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Vesoljska tehnika - Smernice za ravni tehnološke zrelosti (TRL)

Space engineering - Technology readiness level (TRL) guidelines

Raumfahrttechnik - Richtlinien zum technischen Reifegrad (TRL)

Ingénierie spatiale - Lignes directrices pour les niveaux de maturité technologique (TRL)

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Space engineering - Technology readiness level (TRL) guidelines

Ingénierie spatiale - Lignes directrices pour les niveaux de maturité technologique (TRL)

Raumfahrttechnik - Richtlinien zum technischen Reifegrad (TRL)

This draft Technical Report is submitted to CEN members for Vote. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

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European Foreword

This document (FprCEN/CLC/TR 17603-11:2020) has been prepared by Technical Committee CEN/CLC/JTC 5 “Space”, the secretariat of which is held by DIN.

This document is currently submitted to the Technical Committee Approval.

It is highlighted that this technical report does not contain any requirement but only collection of data or descriptions and guidelines about how to organize and perform the work in support of EN 16603-11.

This Technical report (FprCEN/CLC/TR 17603-11:2020) originates from ECSS-E-HB-11A.

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

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

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

This document is currently submitted to the CEN CONSULTATION.

Introduction

This Handbook supports the application of the TRL, and provides guidelines to its use in projects and its independent verification within each specific project context.

This Handbook provides guidelines for best practice for interpretation of the requirements contained in ECSS-E-AS-11 and for the implementation of the process of technology readiness assessment for technologies applied to a critical function of an element.

The ECSS-E-AS-11 - "Adoption Notice of ISO 16290 Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment" adopts ISO 16290 with a minimum set of modifications, to allow for reference and for a consistent integration in ECSS system of standards.

TRL is a scale for technology maturity assessment and not a method of technology engineering nor development. TRL is used in R&T&D activities and also in project activities.

For project activities, a technology readiness assessment informs the project manager (until the end of B phase) of the risk when adopting a new technology for a critical function of an element of the system. In the C and D phases TRL is no longer used by the project and the maturity of technology is managed in the critical item list.

For other projects the information of the declared technology maturity can be reused and an assessment of the new project use conditions are considered in the assessment.

In this handbook the three main actors and the respective role of each actor are clearly identified. The three discrete actors are: technology developers, projects teams (using the technology) and the TRA participants (i.e. those who perform the technology readiness assessment).

1 Scope

The present handbook is provided to support the implementation of the requirements of ECSS-E-AS-11 to space projects.

With this purpose, this handbook provides guidelines on the way to assess the maturity of a technology of a product in a given environment, to use the TRL assessment outcome in the product development framework, and to introduce some further refinements for specific disciplines or products to which the TRL assessment methodology can be extended.

The concept of Manufacturing Readiness Level (MRL) is not addressed in this document, whilst the concept of TRL can be applied to the technology-related aspects of manufacturing.

2 References

The following documents are referenced in this text or provide additional information useful for the reader.

EN Reference	Reference in text	Title
EN 16601-00-01	ECSS-S-ST-00-01	ECSS system – Glossary of terms
EN 16603-10	ECSS-E-ST-10	Space engineering – System engineering general requirements
EN 16603-10-02	ECSS-E-ST-10-02	Space engineering – Verification
EN 16603-10-03	ECSS-E-ST-10-03	Space engineering – Testing
EN 16603-10-06	ECSS-E-ST-10-06	Space engineering – Technical requirements specification
EN 16603-10-24	ECSS-E-ST-10-24	Space engineering – Interface management
EN 16603-11	ECSS-E-AS-11	Adoption notice of ISO 16290, Space systems – Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment (1 October 2014)
TR 17603-10-02	ECSS-E-HB-10-02	Space engineering – Verification guidelines
EN 16603-40	ECSS-E-ST-40	Space engineering – Software
EN 16603-70	ECSS-E-ST-70	Space engineering – Ground systems and operations
EN 16601-10-10	ECSS-M-ST-10-01	Space project management – Organization and conduct of reviews
EN 16601-60	ECSS-M-ST-60	Space project management – Cost and schedule management
EN 16601-80	ECSS-M-ST-80	Space project management – Risk management
EN 16602-10	ECSS-Q-ST-10	Space product assurance – Product assurance management
EN 16602-10-04	ECSS-Q-ST-10-04	Space product assurance – Critical-item control
EN 16602-20	ECSS-Q-ST-20	Space product assurance – Quality assurance
EN 16602-20-10	ECSS-Q-ST-20-10	Space product assurance – Off-the-shelf items utilization in space systems
EN 16602-30	ECSS-Q-ST-30	Space product assurance – Dependability
EN 16602-40	ECSS-Q-ST-40	Space product assurance - Safety
EN 16602-60	ECSS-Q-ST-60	Space product assurance – Electrical, electronic and electromechanical (EEE) components

EN Reference	Reference in text	Title
EN 16602-60-13	ECSS-Q-ST-60-13	Space product assurance – Commercial electrical, electronic and electromechanical (EEE) components
EN 16602-70	ECSS-Q-ST-70	Space product assurance – Materials, mechanical parts and processes
EN 16602-70-71	ECSS-Q-ST-70-71	Spaced product assurance – Materials, processes and their data selection
EN 16602-80	ECSS-Q-ST-80	Space product assurance – Software product assurance
	ISO 16290:2013	Space systems - Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment
	Mankins 95 reference (M95r)	TECHNOLOGY READINESS LEVELS, A White Paper, April 6, 1995, John C. Mankins Advanced Concepts Office, Office of Space Access and Technology NASA 1 https://www.hq.nasa.gov/office/codeq/trl/trl.pdf

3 Terms, definitions and abbreviated terms

3.1 Terms defined in other documents

a. For the purpose of this document, the terms and definitions from ECSS-E-AS-11 apply, in particular for the following terms:

1. critical function of an element

   NOTE The synonym of "critical function" is "critical function of an element".

2. element

   NOTE It is important to realize that the term element has a different meaning in ECSS-E-AS-11 (that refer to ISO 16290) than in the ECSS Glossary of terms (ECSS-S-ST-00-02). This guidelines use the term element as defined in ISO 16290.

3. breadboard
4. laboratory environment
5. mature technology
6. operational environment
7. relevant environment
8. reproducible process
9. validation

b. For the purpose of this document the terms from ECSS-S-ST-00-01, except the terms listed in 3.1a apply, in particular for the following terms:

1. commissioning result review
2. component (context EEE)

   NOTE For TRL 4 and TRL 5 the term "component" is understood as "part of a larger whole".

3. environment
4. ground segment
5. technology readiness level

c. For the purpose of this document the terms from ECSS-E-ST-70, except the terms listed in 3.1a. and 3.1b apply, in particular for the following term:

1. Ground Segment QR (GSQR)
2. Operations QR (OQR)
3. Software Requirement Specification (SRS)

3.2 Terms specific to the present document

3.2.1 Research and Technology and Development (R&T&D)

activities to mature from research to technology to development as they are progressing from lower to high TRL levels

3.3 Abbreviated terms and symbols

For the purpose of this document, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
AR	acceptance review
CDR	critical design review
CRR	commissioning readiness review
CIL	critical item list
DM	development model
DD	displacement damage
EEE	electrical, electronic and electromechanical
EM	engineering model
EMC	electromagnetic compatibility
EQM	engineering qualification model
EQSR	equipment qualification status review
ESCC	European Space Components Coordination
FM	flight model
IOOR	In-orbit operations review
ISO	International Standardization Organization
ITT	invitation to tender
LEOP	Launch and early orbit phase
M95r	Mankins 95 reference
MDR	mission definition review
NASA	National Aeronautics and Space Administration
NWIP	new work item proposal
PA	Product Assurance
PCB	printed circuit board
PDR	preliminary design review
PFM	protoflight model
POC	proof of concept
PRR	preliminary requirements review
QM	qualification model

Abbreviation	Meaning
QMS	quality management system
QR	qualification review
RAMS	reliability, availability, maintainability and safety
RF	radiofrequency
R&T&D	Research and Technology and Development
SEE	single event effect
SEL	single event latch-up
SM	structural model
SPR	software problem report
SRF	software reuse file
STM	structural thermal model
TID	total ionising dose
TM	thermal model
ToR	terms of reference
TP	technology plan
TRA	technology readiness assessment
TRL	technology readiness level
TRSL	technology readiness status list
V&V	verification and validation
WG	working group
w.r.t.	with respect to

4 TRL history and evolution

4.1 History and evolution

The TRL methodology was originated at NASA in the 1970s in order to establish a method by which NASA selected new technology amongst numerous candidates for their complex spaceflight programmes. The scale progressed until 1995 with the definition of nine levels that became the Mankins 95 reference (M95r) [see clause2]. From that moment, the principle of a maturity scale was adopted by many companies and government agencies around the world. However, although they were somewhat similar, different definitions or interpretation of the M95r were used. ECSS decided, in 2008, to first make a harmonization at European level and then to propose to ISO a global harmonization in 2009. This then resulted in an ISO New Work Item Proposal (NWIP) "Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment".

The ISO standard 16290 was published in 2013 and as a result, TRL are now globally harmonized. ECSS actively contributed to this ISO standard by providing members to the ISO WG. The ISO standard concerns the definition and the criteria of assessment, however the procedure for the TRL assessment or the way to use them within a project's framework was not the purpose of the standard. The standard is applicable primarily to space system hardware, although the definitions are used in a wider domain in many cases.

It is important to recognise that the ISO standard introduces some modifications with regards to the M95r previous interpretation in ECSS documents.

4.2 Differences between M95r and ISO 16290 standard as seen by ECSS (European interpretation)

Below is given a summary of the differences between M95r and ISO 16290 standard, supported by Figure 4-1:

- ISO levels 1, 2, 3 and 4 definitions are equivalent to M95r (see clause 2) .
- ISO level 5 is a new intermediate level defined for when breadboards at sub-scales are used (the breadboards used to demonstrate the critical function in a relevant environment are not full scale or full function representations of the flight equipment).
- ISO level 6 is equivalent to M95r level 5.
- ISO level 7 is equivalent to M95r level 6.
- ISO does not recognize M95r level 7 which was "System prototype demonstration in space environment".
- ISO levels 8 and 9 are equivalent to M95r definitions respectively defining "flight qualified" (qualified for flight) and "flight proven" for the actual systems.

Differences between M95r and ISO are summed up in Figure 4-1.