawings completed, number of drawing errors, percentage of lines of code completed, rework percentage, idle time (for example work in progress), change rate and turnover in personnel. The criteria for process measure selection are based on how well enhancement in project performance correlates with improvement in potential customer satisfaction with respect to cost, schedule and risk.	5.4.3.3 e)
11. Measures are defined and used and the data is gathered to permit assessment of customer satisfaction.	5.4.3.3 e)
12. Technical reviews, audits and inspections are conducted against technical plans in accordance with defined schedules to demonstrate conformance of actions and outcomes to planned technical work.	5.4.3.3 f)
13. Typical review objectives include determination of: a) system maturity and how well the solution satisfies requirements; b) traceability of requirements, the validity of assumptions and decision rationale; c) identification of un-resolved issues and those issues not determined during project work; d) related risks, needed resources and adequacy of preparation for conducting the next system life-cycle stage.	5.4.3.3 f)
14. System-of-interest level reviews can be done in conjunction with an enterprise view milestone, decision gate or quality review.	5.4.3.3 f)
15. Non-conformance of deliverable work products, services and processes ought to be recorded and appropriate actions recommended to correct the out-of-conformance condition.	5.4.3.3 g) to I)

Table C.10 — Project Control Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Use of the Project Control Process aids the capture and management of outcomes from project management and technical work including the redirection of that work to overcome obstacles, to respond to changing circumstances or to correct variances.	5.4.4.3 a) 5.4.4.3 b)
2. Requirements management is done in parallel with cost, schedule, quality, configuration, interface, risk and change management activities that track compliance of project agreement and technical requirements.	5.4.4.3 a) 5.4.4.3 b)

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Table C.11 — Decision-making Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. The types of trade-off analyses typically performed during performance of life cycle processes include the following. a) Formal: formally conducted, with results reviewed at technical reviews. Specific formal trade-off analyses are normally identified in an agreement. b) Informal: follows the same methodology of a formal trade-off analysis but requires less documentation and is of less importance to the acquirer. c) Judgmental: selection of a recommended option, based on judgement of the analyst or designer after a less rigorous analysis than that required by a formal trade-off analysis and for which the consequences are not as important. Used when one option is clearly superior to others or time is not available for a more formal approach. Most trade-off analyses performed are of the judgmental type.	5.4.5.3 a) to e)
2. Trade-off analyses are conducted throughout implementation of project and technical processes to resolve conflicts (such as conflicting requirements) and select a recommended solution from a set of defined alternatives (such as optional actions to take for risk resolution, resolutions for requirement conflicts, alternative logical architectural design solutions and alternative physical architectural design solutions). Outcomes from a trade-off analysis include the recommended option, implementation considerations, impacts related to each option, basis of recommendation and assumptions made.	5.4.5.3 c) 5.4.5.3 d) 5.4.5.3 e)

Table C.12 — Risk Management Process

NOTES	ISO/IEC15288 SUBCLAUSE
1. Risk management should not be viewed as an extra activity, as an activity layered on assigned work or as an activity outside a project's responsibility.	5.4.6.3.a)
2. Risk management is a general procedure for resolving risks. Risks are considered resolved when the possible consequences are acceptable. Acceptable means that the project can live with the worst-case outcome. Risk management includes: a) risk planning that includes preparing a risk management plan; b) risk assessment that is used to define the risk including identifying sources and evaluating potential effects; c) risk control that is used to resolve risks and includes developing risk resolution action plans, establishing triggers for implementation of risk resolution action plans, monitoring risk status, implementing risk resolution action plans when a trigger is tripped and correcting deviations from project plans.	5.4.6.3 a) to j)
3. Risk management has two dimensions of awareness, i.e. past and future. The past dimension of risk is based upon past experience and includes benchmarking project measures and lessons learned, measuring actual results with expected results, mapping available resources to requirements with respect to defining and doing the work and implementation of the plan to produce the product. The future dimension is based on transformation of the project vision into goals and objectives used for establishing plans and being aware of the future from which risks and opportunities are identified and the ambiguities of available information and resources as well as the uncertainties uncovered during work.	5.4.6.3 a) 5.4.6.3 i)

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Table C.12 *(continued)*

NOTES	ISO/IEC15288 SUBCLAUSE
4. Risk management includes: a) identification of risk to include sources and related issues, concerns, doubts, uncertainties and assumptions; b) analysis based on established criteria to include estimation of risk probability and consequences and the prioritization of risks; c) planning of alternative strategies for risk resolution, definition of a specific risk action plan for selected approach and establishment of triggers (or thresholds) for taking risk resolution action; d) tracking to include monitoring risk status and comparing thresholds to risk status, using triggers to provide early warning and reporting status based on risk measures; e) resolution of risks by appropriately identifying triggers, implementing an action plan, report results and continuing planned actions till risk is acceptable.	5.4.6.3 a) to i)
5. Risk management tools include for: a) risk identification: risk taxonomy, research, interviews, lessons learned, control charts, affinity diagrams, interrelationship diagrams and system structure or WBS interfaces; b) risk analysis: impact models, probability models, Gantt chart, impact distribution, risk coupling, system structure or WBS interfaces, and ISO risk charts; c) risk alternative strategy planning: ISO risk charts, lessons learned, risk leveraging, warrantees and insurance; d) risk tracking: technical performance measures, earned value, measures and risk watch list; e) risk resolution: impact model, risk watch list, risk template and risk management matrix.	5.4.6.3 a) to f)
6. Keys to successful risk management include the following. a) Right people. People communicate issues, concerns and uncertainties. It is essential to define desired participation, ability and motivation. b) Right Process. Process transforms uncertainty into acceptable risk through risk management activities including execution and definition. c) Right Infrastructure. The organizational culture determines how projects use risk management. The infrastructure is typically specified through appropriate policies and standards and includes identification and dissemination of resources (staff, schedule, budget), requirements (contractual, standards) and expected outcomes (cost, benefit). d) Right information. It is important that the information used to evaluate risks and the status of risks is correct, reliable and timely. e) Right Implementation. It is important to plan risk management and use the appropriate methodologies to perform risk management on a specific project.	5.4.6.3 a) to j)

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Table C.12 *(continued)*

NOTES	ISO/IEC15288 SUBCLAUSE
7. There are three categories of risk to consider: a) project risk – organizational, operational, or contractual concerns including resource constraints, external interfaces, supplier relationships, contractual restrictions, lack of organizational support and vendor unresponsiveness; b) process risk – planning, staffing, tracking, quality assurance and configuration management; c) product risk – technical process implementation, work product characteristics, requirements stability, design performance, complexity and test requirements.	5.4.6.3 b)
8. Risk resolution alternative approaches include: a) acceptance (live with it); b) avoidance (eliminate); c) protection (redundancy); d) reduction (mitigation-risk management culture-do the right processes); e) prevention (team activity-use Integrated product teams); f) anticipation (quantitative risk management measures, prioritize, proactive approach); g) opportunity (look at good outcomes, not just bad ones, everyone’s responsibility, reduce costs, do better than planned); h) research (more information); i) reserves (contingency funding); j) transfer (to another person or organization).	5.4.6.3 f)

Table C.13 — Information Management Process

NOTES	ISO/IEC 15288 SUBCLAUSE
Information management typically includes: planning information; requirements; progress status reports; review data package and other materials for or from acquirer, project management, and technical reviews; design data and schema; lessons learned; the evaluation of input and output information quality; variances and anomalies from validations and verifications and other progress assessments; data deliverables; approved changes; and work authorizations and work orders resulting from management decisions, planning, or approved changes.	5.4.8.3 a)

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C.5 Technical processes notes

Table C.14 — Stakeholder Requirements Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Stakeholder requirements constitute the raw inputs into establishing the problem to be solved (new system concept or modified system based on deficiencies, failures and other anomalies discovered during use).	5.5.2.3 a) to j)
2. The acquirer stakeholder can be internal to the organization (for example another project, marketing organization, parent product team, the product team itself, user, operator, executive manager, supervisor), or external to the organization (for example a procurement agency, prime contractor, another organization, customer, user, operator, owner, purchaser).	5.5.2.3 a)
3. A user is a special case of the acquirer stakeholder who operates a system (for example computer) or who installs a system (for example software) to form a higher-level system (for example a computer or a microchip) in the system structure.	5.5.2.3 a)
4. Interested parties are also referred to as "other stakeholders," or parties other than the acquirer interested in the outcome of the engineering or reengineering work. Other interested party requirements, not necessarily provided by the acquirer in the agreement, include: 1) organizational and project requirements such as those that deal with system markets and organizational processes, 2) environmental, local, national, and international regulations and laws and 3) functional support requirements for system development and integration, production, test, operations and logistics (deployment, training, maintenance, and disposal).	5.5.2.3 a) 5.5.2.3 b)
5. A requirement is typically made up of what has to be done (a function) and how well it has to be done. A function is typically a statement with an actor (noun), an action (verb), and an object (noun) of the action. For example, "The actuator (actor) opens (action) the door (object)."	5.5.2.3 b) 5.5.2.3 g) 5.5.3.3 b)
6. This process includes activities and tasks performed by or for a supplier in the capture and expression of requirements to be met and goals to be pursued in the supply of the system and related services.	5.5.2.3 b)
7. This process involves assuring that requirements for downstream system life cycle concerns [production, test, operations and logistics (deployment, training, maintenance, disposal)] affecting system functionality are identified	5.5.2.3 b)
8. Cost may be a requirement stated as a fixed cost (independent variable) or maximum cost (constraint).	5.5.2.3 c)
9. The context of use statement [as described in the International Standard Note to activity 5.2.3.d)] is a collection of information about the physical, technical, social and cultural elements surrounding a system and an analysis of how these affect (or will affect) how the system is used. The context of use statement is a useful collection of supporting information when preparing the system user and operational requirements. It provides guidance on how and where a system will be used to the designers of the system in considering design alternatives. It is a reference document for the design of validation activities for a system. It is the most detailed source of information about the users of the system and their working environment and is used as the primary guide when selecting users for trials and tests. (See ISO 9241-11 for more information on defining and analyzing context of use.)	5.5.2.3 d) 5.5.4.3 5.5.9.3

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Table C.14 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
10. It is usually not possible to meet all stakeholder (acquirer and other interested party) requirements for a particular system since various stakeholders could have conflicting requirements relative to one another. These conflicts should be identified and resolved during the performance of this process, or as soon as a conflict is identified during activities or one of the other technical processes. The effectiveness assessment, trade-off analysis and risk analysis activities should be used to resolve conflicts.	5.5.2.3 g)
11. Measures of effectiveness (MOEs) should be explicitly identified for each system in the system structure. An MOE is an "operational" measure of success that is closely related to the achievement of the operational objective being evaluated, in the intended operational environment under a specified set of conditions; for example how well the solution achieves the intended purpose. MOEs, which are stated from the user/customer viewpoint, are the customer's key indicators of achieving the objectives for performance, suitability, and affordability across the life cycle.	5.5.2.3 g) 5.5.2.3 j)
12. The stakeholder requirements are the basis for validating the implemented or integrated system that is developed using the technical processes.	5.5.2.3 k) 5.5.9.3 d)
13. Requirements traceability is initiated at this point for tracking requirements and changes to requirements from the stakeholder initial inputs through architectural design.	5.5.2.3 l)

Table C.15 — Requirements Analysis Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Each MOE has a corresponding set of Measures of Performance (MOPs). An MOP is a measure that characterizes physical or functional attributes relating to the system operation. These "system" technical performance indicators are measured under specified testing and/or operational environment conditions. These attributes are considered as important to ensure that the system has the capability to achieve operational objectives. MOPs are used to assess whether the system meets design or performance requirements that are necessary to satisfy the MOEs from which they were derived. MOPs are derived from the solution provider's viewpoint and look at how well the delivered system performs against system level requirements, for example an aspect of the system performance or capability. MOPs often map to key performance requirements in the system specification. They are expressed in terms of distinctly quantifiable performance features, such as speed, payload, range, or frequency. This requires careful definition of MOPs during the Requirements Analysis Process and during logical architecture design and also effective requirements tracing to ensure that the MOPs are in fact identified and designed into the system.	5.5.3.3 d)

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Table C.15 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
2. Each technical requirement statement is validated to ensure that it exhibits the following quality attributes. a) Ability to preserve competitiveness: permits preservation of a competitive stance and is only as constraining on competitive stance as is justified by benefits delivered by requirement. b) Clarity: requirement statement is readily understandable without analysis of meaning of words or terms used. c) Correctness: requirement statement does not contain an error of fact. d) Feasibility: requirement can be satisfied within 1) natural physical constraints, 2) state of the art as it applies to the project and 3) all other absolute constraints applying to the project. e) Focus: requirement is expressed in terms of “what” and “why” or form, fit and function, not in terms of how to develop the products or the materials to be used; detailed requirements that are required to guide detailed design of a product are an exception to this. f) Implementability: requirement statement contains information necessary to enable requirement to be implemented. g) Modifiability: necessary changes to a requirement can be made completely and consistently. h) Removal of ambiguity: allows only one interpretation for meaning of the requirement, for example not defined by words or terms such as “excessive”, “sufficient” and “resistant” that cannot be measured. i) Singularity: requirement statement cannot be sensibly expressed as two or more requirements having different agents, actions, objects or instruments. j) Testability: existence of finite and objective process with which to verify that the requirement has been satisfied. k) Verifiability: can be verified at the level of system structure at which it is stated. l) Abstraction: the correct level of abstraction for the enterprise view stage and maturity of the system.	5.5.3.3 f)
3. Technical requirement statements in pairs and sets are validated to ensure that it exhibits the following quality attributes. a) Absence of redundancy: each requirement is specified only one time. b) Connectivity: all terms within a requirement are adequately linked to other requirements and to word and term definitions so that individual requirements relate properly to other requirements as a set. c) Removal of conflicts: requirement is not in conflict with other requirements or within itself.	5.5.3.3 f)
4. To help ensure achievability of requirements the supplier should consider: a) existing system elements such as commercial-off-the-shelf, known as COTS, that can help reduce development time and cost but may increase complexity; b) introduction of new technology that can provide a competitive edge; c) possible physical solutions; d) new interfaces that can be introduced.	5.5.3.3 f)

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Table C.15 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
5. The resulting set of technical requirements is validated as being necessary and sufficient for designing the system-of-interest architectural design solution. This includes as appropriate: a) downward traceability of the validated set of stakeholder requirements to the set of defined technical requirements; b) upward traceability of the individual technical requirement statements, from the set of defined technical requirements, to the validated sets of stakeholder requirements; c) confirmation that assumptions and derived requirements are valid and consistent with the system and related services being engineered or re-engineered; d) resolution of identified voids, variances, and conflicts including: 1) confirmation that appropriate action has been taken when the set of defined technical requirements is not upward traceable to the validated set of stakeholder needs, 2) determination whether non-sourced (orphaned) requirements or constraints were introduced and whether they are desired by appropriate stakeholders, 3) omitted requirements are added to the set of defined technical requirements, as appropriate, when stakeholder needs are not adequately reflected in the set of defined technical requirements, 4) proof that re-validation of the set of technical requirements has been done when a change is needed to one of the validated sets of stakeholder needs and that the appropriate activities and tasks of the stakeholder needs definition process and requirements analysis process were performed again, as appropriate.	5.5.3.3 g)

Table C.16 — Architectural Design Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Architectural design is concerned with developing satisfactory and feasible system concepts for the set of derived technical requirements, maintaining the integrity of those concepts throughout development, ensuring that the built system for use is appropriately certified against design description specifications during verification and applicable stakeholder requirements during validation and assuring system concept configuration integrity throughout utilization and support stages. The completed architectural design should be used throughout the system life cycle to predict and track fitness for use and for assessing changes to the system.	5.5.4
2. The requirements for enabling systems come from 1) user or customer or assigned requirements and other stakeholder needs for the system and 2) derived technical requirements for systems and generated applying the Architectural Design Process. Thus, initiation of enabling system development or procurement (a function of the project's system boundary) is dependent on the completion of the architectural design solution for the system being engineered or re-engineered and also the applicable system life cycle stage and related engineering view activity or enterprise view stage.	5.5.4.3 a) 5.5.4.3 b) 5.5.4.3 g) 5.5.4.3 i)

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Table C.16 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
3. Logical architectural design includes looking at various logical decompositions and other representations of requirements. There is no set format or form for the various representations. The format or form selected is that which best defines the functional, behaviour or data flow or data structure, as appropriate, and that allows best assignment to potential physical elements, manual operations or enabling systems for generating alternative physical architectural design solutions.	5.5.3.3 a)
4. The defined technical requirements are appropriately allocated to the generated logical architectural design representations. From the various representations a set of derived technical requirements is generated that is used for architectural design. There can be unassigned technical requirements after this allocation is completed. These are assigned directly to alternative physical architectural design solutions.	5.5.3.3 a)
5. In allocating logical representation requirements and derived technical requirements the following are considered as to whether they provide requirements that could best be done: a) by enabling systems associated with development and integration, production, test, operations, support or retirement; b) manually or by facilities, material or data; c) by hardware, software and firmware physical element (new or existing).	5.5.4.3 b)
6. The Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process are repeated for each successive lower level in the system structure until specified requirements for all system elements have been defined or until the defined system element can be built, reused or purchased. If further development is required for a system element, the development could be undertaken using an appropriate system element development standard such as ISO/IEC 12207 for software.	5.5.4.3 b) 5.5.4.3 c) 5.5.4.3 h)
7. During architectural design it can be necessary to repeat the Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process, if it is determined that requirements cannot be met because of unresolved issues related to the solution factors (see architectural design expected outcomes) or adverse cost, schedule, performance or risk impacts for available alternatives.	5.5.4.3 b) 5.5.4.3 c) 5.5.4.3 j)

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Table C.16 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
8. In determining the preferred physical architectural design solutions, analyses of each alternative is made with the following considerations: a) physical interfaces (human, form, fit, function, data flow and interoperability): 1) among identified physical elements of the physical design solution, 2) with other system elements of the system structure, 3) with enabling systems, 4) with external systems; b) the variability and the sensitivity to variability for each identified critical performance parameter; c) technological needs necessary to make alternative solution effective, the risks associated with introduction of new or advanced technologies to meet derived technical requirements and alternative lower-risk technologies that could be substituted for unacceptable higher risk technologies; d) availability of off-the-shelf end products (non-developmental hardware or reusable software). If not exactly suitable, determine the cost and risks in modifying an off-the-shelf system element to satisfy design and interface requirements; e) effect of design considerations to maintain or make a physical solution alternative competitive with potential or existing competitor products; f) further design efforts that could be needed to accommodate redundancy and to support graceful degradation when the results of failure modes, effects and criticality of failure analyses have an unacceptable or high criticality rating; g) degree to which the performance of the derived technical requirements are satisfied by each alternative physical solution; h) degree to which attributes of security, safety, producibility, testability, ease of deployment, installability, operability, supportability, maintainability, trainability and disposability are capable of being designed in; i) needs, requirements and constraints for enabling systems; j) capacity to evolve, or be re-engineered, incorporate new technologies, enhance performance, increase functionality or other cost-effective or competitive improvements, when the system is in production or in the marketplace; k) limitations that can preclude the capability of the system-of-interest or system element and related services to evolve (technology refresh or technology insert); l) advantages and disadvantages of implementing the system element or of doing integration within the organization or going to an established supplier; m) advantages and disadvantages of using standardized system elements, protocols, interfaces and so forth; n) integration concerns that could include: 1) potential hazards to other systems, operators or the environment, 2) built-in test and fault-isolation test requirements, 3) ease of access, ready disassembly, use of common tools, part count effect, advantage of modularity, standardization and less need for cognitive skills, 4) dynamic or static conflicts, inconsistencies and improper functionality of the integrated elements that make up the solution.	5.5.4.3 c) to g)

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Table C.16 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
9. In arriving at an architectural design solution that involves humans and human constraints such as physical space limits, climatic limits, eye movement, arm or finger reach, information rates and ergonomics should be considered. Also human usability factors should be analyzed. These factors affect human interactions with other systems and human interfaces to the system throughout the system life.	5.5.4.3 d)
10. Scale models, purpose models, behavioural models, mathematical models and managerial models can be used during architectural design to develop and communicate design solutions. The specific type model depends on the applicable enterprise view stage, its purpose or agreement requirements.	5.5.4.3 f) to h)
11. The Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process are also used for developing enabling system solutions after the requirements for such development are identified and defined as a result of defining the system-of-interest or system element being developed. Enabling system development or procurement of enabling systems is applicable for each system -of-interest and system element in the system structure.	5.5.4.3 g) 5.5.4.3 i)
12. The specification (specified requirements) generated by physical architectural design can be of two kinds – performance and detailed. Which kind generated is generally dependent on the next step in development or how they will be used. If the next step is development of a lower level system and it is desired that the supplier have flexibility to be innovative in providing an acceptable solution, performance specifications are used. Performance specifications are used when it is appropriate to state requirements in terms of: a) the required results without stating the method for achieving the required results; b) function (what should be accomplished) and performance (how well each function should be performed); c) the environment in which the system-of-interest or system element should perform these functions; d) the interface and inter-changeability characteristics; e) the means for verifying compliance.	5.5.4.3 h)
13. The initial or “develop to” specifications generated by the above activities provide the input acquirer requirements for initiating development of the next lower level of systems, if any. These initial specifications are finalized after the Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process are applied to each of the lower level system elements. Specifications describe the required characteristics of systems in the system structure and include the functional and performance requirements, interface requirements, the environments in which the systems are required to perform their functions, physical characteristics and attributes, the basis for evaluating verification and validation test systems, the methods for verifying compliance, intended uses and enabling system requirements.	5.5.4.3 h)
14. The Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process are applied to subsequent lower level system elements until the resulting architectural design solution can be built, purchased or further developed using a standard such as ISO/IEC 12207 for software implementation.	5.5.4.3 h)
15. The Implementation Process, Integration Process, Verification Process, Transition Process and Validation Process are used for the realization of systems within the system structure from the bottom up.	5.5.4.3 h)

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Table C.16 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
16. Detail specifications should be used when it is appropriate to state design requirements in terms of one or more of the following: a) material to be used; b) how a requirement should be achieved; c) how a system should be fabricated or constructed.	5.5.4.3 h)
17. Resulting sets of architectural design solutions and related derived technical requirements should be evaluated to show as applicable that each set of derived technical requirement statements for the physical solution has acceptable quality to include: a) confirmation that intended functions of the system and related services (expressed by the derived technical requirements and technical requirements allocated directly to the physical solution) are correctly implemented; b) system and related services constraints, including interfaces, are satisfied; c) resolution of identified voids, variances, and conflicts including: 1) re-write of derived technical requirements to be of acceptable quality, 2) confirmation that appropriate action has been taken when the specified requirements are not upward traceable to the set of derived technical requirements driving the architectural design solution and the technical requirements allocated directly to solution physical entities, 3) determination whether non-sourced (orphaned) specified requirements were introduced, whether they were intended to be included and whether they are desired by appropriate stakeholders, 4) omitted derived technical requirements have been added to the architectural design solution when derived technical requirements were determined inadequately reflected in the selected architectural design solution, 5) identification and recording of actions taken to eliminate non-sourced specified requirements, to establish the correct set of derived technical requirements or to revise the set of validated technical requirements, 6) proof that re-verification of the specified requirements has been done when a change is needed to the set of validated technical requirements and that the appropriate activities and tasks of the requirements analysis process and architectural design process were re-performed, as appropriate, 7) proof that re-verification tests were repeated when test outcome variations and anomalies were traced to poor verification conduct or to inadequate verification environment.	5.5.4.3 h) 5.5.4.3 j)
18. The baseline description of the architectural design solution is used for configuration management of the system-of-interest or system element.	5.5.4.3 i)
19. It also can be necessary to re-engineer the system architectural design solutions for systems or the system-of-interest higher in the system structure than the one being engineered or re-engineered.	5.5.4.3 j)

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Table C.16 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
20. Resulting sets of logical architectural design representations and related derived technical requirements are also validated to show as applicable that each set of derived technical requirement statements is of acceptable quality and include: a) confirmation that assumptions and decisions with respect to forming the sets of logical architectural design representations and derived technical requirements are valid and consistent with the technical requirements for the system and related services being engineered; b) resolution of identified voids, variances and conflicts including: 1) re-write derived technical requirements to be of acceptable quality, 2) confirmation that appropriate action has been taken when the requirements within the various sets of logical architectural design representations are not upward traceable to the validated set of technical requirements, 3) determination whether non-sourced (orphaned) requirements or constraints within a set of logical architectural design representations were introduced and whether they are desired by appropriate stakeholders, 4) identification of technical requirements that were not adequately reflected in the set of derived technical requirements. These should be added to the appropriate sets of logical architectural design representations, if possible, 5) identification of technical requirements not assignable to the sets of logical architectural design representations. These should be directly assigned as physical architectural design requirements, 6) identification and recording of actions taken to eliminate non-sourced requirements, to establish derived requirements or to revise the set of validated technical requirements, 7) proof that re-validation of the sets of logical architectural design representations and related derived technical requirements has been done when a change is needed to the set of validated technical requirements and that the appropriate activities and tasks of the Requirements Analysis Process were re-accomplished, as appropriate.	5.5.3.3 j)

Table C.17 — Implementation Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Any system element can be modelled based on the maturity of its definition as well as the applicable enterprise view stage, milestone or decision gate and associated exit criteria.	5.5.5.3 a)
2. The system element is either a single product (for example component or part) or composite of products (for example subassembly, line replaceable unit) depending on its level in the system structure and its ability to be built, purchased or implemented using a standard such as ISO/IEC 12207.	5.5.5.3 c)
3. System elements consisting solely of hardware items can be 1) purchased off-the-shelf from a supplier or vendor, 2) fabricated in-house or 3) from in-house, off-the-shelf supply.	5.5.5.3 c)
4. System elements consisting solely of software items can be 1) purchased from a supplier or vendor, 2) coded in-house or 3) reused.	5.5.5.3 c)

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Table C.17 *(continued)*

NOTES	ISO/IEC 15288 SUBCLAUSE
5. System elements that are composites of hardware and software, but exist as off-the-shelf items, can be purchased from a supplier or reused.	5.5.5.3 c)
6. Aspects to consider in forming the implementation strategy include: a) whether implementation produces a novel system element, or a system element that is reproduced according to existing design and implementation data or is an adaptation of an existing system element; b) standard practices that govern the relevant implementation technology, technical discipline or product sector; c) safety, security, privacy and environmental factors; d) implementation location and environment; e) implementation skills, their availability and sustainability; f) the materials selected for fabrication, consumable materials and by-products; g) operator characteristics; h) period over which repeated instances of implementation is required.	5.5.5.3 a)
7. The implemented system elements are verified using the appropriate process prior to delivery to an acquirer. Validation can be performed before delivery or prior to completion of the integration process based on agreement requirements.	5.5.5.3 d)
8. The “as-built” configuration should be recorded and maintained throughout the system life cycle.	5.5.5.3 d)

Table C.18 — Integration Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Prior to integrating lower level systems into the desired composite system ensure that each system has been appropriately validated by the supplier or in-house.	5.5.6.3 e)
2. System validation test results, documentation and procedures, as appropriate, should be reviewed prior to integration being performed.	5.5.6.3 e)

Table C.19 — Verification Process

NOTES	ISO/IEC 15288 SUBCLAUSE
It could be necessary to have the supplier re-engineer a defective system of the composite system being verified. It could also require the application of Stakeholder Requirements Definition Process, Requirements Analysis Process and Architectural Design Process to obtain a correct set of specifications for verification. This can create the need for re-engineering systems lower in the system structure that make up the composite system being verified, and then re-doing the verification process.	5.5.7.3 e) 5.5.7.3 f) 5.5.7.3 g)

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Table C.20 — Transition Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Support of user or operator-training requirements is provided by the enterprise responsible to performing the Resource Management Process activities related to training. An enabling system for training should be developed to include necessary training modules, documents, aids and materials.	5.5.8.3 a) 5.5.8.3 b)
2. It may be necessary to continue to operate some systems while they are being replaced and while installing and certifying the new system and training operators for the new system.	5.5.8.3 f) 5.5.8.3 g)

Table C.21 — Validation Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. Use of simulation and modelling can be useful for studying system performance in the operational environment and for saving costs when live testing is destructive or otherwise impractical.	5.5.9.3 a) 5.5.9.3 b)
2. The final customer for the system-of-interest validates the delivered products using the validation process against the acquirer requirements (often the current ones that may or may not have been incorporated into the products). This can take the form of acceptance tests or initial operational test and evaluation.	5.5.9.3 a) to d)
3. In order to obtain an appropriate system for validation, it could be necessary to have the supplier re-engineer the system. This can create the need for re-engineering systems from lower in the system structure that make up the system being validated.	5.5.9.3 a) 5.5.9.3 b) 5.5.9.3 g)
4. Care should be taken to ensure that the requirements derived to remove variances do not conflict with the set of input or validated stakeholder requirements or the agreement requirements without coordinating such changes with the appropriate stakeholders.	5.5.9.3 d) 5.5.9.3 f) 5.5.9.3 g)
5. Non-conformance variations include incorrect conduct of validation tests, incorrect test design, deficient system design, as-built test item not built to design solution descriptions (drawings, schematics, specifications, interface requirements, etc.) and incorrect, outdated or newly discovered stakeholder requirements. Fault resolution is conducted at a level of resolution consistent with cost effective remedial actions, including re-validation following defect correction or organizational quality improvement actions.	5.5.9.3 d) 5.5.9.3 f)

Table C.22 — Operation Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. The Operation Process is used in any one of the system life cycle stages for the operation of the system and the applicable enabling systems to accomplish stage functionality objectives.	5.5.10.3 a) 5.5.10.3 b)
2. Each life cycle stage has an operation function to carry out the purpose and objectives of that stage. Therefore, the Operation Process is applicable to any stage and could have a different strategy and plan for operating the system and the enabling system applicable to that stage.	5.5.10.3 a) 5.5.10.3 b)
3. During concept and development stages of the system life cycle the operations plan can be the project plan or the engineering plan.	5.5.10.3 a)

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Table C.23 — Maintenance Process

NOTES	ISO/IEC 15288 SUBCLAUSE
1. The Maintenance Process includes any element of logistics support including the training of maintenance personnel, in-service configuration management, operation of depots and maintenance facilities, supply management, supply functions as defined by the agreement or other directives and package, handling, storage, transportation and shipping.	5.5.11.3 a)
2. Each system life cycle stage has a maintenance function to carry out the purpose and objectives of that stage. Therefore, this process is applicable to any stage and can have a different strategy and plan for maintaining the system and the enabling system applicable to that stage.	5.5.11.3 a)
3. In taking corrective actions during maintenance activities the failing item should be isolated down to the planned level of system failure. Resolution should be planned and the situation corrected by either replacement of the failed system, replenishment of consumables or refurbishment of worn or failed parts. After failure resolution, certification of correct performance can be made.	5.5.11.3 a)
4. Appropriate documentation recording maintenance actions and outcomes should be maintained.	5.5.11.3 d) 5.5.11.3 j)

Table C.24 — Disposal Process

NOTES	ISO/IEC 15288 SUBCLAUSE
Each life cycle stage has a disposal function to carry out the purpose and objectives of that stage. Therefore, this process is applicable to any stage and can have a different strategy and plan for disposing the system, models, waste products, non-reparable or non-reclaimable products and undesired by-products from that stage.	5.5.12.3 a)

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