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The new ISO standard on TRL

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The aim of this paper is to present the new ISO standard highlighting what has changed regarding previous definitions and interpretations of the nine levels of TRL (Technology Readiness Levels). In the last two IACs the progress in the preparation of the ISO standard was presented (ref [2] and [3]). This paper is a follow up on the further progress on the standard preparation.
TRLs (Technology Readiness Levels) are the different levels of a metric which aims to assess technology maturity.
They offer a systematic assessment of a given technology in the context of its intended application. They are relevant not only for the development of the technology itself, but also for its integration into units, sub systems and systems. They allow communication between managers and specialists or between specialists of various disciplines and various industrial areas.
They were adopted by many companies and governmental agencies around the world and were "de facto" an international language. However, as this language has not been harmonized and detailed, it was sometimes leading to some misunderstanding. For this reason International Organization for Standardization (ISO) started a project to develop a standard called "Definition of the Technology Readiness Levels (TRL) and their criteria of assessment".
This standard was necessary to ensure that the same scale is used by everyone thus avoiding any ambiguity, and to guarantee a maximum accuracy in the framework of international cooperation. It was also a need in order to be efficient in the business agreements between agencies and industries and in the whole customer-supplier chain.

I. INTRODUCTION

Advanced, new technology sectors (for computing, electronic components, telecommunications, multimedia, aerospace, defense, etc) are increasingly calling upon technology management tools and methods. The context of competitiveness in industry, the international collaboration required for major programmes, and the greater complexity of products and systems all call for the efficient rationalization of technical resources use. An important factor of this rationalization is to have a simple and precise method for communication of technical information between various groups of people (different industry sectors, professions, customers/suppliers, nationalities, etc). TRL (Technology Readiness Level) has the potential to become one of those communication methods.

TRLs are the different levels of a metric (or indicator) which aims to assess technology maturity. They offer a systematic and independent assessment of the discipline in question. They apply not only to the specialists developing the technology itself, but also to those integrating it for system development. These two groups use TRLs in different ways:

- in the first case, to standardise "technology roadmaps" (ref [4]) , determine research priorities and communicate with non-specialists,
- in the second case, during definition phases as a basis for deciding whether to use or integrate specific technology for space missions, with sufficient knowledge of any risks relating to the degree of maturity.

Although TRL was conceived at NASA, it is nowadays being used in both the public and private sectors and, more importantly, in projects that require international collaboration.

However, there are different interpretations of these levels throughout the world and that needs to be corrected for the full potential of TRL to be achieved.

This paper aims to present the Final Draft International Standard 16290 (FDIS 16290) "Definition of the Technology Readiness Levels (TRLs) and their criteria of assessment" (ref [5]) to be published in 2013.

This paper is organized as following: section II presents a historical background, section III provides an overview of the FDIS, section IV describes what has changed regarding previous definitions and interpretations and section V concludes this paper.

II. HISTORICAL CONTEXT

The TRL methodology was originated at NASA Headquarters in 1974. Then the scale progressed until 1995 with the definition of nine levels (ref [1]; see Figure 1). The principle of a maturity scale has been adopted by many companies and government agencies around the world. However, although they are somewhat similar, different definitions are used by different agencies.

In 2001, the American Deputy Under Secretary of Defense for Science and Technology issued a memorandum that endorsed the use of TRLs in new major U.S programs. U.S. government acquisition programs are now required to certify that Critical Technology Elements have been demonstrated in a relevant environment (TRL 6) at program initiation.

In July 2005 at the "1st Symposium on Potentially Disruptive Technologies and their Impact in Space Programs" in Marseille (France), following a CNES initiative, ESA, NASA, JAXA and CNES decided to start coordination of the scale. At that time, JAXA was wishing to merge several levels in one to simplify the process, ESA scale was with 8 levels, CNES and NASA/DOD were using 9 levels. The first step was to decide altogether to use 9 levels as presented in the "JC Mankins 1995" scale (JC M 95).

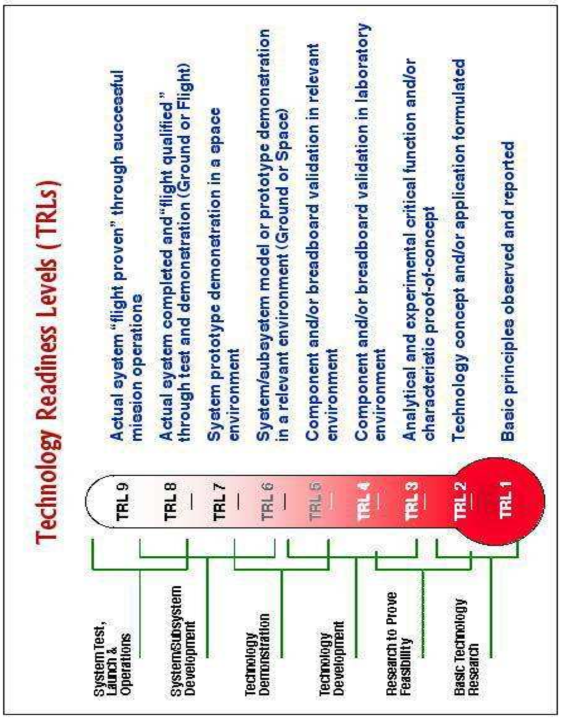

Fig. 1: NASA definition of TRL (JC M 95).
Source: JC Mankins, 1995

In order to avoid ambiguity and different interpretation and to guarantee a maximum accuracy when using this reference scale in international partnerships, European Cooperation for Space Standardization (ECSS), decided, in 2009, to propose a New Work Item (NWI) to the International Organization for Standardization (ISO).

ISO is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out by ISO technical committees. Each member body interested in a subject for whom a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

III OVERVIEW OF THE ISO FDIS 16290

After a short introduction the document is composed of 4 clauses:

1. Scope
2. Terms and definitions
3. Technology Readiness Levels (TRLs)
4. Summary table

One should notice that the introduction makes clear that the detailed procedure for the TRL assessment is to be defined by the relevant organisation or institute in charge of the activity and not part of this document limited to levels definition and to the criteria of assessment.

III.I Scope

The scope is just recalling the aim of the document, making clear that it is limited (although it could be used in a wider domain) to space system hardware.

III.II Terms and definition

This clause defines terms and definitions used in the document with two objectives:

1. to make sure that the interpretation of the scale is the same by all the users (avoiding ambiguities and vagueness),
2. to have a self-contained document (not referring to some other glossary).

The key terms defined are the following: breadboard, critical function of an element; critical part of an element; element; element function; functional performance requirements; laboratory environment; mature technology; mission operations; model; operational environment; operational performance requirements; performance; performance requirements; process; relevant environment; reproducible process; requirement; technology; validation; verification.

III.III Technology Readiness Levels (TRLs)

This clause is the main one of the document. A general sub-clause, give first some answers to what could be "FAQ" (frequently asked questions) as for example: "

- What is a mature technology?

- To which element of a system is the scale applicable?
- Is there any prerequisite for TRL assessment?
- What happens to the TRL when the element is used in a different system or environment? When the element is re-build/re-used? When it becomes obsolete or when a specific knowledge has been lost?
- Does TRL give indications on remaining efforts or costs?
- What happens when the element under consideration comprises sub elements with various TRLs?

Then 9 sub-clauses are describing the 9 levels of the scale. Each sub-clause presents for its specific level:

1. the activities and achievement to be reached,
2. the characterisation of performance requirement to be established,
3. some relevant examples.

The 9 levels are named as follows (in bold characters are the amended names compared with the “JC M 95”):

1. TRL 1 - Basic principles observed and reported;
2. TRL 2 -Technology concept and/or application formulated;
3. TRL 3 - Analytical and experimental critical function and/or characteristic proof-of-concept;
4. TRL 4 - Component and/or breadboard functional verification in laboratory environment;
5. **TRL 5 - Component and/or breadboard critical function verification in a relevant environment;**
6. **TRL 6 - Model demonstrating the critical functions of the element in a relevant environment;**
7. **TRL 7 - Model demonstrating the element performance for the operational environment;**
8. **TRL 8 – Actual system completed and accepted for flight (“flight qualified”);**
9. TRL 9 - Actual system “flight proven” through successful mission operations.

III.IV Summary table

This last clause proposes a table where for each level it is summarized the *“Milestone achieved for the element”* and the *“Work achievement (documented)”*, (see example for TRL 5 in Fig.2)

Technology Readiness Level	Milestone achieved for the element	Work achievement (documented)
TRL 5: Component and/or bread-board critical function verification in a relevant environment	Critical functions of the element are identified and the associated relevant environment is defined. Breadboards not full-scale are built for verifying the performance through testing in the relevant environment, subject to scaling effects.	Preliminary definition of performance requirements and of the relevant environment. Identification and analysis of the element critical functions. Preliminary design of the element, supported by appropriate models for the critical functions verification. Critical function test plan. Analysis of scaling effects. Breadboard definition for the critical function verification. Breadboard test reports.

Fig. 2: Example of summary table for TRL 5

IV. COMPARING ISO STANDARD WITH “JC M 95” AND ITS INTERPRETATIONS

ISO and “JC M 95” definitions are equivalent and interpretation is identical until the level 4. At this level a laboratory breadboard model of the element is integrated to establish that the “pieces” will work together to demonstrate the basic functional performance of the element. The validation is “low fidelity” compared to the eventual system, and is limited to laboratory environment. Equivalence and identical interpretation is also true for levels 8 and 9 respectively defining *“flight qualified”* for the actual system and *“mature technology”*.

“JC M 95” level 7 which was *“System prototype demonstration in space environment”* has been removed in ISO as it was very often not used and, in some cases, a “JC M 95” level 7 appeared to be more mature than a level 8.

IV.I ISO levels 5 and 6

IV.I.I versus US interpretation of "JC M 95"

For the US side it was very important to keep its interpretation of level 6 as it is considered as "the gateway to a program". ISO is keeping the consistency with US regulation at this level. However ISO definition for level 5 is more accurate to differentiate "JC M 95" levels 5 and 6 by making clearer that at level 5 "the element feasibility can be considered as demonstrated, subject to scaling effects". Thus, ISO level 5 appears now as an intermediate stage to level 6, used when models at sub-scales are necessary.

IV.I.II versus European interpretation of "JC M 95"

For European space community ISO level 6 is equivalent to "JC M 95" level 5 and ISO level 5 is a new intermediate level, used when models at sub-scales are necessary.

IV.II ISO level 7

IV.II.I versus US interpretation of "JC M 95"

ISO level 7 is a new level in which activities were previously performed, during system development, on the way to reach "JC M 95" level 8 but not identified as a formal level. For ISO, at this level *"performance is demonstrated for the operational environment, on the ground or, if necessary, in space. A representative model, fully reflecting all aspects of the flight model design, is build and tested with adequate margins for demonstrating the performance in the operational environment."*

IV.II.II versus European interpretation of "JC M 95"

ISO level 7 is equivalent to "JC M 95" level 6.

V. CONCLUSION

This paper presented the ISO FDIS 16290, which aims to standardise technology maturity levels, and its differences with the previous reference "JC M 95" which had various interpretations in US and Europe.

The space community convergence could appear relatively long to achieve, however the ISO initiative highlighted the previous divergences in understanding the 9 levels.

The new scale is now internationally harmonized and can be used without any ambiguity. It becomes a communication language to be used in international projects by public and private organizations worldwide.

The Final Draft International Standard, produced by the ISO WG, is in the voting process which began on the 8th of July 2013 and should terminate on the 8th of September 2013. So, the new standard should be published in time to be available a few days before IAC 2013.

ACKNOWLEDGEMENT

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