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Systems engineering — Application and management of the systems engineering process

Ingénierie des systèmes —- Application et management du processus d'ingénierie des systèmes

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IEEE Standards

IEEE Std 1220™-2005
(Revision of
IEEE Std 1220-1998)

1220™

IEEE Standard for Application and Management of the Systems Engineering Process

Withdrawn

IEEE Computer Society

Sponsored by the
Software and Systems Engineering Standards Committee

IEEE

3 Park Avenue, New York, NY10016-5997, USA

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IEEE Standard for Application and Management of the Systems Engineering Process

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Sponsor

Software and Systems Engineering Standards Committee
of the
IEEE Computer Society

Approved 20 March 2005

IEEE-SA Standards Board

Abstract: The interdisciplinary tasks, which are required throughout a system's life cycle to transform customer needs, requirements, and constraints into a system solution, are defined. In addition, the requirements for the systems engineering process and its application throughout the product life cycle are specified. The focus of this standard is on engineering activities necessary to guide product development while ensuring that the product is properly designed to make it affordable to produce, own, operate, maintain, and eventually to dispose of, without undue risk to health or the environment.

Keywords: acquire, analysis, architecture, building block, design, development, component, hardware, interface, life cycle processes, software, supplier, synthesis, system, system life cycle, systems engineering, technical management, validation, verification

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IEEE Introduction

This introduction is not part of IEEE Std 1220-2005, IEEE Standard for Application and Management of the Systems Engineering Process.

History

IEEE Std 1220 was initially published in January 1995 as a trial-use standard. After the two-year trial-use period, the document was revised and balloted in 1998 for full publication in 1999.

The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) formed a joint body to collaborate in fields of mutual interest for worldwide standardization efforts. ISO/IEC established a joint technical committee for international standards development, ISO/IEC JTC 1, Information Technology. In parallel with IEEE Std 1220 developments, ISO/IEC JTC 1, Subcommittee 7 (SC7), Software and Systems Engineering, began generation of ISO/IEC 15288:2002 [B3].[a] ISO/IEC 15288:2002 provides a framework based on a broad set of processes that an organization or project may employ to perform or manage the stages of a system's life cycle. ISO/IEC 15288:2002 supports the full life cycle of systems—from conception through retirement—as well as the acquisition and supply of systems.

It is the intent of ISO/IEC 15288:2002 to establish standard life cycle process descriptions suitable for most man-made systems. As such, the processes and terminology of the standard are defined at an appropriately high level of abstraction. ISO/IEC 15288:2002 does not prescribe, nor provide, detailed system engineering process definitions or methods and procedures to address detail process requirements derived from the application of this standard. ISO/IEC TR 19760:2003 [B4], the companion guide for ISO/IEC 15288:2002, lists several standards, including IEEE Std 1220-1998, that cover engineering disciplines at a lower-tier level and are suitable for implementation with ISO/IEC 15288:2002.

This revision of IEEE Std 1220-1998 is a result of an ongoing harmonization of the standards of the IEEE Computer Society's Software and Systems Engineering Standards Committee (S2ESC) and the corresponding international standards committee, ISO/IEC JTC1/SC7. This initial alignment of IEEE Std 1220-1998 with ISO/IEC 15288:2002 was developed in cooperation with ISO/IEC JTC1/SC7 and included participation of the International Council on Systems Engineering (INCOSE). The next step towards harmonization of these two standards would be the submission of IEEE Std 1220-2005 for a "fast-track" ballot with ISO/IEC JTC1/SC7 followed by a coordinated revision.

The IEEE Computer Society has embraced the top-level framework provided by ISO/IEC 15288:2002 and has adopted ISO/IEC 15288 as IEEE Std 15288™-2004. The IEEE Computer Society offered to align IEEE Std 1220-1998 with ISO/IEC 15288:2002 to facilitate the joint use of the two standards to manage system engineering efforts. The purpose of this revision of IEEE Std 1220-1998 is to identify key similarities and differences in the two standards and demonstrate how they can be used together while minimizing the impact of ISO/IEC 15288:2002 on current IEEE Std 1220-1998 users who may not employ ISO/IEC 15288:2002.

The key differences between this version of the standard, IEEE Std 1220-2005, and the 1998 version are as follows:

a) Inclusion of explanations regarding key differences between IEEE Std 1220-1998 and ISO/IEC 15288:2002 in areas such as terminology and structure

b) Minimal adjustments to some IEEE Std 1220-1998 terms and definitions for alignment with ISO/IEC publication requirements

c) Clarification of the distinction between requirements and recommendations of the standard

[a]The numbers in brackets correspond to those of the bibliography in Annex D.

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d) Update of the conformance clause for alignment with IEEE standards style and rules

Most of the IEEE Std 1220-1998 content remains the same in this version. Explanations to facilitate use of IEEE Std 1220 with ISO/IEC 15288:2002 are contained in a new Annex C.

Purpose

This standard defines the requirements for an enterprise's total technical effort related to development of products (including computers and software) and processes that will provide life cycle support (sustain and evolve) for the products. It prescribes an integrated technical approach to engineering a system and requires the application and management of the systems engineering process throughout a product life cycle. The systems engineering process is applied recursively to the development or incremental improvement of a product to satisfy market requirements and to simultaneously provide related life cycle processes for product development, manufacturing, test, distribution, operation, support, training, and disposal.

The concept of systems engineering embodied in this standard provides an approach for product development in a system context. It is not meant to describe what an organizational entity called systems engineering does or a job position for which a systems engineer is responsible. Rather, it encompasses what all organizational entities and all enterprise and project personnel must accomplish to produce a quality, competitive product that will be marketable, will provide an acceptable return on investment to the enterprise, will achieve stakeholder satisfaction, and will meet public expectations.

The fundamental systems engineering objective is to provide high-quality products and services, with the correct people and performance features, at an affordable price, and on time. This involves developing, producing, testing, and supporting an integrated set of products (hardware, software, people, data, facilities, and material) and processes (services and techniques) that is acceptable to stakeholders, satisfies enterprise and external constraints, and considers and defines the processes for developing, producing, testing, handling, operating, and supporting the products and life cycle processes. This objective is achieved by simultaneous treatment of product and process content to focus project resources and design decisions for the establishment of an effective system design. This involves an integrated handling of all elements of a system, including those related to manufacturing, test, distribution, operations, support, training, and disposal.

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James Moore, *IEEE CS Liaison to ISO/IEC JTC1/SC7*
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Mark Wilson
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The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

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Scott Duncan
Clint Early, Jr.
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James Sanders
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Carl Singer
Mitchell Smith
Luca Spotorno
Thomas Starai
David Walden
John Walz
Oren Yuen
Li Zhang

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The following organizational representative voted on this standard:

Lorraine Pajerek, INCOSE

In addition, this standard was coordinated with the following organizations:

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IEEE Standard for Application and Management of the Systems Engineering Process

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1. Overview

1.1 Scope

This standard defines the interdisciplinary tasks that are required throughout a system's life cycle to transform stakeholder needs, requirements, and constraints into a system solution. This standard is intended to guide the development of systems for commercial, government, military, and space applications. The information applies to a project within an enterprise that is responsible for developing a product design and establishing the life cycle infrastructure needed to provide for life cycle sustainment.

This standard specifies the requirements for the systems engineering process (SEP) and its application throughout the product life cycle. It does not attempt to define the implementation of each system life cycle process, but addresses the issues associated with defining and establishing supportive life cycle processes early and continuously throughout product development. In addition, the standard does not address the many cultural or quality variables that should be considered for successful product development. The standard focuses on the engineering activities necessary to guide product development while ensuring that the product is properly designed to make it affordable to produce, own, operate, maintain, and eventually to dispose of, without undue risk to health or the environment.

The requirements of this standard are applicable to new products as well as incremental enhancements to existing products. It applies to one-of-a-kind products, such as a satellite, as well as products that are mass-produced for the consumer marketplace. The requirements of this standard should be selectively applied for each specific system-development project. The role of systems engineering within the enterprise environment is described in Annex A.

The content of this standard describes an integrated approach to product development, which represents the total technical effort for the following:

a) Understanding the environments and the related conditions in which the product may be utilized and for which the product should be designed to accommodate

b) Defining product requirements in terms of functional and performance requirements, quality factors, usability, producibility, supportability, safety, and environmental impacts

c) Defining the life cycle processes for manufacturing, test, distribution, support, training, and disposal, which are necessary to provide life cycle support for products

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1.2 Purpose

The purpose of this document is to provide a standard for managing a system from initial concept through development, operations, and disposal. The inclusion of computers and associated software in today's products has made the need to engineer each of those products as a total system more acute. The human, physical, and software components should all be addressed to optimize overall system performance.

This standard, IEEE Std 1220-2005, may be used in conjunction with ISO/IEC 15288:2002 [B3].[1] This standard generally prescribes more detailed systems engineering process and management requirements that complete or complement the process activities described in ISO/IEC 15288:2002. However, ISO/IEC 15288:2002 provides additional process definition and guidance that supports life cycle model definition and application of the systems engineering process across a system's life cycle.

1.3 How to use this standard

1.3.1 Conformance

Normative provisions of this standard, which are indicated by a "shall" statement, are requirements to claim conformance to this standard. Provisions that are indicated by a "should" statement are recommendations. An enterprise that desires to claim conformance with this standard demonstrates conformance by defining and implementing procedures for accomplishing all normative provisions.

1.3.2 Recommendations and tailoring

The enterprise should also incorporate select recommended and optional provisions into their procedures and should ensure that each project within the enterprise complies with these procedures.

Clause 4 provides some normative provisions and recommendations for implementing systems engineering within an enterprise or on a project. Normative provisions of Clause 4 include the development and maintenance of enterprise policies and procedures. Enterprise policies and procedures that describe the application of the systems engineering process (SEP) throughout a project life cycle typically provide the basis for project-specific application of the enterprise's SEP. Therefore, it is expected that an enterprise would establish and maintain such policies and procedures.

Clause 6 defines the SEP, which is accomplished iteratively to define system products and life cycle processes. Thus, the initial provision that defines each subprocess (requirements analysis, functional analysis, etc.) includes a "shall" statement to ensure that an enterprise's SEP addresses each subprocess and the tasks for performance of that subprocess. The remaining subclauses, when specified within the definition of a subprocess, are recommended to provide flexibility in adapting the subprocess and the task definitions of the SEP for the purposes and typical system engineering efforts of the enterprise. Clause 6 describes the recommended approach to project tailoring of the enterprise SEP, which would be applied for any particular project iteration of the SEP as described in Clause 5.

The initial provision of Clause 5 contains a "shall" statement to ensure that the project addresses application of the SEP throughout the system life cycle. The remaining provisions under Clause 5 describe recommended and optional activities that a project commonly performs when applying the SEP during each stage of a typical system life cycle. The recommended and optional activities of Clause 5 should be considered by the project during tailoring of the enterprise SEP for any particular iteration of the SEP throughout the system life cycle. This approach provides the project with the flexibility needed to address different levels of system development and appropriate rigor of SEP application throughout various system life cycle stages.

[1]The numbers in brackets correspond to those of the bibliography in Annex D.

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1.3.3 System paradigm

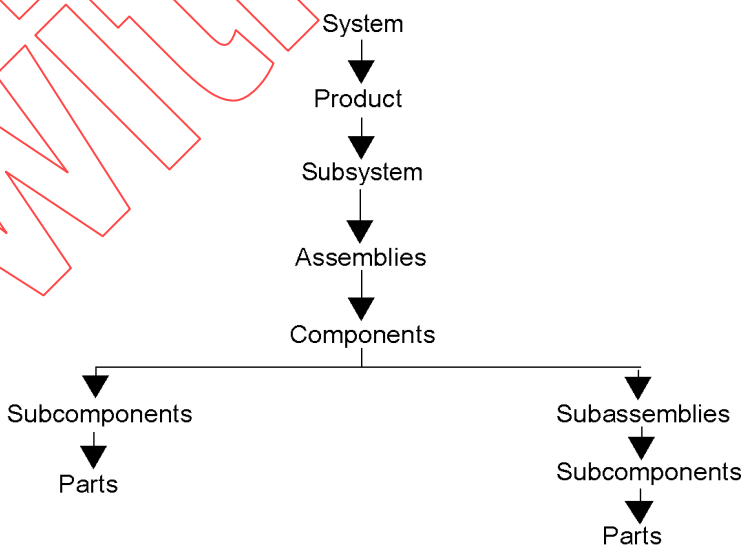
The description of the SEP, and its application throughout the life cycle, demands the use of a system paradigm to aid the presentation of this material. The terms used to support this paradigm are defined in Clause 3. As enterprises and projects gain familiarity with the paradigm, they may substitute more familiar terms that are applicable to their industry or business practices. The system paradigm is the foundation of this standard and is described in the following subclauses to support the different uses of the term system.

On a large scale, there are biological systems, ecological systems, weather systems, solar systems, etc. Thus, a system can be viewed as an element of a larger system, and the challenge is to understand the boundary of the system, which is the focus of the development effort, and the relationships and interfaces between this system and other systems. The focus of this standard is product-oriented systems such as the automobile, the airplane, or information systems.

1.3.3.1 Hierarchy of system elements

A system is typically composed of related elements (subsystems and components) and their interfaces. Additionally, elements include the people required to develop, produce, test, distribute, operate, support, or dispose of the element's products, or to train those people to accomplish their role within the system. Figure 1 provides a hierarchy of names for the elements making up a system. This generic system hierarchy is a key concept within this standard because it ties the system architectures, specification and drawing trees, system breakdown structure (SBS), technical reviews, and configuration baselines together. Many elements within the system hierarchy can be considered a "system" by the classical definition, but actually represent subsystems within the system hierarchy. Likewise, the life cycle processes represent subsystems within the overall system hierarchy.

Complex components represent system elements that are composed of hardware, software, and/or humans, which are recognizable in terms of life cycle process (how to design, test, produce, support, etc., is known), and the domain-specific engineering team assumes responsibility for the development of the complex components. This is a judgment call—complex components may demand the rigors of the SEP or may be well suited for component development teams.



Elements of the system may include hardware, software, and humans dependent on the system definition.

Figure 1—Hierarchy of elements within a system

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The human elements are integral to the systems hierarchy and may be present at any level. The human elements are not identified in the system hierarchy since the intent of the hierarchy is to identify the system element for which the system is being defined, and the human/system integration issues should be addressed in terms of the human's role in operating, producing, supporting, etc.

The hierarchy of elements within a system is provided to illustrate that systems may be comprised of other systems (subsystems), which represent complex elements for which no existing design solution or supplier can be identified. The number of levels of subsystem or complex components is dependent on the complexity of the system being developed. The SEP is applied at each level in the system hierarchy for which the system element is a complex item for which no available design solution, or existing producer, can be identified. Once a system element can be identified with a hardware, software, or human element, the discipline-specific design methodologies are utilized to design the system element.

1.3.3.2 Building block structure

The basic building blocks of a system are depicted in Figure 2—the system, its related product(s), the life cycle processes required to support the products, and the subsystems that make up the product(s). Each life cycle process—development, manufacturing, test, distribution, operation, support, training, or disposal—is itself like a system in that products should be developed to fulfill the purpose of the life cycle process. For example, a product should be manufactured. Manufacturing is a life cycle process. The products associated with the manufacturing life cycle process include special equipment, tools, facilities, and production processes and procedures. The products that make up life cycle processes may also require life cycle sustainment in that they may be required to be developed, tested, manufactured, distributed, operated, supported, trained, and disposed of.

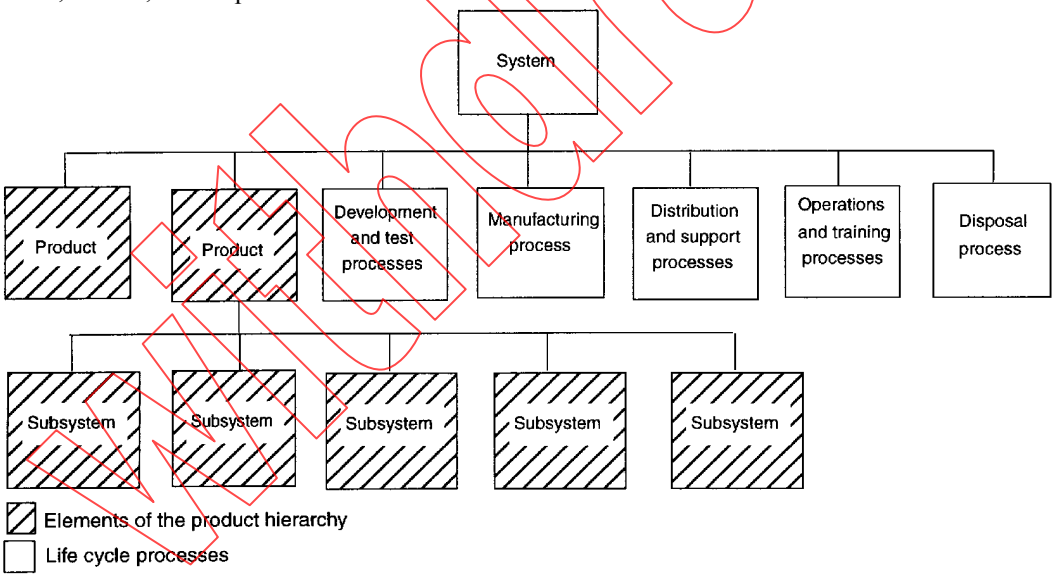

Figure 2—Basic building blocks of a system

1.3.3.3 Product and life cycle process definition

Figure 3 depicts the life cycle processes, eight essential functional processes that may be necessary to provide total consumer satisfaction and meet public acceptance. Once the need for a life cycle process is identified, the life cycle process is treated as a system, and the SEP is applied to define, design, and establish the life cycle process and the supporting products and processes, to maintain the life cycle process in an operational condition.

a) *Development.* The planning and execution of system and subsystem definition tasks required to evolve the system from stakeholder needs to product solutions and their life cycle processes.

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b) *Manufacturing.* The tasks, actions, and activities for fabrication and assembly of engineering test models and brass-boards, prototypes, and production of product solutions and their life cycle process products.

c) Test

1) The tasks, actions, and activities for planning for evaluation and conducting evaluation of synthesis products against the functional architecture or requirements baseline, or the functional architecture against the requirements baseline.

2) The tasks, actions, and activities for evaluating the product solutions and their life cycle processes to measure specification conformance or stakeholder satisfaction.

d) *Distribution.* The tasks, actions, and activities to initially transport, deliver, assemble, install, test, and check out products to effect proper transition to users, operators, or consumers.

e) *Operations.* The tasks, actions, and activities that are associated with the use of the product or a life cycle process.

f) *Support.* The tasks, actions, and activities to provide supply, maintenance, and support material and facility management for sustaining operations.

g) *Training.* The measurable tasks, actions, and activities (including instruction and applied exercises) required to achieve and maintain the knowledge, skills, and abilities necessary to efficiently and effectively perform operations, support, and disposal throughout the system life cycle. Training is inclusive of the tools, devices, techniques, procedures, and materials developed and employed to provide training for all required tasks.

h) *Disposal.* The tasks, actions, and activities to ensure that disposal or recycling of destroyed or irreparable consumer and life cycle processes and by-products comply with applicable environmental regulations and directives.

A typical system is composed of products developed by the enterprise or by suppliers/subcontractors. Each supplier/subcontractor considers its product as part of its system. The organization that purchases these products for integration into a higher-level system should refer to these products as subcomponents, components, complex components, or subsystems, depending on the significance of the element in contributing to the system's performance, functionality, and costs.

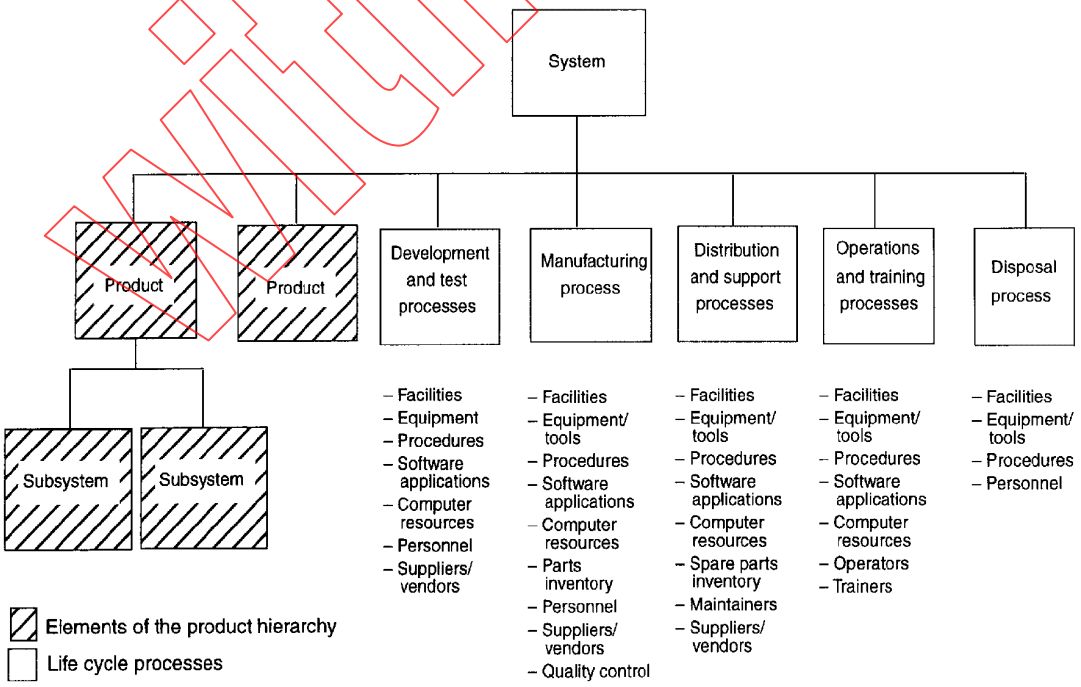

Figure 3—Life cycle process definition

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The design of the products and life cycle processes should consider the human as an element of the system in terms of operators, maintainers, manufacturing personnel, training personnel, etc., for the purpose of understanding the human/system integration issues and ensuring that the system products are producible, maintainable, and usable, and that the system processes are effectively established to ensure production quality levels and reduce overall ownership cost. Thus, Figure 3 depicts the human elements associated with the system products and processes. The operational process addresses the operation of the product(s) and aids in the identification of operational procedures and human cognitive and anthropomorphic considerations necessary to ensure system usability.

The definitions of system elements are generated by activities of the SEP. This process is described in detail in Clause 6. The SEP is used during each level of development to structure systems engineering activities that identify technical requirements and desired system behaviors, and synthesize the system design.

1.4 Organization of this standard

— Clause 1 provides the scope, purpose, and organization of this standard.

— Clause 2 provides the normative references applicable to this document.

— Clause 3 establishes the meaning of terms and acronyms, as used in this standard.

— Clause 4 establishes requirements for planning and implementing an effective systems engineering capability within an enterprise.

— Clause 5 provides a description of the application of the SEP through system definition, subsystem definition, production, and support.

— Clause 6 provides the detailed tasks of the SEP to be tailored and performed to develop product solutions and their supporting life cycle processes.

— Annex A discusses the SEP as the total technical effort responsible for establishing the product design and life cycle support products within an enterprise.

— Annex B provides a template to help an enterprise prepare a systems engineering management plan.

— Annex C discusses some of the key differences between IEEE Std 1220 and ISO/IEC 15288:2002 [B3].

— Annex D provides bibliographic references.

2. Normative references

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

IEEE Std 610.12™-1990 (Reaff 2002), IEEE Standard Glossary of Software Engineering Terminology.[2]

[2]IEEE publications are available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (http://standards.ieee.org/).

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