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Environmental Management
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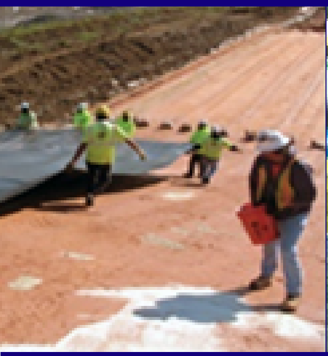
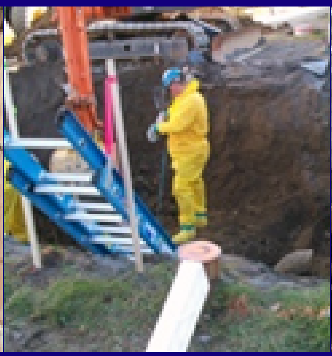
Standard Review Plan (SRP)

Technology Readiness Assessment Report


Corporate Critical Decision (CD) Review and Approval Framework Associated with Nuclear Facility Capital and Major Construction Projects

March 2010

Office of Environmental Management
U.S. Department of Energy
Washington D. C. 20585

U.S. Department of Energy
Office of Environmental Management

Technology Readiness Assessment (TRA) / Technology Maturation Plan (TMP) Process Guide

March 2008

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1.0 INTRODUCTION

1.1 Document Purpose

This document has been developed to guide individuals and teams that will be involved in conducting Technology Readiness Assessments (TRAs) and developing Technology Maturation Plans (TMPs) for the U.S. Department of Energy's Office of Environmental Management (DOE-EM). The Process Guide is intended to be a 'living document' and will be modified periodically as the understandings of TRA/TMP processes evolve.

2.0 OVERVIEW OF TECHNOLOGY READINESS ASSESSMENTS AND TECHNOLOGY MATURATION PLANS

2.1 Objectives of TRAs and TMPs

TRAs provide a snapshot in time of the maturity of technologies and their readiness for insertion into the project design and execution schedule. TMPs detail the steps necessary for developing technologies that are less mature than desired to the point where they are ready for project insertion. TRAs and TMPs are effective management tools for reducing technical risk and minimizing potential for technology driven cost increases and schedule delays.

2.2 The TRA

> "A TRA is a systematic, metric-based process and accompanying report that assesses the maturity of certain technologies [called Critical Technology Elements (CTEs)] used in systems." [2003 *DoD Technology Readiness Assessment Deskbook* (updated May 2005)]

The TRA is an assessment of how far technology development has proceeded. It is not a pass/fail exercise, and is not intended to provide a value judgment of the technology developers or the technology development program. A TRA can:

- Identify the gaps in testing, demonstration and knowledge of a technology's current readiness level and the information and steps needed to reach the readiness level required for successful inclusion in the project;
- Identify at-risk technologies that need increased management attention or additional resources for technology development; and
- Increase the transparency of management decisions by identifying key technologies that have been demonstrated to work or by highlighting immature or unproven technologies that might result in increased project risk.

A TRA evaluates technology maturity using the Technology Readiness Level (TRL) scale that was pioneered by the National Aeronautics and Space Administration (NASA) in the 1980s. TRL indicates the maturity of a given technology, as defined in Table 1. Figure 1 provides a schematic of the meaning of the TRLs in the context of DOE EM projects. The TRL scale ranges from 1 (basic principles observed) through 9 (total system used successfully in project operations). TRL is not an indication of the quality of technology implementation in the design. However, technology testing results are critical in determining the TRL. Testing must be done in the proper environment and the technology tested must be of an appropriate scale and fidelity. TRL requirements and definitions regarding testing "scale," "system fidelity," and "environment" are provided in Tables 2 and 3.

Figure 1 Schematic of DOE Technology Readiness Levels

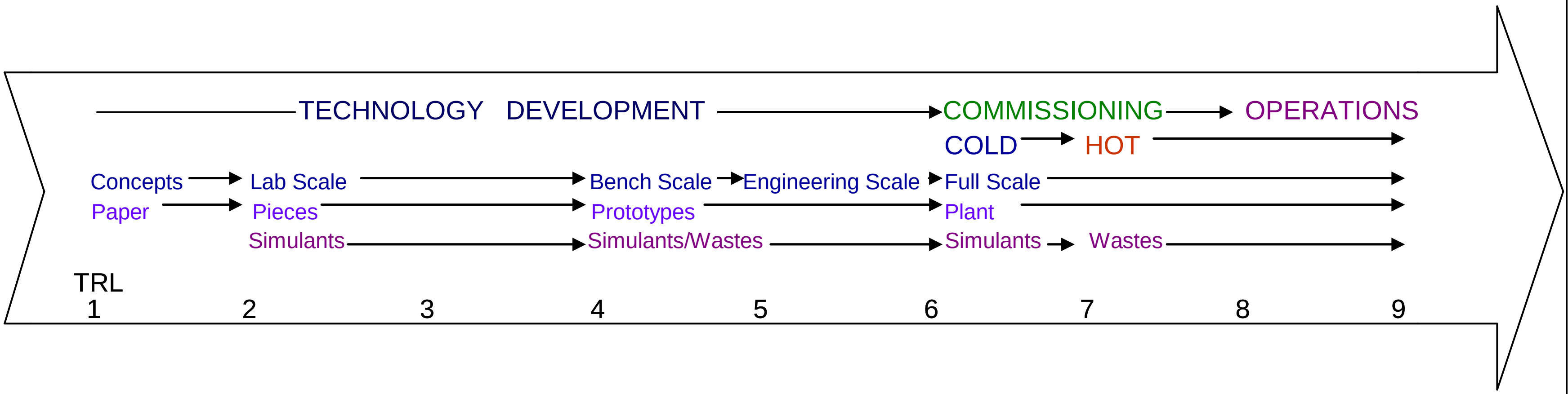


Table 1 Technology Readiness Levels

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
System Operations	**TRL 9**	Actual system operated over the full range of expected conditions.	The technology is in its final form and operated under the full range of operating conditions. Examples include using the actual system with the full range of wastes in hot operations.
System Commissioning	**TRL 8**	Actual system completed and qualified through test and demonstration.	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system with actual waste in hot commissioning. Supporting information includes operational procedures that are virtually complete. An ORR has been successfully completed prior to the start of hot testing.
	TRL 7	Full-scale, similar (prototypical) system demonstrated in relevant environment	This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning[1]. Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete.
Technology Demonstration	**TRL 6**	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology's demonstrated readiness. Examples include testing an engineering scale prototypical system with a range of simulants.[1] Supporting information includes results from the engineering scale testing and analysis of the differences between the engineering scale, prototypical system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. TRL 6 begins true engineering development of the technology as an operational system. The major difference between TRL 5 and 6 is the step up from laboratory scale to engineering scale and the determination of scaling factors that will enable design of the operating system. The prototype should be capable of performing all the functions that will be required of the operational system. The operating environment for the testing should closely represent the actual operating environment.
Technology Development	**TRL 5**	Laboratory scale, similar system validation in relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants[1] and actual waste[2]. Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actual application. The system tested is almost prototypical.
	TRL 4	Component and/or system validation in laboratory environment	The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants and small scale tests on actual waste[2]. Supporting information includes the results of the integrated experiments and estimates of how the experimental components and experimental test results differ from the expected system performance goals. TRL 4-6 represent the bridge from scientific research to engineering. TRL 4 is the first step in determining whether the individual components will work together as a system. The laboratory system will probably be a mix of on hand equipment and a few special purpose components that may require special handling, calibration, or alignment to get them to function.
Research to Prove Feasibility	**TRL 3**	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development (R&D) is initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative tested with simulants.[1] Supporting information includes results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. At TRL 3 the work has moved beyond the paper phase to experimental work that verifies that the concept works as expected on simulants. Components of the technology are validated, but there is no attempt to integrate the components into a complete system. Modeling and simulation may be used to complement physical experiments.
Basic Technology Research	**TRL 2**	Technology concept and/or application formulated	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies. Supporting information includes publications or other references that outline the application being considered and that provide analysis to support the concept. The step up from TRL 1 to TRL 2 moves the ideas from pure to applied research. Most of the work is analytical or paper studies with the emphasis on understanding the science better. Experimental work is designed to corroborate the basic scientific observations made during TRL 1 work.
	TRL 1	Basic principles observed and reported	This is the lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties or experimental work that consists mainly of observations of the physical world. Supporting Information includes published research or other references that identify the principles that underlie the technology.

[1] Simulants should match relevant physical and chemical properties.

[2] Testing with as wide a range of actual waste as practicable; and consistent with waste availability, safety, ALARA, cost, and project risk is highly desirable

Table 2 TRL Scale, Fidelity, and Environment Definitions

Scale	
Full Plant Scale	Matches final application
Engineering Scale[1]	Typical (1/10 < system < Full Scale)
Laboratory/Bench[1]	< 1/10 Full Scale

[1] The Engineering Scale and Laboratory/Bench scale may vary based on engineering judgment.

System Fidelity	
Identical System Configuration	-matches final application in all respects
Similar Systems Configuration	-matches final application in almost all respects
Pieces	-system matches a piece or pieces of the final application
Paper	-system exists on paper (i.e., no hardware system)

Environment (Waste)	
Operational (Full Range)	Full range of actual waste
Operational (Limited Range)	Limited range of actual waste
Relevant	Simulants plus a limited range of actual wastes
Simulated	Range of simulants

Table 3 TRL Testing Requirements

TRL Level	Scale of Testing	Fidelity	Environment[1,2]
9	Full	Identical	Operational (Full Range)
8	Full	Identical	Operational (Limited Range)
7	Full	Similar	Relevant
6	Engineering/Pilot Scale	Similar	Relevant
5	Lab/Bench	Similar	Relevant
4	Lab	Pieces	Simulated
3	Lab	Pieces	Simulated
2		Paper	
1		Paper	

[1] Simulants should match relevant physical and chemical properties
[2] Testing with as wide a range of actual waste as practicable; and consistent with waste availability, safety , ALARA, cost, and project risk is highly desirable

In 1999 the General Accounting Office (GAO) (GAO/NSIAD-99-162) recommended that the DoD adopt NASA's TRLs as a means of assessing technology maturity prior to transition. 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 using TRLs, as defined in the 2003 *DoD Technology Readiness Assessment Deskbook* (updated in May 2005 [DOD 2005]). Recent legislation (2006) has specified that the DoD must certify to Congress that the technology has been demonstrated in a relevant environment (TRL 6) prior to transition of weapons system technologies to design or justify any waivers. TRL 6 is also often used as the level required for technology insertion into design by NASA.

In March of 2007, the GAO recommended that DOE adopt the NASA/DoD methodology for evaluating technology maturity. Language supporting the GAO recommendation was incorporated in the House version of the 2008 DOE-EM budget legislation.

2.3 The Technology Maturation Plan

The TMP is a planning document that lays out the activities required to bring immature CTEs up to the desired TRL. It includes preliminary schedules and rough order of magnitude cost estimates that allow decision makers to determine the future course of technology development. Normally the TMP will be followed by detailed test plans that provide more accurate cost and schedule information that can be incorporated into the project baseline. See Section 4.0 for more information on the TMP.

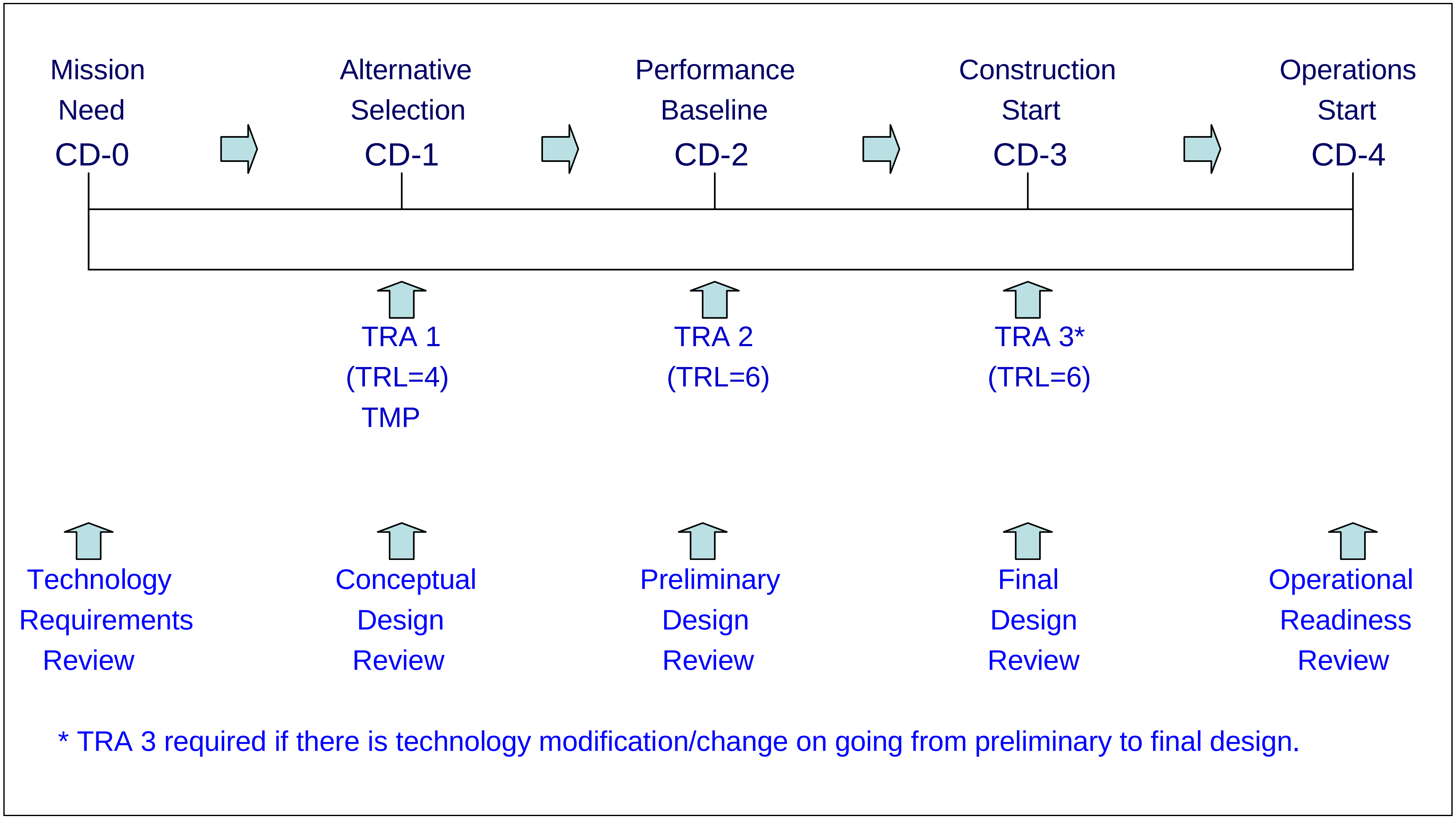
2.4 The Relationship of TRAs and TMPs to DOE Critical Decisions

While the TRA/TMP process is not currently required by DOE Order 413.3A, in the realm of program and project management, the TRA/TMP process can serve as one of the tools employed to help make the Critical Decisions required by DOE Order 413.3A:

> *The five Critical Decisions are major milestones approved by the Secretarial Acquisition Executive or Acquisition Executive that establish the mission need, recommended alternative, Acquisition Strategy, the Performance Baseline, and other essential elements required to ensure that the project meets applicable mission, design, security, and safety requirements. Each Critical Decision marks an increase in commitment of resources by the Department and requires successful completion of the preceding phase or Critical Decision. Collectively, the Critical Decisions affirm the following:*
>
> • *There is a need that cannot be met through other than material means* [CD-0]*;*
> • *The selected alternative and approach is the optimum solution* [CD-1]*;*
> • *Definitive scope, schedule and cost baselines have been developed* [CD-2]*;*
> • *The project is ready for implementation* [CD-3]*; and*
> • *The project is ready for turnover or transition to operations* [CD-4].

The recommended guidance is to conduct TRAs during conceptual design and preliminary design processes; and at least 90 days prior to CD milestones. Figure 2 shows how TRAs and other key reviews support each of the CDs. (There are numerous additional requirements for each CD. See Table 2 of DOE O 413.3A for a complete listing.)

Figure 2 Suggested Technology Readiness Assessments and Other Review Requirements for Critical Decisions



Note: Refer to Doe Order 413.3A for Critical Decision criteria

CD-0, Approve Mission Need: identification of a mission-related need and translation of this gap into functional requirements for filling the need
The mission need is independent of a particular solution and should not be defined by equipment, facility, technological solution, or physical end item (413.3A). The focus for Technology Assessment, at this stage, is on clear statement of the requirements of the input and the desired output of the process. For waste processing, this would include characterization of the waste as well as definition of requirements for the processing and the waste form. A Technology Requirements Review should be performed to assess the adequacy of requirements definition and characterization information and determine if any additional work is necessary. If additional work is necessary to adequately define technical scope of the project, a detailed plan with a proposed schedule should be developed.

CD-1, Alternative Selection and Cost Range: identification of the preferred technological alternative, preparation of a conceptual design, and development of initial cost estimates
A TRA and a TMP should be performed during conceptual design to support the CD-1 approval process. A TRA/TMP supporting CD-1 may be used to (a) assess the relative maturity and maturation requirements of competing technologies and provide a basis for input into the selection amongst them; and/or (b) assess the maturity and maturation requirements of the selected technology. Prior to CD-1 approval, all CTEs of the design should have reached TRL 4 and a TMP that details the strategies for bringing all CTEs to TRL 6 should have been prepared. If a technology is assessed at less than TRL 4, then the TMP and rationale for proceeding with a CTE(s) with a lower TRL(s) should be specifically briefed to the Approval Authority as part of the CD-1 approval process.

CD-2, Performance Baseline: completion of preliminary design, development of a performance baseline that contains a detailed scope, schedule, and cost estimate
The process of technology development, in accordance with the approved TMP, should support all CTEs reaching TRL 6. Attainment of TRL 6 indicates that the technology is ready for insertion into detailed design. If a technology is assessed at less than TRL 6, then the TMP and rationale for proceeding with a CTE(s) with a lower TRL(s) should be specifically briefed to the Approval Authority as part of the CD-1 approval process.

CD-3, Start of Construction: completion of essentially all design and engineering and beginning of construction, implementation, procurement, or fabrication
A TRA is only required if there is significant technology modification as detailed design work progresses. If substantial modification of a technology occurs, the TRA should be performed and a focused TMP developed to ensure that the modified technology has attained TRL 6 prior to its insertion into the detailed design and baseline.

CD-4, Start of Operations: readiness to operate and/or maintain the system, facility, or capability
Successful completion of an Operational Readiness Review (ORR) corresponds to attainment of TRL 7/8.

2.5 The Relationship of TRAs and TMPs to External Technical Reviews (ETRs)

DOE-EM has also recently issued guidance for the conduct of External Technical Reviews (ETRs); as described in the Guide:

> "The purpose of an ETR is to reduce technical risk and uncertainty. ETRs provide pertinent information for DOE-EM to assess technical risk associated with projects and develop strategies for reducing the technical risk, and provide technical information needed to support critical project decisions. Technical risk reduction increases the probability of successful implementation of technical scope. In general, an ETR assesses technical bases, technology development, and technical risk identification and handling strategies."

The use of these two review processes could overlap. In general, it is anticipated that TRAs, and the associated TMPs, will be focused on the development status of technologies; ETRs, on the other hand are likely to be used for reducing the risk and/or uncertainty associated with a particular technical issue. If there is uncertainty as to which process to use, EM-20 staff should be consulted.

3.0 TECHNOLOGY READINESS ASSESSMENT PROCESS

3.1 Process Overview

The TRA/TMP process diagram is depicted in Figure 3. Associated detailed guidance is provided in Sections 3.4, 3.5 and 4.0. The TRA is divided into two stages: assessment planning and assessment execution.

The Assessment Planning Stage (Section 3.4) begins when it is determined that a TRA is required. Assessment planning involves selection of the TRA team, development of a TRA Plan and review of critical documents. The Assessment Planning Stage ensures pertinent information required to successfully perform the TRA is documented and readily available to the TRA team.

The Assessment Execution Stage (Section 3.5) begins with the onsite assessment activities. Assessment activities involve identification and evaluation of critical technology elements (CTEs), determination of TRLs, TRA reporting and a close-out briefing. The Assessment Stage ensures appropriate data are gathered, appropriate elements are assessed, and assessment results are adequately documented.

The TMP preparation (Section 4.0) begins after the factual accuracy review is conducted on the drafted TRA Report. The TMP ensures the actions required to develop the technologies to the required levels are documented.

A typical timeline for a TRA is provided in Table 4. A typical timeline for a TMP is provided in Table 5. However, the timing for each of these will vary considerably based on the complexity of the project.

Figure 3 Technology Readiness Assessment Process Diagram

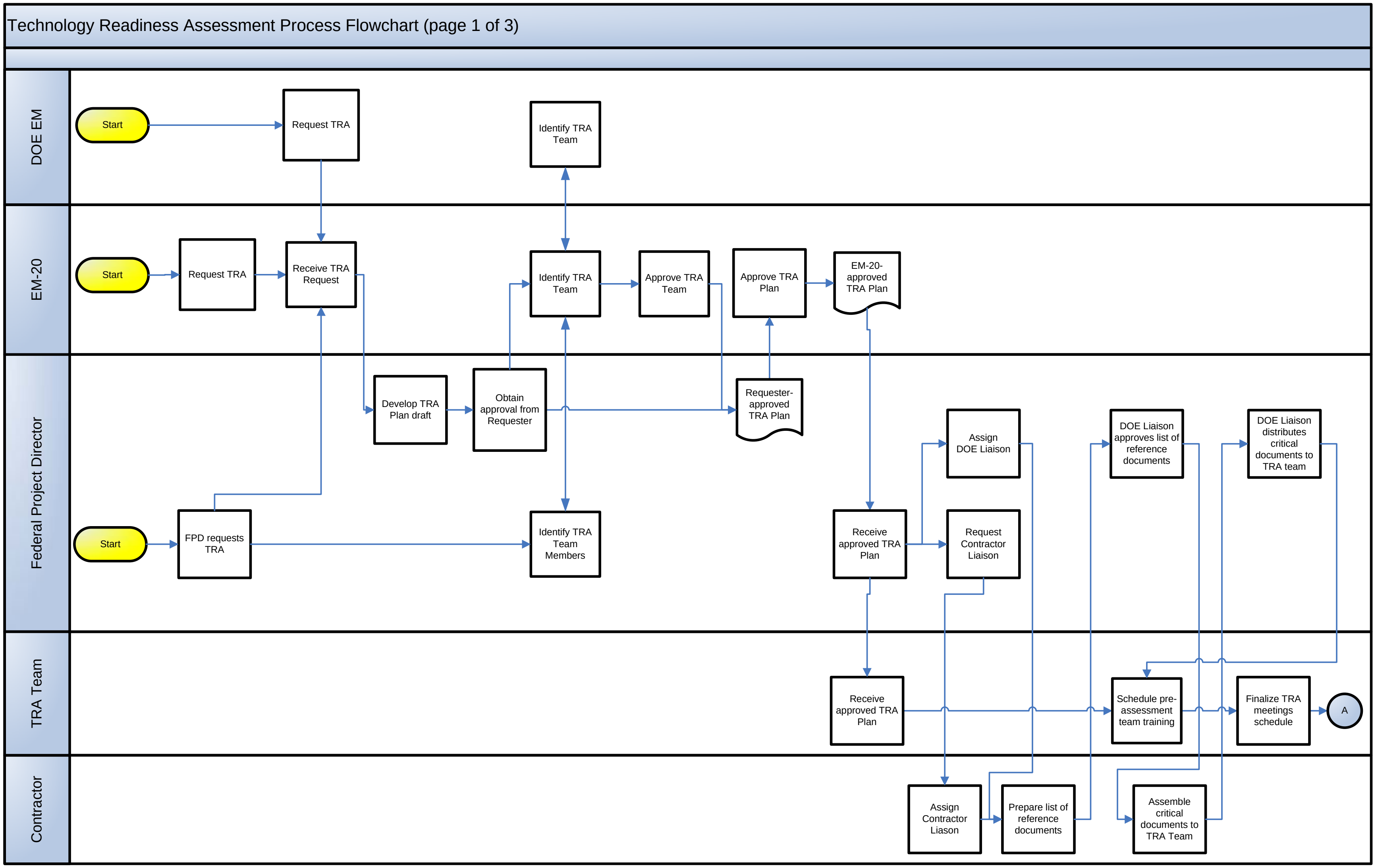


Figure 3 Technology Readiness Assessment Process Diagram (continued)

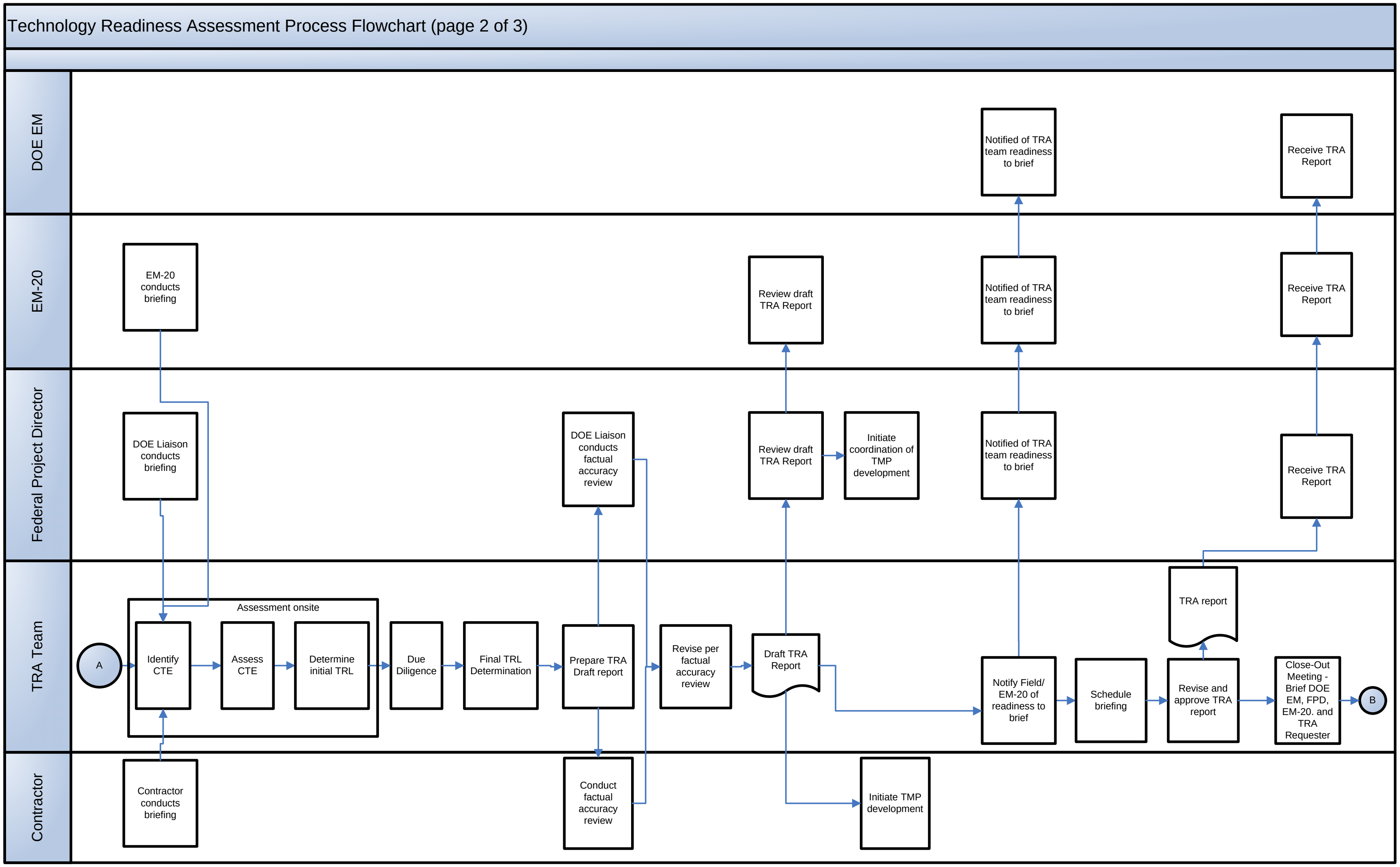


Figure 3 Technology Readiness Assessment Process Diagram (continued)

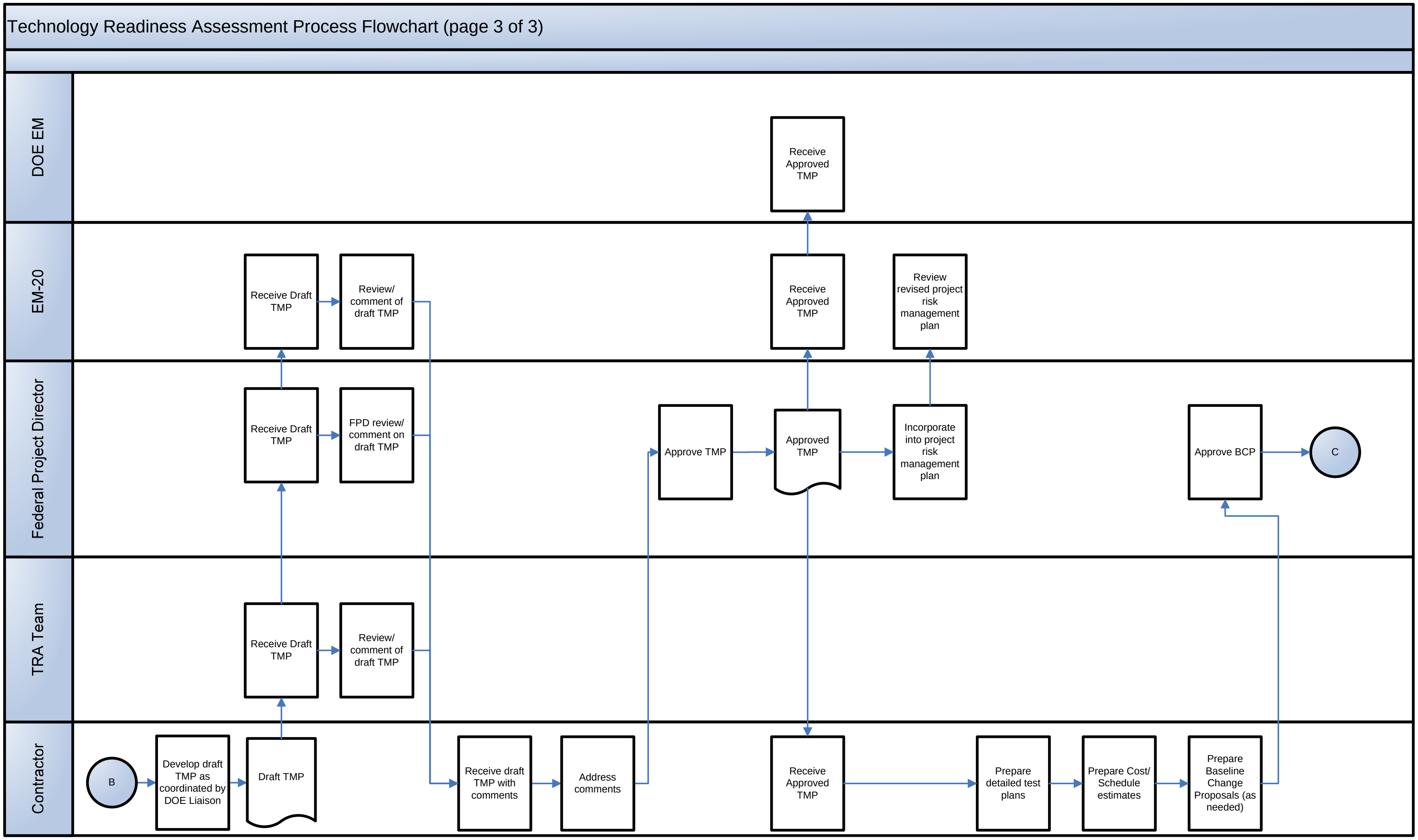


Table 4 Typical TRA Timeline

Activity	Typical Time Frame
TRA Requested	Time 0
TRA Plan Submitted to EM-20	Week 2
TRA Team Established by EM-20	Week 8
Critical Documents Distributed to Team	Week 12
Onsite Assessment Activities Begin	Week 16
Draft TRA Report Issued for Comment	Week 20
Final TRA Report Issued	Week 24

Table 5 Typical TMP Timeline

Activity	Typical Time Frame
Begin TMP	Week 0
Draft TMP Completed	Week 8
Review TMP	Week 10
Final TMP	Week 12
Prepare Test Plans Including Cost and Schedule	Week 20
Approve Test Plans	Week 24
Incorporate Test Plans Into Baseline	Project Dependent

3.2 Key Roles and Responsibilities

3.2.1 DOE EM

- Requests a TRA as appropriate.
- Recommends potential TRA Team candidates to EM-20.
- Approves TRA Plans for TRAs requested by DOE EM.
- Reviews drafted TRA Report for TRAs requested by DOE EM.
- Approves TMP for TRAs requested by DOE EM.

3.2.2 EM-20

- Owns the TRA/TMP process.
- Requests a TRA.
- Provides input to the Requester for development of TRA Plans.
- Identifies, approves and establishes the TRA Team.
- Trains team members on the TRA/TMP process.
- Approves all TRA Plans.
- Reviews all TRA Reports.

- Reviews all TMPs.
- Briefs TRA team at Kickoff Meeting

3.2.3 Federal Project Director

- Requests a TRA.
- Assigns a DOE Liaison.
- Prepares TRA Plans for TRAs requested by the Federal Project Director.
- Requests assignment of Contractor Liaison.
- Performs factual accuracy review of drafted TRA Report.
- Reviews and approves TMP.
- Incorporates TMP details into project risk management plan.

3.2.4 DOE Liaison

- Serves as the primary DOE interface with the TRA Team.
- Reviews and approves the list of reference documents to be provided to the TRA team to ensure completeness and absence of bias.
- Distributes documents assembled by the Contractor Liaison to the TRA Team.
- Conducts TRA Kickoff Meeting jointly with Team Leader.
- Provides administrative and technical editing support to the TRA Team as needed.
- Coordinates the factual accuracy review of the TRA Report.
- Reviews factual accuracy review comments to ensure they are within the factual accuracy scope.
- Assembles factual accuracy review comments and forwards to the TRA Team Leader.

3.2.5 Contractor

- Assigns a Contractor Liaison.
- Provides technology information in the form of tours, briefings, documents and test information.
- Performs factual accuracy review of drafted TRA Report.
- Prepares the TMP.
- Prepares detailed test plans that implement the TMP.
- Implements test plans.

3.2.6 Contractor Liaison

- Compiles and distributes a listing of technology elements to the TRA Team.
- Serves as the conduit for communication between the TRA Team and Contractor.
- Coordinates with the Team Leader on arrangements, facilities and resources at the site for the assessment.
- Coordinates briefings and tours of site facilities for the TRA Team as applicable.
- Coordinates the conduct of the Contractor factual accuracy review of the TRA Report.

- Coordinates the Contractor reviews of the TRA report and TMP.

3.2.7 Team Leader

- Serves as the TRA Team primary point of contact.
- Reviews Team Members' qualifications to ensure that the team has the appropriate expertise and sufficient capability to execute the assessment.
- Develops TRA schedule with input from EM-20 and team members.
- Is accessible during the entire review process, and actively participates in the process described in the TRA plan. This commitment includes development of written input, and participation in team meetings.
- Organizes the team's work and makes assignments so that the Team Members' on-site time is well spent and will provide the required products.
- Reviews the TRA request to assure that specific topics or emphasis requested are properly understood and identified in the TRA plan. Obtains clarification from the requesting DOE official, as appropriate.
- Coordinates arrangements and agenda for the TRA with the DOE Liaison.
- Accepts requests for additional information from team members following initial review of materials provided in advance; communicates these requests to the DOE Liaison; obtains agreement on time for responses to requests.
- Conducts team conference call approximately two weeks prior to beginning the TRA to confirm arrangements and to clarify questions from the team members.
- Coordinates team's arrival at the site of the assessment. Identifies required check-in at site security office and time and place for initial team meeting with project officials.
- Presents initial briefing describing review team charge and review process to on-site project participants.
- Participates as a subject-matter-expert for assigned technology areas.
- Requires team members to provide summary bases for all TRL determinations to allow team review and discussion.
- Establishes responsibilities among team members and timelines for completion of detailed write-ups supporting assessment results.
- Conducts and provides a copy of the exit brief for on-site project participants with support from team members as appropriate.
- Assembles and edits initial and final drafts of the TRA report and all briefings.
- Reviews and consolidates all Team comments to ensure consistency throughout the report.
- Provides a draft copy of the report to all members of the Review Team for final consensus on the content and to the Federal Project Director for a review for factual accuracy of the observations included.
- Incorporates team member comments as appropriate as the final authority on the report content. Corrects errors in fact identified by the project team review. Because a significant level of effort may be required to incorporate comments, the Team Leader may task Team Members to rewrite their sections as appropriate.
- Approves the final report and issues report to the Federal Project Director.

3.2.8 Team Members

- Serve as subject matter experts in technical areas relevant to the technology under review. They are independent from the entities responsible for decision-making and implementation of the technology being reviewed. Specifically, they shall not be individuals who are from offices assigned direct line management responsibility for the work being reviewed.
- Objectively assess technologies, determine associated TRLs and document associated bases for the TRL determinations.
- Review all advanced materials provided prior to the assessment and advise the Team Leader, if additional information is needed.
- Finalize listing of CTEs to be assessed.
- Participate in all pre-assessment conference calls.
- Be willing and capable of staying on-site during assessment execution, and to actively participate in the process described in the Team Meeting.
- Ensure receipt of all advance documentation and advise the Team Leader if other arrangements need to be made.
- Participate in the on-site assessment.
- Submit draft input in accordance with this guidance.
- Prepare questions resulting from review of advanced material received and provide to Team Leader in advance. Only the Team Leader will coordinate with the site.
- Communicate directly with identified project participants to clarify understanding of material review.
- Seek clarification from project participants concerning perceived omissions or deficiencies.
- Prepare written comments on a timely basis as required by the Review.
- Ensure their comments are unclassified and coordinate their comments with an Authorized Derivative Classifier if there is a question.
- Review draft report to assure determinations are accurately described and to identify possible conflicts.
- Ensure availability for follow-up consultations.

3.3 TRA Team Independence

Independence of the TRA Team (Team Leader and Team Members) is a key requirement for conducting TRAs. Ideally, the TRA Team should be comprised of individuals from a different organization and site than is being assessed. In any event, the Team Leader should be a DOE employee (or DOE consultant) from a different organization than is being assessed. However, selection of purely independent TRA Teams may not be possible due to the subject matter being assessed, the availability of subject matter experts, and the timing of assessments. As a minimum, the Team Leader and Team Members must be independent from the project team implementing the technical scope; the Team Leader should not be from the organization responsible for the implementation of the technology being assessed. For example, Team Members should not be DOE employees or contractors affiliated with the project (or competing projects) to be reviewed.

Any exceptions to the guidelines for TRA Team independence require approval by EM-20.

3.4 Assessment Planning

The steps in planning a TRA are summarized below. These steps are illustrated in the Technology Readiness Assessment Process Diagram in Figure 3, and additional information regarding the major steps is provided in the sections that follow.

1. DOE EM, EM-20, or the Federal Project Director requests a TRA. The TRA Request must be written to include a brief description of scope, desired completion date, funding source and the purpose for the request (e.g., upcoming critical decision, technology down selection). An annual schedule of TRAs will be established for DOE EM projects.
2. The Federal Project Director, with input from EM-20, develops a TRA Plan that outlines how the review will be conducted. The TRA Plan contains the elements detailed in Section 3.4.1 and in Attachment A.
3. The TRA Requester and EM-20 approve the TRA Plan and forward the approved plan to the Federal Project Director.
4. EM-20, with input from other entities with a vested interest (e.g., DOE EM, the Federal Project Director), establishes the TRA Team. In establishing the team, EM-20 ensures available funding, approved contractual agreements and Team Member availability. Refer to Section 3.3 for guidance regarding Team independence.
5. The Federal Project Director assigns a DOE Liaison.
6. The Contractor assigns a Contractor Liaison.
7. The Contractor Liaison compiles a listing of reference documents for the technology to be reviewed and distributes critical documents to the DOE Liaison who forwards them to the TRA Team. Considerations for the identification and distribution of critical documentation are provided in Section 3.4.2.
8. The Team Leader conducts a pre-assessment team training meeting. The purpose of the pre-assessment team training meeting is to provide the team an overview of the TRA/TMP process, to review the TRA Plan, and the subject technology.
9. The TRA Team develops and finalizes the TRA meetings schedule.
10. The Contractor Liaison coordinates availability of onsite resources/equipment needed by the TRA Team. Typical considerations regarding onsite meeting facilities and resources are provided in Section 3.4.3.
11. Table 6 provides a listing of implementation tips for Assessment Planning.

3.4.1 TRA Plan

The Federal Project Director is responsible for developing the Plan. The Plan is a detailed working plan for conduct of the TRA. Successful implementation of the plan relies on the Review Team, DOE EM-20, and the Contractor. Therefore, the Federal Project Director should actively seek the input of these entities during development of the plan. The developed Plan is submitted by the Federal Project Director to the TRA Requester and DOE EM-20 for approval. DOE EM-20 ensures allocation of required funding.

The TRA Plan:

- Identifies the TRA requester.
- Identifies the technology (or technologies) being assessed.
- Establishes the scope of the assessment.
- Provides a listing of the TRA Team.
- Identifies the estimated cost for conduct of the TRA.

- Provides a milestone and deliverables schedule.

While the structure of each TRA Plan is the same, the content is specifically tailored for each project. The TRA Plan helps the TRA Team coordinate activities during the assessment.

See Attachment A for additional information regarding the format of the TRA Plan.

3.4.2 Documentation for Review

An important aspect of planning the TRA is the advanced review of critical documentation. The Contractor Liaison is responsible for coordinating the identification and distribution of critical documentation. To the maximum extent possible, the critical documentation should be distributed to Team Members (via the DOE Liaison) at least 4 weeks prior to the scheduled assessment. Submission of the critical documentation is expected to be as an entire package and represent a 'current state' of development.

The critical documentation pertinent to a TRA varies but generally includes: design reports, technology reports, technology bases documents, value engineering studies, technology alternatives studies, relevant regulatory information, and DOE or program reference documents.

3.4.3 Onsite Meeting Facilities, Resources and Logistics

Prior to the onsite assessment, the Team Leader, DOE Liaison and the Contractor Liaison discuss the facilities and equipment needed during the conduct of the TRA. Typical considerations regarding onsite meeting facilities,, resources and logistics are:

- Conference Room in un-cleared area or in area accessible to un-cleared team members with cleared team member escorts, if necessary.
- Office space, two (2) additional offices for small group discussions (accessible to un-cleared team members with cleared team member escorts if necessary).
- Teleconference capability.
- Computer with printing capabilities, Microsoft Word and PowerPoint installed.
- Telephone, internet and Fax access.
- Define site/project clearance requirements for personnel related equipment such as government and non-government owned laptop computers.
- Process site badge(s) as necessary.
- Identify security information for site visit.
- Identify personnel to conduct classification reviews of documentation generated during the review.
- Define training required by Team Members for access to facilities.

The Contractor Liaison ensures that the requested resources are readily available at the start of the onsite assessment. Additional resources identified after the start of Assessment Activities are communicated to the Contractor Liaison by the Team Leader. Proper planning should eliminate the need for additional resources; however, the expectation is that the Contractor Liaison will respond promptly to any additional resource requests.

Table 6 Implementation Tips for Assessment Planning

Planning

- Define the assessment scope clearly and concisely. The definition should describe what is within the scope of the assessment and what is not in the scope of the assessment.
- Up-front review of documents by the Review Team will streamline initial meetings (e.g., Kick-Off meeting) by reducing the need for overviews.
- Early in the assessment, address how responses to assessment criteria and the associated bases will be reported and tracked.

Team Selection

- Team members should be independent of any corporate accountability or responsibilities for managing the technology being assessed.
- Team members should be free of any conflict-of-interest with respect to potential benefit due to recommendations identified during the assessment
- The Team Leader should have demonstrated ability regarding preparation, scheduling, organization and execution of assessment team activities.
- Industrial experts (for technologies that are industrial in size and therefore different than many of the Laboratory technologies) and experts from other laboratories with similar technologies should be considered.
- Ensure that there are firm commitments from the team members and/or identify any conflicts early.
- Allow time and funding for the acquisition of team members through contracts.
- Team size will be dictated by project complexity and size and reviewer expertise. There should be at least 1 assessor with expertise in each major technical area of the project.

Team Readiness

- Conduct team building activities early in the TRA process to improve interactions and communications.
- Establish team communication guides early, i.e. status calls, distribution lists.

3.5 Assessment Execution

The steps in conducting a TRA are summarized below. These steps are illustrated in the Technology Readiness Assessment Process Diagram in Figure 3, and additional information regarding the major steps is provided in the sections that follow.

1. The TRA Team Leader and the DOE Liaison conduct a Kick-Off Meeting at the assessment site location.
2. The Contractor provides briefings and conducts tours of site facilities applicable to the development of the technology being assessed.
3. Based on the process descriptions, the Team finalizes the list of CTEs.
4. The Team reviews pertinent documentation and applies the TRL assessment criteria to determine the TRL for each CTE. The documented bases for the criteria scoring are recorded during the meeting. To aid in review of TRL determinations, each Team Member maintains adequate notes from their information-gathering activities.
5. Team members conduct due diligence reviews of the TRL determinations via detailed document reviews to ensure that the bases for the scoring are fully supported in the appropriate technical reports. TRL determinations are finalized after the due diligence review.
6. The Team Leader is responsible for keeping the Federal Project Director and EM-20 informed of the progress of the TRA and TRL determinations as they are identified. This may include periodic meetings during the onsite assessment period. The frequency and formality of these updates is dependent on the length of the assessment period.
7. The Team prepares the initial draft TRA Report.
8. The Team reviews the draft TRA Report to ensure the report is clear, concise and within the scope of the assessment.
9. The DOE Liaison and Contractor perform a factual accuracy review of the draft TRA Report. Then, the Team revises the draft report as needed based on the factual accuracy review.
10. The Contractor initiates development of the TMP based on the draft TRA report.
11. The revised draft TRA report is submitted to the Federal Project Director, EM-20, and, DOE-EM management (if DOE EM was the TRA Requester) for review. The Team revises the TRA Report based on comments received and approves the final report.
12. The final TRA report is distributed to the Federal Project Director, EM-20, and DOE-EM management.
13. The Team Leader conducts a Close-Out Meeting with Federal Project Director, EM-20, and DOE-EM management on the determined TRLs, their bases, and needs identified to mature the technology.
14. Table 7 provides a listing of implementation tips for Assessment Execution.

3.5.1 Kick-Off Meeting

The Kick-Off Meeting marks the start of Assessment activities. The purpose of the Kick-Off Meeting is to 1) introduce the TRA Team and key project personnel, 2) review the primary objective of the TRA and the identified assessment criteria, 3) convey the logistics for TRA activities, and 4) begin the TRA assessment. The Federal Project Director and the DOE Liaison are responsible for the Kick-Off Meeting. Attendance is usually limited to the Team Members, DOE EM-20, TRA Requestor, Contractor Liaison, and Contractor personnel.

At the Kick-Off Meeting, briefings are presented by EM-20 and Federal Project Director. EM-20 should brief the TRA team to describe 1) related technology experience elsewhere in the DOE complex and ongoing related technology maturation efforts and 2) how the TRA/TMP results will be used in specific future EM decisions. Contractor personnel provide an overview of the technology and its development status. Briefings will be in the form of formal presentations to the Team using support materials such as view graphs, charts, drawings, or photos. Presentations should allow for questions and answers within the allotted time. Detailed information should be transmitted via supplemental handouts. The Team is the primary audience for the presentations, but other individuals may attend, particularly if their presence would be advantageous in answering questions from the Team. When the agenda calls for discussion time, or at the conclusion of a particular topic presentation, a more informal round-table format is appropriate. These presentations should also address questions submitted by the Team in advance. Pre-existing presentations may be utilized if still current.

A sample Kick-Off meeting agenda is provided in Attachment C. As shown in Attachment C, a tour of the facilities should be included if this information will aid the Team's understanding of the project and/or technology being reviewed.

3.5.2 Critical Technology Elements (CTE) Identification

The following is the definition of a CTE as provided by DoD Technology Readiness Assessment (TRA) Deskbook, May 2005:

> A technology element is "critical" if the systems being acquired depend on the technology element to meet operational requirements (with acceptable development cost, and schedule and with acceptable production and operations costs) and if the technology element or its application is either new or novel. Said another way, an element that is new or novel or being used in a new or novel way is critical if it is necessary to achieve the successful development of a system, its acquisition, or its operational utility.

CTE identification is fundamental to the TRA process. The TRA Team is responsible for identifying and documenting CTEs. Early in TRA planning, the Team Leader requests that the Contractor Liaison compile a list of technology elements. This listing should be based on a comprehensive review of the project's established work breakdown structure and process flowsheets. The Team then determines the CTEs using a 2-step process, which utilizes two sets of questions to evaluate each technology element. The questions are provided in Attachment B. A technology element must have a positive response to at least one question in each question set for a determination as a CTE.

Team discussions should be utilized to resolve any disagreements between Team Members on CTE determinations. If consensus cannot be reached, the Team Leader makes the CTE determination. Also, the Federal Project Director has the discretion to add CTEs to the listing generated by the Team.

3.5.3 Technology Readiness Level Assessment

A modified version of the DoD TRL Calculator has been used extensively during the conduct of DOE-EM TRAs. The TRL Calculator is a two-step process. First, a set of top-level questions (Table D1 of Attachment D) is used to determine the anticipated TRL. The anticipated TRL is determined from the question with the first "yes" answer. Second, evaluation of the detailed questions (Tables D2 through D7 of Attachment D) is started one level below the anticipated TRL. To attain a specific TRL, the CTE must receive a "yes" response to <u>all</u> questions at the TRL level. If it is determined from the detailed questions that the technology has not attained the maturity of the starting level, then the next levels down are evaluated in turn until the TRL is determined.

TRLs are documented within the TRA Report. As a minimum, the TRL should be expressed numerically and described in text. Additionally, the basis for the TRL determination should be clearly and concisely documented.

3.5.4 Due Diligence Reviews

Following the initial TRL determination, individual Team Members conduct due diligence reviews by detailed study of reference documents and, if needed, by personal interviews. Even though some Contractor personnel provide presentations to the Team as a whole, individual reviewers may be assigned responsibility for analyzing and assessing assigned CTE TRLs and providing a written report of their TRL determination and supporting basis. To improve efficiency during the interview process, breakout sessions should be scheduled to allow non-related interviews to be held concurrently. To the extent possible, more than one Team Member should be present for all interview sessions.

As interviews and document reviews are completed, the details of the review should be documented. The information collected should provide the Team the ability at a later date to understand the CTE, responses to TRL criteria, the TRL determination, and the associated bases.

3.5.5 TRA Report

The purpose of the report is to document a description of the process used to conduct the TRA and a comprehensive explanation of the assessed TRL for each CTE. The Team Leader is responsible for coordinating the report preparation with detailed input from Team Members. See Attachment F for the format of the report. The report is divided into sections that may be assigned to individual Team Members. The Team Leader compiles an initial draft of the report. A designated editor (not a Team Member) will review the draft report for consistency in writing style and format without changing content. The draft report will then be provided to the Review Team for a final review. It will also go to the Federal Project Director and Contractor for a factual accuracy check as described in Section 3.5.6. To expedite the schedule, these two reviews are often accomplished in parallel. Comments will be resolved by the Team and incorporated by the editor. The Team Leader will issue the revised draft report to the Federal Project Director, EM-20, and DOE-EM management. Comments will be provided to the Team Leader for incorporation into the final TRA report. The Team Leader will enlist Team members to assist in comment resolution as needed. After these comments have been addressed, the Team will review and approve the final TRA report.

Lessons learned that benefit future TRAs and/or technology development projects may be identified during the conduct of a TRA. These lessons learned should be documented within the TRA Report or they may be documented in a separate document. In the case of a separate lessons learned document, the TRA report should be referenced within the document and the document should be filed with the TRA report.

3.5.6 Factual Accuracy

The Federal Project Director and Contractor conduct a factual accuracy review of material presented in the draft report. The purpose of the factual accuracy review is to identify any items of fact that are inaccurate. Factual accuracy reviews do not include challenging the TRL scores and technical issues identified by the Team Members. However, the Team will correct errors in fact that may result in a change in TRL scores or identified technical issues.

3.5.7 Close-Out Meeting

The Close-Out Meeting, conducted after completion of the final TRA report, marks the end of Assessment activities. The Team Leader is responsible for presenting the results of the assessment at the Close-Out Meeting. The purpose of the Close-Out Meeting is to brief the Federal Project Director, EM-20, and DOE-EM management on TRL determinations and associated bases. A sample Close-Out Meeting agenda is provided as Attachment G.

The Team Leader or individual Team Members assigned to each CTE should make informal presentations that describe the assessment results relative to TRL determinations and highlight those CTEs that do not meet the maturity expectations. The Team will respond to any questions raised by the DOE EM-20, the Federal Project Director or the Contractor. Copies of materials presented at the Close-Out Meeting are usually made available to meeting attendees. The Close-out meeting may also include a briefing by the Federal Project Director or Contractor on their path forward for preparing a Technology Maturation Plan, if needed.

Table 7 Implementation Tips for Assessment Execution

<u>Status Meetings</u>

- Maintain a regular form of communication between the Team and the Project such that neither is caught off guard by new information. Typically this is a daily meeting during assessment activities.

<u>Issue Capture and Resolution</u>

- A database or table format is recommended to capture the technology elements assessed, responses to assessment criteria and determined TRLs to facilitate the review and track open items.
- A standard form for capturing information should be used. Standard items should include: name, e-mail, phone number, technology element, document identification, specific criteria, response, and follow-up items.
- The Team should have a process for handling differences in professional opinions.

<u>Report Preparation</u>

- Include a technical editor as a resource to the team to help in finalizing reports.
- Build the assessment report as the review progresses rather than waiting until the assessment activities are complete.

<u>Comment Resolution</u>

- Reviewers are responsible for resolving comments within their assigned technology expertise.
- The Team Leader resolves comments that are not specific to a particular technology area.
- Team Members may document non-resolvable differences of opinion in a “minority report”.

<u>Report Distribution / Approval / Closeout</u>

- The Team Leader should establish the distribution list for the report early in the assessment.

4.0 TECHNOLOGY MATURATION PLAN

4.1 Process Overview

The purpose of the TMP is to describe planned technology development and engineering activities to mature CTEs that did not receive a TRL of 6 or higher. The TMP should provide the relationship between the planned technology development and the status of the project, particularly any upcoming Critical Decisions. In a very limited number of instances, the Federal Project Director may be of the opinion that a CTE receiving a TRL of 5 already has a maturation plan that is well understood, planned, scheduled for timely completion, and adequately funded. In this case, the TMP should reflect the opinion of the Federal Project Director and a TMP briefing should be conducted as part of Critical Decision.

4.2 TMP Preparation

The major steps in preparing a TMP are summarized below and are illustrated in the Technology Readiness Assessment Process Flowchart (Figure 3).

1. The Contractor prepares the draft Technology Maturation Plan. Additional information on the desired content of the plan is provided below and in Attachment G.
2. The Contractor provides the draft report to the TRA Team, Federal Project Director and EM-20 for review. To expedite the schedule, these three reviews are often accomplished in parallel. The reviews verify 1) responsiveness to gaps identified in the draft TRA, 2) reasonableness of the proposed approach, and 3) reasonableness of the proposed schedule and costs associated with technology maturation requirements.
3. As applicable, the Contractor resolves review comments, revises the TMP, and forwards the revised TMP to the Federal Project Director.
4. The Federal Project Director approves and distributes the final report to the Contractor, DOE EM-20, and the DOE-EM management.
5. The Federal Project Director incorporates TMP details into project risk management plan and forwards the revised project risk management plan to EM-20 for review.

As described in Attachment G, the TMP should summarize any previous Independent Technical Reviews, other technical assessments, and any previous TRAs that may have contributed to the need for the TMP. This summary should include the TRLs for each CTE as documented in the latest TRA. Previous technology development activities that brought the technology to its current state of readiness should be described. Also, ongoing technology development must be included because completion of this ongoing work will define the starting point for the TMP. The TMP should describe the approach used in defining the additional, required technology development activities that will be conducted. Approaches may include evaluating incomplete criteria in the TRL calculator, risk assessments, and value engineering.

In preparing the TMP for relatively mature technologies, TRA results should be evaluated using a risk evaluation and value engineering approach. Figure 4 provides a diagram of the technology maturation planning process. An identified technology readiness issue (or technology need) is evaluated using the systems engineering functions and requirements analysis. Then, a first order risk evaluation is conducted to determine whether the current path can be followed with negligible risk or if alternatives (current path with modifications or a new system) should be pursued. A more detailed, second order risk evaluation is conducted to determine if the modifications or new system alternatives have sufficient payoff to be incorporated into the TMP.

In describing the required technology development activities, specific maturation plans must be prepared for each CTE assessed at less than TRL 6. The plans for each CTE must include:

- Key Technology Addressed
- Objective
- Current State of Art
- Technology Development Approach
- Scope
- Schedule
- Budget

The high-level schedule and budget (including the total maturation costs) that incorporate the major technology development activities for each CTE must be provided. Any major decision points such as proceeding with versus abandoning the current technology or selection of a backup technology, should be included in the schedule. More detailed schedules will be prepared for executing and managing the work.

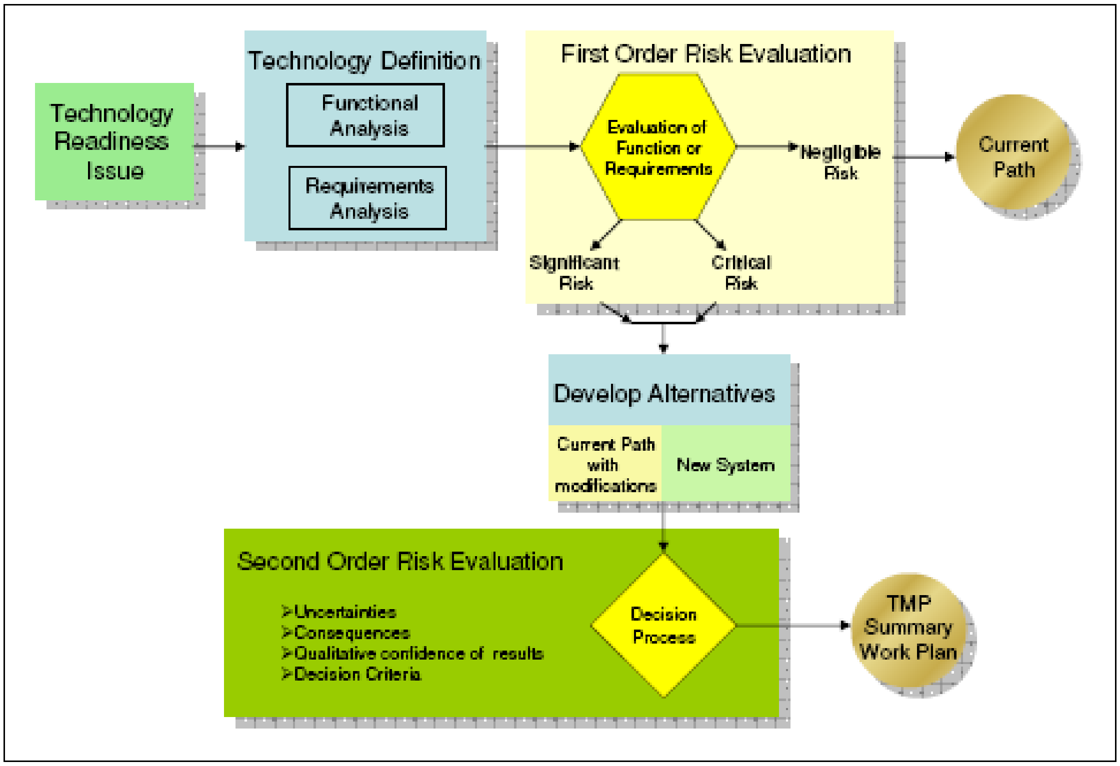
4.3 TMP Execution

After the TMP has been approved, the Contractor will prepare detailed test plans to conduct the technology development activities described in the TMP. These test plans will define the test objectives, relevant environment (stimulant versus actual waste), the scale of the planned tests, and performance targets (or success criteria) for the tests. Then, more detailed cost and schedule estimates will be prepared by the Contractor to support preparation of a Baseline Change Proposal (BCP), if needed. The Federal Project Director will approve any needed BCPs.

The contractor may conduct the technology development in house or work with DOE to select a technology developer by open procurements to industry, solicitations from EM-20, identification of national laboratories with appropriate expertise, etc. Schedule status will be maintained by the contractor based on periodic updates from the technology development performer. Any significant changes in scope and schedule will require formal change control by the contractor and DOE organization providing the funding.

Technical reports will be written as major technology development tasks are completed. A Final Technical Report will be prepared when all of the technology development tasks in the TMP have been completed as required by the TRL 6 criteria.

Figure 4 Technology Maturation Planning Process



5.0 ATTACHMENTS

Attachment A, TRA Plan
Attachment B, CTE Identification Criteria
Attachment C, Kick-Off Meeting Agenda
Attachment D, TRL Assessment Criteria
Attachment E, TRA Report Format
Attachment F, Close-Out Meeting Agenda
Attachment G, Technology Maturation Plan Format

Attachment A, TRA Plan
(Page 1 of 3)

1.0 INTRODUCTION

Briefly state who requested the TRA, what organization is responsible for conducting the TRA, and what technology is to be assessed. State where the technology is being developed (i.e., facility, site).

2.0 PURPOSE

Briefly state the objective of the TRA. Specifically, state how the customer will use the results from the TRA. Additionally, state any other drivers for conduct of the TRA (e.g., Critical Decision milestone support, technology downselect support).

3.0 TECHNOLOGY BACKGROUND

Provide a general description of the technology and the project supported by the technology. The description should include details regarding the function that the technology accomplishes for the project and a brief summary of status of the technology development. Additionally, summarize the results of any previous TRAs conducted on the technology.

4.0 TRA Team

Include a table that lists the position, title, name and area of expertise of each TRA Team Member.

Position	*Title*	*Company*	*Name*	*Area of Expertise*
Team Leader	*Person 1 Title*	*Person 1 company*	*Person 1 name*	*Person 1 expertise*
Team Member	*Person 2 Title*	*Person 2 company*	*Person 2 name*	*Person 2 expertise*
Team Member	*Person 3 Title*	*Person 3 company*	*Person 3 name*	*Person 3 expertise*
Team Member	*Person 4 Title*	*Person 4 company*	*Person 4 name*	*Person 4 expertise*

5.0 TRA ESTIMATED SCHEDULE

Task Number	Projected Duration	Task Description
1	6 weeks	Establish TRA Team
2	4 weeks	Distribute critical documents to Team
3	4 weeks	Conduct onsite assessment activities
4	4 weeks	Draft TRA Report
5	4 weeks	Issue Final Report

6.0 TRA ESTIMATED COST

Provide an estimate of the total man-hours and associated cost for conduct of the TRA. Additionally, state the organization responsible for funding the TRA.

7.0 DEFINITIONS

8.0 REFERENCES

Attachment B, Critical Technology Elements (CTE) Identification Criteria

A CTE is identified if there is at least one positive response for each set of criteria

Set 1 - Criteria	Yes	No
• Does the technology directly impact a functional requirement of the process or facility?		
• Do limitations in the understanding of the technology result in a potential schedule risk, i.e., the technology may not be ready for insertion when required?		
• Do limitations in the understanding of the technology result in a potential cost risk, i.e., the technology may cause significant cost overruns?		
• Are there uncertainties in the definition of the end state requirements for this technology?		

Set 2 - Criteria	Yes	No
• Is the technology new or novel?		
• Is the technology modified?		
• Has the technology been repackaged so a new relevant environment is realized?		
• Is the technology expected to operate in an environment and/or achieve performance beyond its original design intention or demonstrated capability?		

Attachment C, Kick-Off Meeting Agenda

Topic	Presenter
Review Team and Field Office Introductions	Team Leader and Field Office Representative or Contractor Liaison
Purpose of Assessment	Team Leader
Scope of Assessment	Team Leader
TRA Process Overview	Team Leader
Technology overview and status	Field Office Representative or Contractor Liaison
Site tour (as needed)	Field Office Representative or Contractor Liaison
Begin assessment process	Team

Attachment D, Technology Readiness Level Assessment Criteria

Table D1. Top Level Questions for Determining Anticipated TRL

Top-Level Question		Yes/No	If Yes, Then Basis and Supporting Documentation
TRL 9	Has the actual equipment/process successfully operated in the full operational environment (hot operations)?		
TRL 8	Has the actual equipment/process successfully operated in a limited operational environment (hot commissioning)?		
TRL 7	Has the actual equipment/process successfully operated in the relevant operational environment (cold commissioning)?		
TRL 6	Has prototypical engineering scale equipment/process testing been demonstrated in a relevant environment?		
TRL 5	Has bench-scale equipment/process testing been demonstrated in a relevant environment?		
TRL 4	Has laboratory-scale testing of similar equipment systems been completed in a simulated environment?		
TRL 3	Has equipment and process analysis and proof of concept been demonstrated in a simulated environment?		
TRL 2	Has an equipment and process concept been formulated?		
TRL 1	Have the basic process technology process principles been observed and reported?		

Attachment D, Technology Readiness Level Assessment Criteria (continued)

Table D.2. TRL 1 Questions for Critical Technical Element

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		1. "Back of envelope" environment	
T		2. Physical laws and assumptions used in new technologies defined	
T		3. Paper studies confirm basic principles	
P		4. Initial scientific observations reported in journals/conference proceedings/technical reports.	
T		5. Basic scientific principles observed and understood.	
P		6. Know who cares about the technology, e.g., sponsor, funding source, etc.	
T		7. Research hypothesis formulated	
T		8. Basic characterization data exists	
P		9. Know who would perform research and where it would be done	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment D, Technology Readiness Level Assessment Criteria (continued)

Table D.3. TRL 2 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
P		1. Customer identified	
T		2. Potential system or components have been identified	
T		3. Paper studies show that application is feasible	
P		4. Know what program the technology would support	
T		5. An apparent theoretical or empirical design solution identified	
T		6. Basic elements of technology have been identified	
T		7. Desktop environment (paper studies)	
T		8. Components of technology have been partially characterized	
T		9. Performance predictions made for each element	
P		10. Customer expresses interest in the application	
T		11. Initial analysis shows what major functions need to be done	
T		12. Modeling & Simulation only used to verify physical principles	
P		13. System architecture defined in terms of major functions to be performed	
T		14. Rigorous analytical studies confirm basic principles	
P		15. Analytical studies reported in scientific journals/conference proceedings/technical reports.	
T		16. Individual parts of the technology work (No real attempt at integration)	
T		17. Know what output devices are available	
P		18. Preliminary strategy to obtain TRL Level 6 developed (e.g. scope, schedule, cost)	
P		19. Know capabilities and limitations of researchers and research facilities	
T		20. The scope and scale of the waste problem has been determined	
T		21. Know what experiments are required (research approach)	
P		22. Qualitative idea of risk areas (cost, schedule, performance)	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment D, Technology Readiness Level Assessment Criteria (continued)

Table D.4. TRL 3 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		1. Academic (basic science) environment	
P		2. Some key process and safety requirements are identified	
T		3. Predictions of elements of technology capability validated by analytical studies	
P		4. The basic science has been validated at the laboratory scale	
T		5. Science known to extent that mathematical and/or computer models and simulations are possible	
P		6. Preliminary system performance characteristics and measures have been identified and estimated	
T		7. Predictions of elements of technology capability validated by Modeling and Simulation (M&S)	
M		8. No system components, just basic laboratory research equipment to verify physical principles	
T		9. Laboratory experiments verify feasibility of application	
T		10. Predictions of elements of technology capability validated by laboratory experiments	
P		11. Customer representative identified to work with development team	
P		12. Customer participates in requirements generation	
P		13. Requirements tracking system defined to manage requirements creep	
T		14. Key process parameters/variables and associated hazards have begun to be identified.	
M		15. Design techniques have been identified/developed	
T		16. Paper studies indicate that system components ought to work together	
P		17. Customer identifies technology need date.	
T		18. Performance metrics for the system are established (What must it do)	
P		19. Scaling studies have been started	
M		20. Current manufacturability concepts assessed	
M		21. Sources of key components for laboratory testing identified	
T		22. Scientific feasibility fully demonstrated	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment D, Technology Readiness Level Assessment Criteria (continued)

Table D.4. TRL 3 Questions for Critical Technical Elements (Continued)

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		23. Analysis of present state of the art shows that technology fills a need	
P		24. Risk areas identified in general terms	
P		25. Risk mitigation strategies identified	
P		26. Rudimentary best value analysis performed for operations	
T		27. Key physical and chemical properties have been characterized for a number of waste samples	
T		28. A simulant has been developed that approximates key waste properties	
T		29. Laboratory scale tests on a simulant have been completed	
T		30. Specific waste(s) and waste site(s) has (have) been defined	
T		31. The individual system components have been tested at the laboratory scale	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment D, Technology Readiness Level Assessment Criteria (continued)

Table D.5. TRL 4 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		1. Key process variables/parameters been fully identified and preliminary hazard evaluations have been performed.	
M		2. Laboratory components tested are surrogates for system components	
T		3. Individual components tested in laboratory/ or by supplier	
T		4. Subsystems composed of multiple components tested at lab scale using simulants	
T		5. Modeling & Simulation used to simulate some components and interfaces between components	
P		6. Overall system requirements for end user's application are <u>known</u>	
T		7. Overall system requirements for end user's application are <u>documented</u>	
P		8. System performance metrics measuring requirements have been established	
P		9. Laboratory testing requirements derived from system requirements are established	
M		10. Available components assembled into laboratory scale system	
T		11. Laboratory experiments with available components show that they work together	
T		12. Analysis completed to establish component compatibility (Do components work together)	
P		13. Science and Technology Demonstration exit criteria established (S&T targets understood, documented, and agreed to by sponsor)	
T		14. Technology demonstrates basic functionality in simulated environment	
M		15. Scalable technology prototypes have been produced (Can components be made bigger than lab scale)	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment D, Technology Readiness Level Assessment Criteria (continued)

Table D.5. TRL 4 Questions for Critical Technical Elements (Continued)

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
P		16. Draft conceptual designs have been documented (system description, process flow diagrams, general arrangement drawings, and material balance)	
M		17. Equipment scale-up relationships are understood/accounted for in technology development program	
T		18. Controlled laboratory environment used in testing	
P		19. Initial cost drivers identified	
M		20. Integration studies have been started	
P		21. Formal risk management program initiated	
M		22. Key manufacturing processes for equipment systems identified	
P		23. Scaling documents and designs of technology have been completed	
M		24. Key manufacturing processes assessed in laboratory	
P/T		25. Functional process description developed. (Systems/subsystems identified)	
T		26. Low fidelity technology “system” integration and engineering completed in a lab environment	
M		27. Mitigation strategies identified to address manufacturability/ producibility shortfalls	
T		28. Key physical and chemical properties have been characterized for a range of wastes	
T		29. A limited number of simulants have been developed that approximate the range of waste properties	
T		30. Laboratory-scale tests on a limited range of simulants and real waste have been completed	
T		31. Process/parameter limits and safety control strategies are being explored	
T		32. Test plan documents for prototypical lab- scale tests completed	
P		33. Technology availability dates established	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Table D.6. TRL 5 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		1. The relationships between major system and sub-system parameters are understood on a laboratory scale.	
T		2. Plant size components available for testing	
T		3. System interface requirements known (How would system be integrated into the plant?)	
P		4. Preliminary design engineering begins	
T		5. Requirements for technology verification established	
T		6. Interfaces between components/subsystems in testing are realistic (bench top with realistic interfaces)	
M		7. Prototypes of equipment system components have been created (know how to make equipment)	
M		8. Tooling and machines demonstrated in lab for new manufacturing processes to make component	
T		9. High fidelity lab integration of system completed, ready for test in relevant environments	
M		10. Manufacturing techniques have been defined to the point where largest problems defined	
T		11. Lab-scale, similar system tested with range of simulants	
T		12. Fidelity of system mock-up improves from laboratory to bench-scale testing	
M		13. Availability and reliability (RAMI) target levels identified	
M		14. Some special purpose components combined with available laboratory components for testing	
P		15. Three dimensional drawings and P&IDs for the prototypical engineering-scale test facility have been prepared	
T		16. Laboratory environment for testing modified to approximate operational environment	
T		17. Component integration issues and requirements identified	
P		18. Detailed design drawings have been completed to support specification of engineering-scale testing system	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Table D.6. TRL 5 Questions for Critical Technical Elements (continued)

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		19. Requirements definition with performance thresholds and objectives established for final plant design	
P		20. Preliminary technology feasibility engineering report completed	
T		21. Integration of modules/functions demonstrated in a laboratory/bench-scale environment	
T		22. Formal control of all components to be used in final prototypical test system	
P		23. Configuration management plan in place	
T		24. The range of all relevant physical and chemical properties has been determined (to the extent possible)	
T		25. Simulants have been developed that cover the full range of waste properties	
T		26. Testing has verified that the properties/performance of the simulants match the properties/performance of the actual wastes	
T		27. Laboratory-scale tests on the full range of simulants using a prototypical system have been completed	
T		28. Laboratory-scale tests on a limited range of real wastes using a prototypical system have been completed	
T		29. Test results for simulants and real waste are consistent	
T		30. Laboratory to engineering scale scale-up issues are understood and resolved	
T		31. Limits for all process variables/parameters and safety controls are being refined	
P		32. Test plan for prototypical lab-scale tests executed – results validate design	
P		33. Test plan documents for prototypical engineering-scale tests completed	
P		34. Risk management plan documented	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Table D.7. TRL 6 Questions for Critical Technical Elements

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
T		1. The relationships between system and sub-system parameters are understood at engineering scale allowing process/design variations and tradeoffs to be evaluated.	
M		2. Availability and reliability (RAMI) levels established	
P		3. Preliminary design drawings for final plant system are complete	
T		4. Operating environment for final system known	
P		5. Collection of actual maintainability, reliability, and supportability data has been started	
P		6. Performance Baseline (including total project cost, schedule, and scope) has been completed	
T		7. Operating limits for components determined (from design, safety and environmental compliance)	
P		8. Operational requirements document available	
P		9. Off-normal operating responses determined for engineering scale system	
T		10. System technical interfaces defined	
T		11. Component integration demonstrated at an engineering scale	
P		12. Scaling issues that remain are identified and understood. Supporting analysis is complete	
P		13. Analysis of project timing ensures technology will be available when required	
P		14. Have established an interface control process	
P		15. Acquisition program milestones established for start of final design (CD-2)	
M		16. Critical manufacturing processes prototyped	
M		17. Most pre-production hardware is available to support fabrication of the system	
T		18. Engineering feasibility fully demonstrated (e.g. would it work)	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Table D.7. TRL 6 Questions for Critical Technical Elements (continued)

T/P/M	Y/N	Criteria	Basis and Supporting Documentation
M		19. Materials, process, design, and integration methods have been employed (e.g. can design be produced?)	
P		20. Technology "system" design specification complete and ready for detailed design	
M		21. Components are functionally compatible with operational system	
T		22. Engineering-scale system is high-fidelity functional prototype of operational system	
P		23. Formal configuration management program defined to control change process	
M		24. Integration demonstrations have been completed (e.g. construction of testing system)	
P		25. Final Technical Report on Technology completed	
M		26. Process and tooling are mature to support fabrication of components/system	
T		27. Engineering-scale tests on the full range of simulants using a prototypical system have been completed	
T		28. Engineering to full-scale scale-up issues are understood and resolved	
T		29. Laboratory and engineering-scale experiments are consistent	
T		30. Limits for all process variables/parameters and safety controls are defined	
T		31. Plan for engineering-scale testing executed - results validate design	
M		32. Production demonstrations are complete (at least one time)	

T-Technology, technical aspects; M-Manufacturing and quality; P-Programmatic, customer focus, documentation

Attachment E, TRA Report Format
(Page 1of 1)

<u>REPORT CONTENT:</u>

EXECUTIVE SUMMARY

Briefly state who requested the TRA, what organization was responsible for conducting the TRA, what technology was assessed. Provide a summary table of the CTEs and corresponding TRLs determined during the review

INTRODUCTION

Technology Reviewed
Provide a detailed description of the technology that was assessed.

TRA Process
Provide an overview of the approach used to conduct the TRA. Reference applicable planning documents.

RESULTS
Provide the following for each Critical Technology Element assessed:

- ***Function***
  Describe the CTE and its function.
- ***Relationship to Other Systems***
  Describe how the CTE interfaces with other systems.
- ***Development History and Status***
  Summarize pertinent development activities that have occurred to date on the CTE.
- ***Relevant Environment***
  Describe relevant parameters inherent to the CTE or the function it performs.
- ***Comparison of the Relevant Environment and the Demonstrated Environment***
  Describe differences and similarities between the environment in which the CTE has been tested and the intended environment when fully operational.
- ***Technology Readiness Level Determination***
  State the TRL determined for the CTE and provide the basis justification for the TRL.
- ***Estimated Cost/Schedule***
  State the estimated cost and time requirements, with associate uncertainties, and programmatic risks associated with maturing each technology to the required readiness level.

ATTACHMENTS
Include the following planning documents:

- *TRA Plan*
- *Supporting documentation for identification of Critical Technology Elements*
- *Completed tables:*
  - *Top Level Questions for Determining Anticipated TRL (Attachment D Table D1)*
  - *TRL Questions for Critical Technical Element (Attachment D Tables D.2 through D.7)*
- *List of support documentation for TRL determination*
- *Technology Readiness Level Summary table*
- *Team biographies*

Attachment F, Close-Out Meeting Agenda

Topic	Presenter
Purpose of Meeting	Team Leader
Presentation of TRA results ▪ Summary of TRLs Recommendations ▪ Conclusions	 Team Leader Responsible Team Member(s) Team Leader
Discussion	All
Path Forward for TMP issuance	Team Leader

Attachment G, Technology Maturation Plan Format

(Note: The TMP is a high level summary document. It is not a collection of detailed test plans.)

TABLE OF CONTENTS
LIST OF TABLES
LIST OF FIGURES
ABBREVIATIONS AND ACRONYMS

1.0 INTRODUCTION

- Purpose of the Project
  Provide a brief summary of the project's mission, status, technology(s) being deployed, etc.
- Purpose of the Technology Maturation Plan
  Describe the objectives and content of this Technology Maturation Plan (TMP) and relate it to the status of the project and any upcoming Critical Decisions.

2.0 TECHNOLOGY ASSESSMENTS OF THE PROJECT

- Summary of Previous Independent Technical Reviews
  Summarize any previous Independent Technical Reviews or other technical assessments that may have contributed to the need for a Technology Readiness Assessment (TRA) and this TMP.
- Summary of Previous Technology Readiness Assessment(s)
  Describe the results of previous TRAs with particular emphasis on the latest TRA that is driving this TMP. Include the definition of Technology Readiness Levels as used in the TRA. Discuss the Critical Technology Elements (CTEs) that were determined for the project.
- Technology Heritage
  Summarize the previous technology development activities that brought the technology to its current state of readiness. Include discussions of any full-scale plant deployments of the technology in similar applications.
- Current Project Activities and Technology Maturation
  Describe ongoing technology development activities (if any) that were initiated prior to this TMP. Completion of these activities should define the starting point for this TMP.
- Management of Technology Maturity
  Indicate the DOE and contractor organizations that will be responsible for managing the activities described in this TMP. Include a brief discussion of key roles and responsibilities.

3.0 Technology Maturation Plan

- Development of Technology Maturation Requirements
  Describe the approach used in defining the required technology development activities that will be conducted as described in this TMP. These could include evaluating incomplete criteria in the TRL Calculator, risk assessments, and value engineering.
- Life-Cycle Benefit
  Briefly discuss life-cycle benefits to the project that will result from successful completion of the TMP technology development activities.

ATTACHMENT G, Technology Maturation Plan Format continued

- Specific Technology Maturation Plans
  Maturation plans for each CTE will be described following the format below for each CTE that was defined in the latest TRA.
  - CTE A
    - Key Technology Addressed *(Describe the function that the CTE carries out in the project.)*
    - Objective *(Succinctly state the objective of the CTE)*
    - Current State of Art *(Describe in one paragraph the current status of the CTE including the specific TRL assigned in the latest TRA.)*
    - Technology Development Approach *(In paragraph form, describe how the needed technology development work to reach TRL 6 will be performed. This could include the performing organization, location, simulant versus actual waste, etc.)*
    - Scope *(Provide a list of the key steps to be taken in performing the work. Include a table that gives milestones, performance targets, TRL achieved at milestones, and a rough order of magnitude cost of development.)*
  - CTE B
    - Key Technology Addressed
    - Objective
    - Current State of Art
    - Technology Development Approach
    - Scope
  - CTE C (etc., as needed)

4.0 TECHNOLOGY MATURITY SCHEDULE

Provide and briefly discuss a high-level schedule of the major technology development activities for each CTE. Any major decision points such as proceeding with versus abandoning the current technology, selection of a back-up technology, etc. should be included. Detailed schedules should be given in test plans or used for status meetings during implementation.

5.0 SUMMARY TECHNOLOGY MATURITY BUDGET

Present the rough order of magnitude costs to reach TRL 6 for each major technology development activity for all CTEs in the project. Include the total technology maturation costs.

6.0 REFERENCES

Appendix A. Crosswalk of identified in previous independent reviews and assessments (if applicable)
Appendix B. Technology Readiness Level Calculator As Modified For DOE Office of Environmental Management
Table 1. Technology Readiness Levels Used in this Assessment (taken from DoD)
Table 2, etc. Table(s) for each CTE, listing of test activities, planned completion date, performance targets, resulting TRL level as each increment of testing is completed, and rough order of magnitude costs.
Table X. Technology Maturity Budget for Project
Figure 1. Process Flow Diagram (for technology being assessed)
Figure 2. Technology Maturity Schedule
Figure 3. Project Execution Strategy Diagram