New Developments in the Technology Readiness Assessment Process in US DOE-EM – 13247

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ABSTRACT

A Technology Readiness Assessment (TRA) is a systematic, metric-based process and accompanying report that evaluates the maturity of the technologies used in systems; it is designed to measure technology maturity using the Technology Readiness Level (TRL) scale pioneered by the National Aeronautics and Space Administration (NASA) in the 1980s. More recently, DoD has adopted and provided systematic guidance for performing TRAs and determining TRLs. In 2007 the GAO recommended that the DOE adopt the NASA/DoD methodology for evaluating technology maturity. Earlier, in 2006-2007, DOE-EM had conducted pilot TRAs on a number of projects at Hanford and Savannah River. In March 2008, DOE-EM issued a process guide, which established TRAs as an integral part of DOE-EM's Project Management Critical Decision Process. Since the development of its detailed TRA guidance in 2008, DOE-EM has continued to accumulate experience in the conduct of TRAs and the process for evaluating technology maturity. DOE has developed guidance on TRAs applicable department-wide. DOE-EM's experience with the TRA process, the evaluations that led to recently developed proposed revisions to the DOE-EM TRA/TMP Guide; the content of the proposed changes that incorporate the above lessons learned and insights are described.

INTRODUCTION

General

A Technology Readiness Assessment (TRA) is a systematic, metric-based process and accompanying report that evaluates the maturity of the technologies proposed for use in systems. A TRA measures technology maturity using the Technology Readiness Level (TRL) scale pioneered by the National Aeronautics and Space Administration (NASA) in the 1980s [1]. The TRL scale ranges from 1 (basic principles observed) through 9 (total system used successfully in project operations). In 1999, the General Accounting Office (GAO, now the General Accountability Office) recommended that the Department of Defense (DoD) adopt the use of NASA's TRLs as a means of evaluating technology maturity [2]. In 2001, the Deputy Undersecretary of Defense for Science and Technology issued a memorandum that endorsed the use of TRLs in new major programs. Subsequently, the DoD developed detailed guidance for performing TRAs [3].

Development of the DOE-EM TRA/TMP Guide

In 2007 the GAO recommended that the DOE adopt the NASA/DoD methodology for evaluating technology maturity [4]. Prior to this GAO recommendation, in 2006-2007, DOE-EM had already conducted pilot TRAs on a number of projects including Hanford's Waste Treatment and Immobilization Plant, Savannah River's Tank 48, and Hanford's K-Basins—these TRAs adapted existing DoD guidance (above) for use In DOE projects. In March 2008, DOE-EM issued its *Technology Readiness Assessment (TRA)/Technology Maturation Plan (TMP) Process Guide* (Guide) [5], which established the TRA process as an integral part of DOE-EM's Project Management Critical Decision Process. Similar to DoD and NASA, DOE-EM expects that TRLs will be determined prior to critical project management decisions. For example, DOE-EM anticipates that a TRL of 4 will be achieved when a project reaches completion of a conceptual design, and a TRL of 6 will be met prior to incorporation of a technology into the detailed design process for a project.

The 2008 Guide described:

- the objectives of the TRA/TMP process including the relationship of TRAs/TMPs to DOE's Critical Decisions and acqusition process;
- the TRA/TMP process including the roles and responsibilities of key personnel and the details of TRA execution; and
- the preparation and execution of the TMP.

It also contained the initial set of TRL Calculator questions to be used in DOE-EM; these questions provide the detailed means for assessing the maturity of a technology. It should be noted that the TRL Calculator questions evolved as EM gained experience in the process; each set of questions is approved for use prior to a specific TRA by the cognizant headquarters technical staff and field project leadership.

The DOE TRA Standard

In its seminal review of project management in the DOE [6], the National Research Council (NRC) of the National Academy of Sciences (NAS) made sweeping recommendations that resulted in an overhaul of the requirements and practice of managing projects in the Department. The effort to implement these recommendations, as modified to address subsequent reviews and assessments, has resulted in a revised DOE Order [6] and set of guidance document for implementation of that Order.

In furtherance of this objective to improve project management practices within the Department, DOE's Office of Management and Administration (DOE-MA), has issued a number of documents that provide detailed guidance for aspects of project management. In 2009, taking advantage of technical and process information in the DOE-EM TRA/TMP Guide (above), the Department issued a guide which: (1) promulgated DOE-wide expectations for the TRA process and (2) described the relationship of the TRA process and the determination of TRLs to DOE's Critical Decisions in project management.[8

DISCUSSION

Since the development of its detailed TRA guidance in 2008, DOE-EM has continued to accumulate lessons learned regarding the conduct of TRAs and the process for technology maturation. Insights gained have been piloted in subsequent TRAs, normally through the development of draft changes to the process which are reviewed within the TRA Team and reviewed and approved by headquarters and field project managers, as part of the TRA Plan (required to execute the assessment). Several improvements have been piloted over the past several years, they are documented in the final TRA reports issued as a part of the process and discussed further below.

DOE-EM TRA Experience

DOE-EM conducted its first three TRAs on parts of the Hanford Waste Treatment and Immobilization Plant (WTP) in 2006-7. These initial TRAs utilized a slightly modified version of the Technology Readiness Level (TRL) Calculator originally developed by the Air Force Research Laboratory (AFRL).[9] This tool is a standard set of questions addressing hardware, software, program, and manufacturability questions that is implemented in Microsoft Excel™. DOE-EM TRAs, listed below, employed the TRL Calculator question sets, a number of which required modification to make them more relevant to radioactive waste processing.

Table 1:DOE-EM TRAs

TRA	Technology/Facility	Final Report
TRA-1	Hanford WTP Analytical Laboratory, Balance of Facilities, Low Activity Waste Vitrification Facility	2007
TRA-2	Hanford WTP High Level Waste Vitrification Facility	2007
TRA-3	Hanford WTP Pretreatment Facility	2007
TRA-4	Hanford K Basins Sludge Treatment Process	2007
TRA-5	Savannah River Tank 48H Waste Treatment	2007
TRA-6	Oak Ridge U-233 Downblending and Disposition Project	2008
TRA-7	Savannah River Salt Waste Processing	2009
TRA-8	Hanford K Basins Sludge Treatment Process	2009
TRA-9	Idaho National Laboratory Calcine Disposition Project (Preliminary TRA)	2011
TRA-10	Savannah River Small Column Ion Exchange Program	2011
TRA-11	Hanford WTP Software/Process Control	2012
TRA-12	Hanford K Basins Sludge Treatment Process	2012

This set of reports, in and of itself, presents a clear record of the progress of TRA practice within DOE-EM. These final TRA reports and summaries of the reports can be found on the DOE-EM web-site at www.em.doe.gov/EM20Pages/TankWasteReferencePage.aspx#TRA

Evolution and Use of Process Integration Checklists

An initial step in TRAs is to decompose the technology under assessment into its components and/or sub-systems (referred to in the TRA process as "Technology Elements"). Next, the TRA Team evaluates whether the use of the component/sub-system is both: (1) *critical* to the successful implementation of the technology under assessment and (2) *novel* in its application. If so, such components are designated Critical Technology Elements (CTEs) for the purpose of the TRA evaluation. The TRL Calculator Checklists for TRAs 1-6 provide a set of detailed questions that allow a TRA team to evaluate individual CTEs.

Concerns have been raised, both within DOE-EM and elsewhere [10], that even if the individual CTEs were judged ready for incorporation into project design, it might still be possible that the integrated system might still fail to meet processing requirements. In other words, would the combination of individual technologies produce an overall process that will accomplish project goals and be effectively integrated with other site systems? Beginning with the TRA of the Savannah River Salt Waste Processing in 2009 (TRA-7), Process Integration Checklists were developed to evaluate attributes of integration and added to the TRL Calculator under the title of "Waste Processing System" (WPS). These checklists cover the top-level questions listed below, by addressing a series questions detailing the attributes of process integration.

- Can the WPS accept the full range of wastes to be processed?
- Will the WPS produce a product or products that can be dispositioned?
- Are all WPS technology interfaces and dependencies determined, understood and addressed?

Development and Use of the Process Controls and Process-related Software Checklist

Several TRAs have been performed in the recent past with the specific goal of assessing the maturity level of systems design to operate waste treatment systems, in addition to software that has been used to develop modules in the systems or program components within these systems. This reflected early DOE-EM experience that such systems and equipment were often developed later in the design process, or did not always screen as CTEs--but could have substantial impact on project success.

To develop appropriate TRL checklists, reference was made to DoD Technology Readiness Assessment Deskbook (above) and recommendations from the Air Force Research Laboratory on the conduct of software TRAs [11]. Since projects for which these reviews were in the latter stages of design, the checklist was developed at TRL 6 [12].

The identification of CTEs for process control systems and process-related software is dependent on the type of system and complexity of the systems. A single CTE could be used if the process control system is relatively simple, and little software is used in the system. On the other hand, for complex systems, breaking the review into appropriate CTEs will allow greater granularity. Both approaches have been used and are documented in the associated final TRA reports (discussed above).

Several points to consider when conducting a TRA of a process control system and process-related software have been identified in the course of the previous assessments:

- The TRL checklists developed to-date have been based on achieving a TRL of 6 (at CD-2, or the project/program equivalent). Thus, in adjusting the calculator questions to a specific project terms such as "Preliminary Design" or "Final Design" may need to be revised to what is expected for that project/program or stage in development.
- The TRL 6 calculator questions are intended to address both process control systems and process-related software. However, for complex process control systems, which may include a number of subsystems or a tiered architecture, an approach that evaluates appropriate sub-systems as CTEs, along with an integrated view of the system TRL determination may be appropriate. In the case of complex systems, tailoring of the TRL checklists developed thus far is encouraged.
- The use and control of manufacturer-provided software for component configuration purposes is included in the checklist.
- Completion of the TRL 6 evaluation for process control system and process-related software shares a number of attributes with completion of the TRL calculator in use for "Waste Processing Systems". There are several areas of potential overlap between these two new tools (e.g., "integrated testing") and TRA Teams performing both reviews are encouraged to integrate these efforts.

Role of Project Self-Assessments in the DOE-EM TRA Process

DOE-EM projects found that the TRA/TMP process was useful as a guide for technology development. Because the process is structured, criteria-based, and clearly documented ("transparent") it:

- imposes a consistent level of decision-making discipline on DOE and the Contractor;
- improves technical communication between DOE and its Contractors and provide a common language and structure for technology development;
- clearly defines testing and documentation expectations;
- is a useful tool for comparing candidate technologies; and
- identifies specific actions to reduce risk and support final commitment to a technology.

These advantages have been recognized by the contractors that operate DOE-EM sites and facilities. During recent TRAs, these contractors have chosen to perform their own self-assessments of technology readiness using the DOE-EM TRA/TMP Guide—as a preparation step prior to the formal DOE TRA. DOE-EM determined that this represented a "best practice" and the latest version of the DOE-EM TRA/TMP Guide incorporates recommendations that projects conduct such self-assessments prior to the final independent TRA.

Confluence of Assessments Near the End of Projects

DOE-EM is moving towards the latter stages of a number of major projects; these include the Salt Waste Processing Facility at Savannah River, the Integrated Waste Treatment Facility in Idaho and the Waste Treatment Facility at the Hanford Site, to name a few. Over the past years, DOE has implemented several initiatives to improve performance in technical, safety and project execution. These initiatives have resulted in a number of requirements and guidance that needs to be addressed as a project moves towards completion. These requirements and guidance are documented in several documents and they include: (1) requirements and guidance on how to meet the requirements for evaluating the operational readiness of new or modified nuclear facilities prior to startup [13, 14], (2) guidance on how to closeout a major project [15], along with (3) the DOE guidance for latter TRLs documented in the DOE TRA standard.

Taken individually, these DOE documents could be viewed to involve a large number of assessments, reviews and reports during the latter stages of the execution of a project. A listing would include the following.

- Readiness review requirements involve a Startup Notification Report (SNR) issued for projects at least one year prior to startup; a Plan of Action (POA) that provides detailed planning information to implement the readiness review requirements for a specific project.
- The readiness review leader identified by the POA then works with his selected review team to develop the detailed Lines of Inquiry (LOIs) that will be used to evaluate operational readiness (which includes a technical review of the process) and, with the team membership and review schedule, make up the major parts of the Implementation Plan (IP) for readiness review; as part of the readiness review, the team is required to review the project/facility Startup Plan for adequacy and the readiness of both process and safety systems to support operations. Corrective action plans are required to address findings identified in the readiness review team's report.
- DOE's TRA guide describes that "detailed" Test Plans are needed to implement the Technology Maturations Plans, which are required when the TRL determined during TRA's at CD-1 and/or 2 to not meet expected levels. The results of the detailed test plans are to be closed out with Technical Reports.
- DOE guidance for project closeout list a number of plans and reports recommended at the end of the project life-cycle, they include: (a) Checkout, Testing and Commissioning Plan, (b) Transition to Operations Plan, (c) Project Acceptance Checklists, (d) Project Closeout Process (to be documented in the Project Execution Plan), and (e) Inspection and Acceptance Report.

Since these processes that are governed by separate DOE requirements and guidance, DOE-EM evaluated the guidance that could be provided to permit as much integration of the technology readiness, operational readiness and project closure processes as was feasible. This guidance is to be issued in the form of further explication of the TRA process, providing a comprehensive

definition for TRL 7. It was couched in terms of integrating technology readiness and project closure activities with the operational readiness activities explicitly required by DOE Order.

- The readiness review planning process can use the TMP as one of its references and completion of the actions associated with the TMP, along with the associated Test Reports, can be candidates for a pre-requisite for the DOE readiness review in the POA. The TMP and Test Reports can also be used as references in the LOIs (in the readiness review IP) that guide the assessments done during the readiness review. If the readiness review is meant to evaluate whether TRL 7A has been achieved (see below), this should be reflected in the POA and Implementation Plan for the readiness review; if desired, this will likely impact the selection of readiness review team members.
- Format and content expectations for the Project Acceptance Checklists and Inspection and Acceptance Report may also be reviewed as part of readiness review planning, if integration of this effort is also planned by the Project Execution Plan and POA for the readiness review. Also, preparation and integration planning by the Integrated Project Team (IPT) can ensure that the expectations and requirements for the Startup Test Plan, required as part of the readiness review process, meets many of the expectations (or all) of the Checkout, Testing and Commissioning Plan and Transition to Operations Plan envisioned in project planning and closure guidance.
- During execution of the readiness review, the detailed technical reviews performed during the readiness review can serve as verification of technical adequacy of systems for both TRL and Project Closure purposes, if properly planned and documented. For ease of use, a draft TRL calculator was developed by DOE-EM to integrate readiness review, TRL determination and several Project Closure documents. To simplify integration with the readiness review process, criteria in the TRL determination checklist were divided into TRL 7A (for items expected to be completed before the start of the DOE readiness review) and TRL 7B (for those items that can only be completed after the Startup Test Plan and Transition to Operations have been completed).

RESULTS

Overall, DOE-EM has completed twelve (12) TRAs. These reports are available on the DOE-EM website for use by others in planning their technology maturation efforts. Further, six (6) TRAs have been completed which have evaluated system integration through the use of the "Waste Processing System" TRL checklist. The maturity of system process controls and associated software have been evaluated in three (3) reviews. These reviews have made available TRL checklists that are applicable for TRL 6. These checklists have been included as "drafts for use" in a draft of a new DOE-EM TRA/TMP Guide which is being prepared for issue.

Also, detailed narrative discussion has been developed that is designed to assist project management, facility operations and systems testing personnel in understanding how apparently independent reporting and evaluation requirements for operational readiness, technology readiness/maturity and project closure can be integrated. Further, a working draft set of technology readiness assessment criteria have been developed that can assist the Integrated Project Team in integrating the above-mentioned reporting and assessment requirements into fewer reviews and reports.

CONCLUSIONS

In the process of conducting fourteen (14) TRAs during the past six years, DOE-EM has developed lessons learned and used those lessons to continually to improve and refine the process. These improvements have been vetted by DOE-EM technical management and project management prior to use and implemented as they became available. The results of using these improvements can be found in the associated final TRA reports and are reflected in the changes planned to the DOE-EM TRA/TMP Guide described above. Looking ahead, DOE-EM has also evaluated the large number of technical evaluations that are required by DOE Orders and Guides near the end of a project and developed guidance for use by its Integrated Project Teams in planning technical assessments near the end of a project. DOE-EM is now in the process of completing an update to the DOE-EM TRA/TMP guide that issues the new TRL Calculator Checklists and the narrative guidance for technical reviews at project's end as draft guidance for comment and use.

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