

Improvement of Planning and Tracking of Technology Maturity Development with Focus on Manufacturing Requirements

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ABSTRACT

This paper details the development of a user-friendly computerised tool created to evaluate the Manufacturing Readiness Levels (MRL) of an emerging technology. The main benefits achieved are to manage technology development planning and tracking, make visually clear and standardised analysis, and improve team communication. The new approach is applied to the Technology Readiness Levels (TRL), currently used by Airbus Research & Technology (R&T) UK.

The main focus is on the improvement of the analysis criteria. The first phase of the study was to interpret the manufacturing criteria used by Airbus at TRL 4, including a brief benchmarking review of similar practices in industry and other Airbus' project management tools. All information gathered contributed to the creation of a complete set of criteria.

In the second phase, a questionnaire format, using the new set of criteria, was used through a user-friendly computer tool, which was programmed to quantify and plot the maturity of a technology into tracking graphs. The graphs presented the status of a technology against a respective 'target' for completion, providing a visual assessment of the missing gaps in development. The tool also emphasises information sharing, by requesting evidence of completed work. Initial validation occurred on two projects at Airbus R&T (with relative success, as excellent feedback was received from technology managers).

In conclusion, this paper presents a technology maturity tracking methodology. Although it was initially developed for use on Airbus' projects, it could easily be adapted to suit other organisations and industry sectors.

KEYWORDS: Aerospace, Technology Readiness Levels, Manufacturing Readiness, Technology Maturity

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INTRODUCTION

The paper starts by providing background information on the use of Technology Readiness Levels (TRLs) and gives a summary of the main issues highlighted both in the literature and also in its practice at Airbus R&T UK. It then focuses on manufacturing related topics and its implications, and criticality to a technology maturity process.

The process of understanding the technical requirements and the project management techniques suitable for assessing

a technology is divided into a benchmarking review and an analysis of internal practices at Airbus. This paper intends to clarify the methodology used to assess technologies rather than defining the technology requirement topics.

The second half of the paper explains how the expanded criteria were adapted into a computer aided interactive questionnaire and how answers were quantified. The paper describes how targets should be set for each item, and how both answers and targets are plotted on the same graph and enable easy and visual identification of demonstration gaps.

The final section of this paper then provides and initial validation of the methodology proposed on two Airbus' projects. It then concludes and summarises the overall results obtained.

TECHNOLOGY MATURITY

Tetlay and John [1] have defined the 21st century as the "Systems century" as the complexity and intense integration of technological products is constantly increasing. They also believe that assessing a system's maturity and readiness during its development life-cycle is imperative in order to achieve success.

Cornford and Sarsfield [2] state that development of new technologies require careful planning including clear requirements, defined milestones, accurate estimates of cost and schedule, and a method for evaluating and mitigating developmental risks.

Technology Readiness Levels

The Airbus Technology Readiness Level (TRL) Methodology is based on the classification originally developed by NASA [3]. It has been derived from the need of establishing a systematic approach to ensure risk-reduction management and measure the maturity of R&T Technology Products.

	TRL1	TRL2	TRL3
Description	Basic principles observed and reported	Technology concept and/or application formulated	Analytical and experimental critical function and/or characteristics proof of concept
Airbus maturity phase	Discover		Understand
	TRL4	TRL5	TRL6
Description	Component and/or breadboard validation in laboratory environment	Component and/or breadboard validation in relevant environment	Systems/sub-systems model or prototype demonstration in a relevant environment
Airbus maturity phase	Adapt		Validate

Figure 1. Airbus Technology Readiness Levels for Research & Technology

The TRL scale runs from 1 to 9 with TRL 1 indicating the lowest level of maturity. R&T Technology Product's lifecycle normally runs from TRL 1 to 6. Levels 1 and 2 indicate a technology at a discovery stage when the concept and application of the technology are formulated. TRL 3 denotes that at least one feasible solution for the technology has been identified and evaluated. TRL 4 and 5 focus on the validation of the concepts defined at TRL 3 and their adaptation to the desired application. A technology at TRL 6 indicates a validation and/or demonstration through a prototype. The mitigation of risks of a fully integrated solution should be provided in a relevant environment.

TRL 7, 8 and 9 are focused on refining the technology and the final industrialisation and operational demonstrations.

Issues highlighted on the use of TRLs

Generalising the TRL approach to maturity assessment could be misleading if taken out of context of specific technology types and application areas. This could lead to an ineffective process being described as mature if it is defined, managed, measured and controlled. Maturity could be better if characterised effectiveness, regardless of the degree of management or the bureaucracy associated [4].

Sausser [5][6][7] has suggested that using TRLs does not account for the integration of more than one technology and the combined impact in a system. As a result there is high probability that the standard TRL method might lead to failure at the integration point. It is therefore highlighted that the assessment of integration maturity is a critical factor to avoid an overall system failure.

Smith [8], argues that TRLs combine together a number of components of readiness into a single level, which leads to unrealistic simplification as it does not allow to weight each critical technology in the system. Also, TRLs on their own are unable to account for the relative contribution between components of various readiness levels through the system life cycle.

A report by the US Joint Defence Manufacturing Technology Panel [9], argues that a TRL provides a scale of readiness only for a point of time and does not indicate the difficulty or even the possibility of further technology maturing at the next TRLs. The report suggests that as TRLs are based on a "single axis, the axis of technology capability demonstration" they do not show risks of integrating a technology into a system. A multi-dimension metric would be more suitable. Moreover, the Department of Defence Interim Guidance states that the issue with TRLs is that there is no guidance for the implementation of the metric in a program [3].

Cornford and Sarsfield [2] believe the most serious limitation of the methodology is the ambiguity of the technology's relevance, as it may be immature to a certain application but mature to a second one. They summarise the main challenges with the use of TRLs in 5 topics:

Table 1. Main challenges associated with the use of TRLs (Cornford and Sarsfield [2])

<i>Subjective assessment</i>	The criteria defined provide room for broad interpretation and a subjective assessment of the maturity of a technology;
<i>Not focused on the system-to-system integration</i>	The TRL methodology generally fails to consider the difficulties to incorporate a “mature” technology into new applications
<i>Not well integrated into cost and risk modelling tools</i>	Inaccuracies in the calculation of the TRL will result in errors in the program cost and schedules estimates
<i>Lacking of definition of terminology</i>	Definition of a “relevant environment” is open to interpretation and could be based on radiation, temperature, vacuum, low gravity, etc. The degree of demonstration performance is also left undefined

Similar issues have been highlighted by personnel using a generic TRL methodology for benchmarking new manufacturing technologies at the UK Airbus R&T. The tendency to use generic criteria for benchmarking diverse technologies and cover all possible applications could lead to an either broad or ambiguous interpretation of the requirements for a specific level of readiness. This issue was certainly a risk to a technology development as potential demonstration gaps could occur and impact the technology development in terms of performance, schedule and/or budget.

In addition, the narrow focus of analysis suggested by the TRL methodology was leading to a lack of communication between sub-development teams in a larger programme, which could result in work overlaps or non completion of tasks.

Manufacturing focus and critical level of maturity

The focus on the Manufacturing Readiness intends to expand the criteria used for this topic to enable a more complete demonstration of the processes capabilities, analysis of design to manufacture, to assembly and to cost, greater understanding of supply chain implications, non-destructive testing (NDT); and ensure production requirements.

The 4th level of maturity was chosen as critical in the development of a product or technology (Refer to [Figure 1](#)). It follows level 3, which includes a successful proof-of-concept work and great understanding of functions and characteristics. From a performance point of view, the validation in a laboratory environment must achieve concept-enabling levels at TRL 4 and support what was earlier formulated.

By level 4 a known application is mandatory as the demand for resources will increase at this level and high investments will be necessary.

Level 5 will then be a continuation of the “adaptation” phase, the solution's risks have to keep on being mitigated and a demonstration is validated on a relevant environment. Level 5 is also very important but would potentially fail if the requirements at level 4 were weak or had not been addressed at all. A successful achievement of level of readiness 5 would then lead to TRL 6, which is also a critical step. When TRL 6 is completed R&T hands the technology over to production.

Based on the critical points mentioned above, level 4 was chosen as an exemplar for this project.

Benchmarking Review

In the aerospace industry, other institutions have already faced issues when using the TRL methodology related to specific manufacturing requirements.

The Department of Defense of the United States (DoD) was one of the first institutions to adapt the original NASA TRL scale [3], and develop detailed Manufacturing Readiness Level (MRL) criteria. The assessment of manufacturing risks and identification of requirements is based on these criteria, and are measured by Manufacturing Readiness Assessments (MRA). This aims to build throughout the acquisition phases and terminate when the program is ready for production, on cost and schedule, meeting performance requirements.

When focusing on the methodology overview of its 4th level of maturity, the required investments have to be identified; processes have to ensure manufacturability, quality, and producibility are in place; key performance parameters have been defined and all special needs for tooling, facilities, material handling and skills identified. At the start of the MRL 4 stage, it is stated that special attention is required for maturation and risk mitigation in order to successfully reach MRL 6.

The MRL threads work as a guide or completeness checklist. The set of questions for each thread has a check box associated to each of them and also asks for measurements and comments on the specific topic.

With influence of the DoD MRL stages, Rolls-Royce developed a set of nine stages, directly comparable to TRLs, of Manufacturing Capability Readiness Levels (MCRLs), which incorporate more detailed questions on topics such as material flow, supply chain management and Information Technology (IT) infrastructure.

With focus on the 4th level of maturity, the main contrast is on the greater pre-production considerations that differ MCRLs to the generic and broader TRL standard.

By MCRL 4 the laboratory demonstration should use representative development equipment, start making initial considerations of skills and facilities, and probable Key Process Variables (KPVs) and control strategy are established. By level 5, actual production equipment has to be involved on basic level demonstrations.

General Electric presented another example of development of manufacturing readiness standards in 2010 [10]. It states that the use of TRLs and MRLs are the right