

LESSONS LEARNED IN PERFORMING TECHNOLOGY READINESS ASSESSMENT (TRA) FOR THE MILESTONE (MS) B REVIEW OF AN ACQUISITION CATEGORY (ACAT)1D VEHICLE PROGRAM

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ABSTRACT

One of the biggest challenges in developing TRA is the determination of the critical technology elements (CTEs). This paper outlines a systematic process used to identify all potential technologies developed by the contractors during the Technology Development (TD) Phase and applies criteria for selection of CTEs. To reduce the subjectivity in the assessment, the relevant technical requirements for each CTE that are important to the customers will be established. These requirements must be met to demonstrate the level of maturity required before entering the Engineering & Manufacturing Development (EMD) Phase. The maturity of a CTE cannot be evaluated in isolation. The paper also includes other system requirements that the CTEs must satisfy before the overall system can be evaluated. A major defense ACAT vehicle acquisition program, Joint Light Tactical Vehicle (JLTV), was used to demonstrate the TRA process in preparation for the MS-B Review with the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASA(ALT)) and the Assistant Secretary of Defense for Research & Engineering (ASD(R&E)) within the Office of the Secretary of Defense (OSD).

Background

Because of its limited budget, the US Government has to select technologies that are mature enough to develop into products among the many immature technologies. All technology developments have cost and time constraints. Since the beginning of the war in Iraq and Afghanistan, the US Army (USA) and US Marine Corps (USMC) wanted to upgrade the protection and other needed capabilities of its light tactical High Multipurpose Mobility Wheeled Vehicle (HMMWV). In 2007, the USA/USMC selected 3 vendors to begin developing a Joint Light Tactical Vehicles Family of Vehicles (JLTV FoV) to replace its aging HMMWV fleet. The all new JLTV has to balance conflicting requirements between protection, performance and payload. Its main objectives are to protect soldiers from mines and improvised explosive devices, move fast and reliable enough to perform tactical missions in rough terrain, and be light enough to be transported and powerful enough to carry heavy loads. In addition, it must be produced affordably at low risk constrained by its program timing. Achieving these goals require technologies to be fairly mature and affordable. Because JLTV is an Acquisition Category 1D program, the Program Management (PM) has to follow the

TRA Guidance released by OSD in determining if the technologies are critical and mature enough to be implemented into the vehicle. For the last 18 months, the US Army Tank Automotive Research and Development Engineering Center (TARDEC) supported JLTV in selecting the CTEs and assessing their technical risks. Prior to MS-B Review, based on DoD Directive 5000.2, all system prototypes shall have been demonstrated in a relevant environment satisfactorily to be considered mature enough to use for product development. The purpose of this paper is to summarize the systematic processes used in selecting and evaluating the maturity of CTEs and the lessons learned during the process.

Process Timing

The original estimate was to complete the whole assessment process in 9 months. The actual time it took was 16 months. Table 1 shows the comparison between the estimated and the actual time required to complete the major tasks. For MS-A Review however, much less information was available for review and therefore the time required to review it should also be proportionately less.

Table 1 TRA Time Estimate versus Actual

Technology Maturity Assessment Tasks	Estimate (days)	Actual (days)
Project planning	15	15
Scope of work	3	3
Collect project data	20	50
Extract technology	15	25
Form SME Team	5	10
Link technology & KPP	2	3
Establish CTE criteria	5	3
Initial CTE screening	5	50
PM/ASA(ALT) Review		10
OSD CTE deliberation		20 parallel
CTE & TMA process brief		10
Collect TRL6 requirements		20
SME Tailor TRL checklist	8	10
Combine CTE TRL checklist & TRL6 technical requirements	4	5
SME TRL6 metrics review		5
PM TRL6 metrics review		10
Test data collection		95 parallel
Organize CTE data		15
Assess CTE technical risks	15	20
Collect SME risk assessments		4
PM review of assessments		5
Finalize CTE assessments		10
Fill in TRL checklist		95 parallel
Calculate TRL/MRL/PRL	20	5
Summarize all assessments	10	10
ASA(ALT) TRL & BOE review		10
Write draft TMA report	50	30
Internal reviews	5	5
Finalize TMA Report	10	10
Total	192d=38wk =9m	353d=71wk =16m

Lesson #1: Many collaboration reviews and information organization tasks were not included in the original planning. If included, the project took 1.8 times longer. A better estimate on TRA project timing should include time required to conduct reviews and information gathering and organization.

Lesson #2: The time required to identify the technologies for each contractor can be significantly reduced if the information is provided by the program engineers or the contractors.

The JLTV has 17 physical subsystems. The same Work Breakdown Structure (WBS) was used by each contractor.

Lesson #3: In order to capture all potential technologies, review and extract all technologies from supporting engineering and design review documents typically categorized by vehicle WBS. Specify key requirements with each technology extracted.

Lesson #4: Before requesting support from subject matter experts (SMEs) and the PM, develop a flowchart (Fig. 1) to show the TRA process and a swimlane chart (Fig. 2 & 3) to show the detail TRA steps combined with roles of each participating organizations. These charts demonstrate how and when team members have to rely on each other to complete the TRA project.

Figure 1 JLTV TRA Process

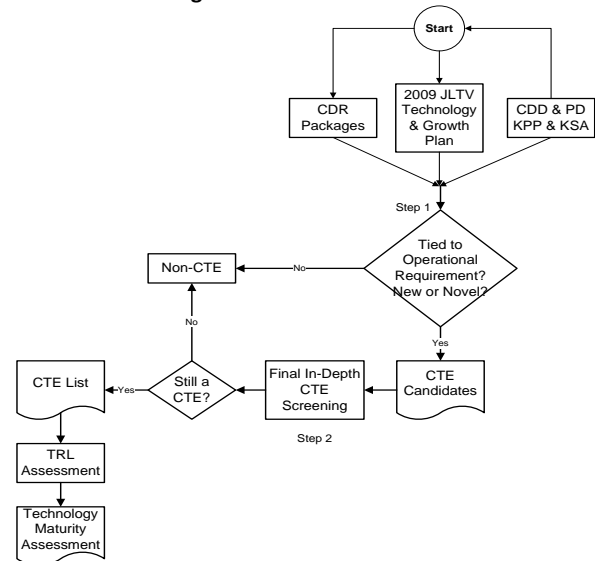
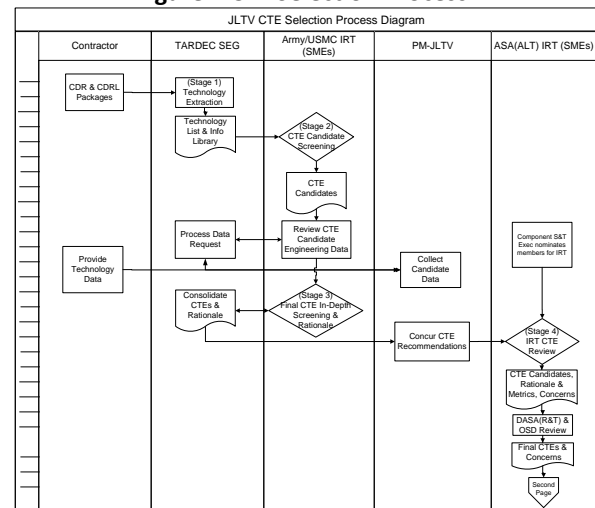


Figure 2 CTE Selection Process



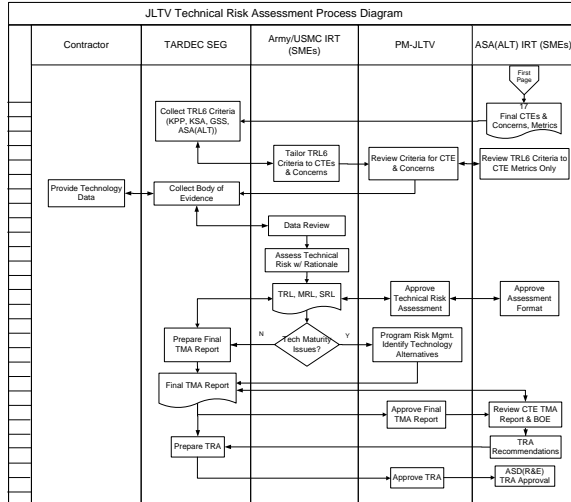
There were 5 organizations involved in the TRA process: PM-JLTV, TARDEC, Army/USMC Independent Review Team (IRT), ASA(ALT) IRT and ASD(R&E) and contractor(s). TARDEC established the IRT by selecting SMEs from the Army and USMC research centers since JLTV is a joint program between USA and USMC. PM selected TARDEC to provide an independent assessment of the CTEs

technical risk/maturity. ASA(ALT) also established a separate IRT consisting of independent experts from the academia, industry and government research centers.

Document (CDD) with identified KPPs and KSAs and/or Purchase Description (PD) requirements if available.

The PD is a complete set of system requirements developed from the CDD, system boundary diagrams and interface analysis, functional analysis, industry and government standards, etc.

Figure 3 Technical Risk Assessment Process



CTE Selection

The MS-B Review mainly focused on the CTEs which are defined by 2 main criteria. First, the system being acquired depends on this technology element to meet Key Performance Parameters (KPP) or Key System Attributes (KSA). Second, the technology or its application is new or in an area that poses major technological risk during design/demonstration. These criteria are expanded upon in Table 2 to assist the CTE identification process.

Table 2 CTE Screening Criteria

Critical Technology Element Screening Criteria		Y/ N	Y/ N
1) Critical	Directly impact an operational Requirement threshold (KPP or WBS)?		
	Significant impact on an improved delivery schedule?		
	Significant impact on program affordability?		
AND			
2) New or novel application	Is the technology new or novel?		
	Is the technology modified?		
	Tech repackaged such that a new relevant Environment is realized?		
	Expected to operate beyond design intention & demonstrated capability?		
Or			
3) High Risk	Is the technology in an area that poses major technological risk during detailed design or demonstration?		

Lesson #5: To determine all key requirements associated with a technology, set up a functional requirement tree using the Capability Development

Lesson #6: Each system requirement should be accompanied by acceptance criteria and verification test procedure. Each test procedure should be based on some functional analysis and mission profile. If it is not, the program can be at risk of failing some relevant environment verification test in the future.

With a little practice, functional and non-functional requirements can be easily linked to any technologies.

Lesson #7: In order to separate the CTEs from non-critical technologies, an independent SME has to review all engineering documents such as test results, failure analysis and corrective action report (FACAR), documented design risks and issues matrix, requirement compliance matrix, failure mode and effect analysis (FMEA), modeling and simulation analysis, interface analysis, trade studies, etc to determine if there was any major technological risk associated with a technology.

The same information is also used to determine if there are any system integration risks or issues. Since all 3 vendors used the same WBS, their design review packages were similar. Any unique or common approaches used by the contractors, issues and difficulties experienced in the design and integration processes and disadvantages or advantages of the competing technologies can be easily compared. After ASA(ALT) IRT and ASD(R&E) review the rationale supporting the selection of the CTEs, they may certify all or some of the CTEs suggested by the PM/TARDEC Team and provide additional recommendations.

Technical Risk Assessment

TARDEC selected 2 methods to assess the overall technical risk of the CTEs.

The first assessment was done primarily by the USA/USMC IRT based on a detail review of contractor’s engineering supporting data including test results.

Lesson #8: Before performing the assessment, a detailed metric has to be developed and agreed upon between the program and USA/USMC IRT. The metric should contain specific detail technical requirements for each CTE, verification methods and acceptance criteria.

It is very tedious to locate all the relevant engineering reports, test results and procedure.

Lesson #9: Rather than having the SMEs to locate the engineering information they need to make the assessment, locate and catalogue all relevant technical data (M&S results, test data and reports, failure incidences and corrective actions, engineering analysis, etc.) so they can easily refer to them while performing the assessment.

Additional information on the design, integration and latest test results can be obtained over a series of meetings between the program and the SMEs. This process will furnish the SMEs with all necessary information to perform the technical risk assessment for each CTE.

Since the beginning of the test program, many system issues were discovered. A system can fail because of design issues, manufacturing flaw, poor integration, etc.

Lesson #10: Failure to meet requirement does not necessarily mean TRL < 6. In case of non-compliance, the SMEs will review the corrective action taken and determine if there is an unacceptable risk for the EMD Phase. A justification will be required.

Lesson #11: To provide a more comprehensive technical risk assessment for each CTE, in addition to Technology Readiness Level (TRL, Ref. 1), it is recommended to include Manufacturing Readiness Level (MRL, Ref. 2) and System Readiness Level (SRL, Ref. 3) in the assessment.

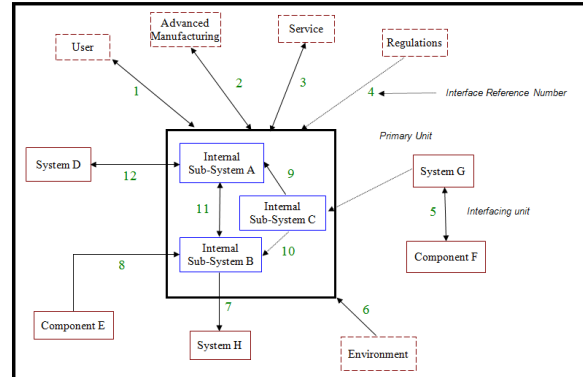
The definitions of TRL, MRL and SRL are given in the Appendix. Based on TRA Guidance, all CTEs entering EMD Phase shall be assessed at least TRL6 (system prototype demonstrated satisfactorily at relevant environment). It is not a DoD requirement that the technology is assessed at MRL6. However, the sources recommend MRL and SRL to be at Level 6.

Lesson #12: MS-B Review focus is on technology maturity, as opposed to engineering and integration risk. The technical risk assessment should mainly

focus on TRL but MRL and SRL should also be mentioned if there are significant manufacturing and integration issues during the Technology Development (TD) Phase.

An example of a boundary diagram is given in Fig. 4.

Figure 4 Typical Boundary Diagram



Lesson #13: The integration of a technology requires a comprehensive boundary diagram consisting of all the external and internal subsystems that have influence on the technology or impacted by it. Their relationships shall be defined in detail with the understanding that these interfaces will be demonstrated in a lab and operational environment.

Most technologies have the following types of interfaces which require specifications:

Mechanical interfaces – size, weight, clearance, tool access, etc.

Electrical interfaces – connectors, cables, energy storage, power consumption, controls, etc.

Electromagnetic interfaces – magnetic fields, radio and optical links, etc.

Thermal interfaces – heat production, dissipation, air conditioning characteristics, etc.

Communication interfaces – analog and digital signals telecommunications, transmission, etc.

Fluid interfaces – air conditioning, compressed air, exhaust gas, lubricating oil, fuel, etc.

Computer interfaces – hardware/software, protocol, users, peripheral, etc.

Lesson #14: Many of the RAM & performance tests, failure root causes and corrective action reports were not complete when maturity assessments were made. It is better to update the assessments at the end of the test phase after test & evaluation engineers summarize the test results.

The second assessment was done using the TRL calculator. This Excel calculator was originally developed by the Air Force Research Lab (AFRL). For

each maturity level, there is a generic list of tasks that need to be performed to bring a technology to that level of maturity. By specifying the percent completion of each of these tasks, the calculator provides a repeatable and standardized method to determine the maturity of any technology. These tasks are divided into technical, manufacturing and programmatic categories for each level of maturity.

Lesson #15: It is recommended to have the program engineers to complete the checklist of tasks at the end of the test phase so that they have all the information needed.

In summary, the TRA lessons learned from the 18 months of supporting the program provide a detail roadmap to a more efficient TRA process that can significantly reduce the time to perform a TRA. However, this does not mean that the assessment can start at a much later time because it may take a long time to collect the required substantiation data to assess the overall technical risks associated with a technology.

APPENDIX:

TRL	Technology Readiness Level (TRA Guidance, ASD(R&E))
1	Basic principles observed and reported.
2	Technology concept and/or application formulated.
3	Analytical and experimental critical function and/or characteristic proof of concept.
4	Component and/or breadboard validation in a laboratory environment.
5	<i>Component and/or breadboard validation in a relevant environment.</i>
6	System/subsystem model or prototype demonstration in a relevant environment.
7	System prototype demonstration in an operational environment.
8	Actual system completed and qualified through test and demonstration.
9	Actual system proven through successful mission operations.
MRL	Manufacturing Readiness Level for Design Thread (MRL Deskbook)
1	Not defined
2	Not defined
3	Relevant materials/processes evaluated for manufacturability using experiments/models.
4	Initial producibility and manufacturability assessment of preferred systems concepts completed. Results considered in selection of preferred design concepts and reflected in TDS key components/technologies.
5	Producibility and manufacturability assessments of key technologies and components initiated as appropriate. Ongoing design trades consider manufacturing processes and industrial base capability constraints. Manufacturing processes assessed for capability to test and verify in production, and influence on operations & support.
6	Producibility assessments and producibility trade studies

	(performance vs. producibility) of key technologies/components completed. Results used to shape Acquisition Strategy, SEP, Manufacturing and Producibility plans, and planning for EMD or technology insertion programs. Preliminary design choices assessed against manufacturing processes and industrial base capability constraints. Producibility enhancement efforts (e.g., Design for Manufacturing Assembly, Etc. (DFX)) initiated.
7	Detailed producibility trade studies using knowledge of key design characteristics and related manufacturing process capability completed. Producibility enhancement efforts (e.g., DFX) ongoing for optimized integrated system. Manufacturing processes reassessed as needed for capability to test and verify potential influence on operations & support.
8	Producibility improvements implemented on system. Known producibility issues have been resolved and pose no significant risk for LRIP.
9	Prior producibility improvements analyzed for effectiveness during LRIP. Producibility issues/risks discovered in LRIP have been mitigated and pose no significant risk for FRP.
10	Design producibility improvements demonstrated in FRP. Process producibility improvements ongoing. All modifications, upgrades, DMSMS, and other changes assessed for producibility.
SRL	System Readiness Level (Australia MoD)
1	Basic principles observed and reported.
2	System concept and/or application formulated.
3	Analytical studies and experimentation on system elements.
4	Sub-system components integrated in a laboratory environment.
5	System tested in a simulated environment.
6	System demonstrated in a simulated operational environment, including interaction with simulations of external systems
7	Demonstration of system prototype in an operational environment, including interaction with external systems.
8	System proven to work in the operational environment, including integration with external systems.
9	Application of the system under operational mission conditions.
TRL	Level of Integration Required Corresponding to TRL (United Kingdom DoD)
1	Interface requirements and impact on other systems are understood at concept level only.
2	Not defined
3	Analytical assessment conducted to establish interface requirements.
4	Interface requirements specified and understood. The likely impact on interfaced systems is generally understood.
5	Interfaces partially demonstrated at System/Sub-system level in a synthetic environment. Impact on other systems is understood, specified and quantified.
6	Interfaces demonstrated at system level in a synthetic / high fidelity environment.
7	Fully integrated with prototype. System interfaces qualified in an operational environment.
8	Final production design validated demonstrating internal and external integration.
9	Not defined

REFERENCES:

- [1] ASD(R&E), "TRA Guidance", April, 2011
- [2] OSD Manufacturing Technology Program, "MRL Deskbook", v2.0, May, 2011
- [3] T. Moon, J. Smith, S. Cook, "Technology Readiness and Technical Risk Assessment for the Australian Defense Organization", 2004