Technology Maturation in Support of DOE 413.3B Project Execution - 16436

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Abstract

The DOE Order 413.3B “Program and Project Management for the Acquisition of Capital Assets” provides program and project management direction for the acquisition of capital assets with the goal of delivering projects within the original performance baseline (PB), cost and schedule, and fully capable of meeting mission performance, safeguards and security, and environmental, safety, and health requirements. Execution of complex DOE 413.3B projects depends, in part, upon the successful integration of a technology maturation program.

The Low Activity Waste Pre-Treatment System (LAWPS) is executing a detailed technology maturation program under the Technology Readiness Level/Technology Maturation Plan (TRL/TMP) guidance of DOE Order 413.3B. The interaction of the technology maturation process and the project execution including technical, programmatic, and contractual execution, has been a critical component for project success.

Introduction

Radioactive and chemical wastes from nuclear weapon production are stored in underground tanks at the Hanford Site, located in the state of Washington. The waste tanks contain a complex and diverse mix of radioactive and chemical waste in the form of sludge, salts, and liquids, necessitating a variety of unique waste retrieval, treatment, and disposition methods. Generically, the tank waste can be characterized as the following:

1. Sludge – Insoluble materials largely consisting of metal hydroxides and oxides that precipitated when acidic wastes from spent nuclear fuel processing and other activities were neutralized and converted to high pH for storage in carbon steel tanks. The sludge waste makes up the largest component that will be processed via high-level waste (HLW) vitrification into a stable glass form.
2. Supernatant – Liquid waste with high sodium content and high pH.
3. Saltcake – a mixture of salts that precipitated from supernatant as the specific gravity was increased by evaporation to reduce tank storage space requirements. Saltcake must be re-dissolved and processed as supernatant waste. The supernatant and saltcake contain the majority of highly radioactive Cs which must be separated and processed with the sludge stream into HLW glass. The decontaminated supernatant will be processed via low-activity waste (LAW) vitrification into a stable glass form.

4. Potential contact-handled transuranic waste (CH-TRU) – a mixture of sludge and saltcake consisting of some 1.4 million gallons in 11 specific single-shell tanks (SSTs). The material in these tanks is being reviewed to determine the potential to transfer to WIPP versus processed on-site into HLW and LAW glass fractions.

In order to begin immobilization of tank waste as soon as practicable, a Direct Feed LAW (DFLAW) flowsheet has been developed. In the DFLAW configuration, tank waste liquids will be provided to the LAW Pretreatment System (LAWPS). The LAWPS will separate the HLW and LAW fractions and provide qualified feed to the LAW Vitrification Facility.

Successful startup and operation of DFLAW requires the completion of engineering, design and construction of numerous facilities, flowsheet stewardship, programs integration across facilities, generation of a series of permits, and development of the regulatory framework to dispose of the waste forms generated. A critical facility in the DFLAW system is the construction of LAWPS, an at-tank pre-treatment system to prepare feed to the WTP-LAW.

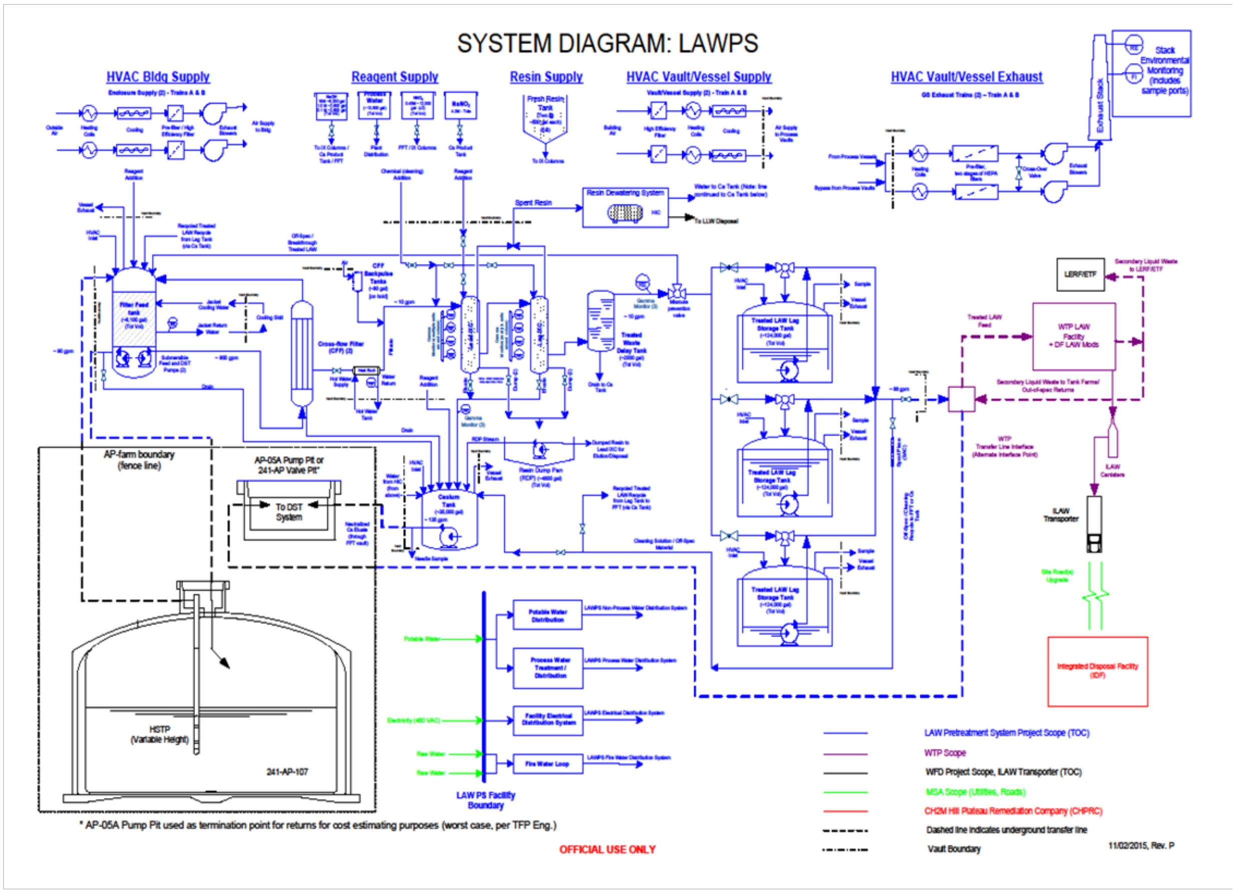
The LAWPS will deploy multiple technologies as managed under DOE Order 413.3B "Program and Project Management for the Acquisition of Capital Assets". In accordance with DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets, Technology Readiness Assessment (TRAs) and Technology Maturation Plans (TMPs) are required for Major Systems Projects (i.e., those with total project cost greater than $750M) prior to Critical Decision (CD) 2. However, they are also highly recommended for smaller projects, as well as Operations Activities, such as technology demonstrations, which involve the development and implementation of new technologies or technologies in new operational environments. Operations Activities are EM's non-capital asset activities that adhere to many of the same management principles as projects. The interaction of the technology maturation, a critical project management tool to reduce risks associated with deploying new or revised technologies, with project execution is described herein.

Low-Activity Waste Pretreatment System (LAWPS) Description

The LAWPS will separate HLW components from LAW components by filtration and ion exchange and store the low activity solution. From the storage system, the LAW will be fed to a new LAW immobilization process (WTP) for conversion to a solidified waste form. The LAWPS focuses on the separation of HLW from the feed stream to result in LAW. Additionally, the LAWPS allows the potential to draw down double-shell tank storage volume and the WTP to begin vitrifying low-activity tank waste earlier than the current projection.

A diagram of the LAWPS flowsheet is shown in Figure 1.

Figure 1. DFLAW System Diagram.



Supernatant will be continuously transferred from the underground DST to the new system via dedicated transfer lines. The supernatant will be received into a Filter Feed Tank (FFT), and then fed into cross-flow filters (CFFs) with the slightly higher solids content waste continuously returned to the DST via dedicated transfer line. The CFFs are sized to be capable of concentrating the supernatant to approximately 10 wt% solids while maintaining the required filtrate production rate.

The filtrate will flow through two IX columns (lead and lag) in series, where elutable spherical resorcinol formaldehyde will be used to capture cesium and return to the tank farms allowing sodium disposition through WTP-LAW. After exiting the lag column, the LAW waste product will be transferred to one of three treated LAW Lag Storage Tanks. Treated LAW will then be transferred from the treated LAW Lag

Storage Tanks to WTP-LAW. The eluant solution from the IX columns containing the removed ^{137}Cs will be received into a Cs product tank. The acidic eluant solution will be neutralized with NaOH and may be adjusted by addition of $NaNO_2$ and then returned to a DST.

The process cycle for use of sRF elutable resin for the removal of Cs includes loading, elution, rinsing, and regeneration. After the loading phase, the Cs will be eluted from the resin bed. In the case where resin has reached its life expectancy, it will be first eluted of Cs and then sluiced from the column into a HIC. The elution process will be completed prior to sluicing. The elution process sequence is the same for both lead and lag columns as follows:

- Displacement of treated LAW using NaOH
- Pre-elution rinse with process water to remove the NaOH
- Elution of Cs using dilute HNO_3
- Post-elution rinse with process water to remove residual HNO_3
- Regeneration of sRF resin from hydrogen form to Na form using NaOH
- Displacement of NaOH regenerant with LAW feed.

Spent IX resin will be loaded into a HIC with the HIC in a cask on a trailer, the LAWPS design includes a HIC load out bay, with a self-engaging dewatering system (SEDS). Water used to sluice the resin will be removed in the HIC and returned to the Cs product tank and then transferred to the DST system.

DOE Order 413.3B and Technology Maturation Planning

The DOE Order 413.3B “Program and Project Management for the Acquisition of Capital Assets” provides program and project management direction for the acquisition of capital assets with the goal of delivering projects within the original performance baseline (PB), cost and schedule, and fully capable of meeting mission performance, safeguards and security, and environmental, safety, and health requirements. The DOE Order 413.3B establishes principles and processes that deliver reliable facilities, systems, and assets that provide a required mission capability. The system is organized into a series of project phases and critical decision (CD) points to ensure the delivery of an operationally effective system.

The major critical decisions in the project process are as follows:

- CD-0, Approve Mission Need: There is a need that cannot be met through other than material means;
- CD-1, Approve Alternative Selection and Cost Range: The selected alternative and approach is the optimum solution;
- CD-2, Approve Performance Baseline: Definitive scope, schedule and cost baselines have been developed;
- CD-3, Approve Start of Construction/Execution: The project is ready for implementation; and
- CD-4, Approve Start of Operations or Project Completion: The project is ready for turnover or transition to operations, if applicable.

The DOE Technology Readiness Assessment Guide provides guidance on implementing (TRA) (TMP) in accordance with DOE Order 413.3B. The initial version of the EM (TRA)/ (TMP) Process Guide was published in March 2008 and numerous lessons learned from project execution and technology readiness assessments (TRAs) were incorporated into the August 2013 revision. The guide recommends a self-assessment of the technology readiness and development of an initial TMP prior to an independent TRA. This approach improves the overall efficiency of the TRA process, while providing a basis for management and control of the technology development and deployment activities conducted by the project/program. It is well understood the TMP is a dynamic/living document that will be modified periodically to accommodate project maturation.

Technology Readiness Assessments (TRAs), Technology Readiness Levels (TRLs) and Technology Maturation Plans (TMPs)

The purpose of a TMP is to establish the principal technology elements (TEs) for the proposed process, and subsequently assess each TE with respect to its potential designation as a critical technology element (CTE), and identify the necessary technology maturation activities to ensure successful deployment of the integrated system. The TMP is a planning document that lays out the activities required to bring immature Critical Technology Elements (CTEs) up to the desired TRL. A technology element is “critical” if the systems being acquired depend on the technology element to meet operational requirements and if the technology element or its application is either new or novel. It should be noted that TMPs is intended to be a dynamic document to enable content modifications as the project progresses. The TMP includes preliminary schedules and rough order of magnitude cost estimates that allow decision makers to determine the future course of technology development. The TMP is followed by detailed test plans that provide more accurate cost and schedule information that can be incorporated into the project baseline.

The TRA is a tool that is used to systematically assess how far technology development has progressed and:

- Identifies 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;
- Identifies at-risk technologies that need increased management attention or additional resources for technology development; and
- Increases the transparency of management decisions by identifying key technologies that have been demonstrated at certain levels of maturity or by highlighting immature or unproven technologies that might result in increased project risk.

A TRL indicates the maturity of a given technology according to the definitions and descriptions in Table 1. The TRL scale ranges from 1 (basic principles observed) through 9 (total system used successfully in project operations).

Table 1: TRL Definitions and Description

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	Actual operation of the technology in its final form, under the full range of operating conditions. Examples include using the actual system with the full range of real wastes.
System Commissioning	TRL 8	Actual system completed and qualified through test and demonstration	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 real waste in hot commissioning.
	TRL 7	Full-scale, similar (prototypical) system demonstrated in a relevant environment	Prototype full scale system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing the prototype in the field with a range of simulants and / or real waste and cold commissioning.

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
Technology Demonstration	TRL 6	Engineering / pilot scale, similar (prototypical) system validation in a relevant environment	Representative engineering scale model or prototype system, which is well beyond the scale tested in TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness and system integration. Examples include testing a prototype with real waste and a range of simulants.
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 system in a simulated environment and/or with a range of real waste and simulants.

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
	TRL 4	Component and / or system validation in laboratory environment	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. For example, mechanical systems, such as robotic retrieval technologies, may require full scale prototype testing to meet TRL 4.
Research to Prove Feasibility	TRL 3	Analytical and experimental critical function and / or characteristic proof of concept	Active research and development 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. Components may be tested with simulants. For some applications, such as mechanical systems, this may include computer and/or physical modeling to demonstrate functionality.
	TRL 2	Technology	Invention begins. Once basic

Relative Level of Technology Development	Technology Readiness Level	TRL Definition	Description
Basic Technology Research		concept and / or application formulated	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 analytical studies.
	TRL 1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties.

It is important to note that TRL levels 1-3 are reserved for research and development activities (basic technology research and feasibility; TRL levels 4-6 are focused on development and testing of specific components culminating in integrated scale testing. In addition TRL levels 4-6 are focused on providing information to the design and engineering of the components. TRL levels 7/8 are focused on cold/hot commissioning, while TRL 9 is reserved for a completed demonstration of the process.

Table 2 provides the TRL requirements and definitions regarding testing scale, system fidelity, and environment. Testing should be performed in the proper environment and the technology tested should be of an appropriate scale and fidelity.

Table 2: DOE relationship of testing recommendations to the TRL

TRL	Scale of Testing[1]	Fidelity[2]	Environment[3]
9	Full	Identical	Operational (Full Range)

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

1. Full Scale = Full plant scale that matches final application
   1/10 Full Scale < Engineering / Pilot Scale < Full Scale (Typical)
   Lab Scale < 1/10 Full Scale (Typical)

2. Identical System – configuration matches the final application in all respects
   Similar System – configuration matches the final application in almost all respects
   Pieces System – matches a piece or pieces of the final application
   Paper System – exists on paper (no hardware)

3. Operational (Full Range) – full range of actual waste
   Operational (Limited Range) – limited range of actual waste
   Relevant – range of simulants + limited range of actual waste
   Simulated – range of simulants

Demonstration of specific TRLs is dependent upon rigorous application of each of the questions outlined within the DOE guidance. The primary changes to the revised TRL calculator are related to early identification of safety related parameter, risk management, and system integration.

The Relationship of TRAs and TMPs to DOE CDs

Figure 2 shows how TRAs and other key reviews support each of the critical decisions. The TRA/TMP process serves as one of the tools employed to help evaluate development progress and obtain CD approval.

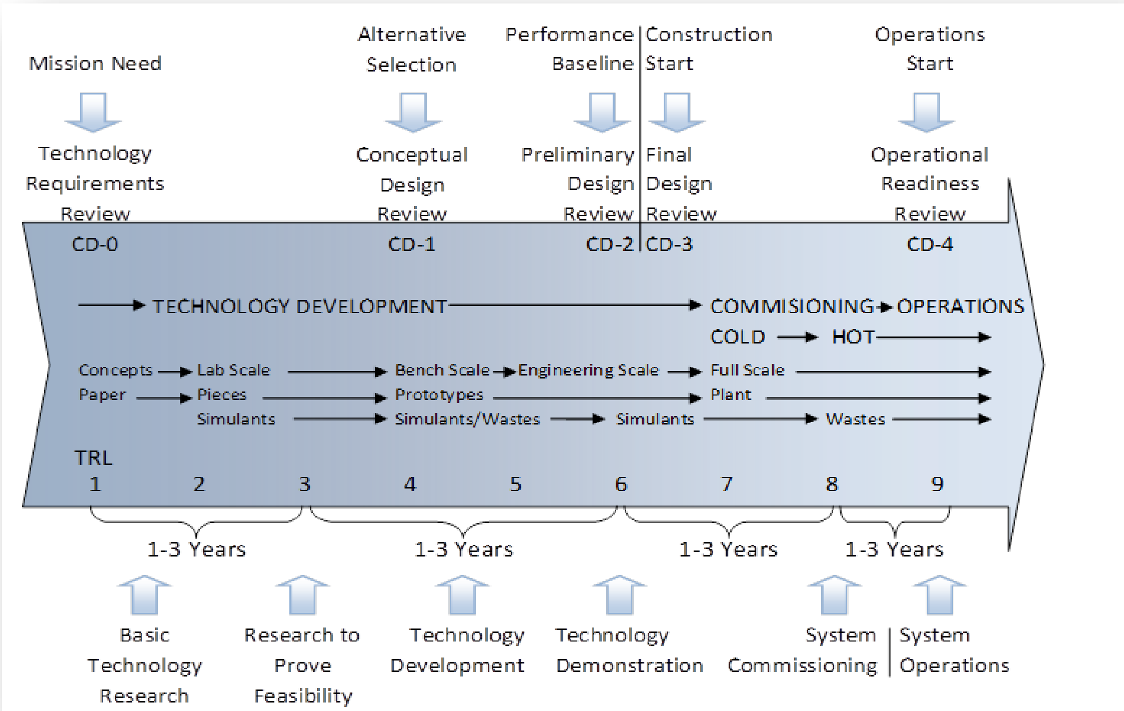


Figure 2: Summary of TRAs and Reviews Supporting Critical Decisions with Typical Time-Frame of Execution

DOE has adopted TRL 6 as the maturity level normally necessary before a technology can be incorporated into final design which correlates to CD-2. However, it is recognized that the DOE is updating the TRL requirements to TRL 7 prior to CD-2 for major system projects and new technologies. The DOE Order 413.3B is being revised to reflect these new requirements, however, LAWPS project does not qualify for these requirements.Prior to start of operations, start-up testing and operational readiness reviews should ensure that the CTEs have advanced to the target maturity (TRL 6 toward TRL 9), as applicable and appropriate. Many of the aspects related to technical maturity are assessed as part of these reviews.

The success of these projects is dependent upon a highly integrated technology maturation effort with the project team. A rigorous application of the technology readiness level guide to project execution provides the necessary tool to ensure sufficient technical maturity to successfully deploy these technologies; and avoid potential cost increases and schedule delays. The DOE Technology Readiness Assessment Guide provides a consistent standard for assessing the technology readiness of project technologies. The guide provides consistent metrics for determining technology readiness terminology to facilitate effective communication, and oversight protocols for reporting and reviewing technology readiness levels.

An assessment of technology readiness is crucial at completion of preliminary and final design where cost and schedule estimates are expected to be accurate and resources are committed to procurement and construction. Proceeding through these critical decision points with a complete technology readiness assessment increases confidence that the specified technologies will function as intended.

Programmatic Definition of Costs

An important designation in the execution of capital asset projects is the programming of funding into correct designations. The DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, provides the general breakout of how project funding is to be used. Specifically for the purposes of technology maturation and technology readiness levels as it relates to project execution, the correct classification of funds is critical to prevent the need for mid-project re-programming.

The Total Project Cost (TPC) is defined to be all costs between CD-0 and CD-4 specific to a project incurred through the startup of a facility, but prior to the operation of the facility. The TPC is a combination of the following:

- Total Estimated Cost (TEC): All engineering design costs (after conceptual design), facility construction costs and other costs specifically related to those construction efforts. TEC will include, but is not limited to: project, design and construction management; contract modifications (to include equitable adjustments) resulting in changes to these costs; design; construction; contingency; contractor support directly related to design and construction; and equipment rental and refurbishment. These costs include Project Engineering and Design (PED) funds typically used for preliminary design, final design and related activities, e.g. baseline development.
- Other Project Costs (OPC): All other costs related to a project that are not included in the TEC. OPCs will include, but are not limited to: research and development; conceptual design and conceptual design report; startup and commissioning costs; NEPA documentation; PDS preparation; siting; and permitting requirements.

In Figure 3, the project **Initiation** and **Definition** phases as well as the project **Closeout** phase use “Operating Funds”. The activities in these phases are described in the DOE Order 413.3B definition of “**Other Project Costs**” (OPC), which is defined as, “All other costs related to a project that are not included in the TEC” (total estimated cost, which is PED and Construction). These descriptions can be extended to the TRL designation and how the funds are to be used for technology maturation activities. The technology maturation activities are funded via operating funds prior to CD-1 (TRL 3) and indicate that PED funding is to be used after CD-1 (post TRL 4) since any technology maturation activities are directly related to design and engineering input.

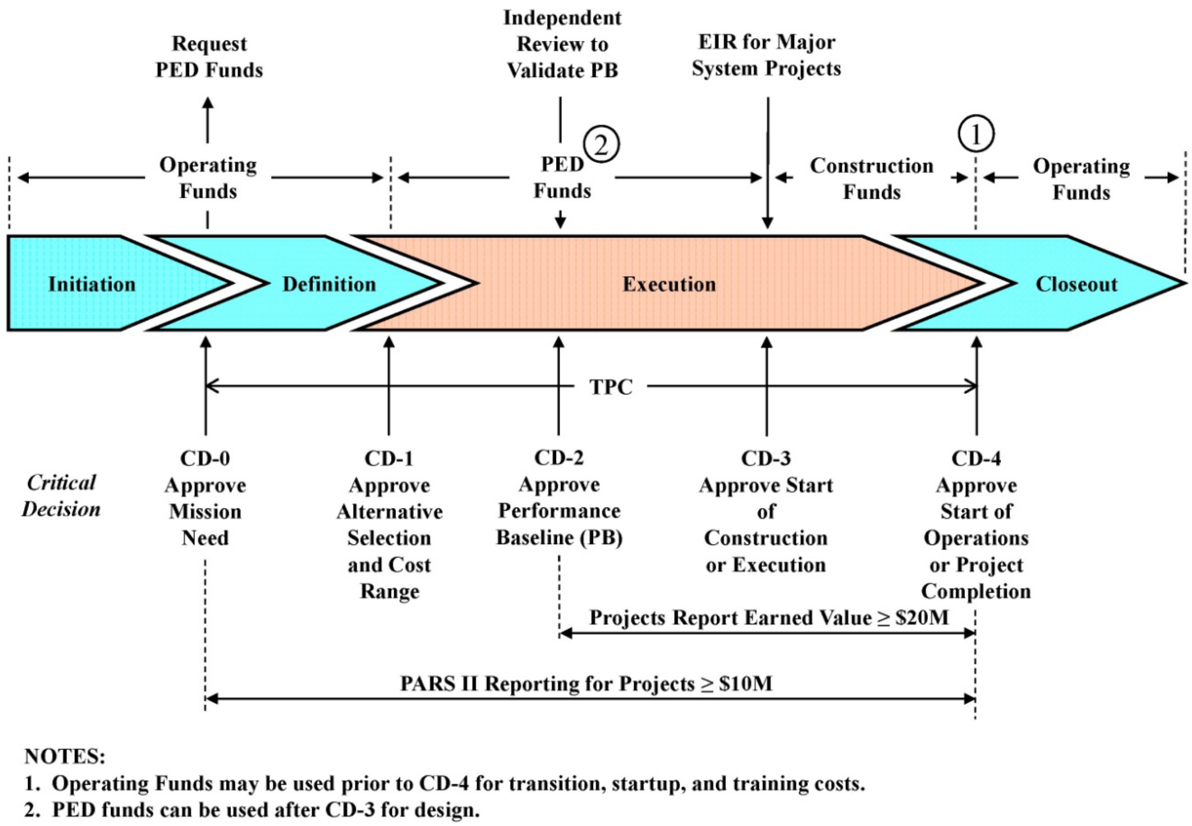


Figure 3: Designation of Funding as Related to CD Phased Development

Application to LAWPS

The LAWPS project is rigorously applying the technology maturation guidelines as part of Project Execution. The LAWPS project has developed a detailed technology maturation plan to guide the necessary development and experimentation as input to project execution. The TMP was developed in the Conceptual Design Phase. The TRL 7 testing will be defined as the project matures and will be documented in revisions to this TMP. Planning for hot commissioning testing (TRL 8) will be captured in system start-up and commissioning planning documents to be prepared during the project execution phase. Similarly, system operations, post CD 4, will bring the treatment system CTEs to TRL 9; any specific testing associated with TRL 9 achievement will be captured in process control plans prepared to support system operations.

The TMP defines each activity in terms of its scope, estimated cost, and completion schedule. The first task completed for this TMP was to identify Technology Elements (TE) based on major subsystems within the LAWPS conceptual flow sheet. A total of 10 TEs were identified. In compliance with the DOE Guide, the 10 TEs were then assessed to identify which TEs are the at-risk technologies essential to the successful operation of the facility, and are new or are being applied in new or novel ways and/or environments. These are categorized as CTEs. The four CTEs identified for the LAWPS in this project phase are:

- TE2 – Cross-flow filtration (CFF) including feed and back-pulse system
- TE3 – Ion exchange using spherical resorcinol-formaldehyde (sRF) resin
- TE4 – Ion exchange eluate neutralization and preparation for return to double-shell tanks (DSTs)
- TE8 – Resin replacement and disposal system

A self -assessment was then completed based on the DOE Guide to determine the current TRL for each of the CTEs. As required by the DOE Guide, the TMP describes the necessary testing to mature each of the CTEs to TRL 6. In addition, the project is implementing prototypic testing at the engineering scale in a relevant environment including integration with other interfacing CTEs. the LAWPS Project is also implementing the DOE G 413.3-4 recommendation that a TRA be performed at least 90 days prior to establishing the project baseline (i.e., CD-2) to determine if the CTEs have reached TRL 6. Further analysis of the necessary information to TRL 7 is currently being developed.

Summary

The integration of technology maturation activities with capital project execution is a critical component in the successful deployment of technologies for tank waste disposition. This integration includes a detailed understanding of the interaction between TMPs, TRLs, TRAs, and the Critical Decision process of DOE 413.3B. The LAWPS project is the only project at the DOE-ORP to utilize the revamped TRA guidance and is being used rigorously in the LAWPS project execution (technically and programmatically) to increase confidence in successful deployment of the selected technologies.