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Vesoljska tehnika - Definicija ravni tehnološke zrelosti in merila za ocenjevanje (ISO 16290:2013, spremenjen)

Space engineering - Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment (ISO 16290:2013, modified)

Raumfahrttechnik - Definition des Technologie-Reifegrades (TRL) und der Beurteilungskriterien (ISO 16290:2013, modifiziert)

Ingénierie spatiale - Définition des Niveaux de Maturité de la Technologie (TRL) et de leurs critères d'évaluation (ISO 16290:2013, modifiée)

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**CEN-CENELEC Management Centre:
Rue de la Science 23, B-1040 Brussels**

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European Foreword

This document (EN 16603-11:2019) has been prepared by Technical Committee CEN/CLC/TC 5 “Space”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2020, and conflicting national standards shall be withdrawn at the latest by May 2020.

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

The text of the International Standard ISO 16290:2013 was approved by CEN/CENELEC as a European Standard with agreed common modifications.

This document originates from ISO 16290:2013 taking into account the specificities of the ECSS Adoption Notice ECSS-E-AS-11C “Space engineering -Adoption Notice of ISO 16290, Space systems - Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment”. These specificities are listed in Clause 5 of this standard.

This document has been developed to cover specifically space systems and will therefore have precedence over any EN covering the same scope but with a wider domain of applicability (e.g. aerospace).

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Technology Readiness Levels (TRLs) are used to quantify the technology maturity status of an element intended to be used in a mission. Mature technology corresponds to the highest TRL, namely TRL 9, or flight proven elements.

The TRL scale can be useful in many areas including, but not limited to the following examples:

a) For early monitoring of basic or specific technology developments serving a given future mission or a family of future missions;

b) For providing a status on the technical readiness of a future project, as input to the project implementation decision process;

c) In some cases, for monitoring the technology progress throughout development.

The TRL descriptions are provided in Clause 3 of this document. The achievements that are requested for enabling the TRL assessment at each level are identified in the summary table in Clause 4. The detailed procedure for the TRL assessment is to be defined by the relevant organization or institute in charge of the activity.

The originating document (ISO 16290:2013) of this document was produced by taking due consideration of previous available documents on the subject, in particular including those from the National Aeronautics Space Administration (NASA), the US Department of Defence (DoD) and European space institutions (DLR, CNES and ESA).

1 Scope

This document defines Technology Readiness Levels (TRLs). It is applicable primarily to space system hardware, although the definitions could be used in a wider domain in many cases.

The definition of the TRLs provides the conditions to be met at each level, enabling accurate TRL assessment.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
acceptance review
activity undertaken to allow the customer to declare acceptance of a product

3.1.2
breadboard
physical model (3.1.12) designed to test functionality and tailored to the demonstration need

3.1.3
commissioning result review
activity undertaken to allow to declare readiness of a product for routine operation and utilization

NOTE 1 to entry: The commissioning result review is held at the end of the commissioning as part of the in-orbit stage verification.

3.1.4
critical function of an element
mandatory function which requires specific technology (3.1.22) verification

Note 1 to entry: This situation occurs when either the element or components of the element are new and cannot be assessed by relying on previous realizations, or when the element is used in a new domain, such as new environmental conditions or a new specific use not previously demonstrated.

Note 2 to entry: Wherever used in this Standard, “critical function” always refers to “technology critical function” and should not be confused with “safety critical function”.

Note 3 to entry: Wherever used in this Standard, “critical function” always refers to “critical function of an element”.

3.1.5
critical part of an element
element (3.1.6) part associated to a critical function

Note 1 to entry: The critical part of an element can represent a subset of the element and the technology verification for the critical function may be achievable through dedicated tests achieved on the critical part only.

Note 2 to entry: Wherever used in this Standard, “critical part” always refers to “technology critical part”.

Note 3 to entry: Wherever used in this Standard, “critical part” always refers to “critical part of an element”.

3.1.6
element
item or object under consideration for the technology readiness assessment

Note 1 to entry: The element can be a component, a piece of equipment, a subsystem or a system.

3.1.7
element function
intended effect of the element (3.1.6)

3.1.8
functional performance requirements
subset of the performance requirements (3.1.16) of an element (3.1.6) specifying the element functions (3.1.7)

Note 1 to entry: The functional performance requirements do not necessarily include requirements resulting from the operational environment (3.1.13).

3.1.9
laboratory environment
controlled environment needed for demonstrating the underlying principles and functional performance

Note 1 to entry: The laboratory environment does not necessarily address the operational environment (3.1.13).

3.1.10
mature technology
technology defined by a set of reproducible processes (3.1.20) for the design, manufacture, test and operation of an element (3.1.6) for meeting a set of performance requirements (3.1.16) in the actual operational environment (3.1.13)

3.1.11
mission operations
sequence of events that are defined for accomplishing the mission

3.1.12
model
physical or abstract representation of relevant aspects of an element (3.1.6) that is put forward as a basis for calculations, predictions, tests or further assessment

Note 1 to entry: The term “model” can also be used to identify particular instances of the element, e.g. flight model.

Note 2 to entry: Adapted from ISO 10795, definition 1.141.

3.1.13
operational environment
set of natural and induced conditions that constrain the element (3.1.6) from its design definition to its operation

EXAMPLE 1 Natural conditions: weather, climate, ocean conditions, terrain, vegetation, dust, light, radiation, etc.

EXAMPLE 2 Induced conditions: electromagnetic interference, heat, vibration, pollution, contamination, etc.

3.1.14
operational performance requirements
subset of the performance requirements (3.1.16) of an element (3.1.6) specifying the element functions (3.1.7) in its operational environment (3.1.13)

Note 1 to entry: The operational performance requirements are expressed through technical specifications covering all engineering domains. They are validated through successful in orbit operation and can be verified through a collection of element verifications on the ground which comprehensively cover the operational case.

Note 2 to entry: The full set of performance requirements of an element consists of the operational performance requirements and the performance requirements for the use of the element on ground.

3.1.15
performance
aspects of an element (3.1.6) observed or measured from its operation or function

Note 1 to entry: These aspects are generally quantified.

Note 2 to entry: Adapted from ISO 10795, definition 1.155.

3.1.16
performance requirements
set of parameters that are intended to be satisfied by the element (3.1.6)

Note 1 to entry: The complete set of performance requirements inevitably include the environment conditions in which the element is used and operated and are therefore linked to the mission(s) under consideration and also to the environment of the system in which it is incorporated.

3.1.17
process
set of interrelated or interacting activities which transform inputs into outputs

Note 1 to entry: Inputs to a process are generally outputs of other processes.

Note 2 to entry: Processes in an organization are generally planned and carried out under controlled conditions to add value.

Note 3 to entry: A process where the conformity of the resulting product cannot be readily economically verified is frequently referred to as a "special process".

[SOURCE: ISO 10795, definition 1.160]

3.1.18
qualification review
activity undertaken to allow the customer to declare qualification of a product

3.1.19
relevant environment
minimum subset of the operational environment (3.1.13) that is required to demonstrate critical functions of the element (3.1.4) performance in its operational environment (3.1.13)

3.1.20
reproducible process
process (3.1.17) that can be repeated in time

Note 1 to entry: It is fundamental in the definition of "mature technology" and is intimately linked to realization capability and to verifiability.

Note 2 to entry: An element developed "by chance", even if meeting the requirements, can obviously not be declared as relying on a *mature technology* if there is little possibility of reproducing the element on a reliable schedule. Conversely, reproducibility implicitly introduces the notion of time in the mature technology definition. A technology can be declared mature at a given time, and degraded later at a lower readiness level because of the obsolescence of its components or because the processes involve a specific organization with unique skills that has closed.

3.1.21
requirement
need or expectation that is stated and to be complied with

Note 1 to entry: Adapted from ISO 10795, definition 1.190.

3.1.22
technology
application of scientific knowledge, tools, techniques, crafts, systems or methods of organization in order to solve a problem or achieve an objective

3.1.23
validation
confirmation, through objective evidence, that the requirements (3.1.21) for a specific intended use or application have been fulfilled

Note 1 to entry: The term "validated" is used to designate the corresponding status.

Note 2 to entry: The use conditions for validation can be real or simulated.

Note 3 to entry: May be determined by a combination of test, analysis, demonstration, and inspection.

Note 4 to entry: When the element is validated it is confirmed that it is able to accomplish its intended use in the intended operational environment (3.1.13).

Note 5 to entry: Adapted from ISO 10795, definition 1.228.

3.1.24
verification
confirmation through the provision of objective evidence that specified requirements (3.1.21) have been fulfilled

Note 1 to entry: The term "verified" is used to designate the corresponding status.

Note 2 to entry: Confirmation can be comprised of activities such as: performing alternative calculations, comparing a new design specification with a similar proven design specification, undertaking tests and demonstrations, and reviewing documents prior to issue.

Note 3 to entry: Verification may be determined by a combination of test, analysis, demonstration, and inspection.

Note 4 to entry: When an element is verified, it is confirmed that it meets the design specifications.

Note 5 to entry: Adapted from ISO 10795, definition 1.229

3.2 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

Abbreviation	Meaning
AR	acceptance review
CRR	commissioning result review
QR	qualification review
TRL	technology readiness level

4 Technology Readiness Levels (TRLs)

4.1 General

A technology for an element intended for an application reaches the maturity level, corresponding to TRL 9, when it is well-defined by a set of reproducible processes for the design, manufacture, test and operation of the element and when, in addition, the element meets a set of performance requirements in the actual operational environment.

The element under consideration is assumed to be a physical part of a system. Systems are generally subdivided into sub-systems with potentially several sub-levels. The element can be any part of the system and is not necessarily a specific sub-system or at a specific sub-level.