Technology Development: From Idea to Implementation -12131

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ABSTRACT

There are good ideas and new technologies proposed every day to solve problems within the DOE complex. A process to transition a new technology from inception to the decision to launch a project with baselines is described. Examples from active technology development projects within Savannah River Remediation (SRR) will be used to illustrate the points. The process includes decision points at key junctures leading to preliminary design. At that point, normal project management tools can be employed.

The technology development steps include proof-of-principle testing, scaled testing and analysis, and conceptual design. Tools are used that define the scope necessary for each step of technology development. The tools include use of the DOE technology readiness guide, Consolidated Hazards Analysis (CHA) and internal checklists developed by Savannah River Remediation. Integration with operating or planned facilities is also included. The result is a roadmap and spreadsheet that identifies each open question and how it may be answered. Performance criteria are developed that enable simple decisions to be made after the completion of each step.

Conceptual design tasks should begin as the technology development continues. The most important conceptual design tasks at this point in the process include process flow diagrams (PFDs), high level Process and Instrumentation Drawings (P&IDs), and general layout drawings. These should influence the design of the scaled simulant testing. Mechanical and electrical drawings that support cost and schedule development should also be developed. An early safety control strategy developed from the CHA will also influence the cost.

The combination of test results, calculations and early design output with rough order of magnitude cost and schedule information provide input into the decisions to proceed with a project and data to establish the baseline. This process can be used to mature any new technology, especially those that must be integrated into complicated flow sheets. Then fully informed decisions can be made to usher technology development ideas through project implementation. Examples from active technology development projects, Tank 48 Treatment and Enhanced Chemical Cleaning, are presented.

INTRODUCTION

How do you go from good idea to a full up design/build project? How do you decide which ideas to continue to mature? What steps are necessary to mature the technology, define scope, cost and schedule to implement technology development?

Technology development in waste processing within the DOE complex can be extremely complex. Most new ideas and technologies require some investment in research and development and design to make field ready. The complicated chemistry and radiological characteristics of the waste introduce numerous constraints on the ability to test in a way to ensure that the technology is ready for field deployment. However, technology development can be approached in a logical integrated fashion using tools already in use within the DOE complex. The model for technology development relies on proof-of-principle testing leading to the creation of a technology development plan.

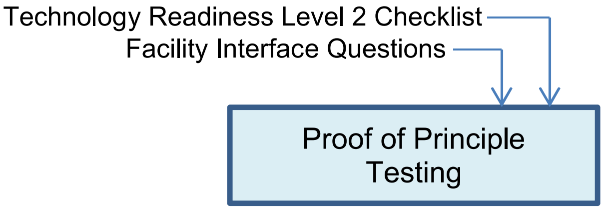
Proof of principle testing is built upon the key attributes of the technology and the major interface requirement with ongoing operations. A successful proof of principle test along with other tools will define the technology development plan. The elements of the technology development plan include scaled testing and analysis, real waste testing, engineering calculations, conceptual design and more detailed interface requirements. The tools used to define the scope of the technology development plan include use of the DOE Technology Readiness Assessment Guide, Preliminary Consolidated Hazards Analysis and internal checklists developed by Savannah River Remediation. Integration with operating or planned facilities is also included. The result is a roadmap and spreadsheet that identifies each open question and how it may be answered with performance criteria.

PROOF OF PRINCIPLE TESTING

In proof of principle testing, the main goal is to discover if the new technology solves the problem. The problem statement and the key attributes needed to solve the problem are defined. These become goals for the first set of scoping tests. For example in SRS Tank 48, testing to decompose potassium tetraphenylborate (KTPB) has been ongoing for a number of years. KTPB is a potential source of benzene, a hazardous and flammable vapor. The proof-of-principle goal for the testing was defined as 99% destruction of KTPB. Enhanced Chemical Cleaning (ECC) is another technology development process that is being considered to improve waste removal and tank closure within SRR. ECC decomposes oxalates following oxalic acid dissolution cleaning of SRS waste tanks. Oxalates formed as a result of oxalic acid dissolution negatively impact downstream processes. The goal for this testing was 90% oxalate destruction to limit the oxalates left behind after chemical cleaning.

Although the DOE Technology Readiness Assessment Guide tool is intended as an external review process, it can be used internally to identify gaps in knowledge. Technology Readiness Level (TRL) questions from the guide for level 2 are appropriate at this stage of exploration. [1] TRL level 2 questions lead to decisions about major functions, performance predictions, need for modeling and simulation, and early thought about the design elements. It is also important to begin the identification of the interfaces of the new technology with existing facilities. High level interfaces with downstream facilities are identified, and important safety parameters for the technology are defined.

Figure 1. Proof of Principle Testing



SRR procedure S4.ENG-08 provides a good high level checklist to determine the impacts of new technology or processes on active facilities. [2] The evaluation should be done for the new process area and the interfacing facilities. See Table 1 for an example of the checklist.

Table I. Facility Interface Checklist per SRR procedure S4.ENG-08

Impact Category	Impact Concern	Engineering Study Required	Experimental Study Required	Risk Accepted	Prior Process Knowledge
Segregation	Immiscible				
	Dissolves				
	Agglomerates				
Volatilization					
Accumulation	Sinks				
	Floats				
	Stays suspended				
	Adheres to surface				
	Overflow				
Reaction					
Product Quality					
Physical Properties	Rheology Change				
Solubility					
Radiolytic	Inhalation Dose				
	Hydrogen Generation				
	Criticality				
Regulatory					
Equipment	Corrosion				

The facility interface checklist identifies impacts and concerns along with a method for resolving the concerns. For Tank 48 the KTPB decomposition process resulted in by products that had the potential to be introduced into the Defense Waste Processing Facility (DWPF). DWPF vitrifies high level waste at SRS. Table II provides an example of the tool that was used to explore the impacts of KTPB destruction on DWPF. [3]

Table II. Actual checklist to determine impact of KTPB destruction on DWPF

Facility/Equipment	What is postulated impact?	How could this be answered?
DWPF Melter	Melter feed is too reducing; noble metals are reduced and short out melter. Melter must be replaced.	1. paper study 2. simulant study 3. actual waste demo
DWPF Melter	Offgas flammability due to high organic content	1. paper study 2. simulant study 3. actual waste demo
DWPF SRAT and SME	High nitrite, nitrate impact hydrogen generation	1. simulant study 2. actual waste demo
DWPF Melter	High sodium impacts	Paper study
DWPF SRAT/SME HLW Tank HLW Evaporator	Do remaining organic species react with other waste	1. paper study 2. simulant study

After the Technology Readiness Level and facility interface evaluations are complete, then those items that require experimental study can be added to the test scope. Simple simulants designed to answer the key attributes should be used. At this stage the tests should be defined as go/no go. Does the technology meet the limit or not? Tests that refine the knowledge can come later. The test scope and goals should be clearly documented to ensure clear communication with the testing organization. The test report should discuss the test goals and the success or failure of the test results compared to the goals.

TECHNOLOGY DEVELOPMENT PROGRAM

If the results of the proof of principle testing are positive and a decision is made to proceed, then the technology development program plan should be developed. The results from the proof of principle testing, even if positive, usually suggest several areas that require deeper exploration. In addition, several tools can be used to add substance to the Technology Development Plan. The facility interface checklist should be reviewed again to determine if there are more subtle questions to be explored or questions that should be explored at a deeper level. TRL level 3 questions can be used. Consolidated Hazards Analysis (CHA) guidewords can be used to define open questions from a safety basis perspective. [4] Table III shows some examples of guidewords used in the CHA process.

Table III. CHA Guidewords

Guidewords		
External Dose	Internal Dose	Shielding
Criticality	Loss of Confinement	Ventilation
Fire	Explosion/Overpressure	Maintainability
Remote Handling	Loss of Services (Utilities)	Effluents/Washing
Corrosion/Erosion	Domino Effects	Extreme Weather
External Hazards	Dropped Load/Impact	Energy
Occupational Safety	Chemical	

In facilities that have active Documented Safety Analyses (DSA), the engineering staff, cognizant of the driving accident analyses and approaches, should be interviewed to ensure that the proper data is collected to support the accident analysis. For example, in SRS tank farm facilities, hydrogen created through corrosion can have a large impact; therefore, tests are designed to provide the necessary data. Questions from the TRA guide are listed below.

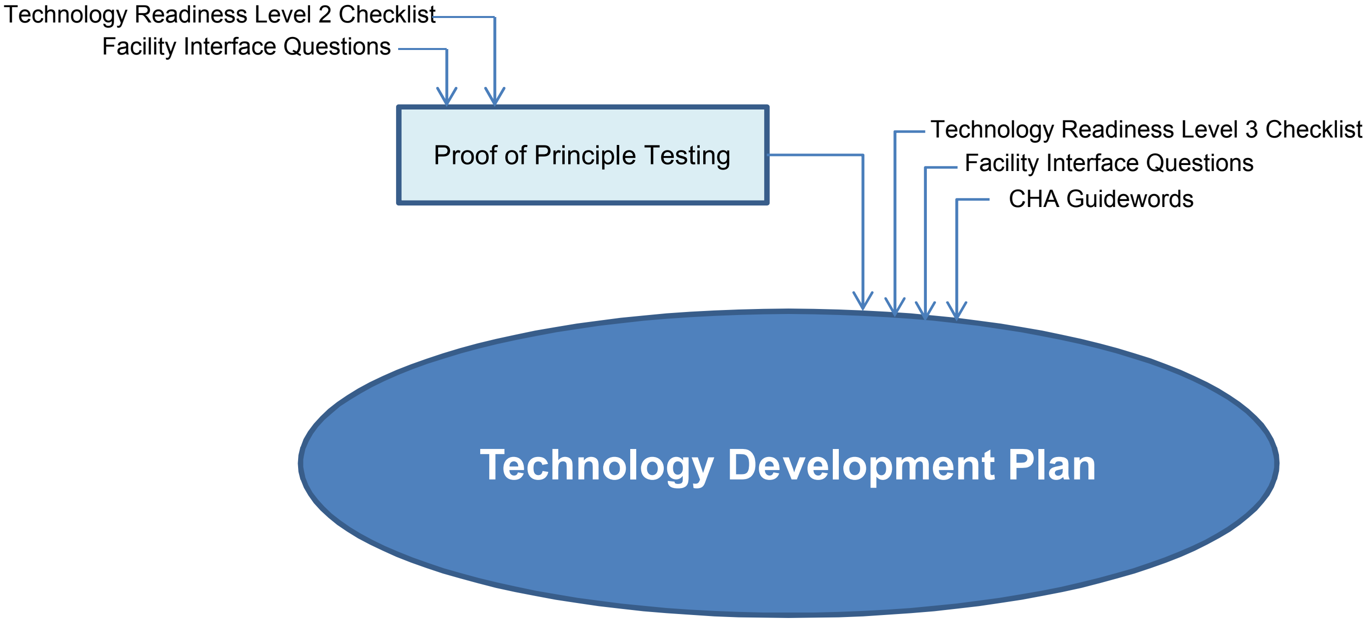
Table IV. Technology Readiness Level 3 Questions

TRL 3 Questions

1. Academic (basic science) environment.
2. Some key process and safety requirements are identified; to include compliance with DOE-STD-1189-2008.
3. Predictions of elements of technology capability validated by analytical studies.
4. The basic science has been validated at the laboratory scale.
5. Science known to extent that mathematical and/or computer models and simulations are possible.
6. Preliminary system performance characteristics and measures have been identified and estimated.
7. Predictions of elements of technology capability validated by Modeling and Simulation (M&S).
8. No system components, just basic laboratory research equipment to verify physical principles.
9. Laboratory experiments verify feasibility of application.
10. Predictions of elements of technology capability validated by laboratory experiments.
11. Customer representative identified to work with development team.
12. Customer participates in requirements generation.
13. Requirements tracking system defined to manage requirements creep.
14. Key process parameters/variables and associated hazards have begun to be identified; to include compliance with DOE-STD-1189-2008.
15. Design techniques have been identified/developed.
16. Paper studies indicate that system components ought to work together.
17. Customer identifies technology need date.
18. Performance metrics for the system are established (What must it do).
19. Scaling studies have been started.
20. Current manufacturability concepts assessed.

All of the inputs are then integrated into the Technology Development Plan.

Figure 2. Technology Development Plan



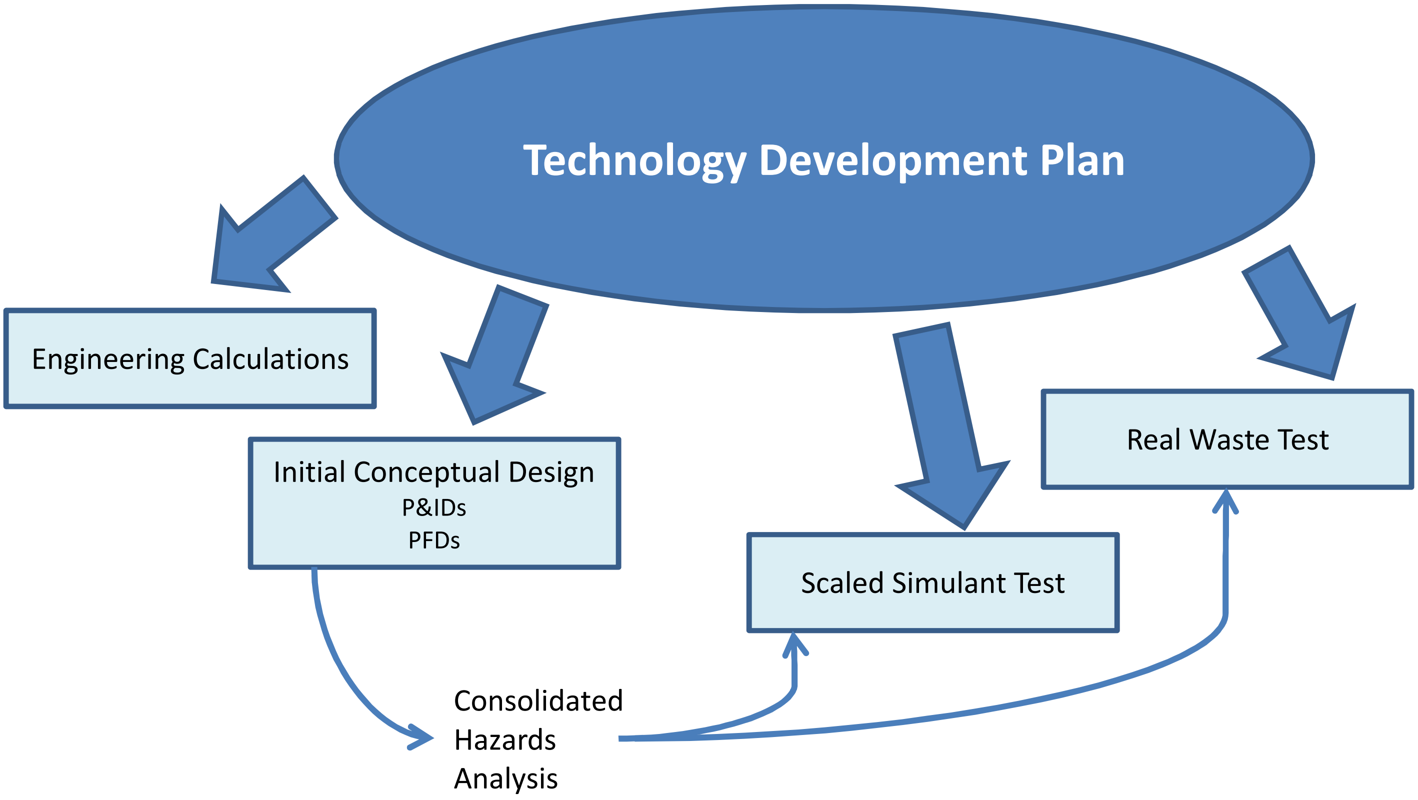
Not all of the issues and questions raised during the Technology Development Plan definition are solved by testing. Some can be solved by engineering calculations or the design evolution; therefore, the Technology Development Plan should show how the team intends to resolve each issue. An example from the Enhanced Chemical Cleaning Technology Development Plan is shown below in Table V. [5]

Table V. Risk, Gap and Resolution for Enhanced Chemical Cleaning

Location/ Unit Op	Project Risk	Roadmap Tech. Gap	Critical Technology	Mitigation/ Resolution
Treatment Tank	sludge different than forecast, Risk 18	Dissolution/removal of solids, Gap 1.A	dissolution/removal of solids, CT#1	Mitigation - increased understanding through studies, Efficacy Testing (complete), Hazardous Simulant Testing & Real Waste Testing
	dissolution does not support performance assessment, Risk 28			
	atypical dissolution at startup, Risk 58			
	unacceptable tank damage from corrosion, Risk 38	tank corrosion, Gap 1.C		Resolution – through Hazardous Simulant (corrosion) Testing documented in SRNL corrosion report (Ref. 20)
	overall bulk gas generation exceeds tank vent	ventilation overpressurization, Gap 1.D		Resolution – Engineering Evaluation with Hazardous Simulant Testing, corrosion data and offgas analysis (Ref. 19&20)
	flammability becomes a concern	hydrogen generation, Gap 1.E		Resolution – Engineering Evaluation based on Hazardous Simulant (corrosion) Testing data (Ref. 20)
		Criticality Gap 1.F		Resolution - Planned F-Area NCSA, H-Area NCSE (Ref. 24)
Transfer Line	degradation of hose, Risk 37	hose-in-hose degradation, Gap 2.A		Resolution – through Hazardous Simulant Testing (hose) & documented by SRNL
Decomposition Reactor		destruction of oxalates, Gap 3.A	destruction of oxalates, CT#2	Resolution - through Efficacy Testing (complete), Hazardous Simulant Testing & Real Waste Testing
	ozone destruction in offgassing, Risk 35			Resolution - through requiring safety related equipment based on PCHAP
Deposition Tank		secondary oxidizer, Gap 4.A		Resolution - evaluated as part of Hazardous Simulant (corrosion) Testing documented in SRNL corrosion report
	solubility of actinides,	criticality/actinide solubility, Gap 4.B		Resolution - through Real Waste Testing documented in SRNL solubility report
	unacceptable tank damage from corrosion, Risk 38	tank corrosion, Gap 4.C		Resolution - through Hazardous Simulant Testing documented in SRNL corrosion report
	oxalate impact on downstrream facilities, Risk 30	processabilitysettling, Gap 4.D		Resolution - through Real Waste Testing, with noted rheology changes documented in SRNL technical report
	Overheating of Tank			Resolution – Design Requirement to show acceptability

The Technology Development Plan will lead to several different outputs as shown below.

Figure 3. Technology Development Plan Outputs



Although the TRA guide recommends 1/10 engineering scale to advance the technology readiness level, this scale of testing is usually cost prohibitive for simpler technologies. Basing the simulant test design on P&IDs and PFDs from early conceptual design becomes very important as balance against smaller scaled tests. Having an initial consolidated hazards analysis that can inform the test design is also an important consideration because safety controls can drive large costs. The simulant used should also be carefully considered. Are the chemical attributes of the simulant more important than the physical attributes for the technology to be tested? For radioactive processes, a test using real waste from the plant is also used to compare to simulant test data. The parameters to be used for comparison purposes must be carefully reviewed since the real waste test design is usually limited by available space to perform the test. If the comparison holds, then confidence in the simulant data is increased. Data from the tests may be used to complete the design. These interfaces among the various outputs can get rather complicated. A logical schedule should be developed to integrate the various parts of the Technology Development Plan.

A clear picture of the continued viability of the technology should develop after the tests are completed, engineering calculations are issued and design is approved. High level costs and schedules can be developed from the available information. While there are always open questions at this point in technology development, risk profiles can be developed. If risks are acceptable and cost/benefit analysis is favorable, then business decisions can be made to proceed with a project or not.

CONCLUSION

This model for technology development integrates several tools and activities to provide a logical method for maturing new ideas and technologies. It provides a framework to develop a good idea into a full up design/build project. This model defines a set of integrated tasks to mature the technology and define scope, cost and schedule necessary to make business decisions for implementing technology development.

REFERENCES

1. Technology Readiness Assessment Guide, DOE G 413.3-4A, 9/15/2011, U.S. Department of Energy, Washington, D.C.
2. Waste Acceptance Criteria, Waste Compliance Plan, and Special Waste Compliance Plan, S4-ENG.08, 9/27/2010, Savannah River Remediation, Aiken, SC.
3. Impact of KTPB destruction on DWPF
4. Consolidated Hazards Analysis Process Program and Methods, SCD-11, 6/30/2011.
5. Ketusky, Combined Technology Development Roadmap and Maturation Plan for Enhanced Chemical Cleaning, SRR-TR-2010-00020, 3/15/2010, Savannah River Remediation, Aiken, SC.