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Systems and software engineering — System of systems (SoS) considerations in life cycle stages of a system

Ingénierie du logiciel et des systèmes — Études du système des systèmes (SdS) dans les étapes du cycle de vie d'un système

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Foreword

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

This second edition cancels and replaces the first edition (ISO/IEC/IEEE 21839:2019), which has been technically revised.

The main changes are as follows:

— added references for interfacing and interoperating systems and general updates from ISO/IEC/IEEE 15288:2023 and ISO/IEC/IEEE 24748-2:2024;

— updated content based on updates to ISO/IEC/IEEE 24748-1:2024, including more recent life cycle models such as DevOps;

— the text has been updated to be aligned with ISO/IEC/IEEE 21840:2026 and ISO/IEC/IEEE 21841:2026.

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

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Introduction

This document is one of three standards dealing with systems of systems (SoS). The relationship among the three standards is described in Annex C.

There is a wide variety of systems in terms of their purpose, domain of application, complexity, size, novelty, adaptability, quantities, locations, life spans and evolution.

This document considers the generic life cycle model defined in ISO/IEC/IEEE 15288 and ISO/IEC/IEEE 24748-1. Selected subsets of these considerations can be addressed throughout the life of systems through the involvement of stakeholders. The goal is to achieve customer satisfaction, so that when delivered, the SoI operates effectively in the operational or business environment which is typically characterized as one or more SoS.

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Systems and software engineering — System of systems (SoS) considerations in life cycle stages of a system

1 Scope

This document provides a set of critical system of systems (SoS) considerations to be addressed at key points in the life cycle of the system of interest (SoI) that is a constituent system that forms a part of an SoS.

This document applies to human-made systems that are configured with one or more of the following: hardware, software, humans, procedures and facilities.

This document also can be productively applied by users of ISO/IEC/IEEE 12207.

This document addresses SoS considerations that apply to systems at each stage of their respective life cycles. It applies to one-of-a-kind systems, mass-produced systems or customized, adaptable systems.

This document does not elaborate in detail the methods or procedures for addressing SoS considerations.

This document does not detail the described documentation in terms of name, format, explicit content and recording media of documentation.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

— IEEE Standards Dictionary Online: available at https://ieeexplore.ieee.org/xpls/dictionary.jsp

NOTE For additional terms and definitions in the field of systems and software engineering, see ISO/IEC/IEEE 24765, which is published periodically as a "snapshot" of the SEVOCAB (Systems and software Engineering Vocabulary) database and which is publicly accessible at www.computer.org/sevocab.

3.1
capability
measure of capacity and the ability of an entity (*system* (3.9), person or *organization* (3.7)) to achieve its objectives

[SOURCE: ISO/IEC 19770-1:2017, 3.10, modified — Note 1 to entry has been removed]

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3.2
constituent system
CS
independent *system* (3.9) that forms part of a *system of systems (SoS)* (3.12)

Note 1 to entry: Constituent systems (CS) can be part of one or more SoS. Each CS is a useful system by itself, having its own development, management, utilization, goals, and resources, but interacts within the SoS to provide the unique *capability* (3.1) of the SoS.

Note 2 to entry: While CS operate independently from each other for their own purposes, they also operate interdependently with each other and other *system elements* (3.10) to produce the SoS outputs. CS are never totally independent, since they work interdependently when operating as part of the SoS. However, they are never totally subservient to the SoS. CS have their own stakeholders and CS remain managerially and operationally independent; managers of CS or CS projects can be unaware, unable or unwilling to make adjustments to address SoS-desired *capabilities* (3.1)

[SOURCE: ISO/IEC/IEEE 21840:—[1)], 3.1.2]

3.3
governance
practice of establishing and enforcing strategic goals and objectives, organizational policies, and performance parameters

[SOURCE: ISO/IEC/IEEE 21840:—, 3.1.4]

3.4
interoperating system
system (3.9) that exchanges information with the *system of interest* (3.13) and uses the information that has been exchanged

[SOURCE: ISO/IEC/IEEE 15288:2023, 3.20]

3.5
life cycle
evolution of a *system* (3.9), product, service, project or other human-made entity from conception through retirement

[SOURCE: ISO/IEC/IEEE 24748-1:2024, 3.24]

3.6
management
system (3.9) of controls and processes required to achieve the strategic objectives set by the *organization's* (3.7) governing body

Note 1 to entry: Management is subject to the policy guidance and monitoring set through corporate *governance* (3.3).

[SOURCE: ISO/IEC/IEEE 21840:—, 3.1.6]

3.7
organization
person or group of people that has its own functions with responsibilities, authorities, and relationships to achieve its objectives

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

[SOURCE: ISO 9000:2015, 3.2.1, modified — Notes to entry have been removed; EXAMPLE has been added.]

1) Under preparation. Stage at the time of publication: ISO/IEC/IEEE FDIS 21839.

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3.8
stage
period within the *life cycle* (3.5) of an entity that relates to the state of its description or realization

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

Note 2 to entry: Stages often overlap.

[SOURCE: ISO/IEC/IEEE 24748-1:2024, 3.48]

3.9
system
arrangement of parts or elements that together exhibit a stated behaviour or meaning that the individual constituents do not

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

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

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

[SOURCE: ISO/IEC/IEEE 15288:2023, 3.46]

3.10
system element
discrete part of a *system* (3.9) that can be implemented to fulfil specified requirements

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

[SOURCE: ISO/IEC/IEEE 15288:2023, 3.47]

3.11
system of systems
SoS
set of *systems* (3.9) or *system elements* (3.10) that interact to provide a unique *capability* (3.1) that none of the *constituent systems* (3.2)can accomplish on its own

Note 1 to entry: System elements can be necessary to facilitate the interaction of the constituent systems in the system of systems.

Note 2 to entry: A collection of systems is not always an SoS. The differences between a system and an SoS are not in the structure of the parts, but rather in the behavioural and managerial independence of those parts. There is no distinct boundary that separates systems from SoS, as the transition between the two is often gradual and context dependent.

[SOURCE: ISO/IEC/IEEE 21840: —, 3.1.11]

3.12
system of systems engineering
SoSE
process of planning, analysing, organizing, developing and integrating the *capabilities* (3.1) of a mix of existing and new *systems* (3.9), including inter-system infrastructure, facilities, and overarching processes into a *system of systems* (3.11) capability that is greater than the sum of the capabilities of the *constituent systems* (3.2)

Note 1 to entry: SoSE also includes testing, modification, maintenance and other post-integration activities.

[SOURCE: ISO/IEC/IEEE 21840: —, 3.1.12]

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3.13
system of interest
SoI
system (3.9) whose *life cycle* (3.5) is under consideration

[SOURCE: ISO/IEC/IEEE 15288:2023, 3.48]

3.14
systems engineering
transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered *systems* (3.11) using systems principles and concepts and scientific, technological and *management* (3.6) methods

[SOURCE: INCOSE-TP-2020-002-06]

4 Concepts

4.1 System of systems

Both individual systems and SoS conform to the accepted definition of a system in that each consists of parts, relationships and a whole that is greater than the sum of the parts; however, while all SoS are systems, not all systems are SoS, even if multiple systems are interacting with each other.

Maier[13] postulated five key characteristics (not criteria) of SoS: operational independence of constituent systems (CS), managerial independence of CS, geographical distribution, emergent behaviour and evolutionary development processes. Maier identified operational independence and managerial independence as the two principal distinguishing characteristics for applying the term “systems of systems”. A system that does not exhibit these two characteristics is not an SoS regardless of the complexity or geographic distribution of its constituents.

An essential characteristic is that each CS within the SoS is operationally independent. While CS operate independently from each other for their own purposes, they also operate interdependently with each other and other elements to produce the SoS outputs. CS are never totally independent, since they work interdependently when operating as part of the SoS. However, they are never totally subservient to the SoS.

In an SoS, systems are also managerially independent. That is, each CS is likely to be managed by organizations with a level of independence, with potentially different goals and objectives for the CS.

In some cases, there can be a designated entity with some type of responsibility that spans an SoS. These managerial arrangements can be loosely defined or more highly structured depending on the particular situation. In other cases, no such entity exists. CS have their own stakeholders and CS remain managerially and operationally independent; managers of CS managers or CS projects can be unaware, unable or unwilling to make adjustments to address SoS-desired capabilities.

4.2 Constituent systems

An essential concept is that the SoS is composed of CS (and can include other system elements) that operationally interact to provide capabilities that no one system or element in the SoS can provide by itself. Each CS is an independent system that provides capabilities to meet its specified mission or business objective and has its own life cycle, management and governance, and technical requirements. CS can include systems which are considered as infrastructure. A CS can be an entity in more than one SoS. An SoS is often composed of existing CS along with new CS which are developed and integrated into the SoS. The focus of this document is a CS as the SoI, as is shown in Figure 1. The considerations provided in this document are with respect to what is necessary to account for the life cycle of the CS or SoI to enable it to interact in the anticipated SoS configurations.

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