Network of National Laboratories for

NNLEMS

Environmental Management and Stewardship

# R&D Roadmap for Hanford Tank Waste Mission Acceleration

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U.S. DEPARTMENT OF ENERGY

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# Executive Summary

In June 2021, the Department of Energy (DOE) Office of Environmental Management (EM) chartered the Savannah River National Laboratory (SRNL), as the DOE-EM's Corporate Laboratory, to lead a team of experts from the Network of National Laboratories for Environmental Management and Stewardship (NNLEMS), academia, and industry to conduct an evaluation of the Hanford tank waste treatment mission and develop a Research & Development (R&D) Roadmap for accelerating the mission. The R&D Roadmap may be used to request additional budget for EM Technology Development (TD) initiatives for fiscal year 2024 and beyond.

Key considerations in the development of the R&D Roadmap include:

- The continuing escalation of cost and time to complete tank waste treatment and closure necessitates new technology improvements to deliver timely risk reduction for the surrounding Hanford communities, site workers, the nation, and the environment. Pursuing technological advances will give decision makers more options, some potentially game changing.
- Given the remaining duration of the Hanford tank waste mission (>50 years), the R&D program should have a diversified investment portfolio that includes opportunities to reduce the risk of achieving the existing baseline without additional escalation of cost and schedule; incremental improvements to the existing baseline that could have significant impacts on the schedule; and transformational technologies that would require additional time to mature, including fundamental research to develop potentially game changing technologies that are presently unknown.
- Alternate technical approaches may be beneficial without increasing the technical risk but may require significant stakeholder engagement and regulatory negotiations and appropriate regulatory document changes in order for the technology to be implemented.
- The NNLEMS team assumes that DOE Manual 435.1-1, *Radioactive Waste Management Manual*, and subsequent DOE Directives, will be applied to selecting disposition paths for the Hanford tank farms' wastes.
- Flexibility in the treatment options or flowsheet is needed, including consideration for treatment strategies by tank farm, matching the hazards of the constituents of concern with potential at-tank or modular options to avoid the need for cross-site transfers to the Waste Treatment and Immobilization Plant (WTP) facilities. This will require facilities that can be retrofitted with new technology (i.e., modular in nature) or new smaller facilities to be built.

Road mapping evaluations indicate that significant schedule and life cycle cost savings could be achieved by transitioning from the current baseline which requires expensive infrastructure to treat the majority of the Hanford tank waste to a vitrified waste form for disposal in a high-level waste (HLW) geological repository or on-site disposal at the Integrated Disposal Facility (IDF) to options that would allow treatment of waste based on the selected disposition path, including use of at-tank or modular options and non-vitrified waste forms that require less expensive treatment facilities/processes. The envisioned resulting shift from the current baseline to an accelerated mission plan supported by R&D is shown in Figures ES-1 and ES-2.

Figures ES-1 and ES-2 represent the baseline and the NNLEMS recommended R&D-enhanced roadmap for the Hanford tank mission, respectively. Both of these figures depict the Hanford tank waste treatment system as "railway station" maps with sets of "tracks" leading from the Hanford tanks in their current state to completion of the Hanford tank waste mission with closed tanks and the waste processed for disposal sites (the "engine barn" at the top of the figure). The multiple colored "tracks" represent the multiple types of waste that must be processed to complete the mission. The thickness of the tracks in Figure ES-2 is a relative representation of the amount of the material processed via that disposal route compared to the baseline quantities depicted in Figure ES-1. The number of dollar signs depicted at the end of each waste track indicate the relative magnitude of the cost for that pathway (i.e., the sum of the waste volume times the costs of processing and disposal). Figure ES-2 depicts four mission level decisions (shown as major switching stations represented by the symbol). Each of these decision points is informed by an R&D portfolio containing key R&D areas (shown as "train stops" depicted by ○), which inform the decision. In many cases, further improvements to an individual waste track will be provided by additional R&D initiatives, following the decision point depicted by the solid "train stops" (●). The relative timing of when the decisions will be made are not reflected by their location on the roadmap. The NNLEMS team evaluated >300 potential R&D ideas, functionally grouped and screened the ideas, and ultimately arrived at the 35 recommended R&D areas depicted in Figure ES-2 based on expert elicitation expected to have the greatest benefit in cost and schedule reduction.

Multiple paths can be taken to complete the Hanford tank mission. These will be dependent on DOE's decision on the technology R&D portfolio to implement; the success of the R&D projects; and the mission level decisions that DOE chooses to pursue. They impact the amount of waste generated for each disposal facility as well as the types and sizes of waste processing facilities needed for each waste stream, and, therefore, the selection of the R&D portfolio needed to reach a mission endpoint. Based on these multiple paths and the objective of schedule acceleration, cost savings, and risk reduction, the NNLEMS team recommends the R&D portfolio depicted in Figure ES-2.

Mission level Decisions that impact the savings that can potentially be achieved by R&D technologies will be made by DOE in consultation with its regulators and with stakeholder input, as appropriate. An estimated time of implementation is provided but, in all cases, making these decisions earlier may help in long-term planning and potentially in schedule and cost savings. The decisions include:

- Selection of waste forms for low-activity waste (LAW) - The present baseline requires vitrification of HLW and LAW. Alternative waste forms, such as grout, could enable opportunities to accelerate the overall tank waste schedule and reduce budget requirements by enabling less expensive infrastructure and disposal options. The implementation time frame is ~2025 - 2035 based on the AoA or the Supplemental LAW decision.
- Pretreatment infrastructure to efficiently meet mission needs - At tank or near-tank pretreatment options could reduce the size/costs of pretreatment facilities and potential HLW vitrification throughput requirements reducing costs and accelerating the schedule. The implementation time frame is ~2025 - 2035 to meet the HLW Facility start date.
- Tank Utilization - Actively maintaining and repairing DSTs for extension of life and use for waste preparation co-located at or near tanks could minimize the need for cross-site transfer lines and construction of new double shell tanks. The implementation time frame is ~2030 - 2050 based on the HLW AoA needs.
- Disposition of transuranic (TRU) waste - The current disposition path for a limited set of tanks is stabilization and disposal in the Waste Isolation Pilot Plant (WIPP). However, permit changes

will be required at WIPP for this to occur. An alternative option is to grout the wastes, producing a non-TRU stabilized waste form that can be disposed as low-level waste. Either option could minimize the need for new transfer lines and expensive infrastructure upgrades required to process the waste through WTP. The implementation time frame is ~2040 - 2050 based on current system planning and informed by the Supplemental LAW waste form decision.

As noted above, key R&D areas identified to support implementation of the Roadmap are shown in Figure ES-2. Each R&D area is color coded consistent with the colors of the waste tracks they support. Investments are needed in waste retrieval, characterization, transport, and closure; waste pretreatment; waste immobilization; and secondary waste treatment R&D to reduce costs and schedule for the Hanford tank waste treatment program. In addition, seven mission enabling R&D areas that crosscut the entire Roadmap have been identified for investigation. R&D areas that begin before the mission decisions are made should be used to inform these decisions.

At the request of DOE, the team also identified “quick win” ideas that could help advance the near-term Hanford mission and could be initiated should funding become immediately available. Five areas were identified, taking into consideration the Office of River Protection (ORP) Grand Challenge proposal concepts and the Washington River Protection Solutions (WRPS) Technology and Innovation Roadmap. The five areas recommended for Quick Win funding include:

- LDR Organics Characterization and Removal/Destruction
- Development of Sludge Preparation Tanks At- or In-Tank
- Tank Life Extension to Support Mission Acceleration and Completion
- Single Shell Tank (SST) Retrieval Infrastructure to Enable Flexible, Timely Waste Mobilization
- Sample Reduction using Material Balance and Real-Time, In-Line Monitoring Approaches for HLW Applications

As part of the charter, DOE requested the team to provide recommendations for implementation of the roadmap. This R&D Roadmap and its integration with previous efforts, including the WRPS Technology and Innovation Roadmap, will serve as the foundation of a balanced portfolio of short- and long-term projects with consideration of both risk and reward. It is recommended that a competitive technology development program (CTDP) process, described below, be implemented and managed by DOE that could result in a balanced R&D portfolio that can evolve as the R&D needs evolve. Further, the development and funding of targeted, long-term research programs is recommended to enable both incremental and transformational approaches to reduce remediation costs and schedule, technical uncertainty, and overall risk. The DOE program funding profile and DOE priorities will dictate the timing and sequencing of R&D projects.

The R&D Roadmap will likely require continuous monitoring and feedback to ensure that Hanford needs are addressed, and that the roadmap informs and enables DOE’s broader goals. Ideally, the R&D Roadmap would be combined with any Hanford Tank Waste Mission roadmaps and be updated on an annual basis, as major technologies are deployed, and/or flowsheet changes are implemented. While the Hanford Tank Waste Mission objective is unlikely to change, feedback from operational systems and newly identified operating issues may arise as seen, for example, with the Savannah River Site tank waste operating mission and the Integrated Waste Treatment Unit sodium bearing waste project at

Idaho. Additionally, changes in federal or state regulations may also warrant revising the roadmap R&D portfolio.

To facilitate transparency and an understanding of the future goals of DOE with the R&D Roadmap, it is recommended that DOE hold an initial open discussion of the R&D Roadmap for the public, either in person or virtual and recorded for further dissemination, with annual public discussions of updates thereafter. A website could also be established with R&D Roadmap information and updates for access by the public to include a contact for those with access restrictions.

In summary, this deliverable includes a portfolio of proposed investments, an overview of the reviewed information, the technology evaluation and selection process, a preliminary cost/benefit analysis of the proposed R&D areas, and a concept for a technology development program for implementation and sustainment of the Hanford Tank Waste Mission R&D Roadmap. Based on the NNLEMS team's initial evaluation and its recommendations for the outcomes for the mission level decisions, implementation of the activities in the proposed R&D roadmap and the deployment of associated technologies has the potential to produce >$150 billion in savings and reduce the mission by 10-20 years. Partial implementation will result in a less significant but still beneficial reduction.

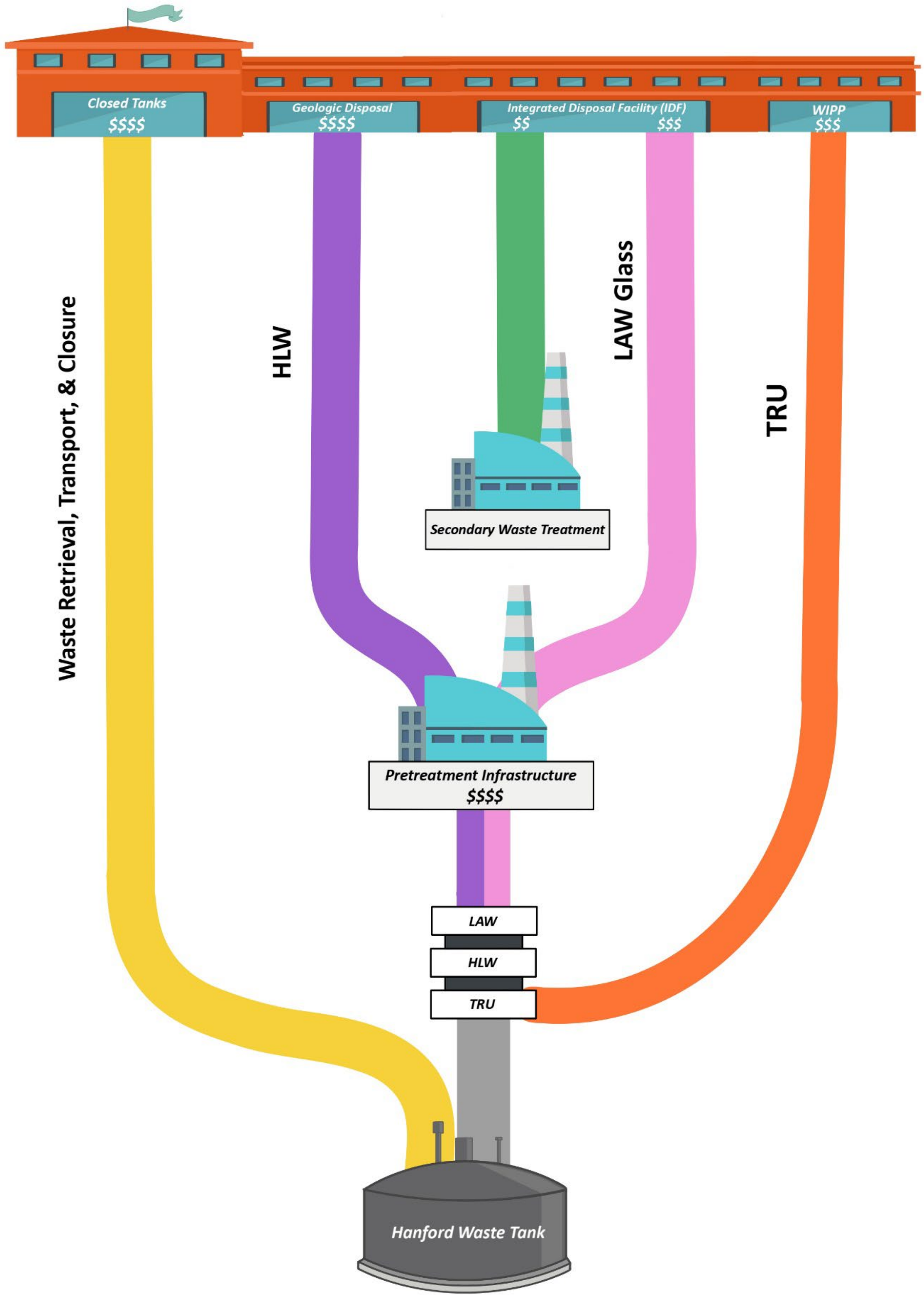
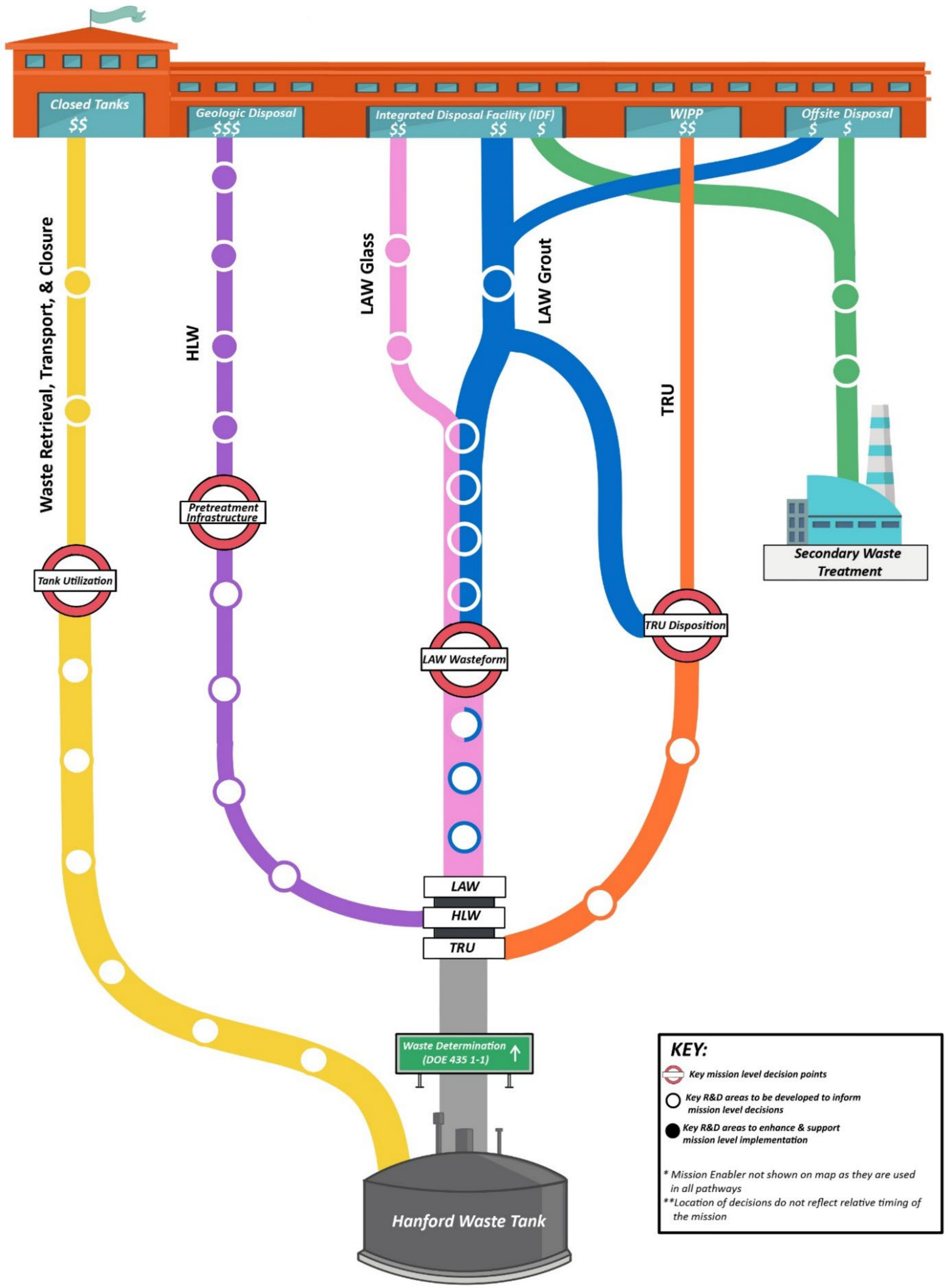



**Figure ES - 1. Baseline Hanford Tank Waste Mission Roadmap**




*Waste Retrieval, Transport, & Closure*

- Increase volume available for tank storage
- Dry waste characterization, monitoring, & retrieval technologies
- Process automation and feedback of monitoring and retrieval technologies
- Risk-based waste retrieval sequencing
- Formulate & install barriers targeted for constituents of concern at tanks or disposal site with active monitoring
- Improved methods to detect/repair leaks for storage tanks
- Improved sampling methods for double shell tanks
- Advanced in-situ characterization methods coupled with improved performance assessment models

*Waste Pretreatment*

- In-tank pretreatment of high level waste sludge
- At-tank pretreatment of high level waste sludge
- RCRA organics removal from tank supernate
- Increased solids concentration during waste processing with water management
- Improved understanding of aluminum chemistry to optimize sludge processing
- Improved supernate filtration processes
- Additives to optimize filtration
- Sodium nitrate separation or destruction technologies
- Plutonium/actinide removal from supernate

*Waste Immobilization & Disposal*

- Cementitious materials development to improve long-term performance
- Improved high level waste glass formulations
- NOX management through sludge washing or offgas abatement
- Improved transport models/performance assessments for waste forms
- Improvement to high level waste glass melter design & throughput
- Waste dewatering/dried waste form

*Secondary Waste Treatment*

- Improved grout waste forms
- Iodine separation in liquid phase
- Iodine separation in gas phase
- Technetium separation technologies
- Process intensification/automation of Effluent Treatment Facility

*Mission Enablers*

Improved equipment decontamination/ disposal options
Real time monitoring for liquid process feeds
Develop system model for infrastructure & technology cost evaluation
Optimize cesium loading on crystalline silicotitanate ion exchange media
Improved offgas treatment/abatement for key air toxics
Alternative disposal options for crystalline silicotitanate ion exchange media
Remote/automated systems

**Figure ES - 2. NNLEMS Team R&D Enhanced Hanford Tank Waste Mission Roadmap**

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## Acronyms

| | |
|---|---|
| ARPA-E | Advanced Research Project Agency - Energy |
| AoA | Analysis of Alternatives |
| BES | DOE Office of Basic Energy Sciences |
| CRESP | Consortium for Risk Evaluation with Stakeholder Participation |
| CTDP | Competitive Technology Development Program |
| DWPF | Defense Waste Processing Facility |
| DFHLW | Direct Feed High Level Waste |
| DFLAW | Direct Feed Low Activity Waste |
| DOE | Department of Energy |
| DL | Disposal Location |
| DST | double shell tank |
| EFRC | Energy Frontier Research Centers |
| EM | DOE Office of Environmental Management |
| EM-1 | Acting Assistant Secretary for Environmental Management |
| ETF | Effluent Treatment Facility |
| FFRDC | Federally Funded Research and Development Center |
| HLW | high level waste |
| IF | Infrastructure & Maintenance |
| IDA | Institute for Defense Analyses |
| IDF | Integrated Disposal Facility |
| INL | Idaho National Laboratory |
| IM | Immobilization |
| IWTU | Integrated Waste Treatment Unit |
| LANL | Los Alamos National Laboratory |
| LAW | Low Activity Waste |
| LAWPS | Low Activity Waste Pretreatment Facility |
| LDR | Land Disposal Restrictions |
| LDRD | Laboratory Directed Research and Development |
| LERF | Liquid Effluent Retention Facility |
| NAWI | National Alliance for Water Innovation |
| NNLEMS | National Network of Laboratories for Environmental Management and Stewardship |
| NDE | Non-destructive Evaluation |
| ORNL | Oak Ridge National Laboratory |
| ORP | Office of River Protection |
| PA | Performance Assessment |
| PNNL | Pacific Northwest National Laboratory |
| PRDs | priority research directions |
| PT | Pretreatment Facility |
| PL | Pretreatment – Liquids |
| PS | Pretreatment - Solids |
| PUREX | Plutonium Uranium Extraction |
| RCRA | Resource Conservation and Recovery Act |
| RD&D | Research, Development, and Deployment |
| RFP | Request for Proposal |

| | |
|---|---|
| RRP | Hanford River Protection Project |
| R&D | Research and development |
| SNL | Sandia National Laboratory |
| SRNL | Savannah River National Laboratory |
| SRS | Savannah River Site |
| SW | secondary waste |
| SST | single shell tank |
| TC | Tank Closure |
| TRU | Transuranic Waste |
| TSCR | Tank Side Cesium Removal |
| TWCS | Tank Waste Characterization and Staging |
| WIR | Waste Incidental to Reprocessing |
| WIPP | Waste Isolation Pilot Plant |
| WR&T | Waste Retrieval & Transfer |
| WT | waste tank |
| WTP | Waste Treatment and Immobilization Plant |
| WM | water management |

# Acknowledgment

In addition to the team members signatories outlined above, the contributions of the expanded team were greatly appreciated and allowed for a more complete product. The following experts and their affiliated institutions are acknowledged:

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# Background

The Department of Energy (DOE) Environmental Management (EM) mission is to "address the nation's Cold War environmental legacy resulting from five decades of nuclear weapons production and government-sponsored nuclear energy research". This entails the complete and safe cleanup of legacy waste and contamination resulting from nuclear weapons development and testing, as well as government-sponsored nuclear energy research. Life-cycle projections for the tank waste treatment, disposition, and facilities remediation mission for DOE-EM represent the largest fraction of the EM liability. With respect to the Hanford mission, the Hanford River Protection Project (RPP) (including retrieval, treatment, and disposition of the tank waste) represents a large fraction of EM's remaining liability. Treatment operations at Hanford commenced in 2022 and are expected to extend into the latter part of the century.

To reduce the EM mission duration and reduce the overall costs, the Senior Advisor for Environmental Management (EM-1) tasked the Network of National Laboratories for Environmental Management and Stewardship (NNLEMS) in June 2021 to conduct an evaluation of the tank waste mission at the Hanford site and to develop a Research & Development (R&D) Roadmap for accelerating the mission. This tasking required the NNLEMS team to "evaluate the existing tank waste program, as well as past proposals for program acceleration, in addition to developing independent proposals to accelerate the tank waste mission." The charter requested "recommendations that included proposals to more efficiently retrieve and treat the tank waste, efficiently implement various immobilization technologies, and efficiently disposition the treated waste" while "accounting for regulatory requirements and agreements" for the proposed alternative approaches. Figure 1 depicts an overview of the Hanford tank waste mission facilities and process operations.

SRNL, as EM's Corporate Laboratory, is the lead for the chartered team and has been responsible for the overall coordination and direction of team activities. The review has been performed by a core team of NNLEMS leadership with direct access to key Subject Matter Experts (SMEs) from the NNLEMS, academia, and industry. These SMEs retain considerable expertise in radioactive liquid waste retrieval, treatment, immobilization, disposition, closure, and associated enabling technologies. Additionally, a few experts from academia and national laboratories with experience outside of the DOE-EM were included on the team to obtain a broader technology perspective. The participants on the review included: Idaho National Laboratory (INL), Los Alamos National Laboratory (LANL), Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), Sandia National Laboratory (SNL), Longenecker & Associates, TechSource Inc., Institute of Defense Analysis (IDA), University of Georgia, Consortium for Risk Evaluation with Stakeholder Participation (CRESP), Florida International University, and Orano Federal Services.

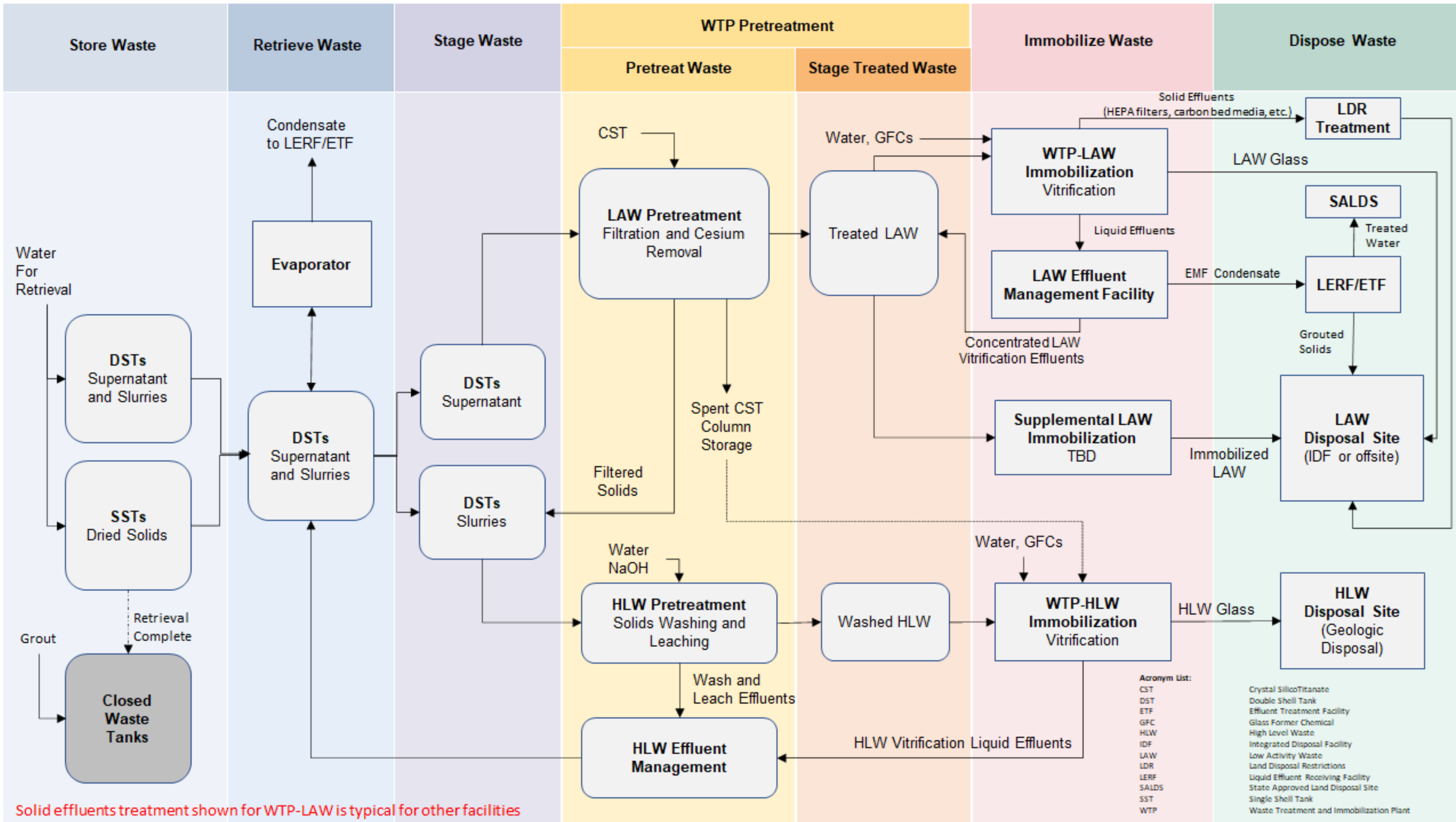



**Figure 1: Hanford Tank Waste Mission Flowsheet and Process Flows**

Given the breadth of the Hanford Tank Waste mission, individual focus area teams were formed, and a lead named for each area from the core NNLEMS laboratories. The technical focus areas included the following:

- Tank Waste Retrieval
- Pretreatment/Feed Preparation
- Immobilization Formulation and Processing
- Waste Disposal
- Regulatory Compliance
- Flowsheet Cost and Schedule Analysis
- Enabling Technologies
  - Process Automation
  - Characterization
  - Robotics
  - Corrosion/Erosion
  - Modeling and Simulation
  - Process Intensification

The team members, their affiliation, and the respective focus areas are provided in Attachment 1. The Hanford NNLEMS team coordinated closely with the Federally Funded Research and Development Center (FFRDC) National Defense Authorization Act (NDAA) Section 3125 analysis of approaches to Supplemental Treatment of Low Activity Waste (LAW) to ensure that applicable strategies developed are considered during this study. Several of the team members participated in both efforts. While focus area teams were formed, frequent communication and cross-communication was held across the focus area teams and within the core team to ensure the system and processing implications of technologies and strategies were well understood across the Hanford tank waste mission. The team also worked closely with the Federal Steering Committee, which includes representatives from the Office of River Protection (ORP), DOE-EM Technology Development Office, the DOE-EM Office of Budget and Planning and the DOE-EM Laboratory Policy Office, to ensure consistency with the integrated technology development program for the EM complex. The charter for the effort is provided as Attachment 2.

# Approach

The review team performed the evaluation in three phases:

- Phase 1: Initiation and Information Gathering
- Phase 2: Development and Evaluation of Potential Technologies with Expanded SME Teams
- Phase 3: Risk-Based Ranking of Concepts and Reporting

A brief explanation of the efforts involved in each phase and key findings and recommendations from each phase are included in the following sections.

## Phase 1 – Initiation and Information Gathering

Many studies and proposals have been generated over the years to provide alternative treatment plans and flowsheets for the Hanford Tank Waste mission. Phase 1 focused on a review of these prior studies and proposals by the core team members to gain an understanding of what has been previously proposed and the potential technology limitations. A kick-off meeting with DOE-EM and ORP leadership allowed the team to understand the current baseline and potential flowsheet modification being pursued for the Hanford River Protection Project and tank waste treatment goals.

Through these efforts, the team gained insight into bottlenecks and previously identified alternative strategies and technologies. Technology advancement and/or new processing knowledge could allow previously evaluated and eliminated options to be reconsidered for this effort. In some instances, past proposals to accelerate the Hanford Tank Waste mission have not been feasible due to regulatory or safety basis concerns. As part of this review, the team identified historical processes or policies that have limited implementation, for discussion with the DOE Steering Team to determine whether new technologies, strategies, or scientific bases exist to provide suitable mitigation approaches to alleviate concerns. An example of a regulatory process is classification and disposal of tank waste under DOE Manual 435.1-1. The NNLEMS team assumed for this evaluation that the current DOE Directive would be applied to dispose of some tank wastes as non-HLW. It is also important to note that Hanford is already implementing DOE Manual 435.1-1 through the Waste to Incidental to Reprocessing (WIR) for LAW, after removal of the cesium. A safety basis example is radiolytic hydrogen generation, which must be considered as a limiting concern in planning for and conducting tank waste disposition. Thus, increasing the understanding of the gas generation mechanism, as well as the rate of release, or improving the detection methods for its presence could reduce some of the conservatism throughout the flowsheet. Understanding how these types of changes can impact technology selection throughout an extended mission is essential to successful implementation of a R&D roadmap designed to accelerate the mission.

As part of the review, the team considered the applicability of technologies to the different types of waste to be treated (e.g., HLW, LAW, Transuranic (TRU) waste, and Secondary wastes) and potential flowsheets and facilities required for their treatment even if not in the baseline Hanford tank waste treatment plan. The documents reviewed as part of this effort are provided as a bibliography in Appendix A.

The gaps, potential barriers, suggested technologies and processing strategies, and potential bottlenecks collected during this background review are captured in Table A - 1 in Appendix A. A designator is provided for the applicable waste type and potential technical focus area. From the information, the core team determined the most viable alternatives, strategies, and/or flowsheets based on their expert opinion. Throughout the development of the R&D Roadmap, the team ensured all ideas were captured even if they were not considered candidates for R&D at the time. This will allow ideas to be revisited should breakthrough or game-changing technologies be discovered in the future.

From this information, the team surmised the following observations and assumptions:

- Processing scenarios reviewed in background documents do not provide acceptable closure end dates within the current funding constraints.
- Issues facing the acceleration of the Hanford Mission are not only technical, but also budgetary, political, and regulatory in nature.
  - Currently, expected near-term budgets appear to restrict the ability to develop and implement technologies and approaches that would achieve reductions in life cycle costs and mission.
  - Alternate technical approaches have the potential to have lifecycle cost benefits without increasing the technical risk but may require significant regulatory negotiations and stakeholder engagement. Therefore, several mission level decisions have been identified pending advancement of technical maturity and resolution of identified concerns.
- Given the duration of the mission (>50 years), R&D scope necessitates a long-term, high risk/ reward component, which will require facilities that can be retrofitted with new technology (i.e., modular in nature) or new smaller facilities to be built.
  - Flexibility in the treatment options or flowsheet should allow waste removal and treatment to proceed while solutions for more technically challenging wastes are pursued. This should include consideration for treatment strategies by tank farm matching the hazards of the constituents of concern with potential at-tank or modular options to avoid the need for cross-site transfers to the Waste Treatment and Immobilization Plant (WTP) facilities. This would have the secondary benefit of mitigating throughput impacts on these facilities that have been predicted to occur throughout the Hanford mission.
  - New right-sized blending/staging tanks could improve throughput and lessen the reliability on existing double shell tanks (DSTs), which is currently a regulator concern.
- Based on operational experience at the Savannah River Site (SRS), the Hanford System Plan evaluations, and the limited evaporative capacity for the tank waste mission, additional evaporator capability and/or effluent management strategies will be needed for the mission.

The core team identified four critical DOE Mission Level Decisions that the team believed would allow staged improvements to the Hanford Tank Waste Mission if partially implemented and accelerate the mission if fully implemented. These decisions would be made by DOE and informed by the R&D Roadmap. Discussions with federal state, local, and tribal officials, as well as members of the public should be considered as part of the framework for the tank waste mission based on engagement with these entities. The decisions, baseline mission, proposed improvement, implementation time frame, the tie for implementation, and the enhanced end state resulting from the decision are shown in Table 1. To reap the greatest benefit, these decisions should be made as soon as possible but the team recognizes the need for engagement and negotiations, as well as potential science and technology development to inform the decisions. Therefore, the implementation time reflects the tie to a decision on facility construction or modification or an existing WTP milestone.

**Table 1: Critical DOE Mission Level Decisions**

| Mission Level Decisions | Baseline | Proposed Improvement | Implementation Time Frame | Tie for Implementation | Enhanced End-state |
|---|---|---|---|---|---|
| Selection of Waste Form for Low Activity Wastes | Glass for DFLAW with on-site disposal; Glass for Supplemental LAW (SLAW) with on-site disposal | Allow non-vitrified waste forms for treatment of Supplemental LAW for on-site and/or off-site disposal | 2025 - 2035 | Enable early West area treatment and SLAW treatment coupled with HLW start-up | Optimized amount of LAW grouted & disposed of on-site consistent with the preliminary FFRDC NDAA Section 3125 study |
| Pretreatment Infrastructure | Pretreatment (PT) Facility is completed with WTP technical issues resolved | Co-locate waste pretreatment at or near tanks to be emptied and closed | 2025-2035 | Sludge preparation capability needed to start HLW Facility | Pretreatment functions brought on-line sooner and at lower costs |
| Tank Utilization | Monitor DST integrity for retrieval & feed staging; Use Waste Receipt Facilities (WRF) for cross site transfers | Actively maintain & repair DSTs for extension of life and use for feed preparation co-located at or near tanks being emptied | 2030-2050 | Feed preparation at tank needed to start HLW and WRFs needed to treat B&T Tank Farms | Minimized need for cross-site transfer lines, WRFs, and new DSTs |
| Disposition of TRU tank wastes | TRU waste from a limited set of tanks dried/packaged for disposal at WIPP | Waste from a limited set of tanks grouted & disposed off-site as LLW | 2040-2050 | Significant infrastructure required for B&T Tank Farm treatment | Optimized amount of LLW grouted & disposed of on-site; Minimized need for cross-site transfer lines and infrastructure upgrades; WIPP permit modification avoided |

## Phase 2 – Development and Evaluation of Potential Technologies with Expanded SME Teams

### Generation of Expanded List of Gaps / Opportunities / Concepts

The expanded team met virtually due to COVID restrictions on August 30 – September 1, 2021. The initial list of barriers, gaps, and ideas were shared with the expanded team of SMEs for consideration and to allow for a focused brainstorming effort. In addition, a structured flowsheet/technology evaluation process was used and involved a systematic review of the functional areas and unit operations of the Hanford tank waste mission with consideration for the types of wastes to be treated. This cross-discipline meeting allowed for system interactions such as potential chemical process changes to be understood across the broader tank waste system. Functional areas considered are listed in Table 2, along with the two-letter designator associated with each functional area. The functional areas were defined by the team to help group the technologies into similar technical focus areas with some representing processes and others representing end states or necessary strategies to complete the mission.

**Table 2: Hanford Tank Waste Mission Functional Areas for Technology Consideration**

| Functional Areas | |
|---|---|
| Waste Tank/Tank Farm (WT) | Immobilization (IM) |
| Waste Disposal Location (DL) | Secondary Wastes (SW) |
| Waste Retrieval and Transport (WR&T) | Water Management (WM) |
| Pretreatment for Supernate (PL) | Tank Closure (TC) |
| Pretreatment for Solids (PS) | Infrastructure Maintenance and Operations (IF) |

Potential unit operations were defined for each functional area. This enabled the identification of game-changing technologies and approaches to help accelerate the tank waste mission, as well as additional gaps and opportunities.

From this information, several re-occurring themes emerged:

- Real-time and/or in-line monitoring characterization methods could reduce sampling and analysis cycle times
- Iodine behavior (capture, retention, mass balance) in the different treatment systems has high uncertainty
- Information on Tc speciation, separation, and stabilization alternatives could improve waste form processing
- Organics treatment technology could allow flexible LAW disposition options
- Waste classification could strongly influence the final disposal locations
- Package certification will be required for most shipments off site, and on-site shipment packages are needed that comply with DOE orders
- Benefits could be gained through advancements in remote or automated processes, size reduction technologies, and the implementation of virtual reality technology to simulate processes

- Cross-site transfer of waste remains a challenge
- Methods and end point basis for retrieval of waste should be explored to minimize waste generation, reduce costs, and mitigate environmental risk
- Alternative or new low temperature waste forms should be considered or be tailored to specific constituents of concern
- Enhancements in the abatement technologies for emissions need to be considered to allow for process optimization (e.g., cycle times and operability)
- Water management challenges (minimization, re-use, evaporation, capacity) have the potential to overwhelm tank capacity and process throughput
- Engineered barriers coupled with monitoring methods could help mitigate tank, piping, or process leaks or long-term environmental risks
- Materials of construction/advanced materials/corrosion & erosion limits should continually be evaluated for implementation given the current and future rate-of-change in materials development
- Alternative technologies and means for removing workers from risk need to continue to be pursued to ensure exposure is as low as reasonably achievable.

The information was summarized in a working spreadsheet by the RPP mission functional area (see Table 2 for the functional areas). The teams identified the affected unit operation, and cross walked the ideas to other mission functional areas with similar ideas or to impacted functional areas should the idea be implemented. An initial set of over 300 ideas were identified and the complete list of the concepts, gaps, and opportunities identified by functional area is provided in Appendix B, Table B - 1 through Table B - 10. Additional information on quantification of the ideas is provided in Appendix B as well. A paired down list for further evaluation was created by combining similar concepts, gaps, and opportunities.

To understand how the ideas collected mapped to current programs underway at Hanford, an assessment was completed to cross walk the concepts collected to the WRPS Technology and Innovation Roadmap (RPP-PLAN-43988, Rev. 5). The WRPS Roadmap helps define and prioritize the current Hanford tank waste R&D programs. Additionally, the team reviewed a select list of the historical Grand Challenges to determine how the concepts connected with challenges and potential gaps identified by the SME teams. The complete list of ORP Grand Challenges was not reviewed due to the proprietary nature of some of the ideas. Details of this process are provided in Appendix B. Table 3 contains a summary of the cross walked WRPS Roadmap and Grand Challenge information with consideration of similarities between the NNLEMS teams generated ideas and the R&D areas identified in the WRPS Roadmap or previous Grand Challenges.

**Table 3: Cross-Reference of Generated Ideas to WRPS Technology & Innovation Roadmap and Select Historical ORP Grand Challenges**

| Area | Count |
|---|---|
| NNLEMS Team Ideas Similar to Funded Technology in WRPS Roadmap | 18 |
| NNLEMS Team Ideas Similar to Unfunded Technology in WRPS Roadmap | 59 |
| **WRPS Roadmap Technologies not Similar to NNLEMS Team Ideas** | **31** |
| Grand Challenge Proposals Similar to NNLEMS Team Ideas | 59 |
| **Grand Challenge Proposals not Similar to NNLEMS Team Ideas** | **7** |

The table above represents a cursory review of the WRPS Roadmap and ORP Grand Challenges indicating similarities in technical focus. However, the technical solutions for the ideas are not necessarily the same. The WRPS Roadmap by nature tends to focus on the near-term mission and enhancements to allow efficient operation as opposed to long-term game-changing investments. The Grand Challenges, on the other hand, were predominantly conceived by the national laboratories so similarities to the ideas generated by the NNLEMS brainstorming effort are not surprising. We note, however, that advancements in technology maturity since the Grand Challenge inception, which were conceived in 2013-2018, have likely occurred.

## Expansion of Ideas and Initial Screening

With this paired down list allocated by functional area, the teams expanded the generated ideas and identified similar concepts to be combined into a condensed list of ideas. This process step ensured that the gaps and opportunities were clearly identified and tied to the Hanford flowsheet with the associated proposed concepts allowing for closure of the gap or realization of the opportunity. Over 100 condensed ideas were identified with concept IDs designated with the two-letter acronym associated with the functional area. A summary of the condensed ideas is provided in Appendix C, Table C - 1 and sorted by functional area as shown in Figure 2.

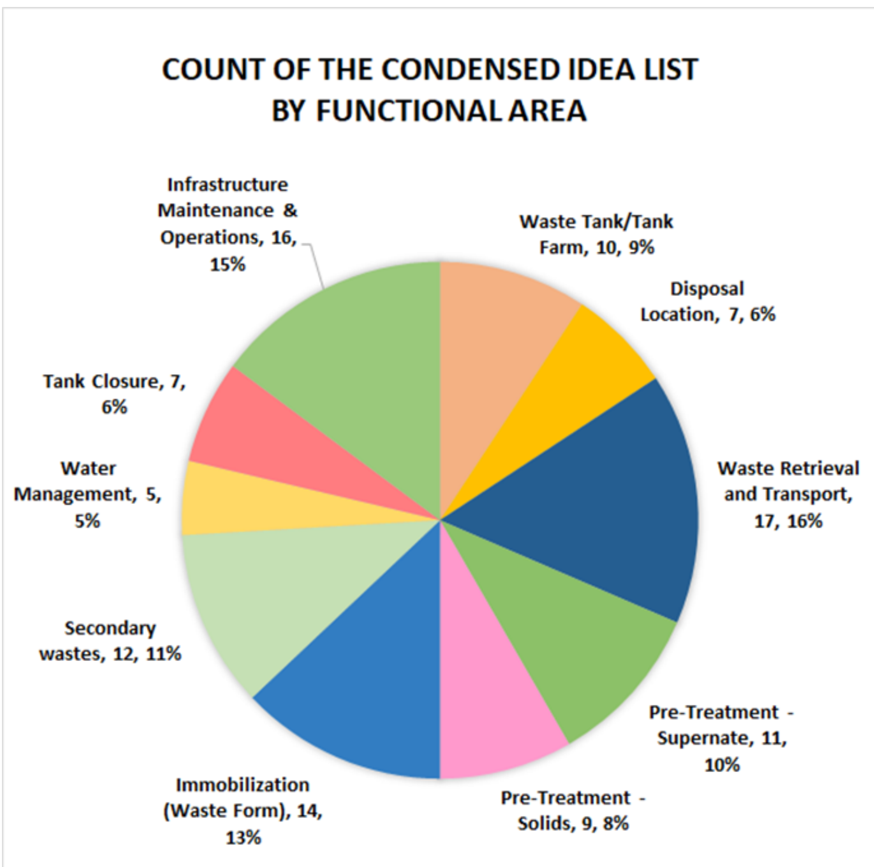



**Figure 2: Count and Percent of the Condensed Ideas by Functional Area**

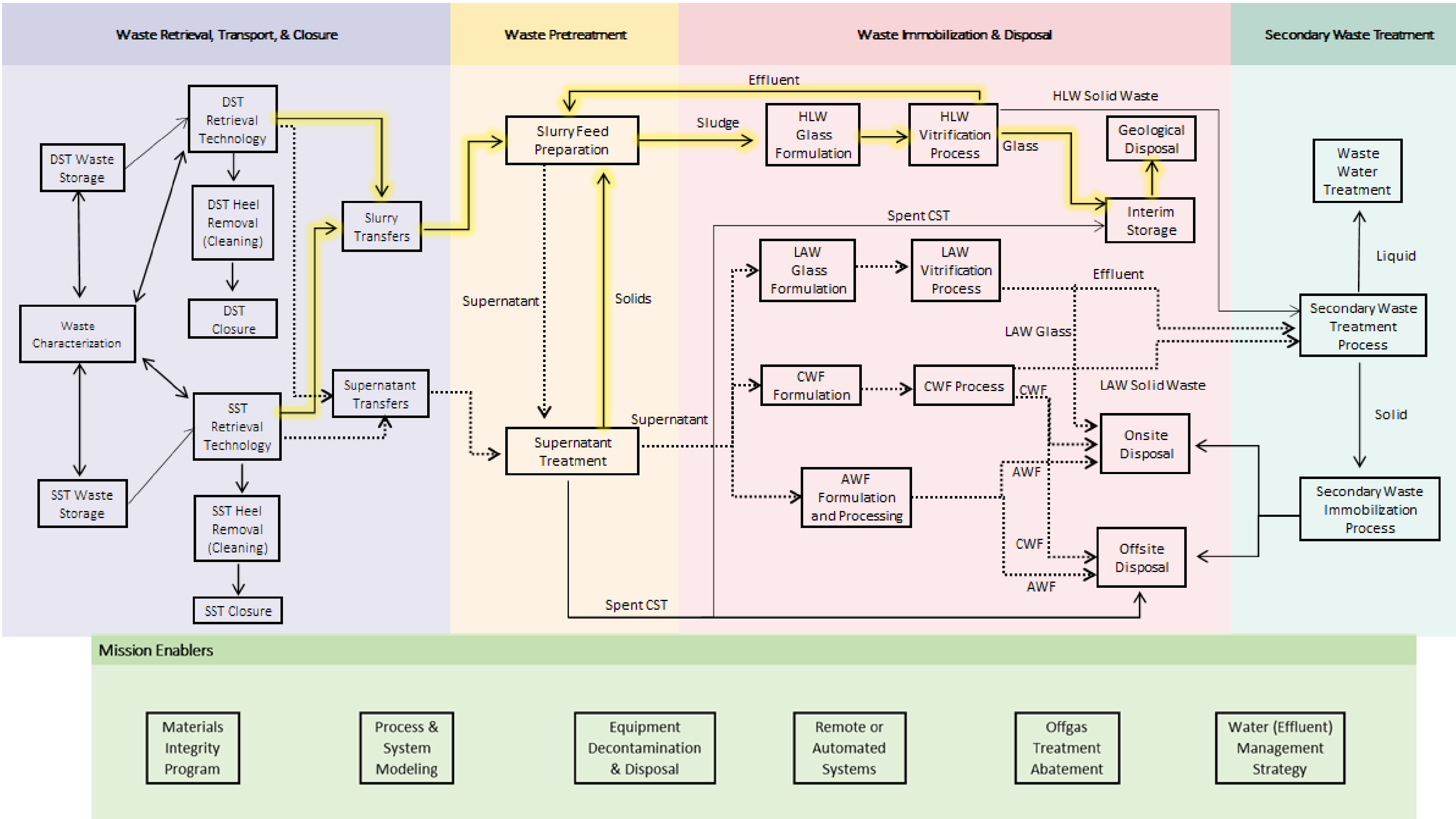
Screening criteria were created to assess the condensed ideas with the individual technical teams providing the information for screening. The individual ideas were determined to be Incremental (i.e., Project implementable in near-medium term within existing Hanford program) or Transformational (i.e., Project either not implementable within Hanford program or long-term to realize). At the start of Phase 2, ~300 ideas consisting of technologies, gaps, and opportunities were generated by the expanded team. These ideas were condensed into ~100 broader concepts to resolve the gaps and opportunities. The SME teams assessed each concept against the screening criteria emphasizing the potential for major benefits (cost, schedule, or risk), cost-effectiveness, probability of achieving the capability, development and implementation costs, cost/schedule benefit, and time to begin realizing the benefit. These were analyzed using the total technology development costs, success of the technology, return on investment based on the cost savings versus overall investment (for development and field installation), schedule savings and rank ordered within the concept focus areas to identify the smaller sub-set using a matrix ranking approach. This screening resulted in a down-selected list consisting of the top 35 concepts with an additional 7 items that should continue to be pursued as part of the baseline technology development program. The ideas not considered for further evaluation were kept in the overall concepts/ideas listing for documentation and future considerations. Details of the screening process and the specific criteria are provided in Appendix C.

Where available, the team relied upon ORP and Hanford contractors' provided information on the actual and estimated costs for facility construction and operating costs to avoid duplication of effort and provide consistent bases for comparison. The data provided for this screening is provided in Appendix C, Table C - 2. Validation of the screening data was provided by the core team and members of the "Flowsheet, Cost, Schedule, Modeling" team.

The team determined that 42 condensed ideas had the potential for a positive impact on the Hanford tank waste mission. Of these 42, seven were combined with another idea to provide a broader and more comprehensive solution for the gap or opportunity. Thus, 35 R&D areas were down selected for the Phase 3 evaluation and ranking. The selections were made based on a rank ordered list, which maximized the cost and schedule savings in combination with a high probability of success for the idea to be eventually implemented in the facilities. In addition, seven other condensed ideas were considered integral to or part of the current baseline process or design; therefore, the team recommends that these ideas continue to be pursued as part of the baseline. These ideas do not necessarily represent significant schedule or cost savings but will help enable the mission and allow for flowsheet maturation. These baseline activities include the following condensed ideas with some of these requiring Hanford site performance and others requiring DOE-EM support:

- IF-1: Improved methods for determining or confirming required piping flush volumes are adequate
- IF-3: Improved understanding of system or material corrosion/erosion to extend service life in low temperature applications
- IF-4: Improved understanding of system or material corrosion/erosion to extend service life in high temperature applications
- IF-9: Assess WIPP disposal capacity for Hanford Remote-Handled TRU and Hanford interim storage capability (DOE-EM)
- WR&T-11: Evaluate and develop more cost-effective alternatives to the cross-site transfer line for transferring wastes
- SW-1: Evaluate and develop process alternatives that do not generate ammonia as a by-product
- SW-7: Optimization of Effluent Treatment Facility (ETF) processes for acetonitrile destruction.

To summarize, 35 R&D areas or condensed ideas were down selected for further evaluation with seven additional ideas recommended for resolution as part of the baseline Hanford tank waste mission to enable operations. Figure 3 depicts the Hanford tank waste mission aligned with the functional areas used for the prioritized list. HLW or sludge solids flow paths are distinguished from the supernatant or LAW flow paths. The figure also depicts some of the options that could be pursued to accelerate the mission.




Key: AWF: Alternative Waste Forms, CWF: Cementitious Waste Forms, CST: Crystalline Silicotitanate, DST: Double Shell Tank, HLW: High Level Waste, LAW: Low Activity Waste
Solid yellow lines represent HLW/Sludge flow paths, dashed lines represent LAW/supernatant flow paths, and the remaining solid lines represent ancillary wastes or flow paths.

**Figure 3. Hanford Tank Waste Mission by Functional Area**

## Generation of Quick Win Ideas for Near-Term Implementation

At the request of DOE-EM, the NNLEMS team identified five "quick win" ideas that could help advance the near-term Hanford mission and could be initiated should funding be immediately available. The goal of the Quick Wins was to identify areas where known technologies exist, and efforts could be started in the near-term with potential near-term returns. The Quick Wins also considered areas where programs had already been initiated and additional focused funding could help provide near-term implementation. Some overlap exists with items identified in the down-selected list.

The five areas included:

- LDR Organics Characterization and Removal/Destruction - Land Disposal Restriction (LDR) organics must be removed or destroyed to sufficient levels to meet the disposal requirements for Hanford tank waste. Establishing a firm removal/treatment requirement for LDR organics is problematic based on the current level of underlying characterization estimates for non-HLW or vitrification disposal options under consideration. This proposal would 1) develop a better understanding of the LDR organic content in the Hanford tank waste and 2) evaluate removal/destruction technologies for their potential treatment.
- Development of Sludge Preparation Tanks At or In-Tank - The baseline WTP HLW feed preparation strategy relies upon the PT Facility to wash the HLW to remove constituents of concern, perform any necessary Al dissolution or Cr leaching, and to concentrate the HLW sludge to maximize waste loading and waste throughput. Due to safety and technical issues, the construction of the Pretreatment Facility has been significantly delayed. At the SRS, these functions have been performed in their DST type tanks when needed and a sequenced approach has been deployed to allow interim technologies or facilities to be deployed to continue the waste treatment mission while technical issues with the baseline facilities are being resolved. To assure the start of HLW sludge treatment as early as possible, technology evaluations and demonstrations are proposed to determine feasible technologies for at-tank or in-tank sludge preparation.
- Tank Life Extension to Support Mission Acceleration and Completion - The 27 double-shell tanks at Hanford serve a critical mission need for storing wastes, receiving retrieved wastes from single-shell tanks, and staging wastes for pretreatment and feeding the WTP. However, many of the DSTs have exceeded their design life, while the remaining are fast approaching their design life, and one DST (AY-102) has been removed from service due to a leak through the primary liner into the annulus. The estimated cost of replacing a DST is >> $250M, which, if required, would likely have an associated lengthy permitting timeline and, thus, added adverse schedule impact. Currently, there is no program in place to be able to repair and return a DST to service after a leak or out-of-spec condition is discovered. This proposal would expand, accelerate, and integrate the structural analysis, corrosion control, full (wall-knuckle-bottom plate) DST non-destructive evaluation (NDE) inspection and analysis, and tank repair methods to enable robust maintenance and return to service for DSTs experiencing primary liner through wall failure or wall thinning.
- SST Retrieval Infrastructure to Enable Flexible, Timely Waste Mobilization - Of the 149 single-shell tanks (SSTs) at Hanford, 133 store more than 28 million gallons of saltcake, sludge, and interstitial liquids (supernatants). The majority of the tanks and corresponding tank farms do

not yet have the necessary infrastructure in-place to support waste retrieval. With the increasing risk of additional SST leaks over time and increasing demand for SST retrievals as waste treatment begins, lower cost and more flexible SST retrieval infrastructure is needed. For example, if another SST was found to be leaking and waste retrieval was determined to be an appropriate and necessary corrective action, there is no readily available infrastructure and proven systems available to utilize for an individual waste mobilization operation. The purpose of this proposal is to identify and develop viable waste retrieval and infrastructure options for individual SSTs across the Hanford site. The scope could also include development of the technology or equipment to allow immobilization of the retrieved wastes to allow permanent stabilization to avoid further strain on DST availability.

- Sample Reduction using Material Balance and Real-Time, In-Line Monitoring Approaches for HLW Applications - The use of Material Balance Approaches (MBA) and Real-Time, In-Line Monitoring (RTIM) for HLW processing has the potential to reduce feed preparation time and analytical turn-around time regardless of the facility to be used to perform the HLW sludge preparation (e.g., Pretreatment Facility or Direct Feed HLW), which in turn can reduce the overall Hanford mission schedule and costs. The evaluation will: 1) consider where and why samples are taken to include the purpose and need for each sample in context of a DFHLW flowsheet; 2) propose methods to allow elimination of each sample to include an evaluation of whether a material balance approach or a real-time monitoring instrument could be utilized to replace each sample; 3) expand the Hanford DFLAW multi-lab and CRESP RTIM program to include DFHLW evaluations.

Complete descriptions for each quick win area are included in Attachment 3 along with information on potential sequencing of the scope to be performed to achieve the idea. Some of these quick wins combined multiple technology focus areas to provide an integrated solution for a specific Hanford challenge. Finally, these ideas were further refined in Phase 3 to develop more specific scopes for Research, Development and Deployment (RD&D) areas.

## Phase 3 – Risk-Based Ranking of Concepts and Reporting

After the down select of the condensed ideas, another expanded team meeting was held to brief the whole team and the DOE Steering Committee on the selected gaps/opportunities. This meeting was held February 8 – 10, 2022. These broader meetings allowed for synergies to be evaluated as well as some assessment of upstream and downstream impacts. This meeting helped finalize the list of concepts for evaluation to allow prioritization and sequencing of the road map.

### Evaluation of the Down Selected Condensed Gaps/Opportunities

Evaluation criteria were finalized during the meeting and included the following:

1. Proposed Technology - Technical Maturity/Process Simplicity
   a. TRL levels or some other metric – has a prototype or demonstration been done? Can it be bought off the shelf or redeployed from elsewhere? Is there basic science involved?
      - Concept – basic science required
      - Lab demonstration
      - Pilot / prototype
      - Full-scale demonstration
        1. In use elsewhere for similar problem
        2. In use elsewhere for application with similar characteristics
      - Commercially available/off the shelf/service
2. Complexity
   a. Number of Unit Operations affected (upstream and downstream impacts)
   b. Required systems integration (High, Medium, Low)
3. Projected timeline for go/no-go deployment decision (technology-specific)
   a. Scoring Approach: < 5 years, 5 - 10 years, > 10 years
4. Estimated Costs to reach go/no-go decision within item #3: Low (< $10M), Medium ($10M - $50M), High (> $50M)
5. Deployment costs (required funding)
   a. Pilots/demos (if any)
   b. Initial full-scale
6. Additional investment over life cycle
   a. Repeated investment
   b. Operating costs
   c. Other costs incurred (e.g., secondary waste, disposition, etc.)
7. Estimated duration post #3 for deployment/construction/commissioning (to first operations)
   a. Quick (< 5 years), Medium (5 – 15 years), Slow (> 15 years)
8. Rough Order Magnitude (ROM) net cost savings
   a. Annual cost (range)
   b. Peak cost (range)
   c. Total savings (range)
9. Schedule acceleration of Hanford mission (range)
10. Net impact on safety/environment (major, minor, none; positive/negative)
11. Project technical/engineering risks of deploying the proposed technology (estimated probability of successful deployment - number)

12. Regulatory permitting/licensing changes required (major/minor/none)
13. Synergies with other proposals
    a. Dependency – must do A in order to do B
    b. Positive reinforcement – A makes B more effective (major/minor)
    c. Mutually exclusive – if you do A, you can't do B
14. Technology or concept applicable to another DOE site.

The sub-set or down-selected list of ideas was further evaluated to better understand the level of development required and the breakdown of development and capital costs and time required for final implementation. Refinements to the cost and schedule savings, as well as potential regulatory aspects to include the estimated time required to implement any required regulatory changes, were included in the final evaluation.

In this final evaluation to determine the most viable concepts, the evaluation spreadsheet was populated with the applicable information for each concept. The technical maturity, complexity, estimated costs, and projected savings and implementation schedule were considered for each idea and the team conducted data collection in smaller functional groups and then compared them as a core team to ensure the fidelity of the input data. ORP provided data on potential operational and life cycle costs, and a budget of $2.5B was assumed for each year of operation. While it is recognized that operating budgets will change over the lifecycle of the project due to escalation and other changes (e.g., DOE program decisions), this allowed all concepts to be compared on a common basis.

The concepts and the inputted information were then analyzed, and rank ordered based on the return on investments over the program life cycle and the schedule savings. As was done in Phase 2, the rank ordered list was based on maximizing the return on investments, overall cost and schedule savings and the probability of success of the technology. The data was determined by the focus area team SMEs based on their knowledge and experience. During the analysis, the Cost & Schedule Modeling team developed the cost savings as a range and the schedule savings in years. The total savings were then calculated as a range over the life cycle of the project. The total saving ranges were assigned scaling factors to make comparisons. The scaled savings were then divided by the estimated investment costs to generate a scaled return on investment (ROI). The nominal unit for ROI is the scaled savings estimate per million dollars in investment ($). This rank ordered list was evaluated collectively by the core team to ensure that they were meaningful, sensible and logical; in addition, the rank ordering was analyzed to maximize safety and minimize risks. The rank ordering was performed as follows:

- This rank ordered list was grouped into a tiered approach to ensure that ideas that had the same ranking were given proper consideration in a balanced portfolio format as: Top Priority, High Priority, and Medium Priority (see Recommended Portfolio of Investments for the R&D Roadmap section for a further description).
- The full list of concepts was further categorized into the following groupings based on their potential implementation time and impact:
    1. Risk Mitigation - not schedule driven but may protect the schedule
    2. Incremental - some concepts fit existing baseline/flowsheet but maybe not all
    3. Transformational - change in the baseline will be required and concept implementation will have mid-range costs
    4. Long-range Program - 10 to 15 years to develop with potential big payoff if successful.

Supplementary details on the evaluation process and the results of the technical team's evaluation are provided in Appendix D, Table D - 1. Information on each of the 35 condensed ideas including the basis for the evaluations is documented in an Idea Sheet, which are provided in Attachment 4. The team envisions using these write ups as the basis for proposal calls to resolve the gaps or realize the opportunities. Additional milestone development and cost estimating should be done during execution of the R&D areas given the current budget and schedules represent engineering judgment of the probability of success, costs, and schedule. While uncertainty does exist, the R&D areas are being compared on a relative basis to enable this assessment and represent only some of the input in the overall prioritization effort.

## Recommended Portfolio of Investments for the R&D Roadmap

The review team functioned as a consensus body when making final decisions on the recommendations from the evaluation. Appendix D provides the details of the rank ordering that was performed to determine the recommended investment portfolio to pursue. This ranking evaluated the approaches to improve efficiency with consideration of estimated reduction of lifecycle costs and acceleration of schedule. This resulted in the identification of three priority levels of potential investments:

- Top Priority: Nine approaches with the highest return on investment and the most schedule acceleration, or high in one attribute and moderate in the other. These approaches include technologies in the categories of Waste Retrieval, Transport, & Closure; Waste Pretreatment; Waste Immobilization & Disposal; and Mission Enablers.
- High Priority: Thirteen approaches with moderate return on investment and moderate schedule acceleration, or high in one attribute and low-to-moderate in the other. These approaches include technologies in the categories of Waste Retrieval, Transport & Closure; Waste Pretreatment; Waste Immobilization & Disposal; Secondary Waste Treatment; and Mission Enablers. This includes WR&T-3b/10a, which was evaluated separately and then combined for the final prioritization.
- Medium Priority: Thirteen approaches with meaningful but lower returns on investment and schedule acceleration. These approaches include ones in the categories of Waste Retrieval, Transport & Closure; Waste Pretreatment; Waste Immobilization & Disposal; Secondary Waste Treatment; and Mission Enablers.

The prioritized rankings including the scaled return on investment are given in Appendix D, Table D - 2. A summary list of the R&D research areas including priority ranking, a brief description of the concept, technical maturity, the technology type, investment costs and time frame, estimated savings in schedule and costs, and the calculated scaled return on investment is provided in Table 4. Deployment of several of these R&D investments will require close coordination or facilitate the critical decisions previously discussed in Table 1. Table 4 also has color coding for each of the R&D areas, which corresponds to information in Figure 6 described below. Two colors indicate that the R&D area can be performed in support of multiple initiatives.

The final list of condensed and combined ideas yielded a recommended investment portfolio of specific technology development areas for future exploration. See Figure 4 for the prioritized concepts mapped by functional area, technology type, and priority.

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**Table 4: Prioritized List of Investment Portfolio**

| Priority | Concept ID | Prioritized Research Area | Concept | R&D Investment | | | | Estimated Savings | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Technical Maturity | Technology Type | Timeframe (years) | Total Cost | ROM Cost Savings | Schedule Acceleration | Estimated ROI* |
| *Waste Retrieval, Transport & Closure* | | | | | | | | | | |
| Top | WR&T-14 | Increase volume available for tank storage | Evaluate through a cost benefit analysis the options of building new tanks, developing a modular/mobile tank system and the reuse of sound single shell tanks for temporary storage of treated and untreated waste. The lack of temporary storage near SST farms limits flexibility for waste treatment options. | Deployable COTS/ GOTS with site specific tailoring | Transformational | 0-5 | $0-10M | $1-10B | 7-10 yrs. | 1000 |
| High | WR&T-3b & 10a | Dry waste characterization, monitoring, & retrieval technologies | Develop dry retrieval equipment and techniques to remove waste from the waste tanks and transport it to the treatment or disposal facilities. Utilize commercially available instrumentation and/or technologies that are in development stage to support measuring the physical and chemical properties of waste. | Full scale demonstration in use elsewhere for similar problems | Incremental | 0-10 | $10-50M | >$25B | 7-10 yrs. | 200 |
| High | WR&T-7b | Process automation & feedback of monitoring and retrieval technologies | Develop process feedback systems to address operational challenges and effectiveness. Use Artificial Intelligence (AI) and edge computing to optimize productivity and give feedback. | COTS mature deployable | Incremental | 0-10 | $50-100M | >$25B | >10 yrs. | 76 |
| High | TC-3 | Risk-based waste retrieval sequencing | Work with the regulators and stakeholders to prioritize retrieval sequencing and timing of tank closures to address the highest risk to the environment. | Full scale demo – elsewhere | Incremental | 0-10 | $0-10M | $1-10B | 3-5 yrs. | 200 |
| High | TC-7, WR&T-2b, DL-1 | Formulate & install barriers targeted for constituents of concern at tanks or disposal site with active monitoring | Develop barriers or caps with additives targeting contaminants of concern for the outside of tanks or disposal sites and demonstrate deployment strategies. These barrier technologies could improve added systems that monitor for any migration of contaminants with responsive systems for mitigating the contaminants. | Pilot to Full scale for similar application | Incremental | 0-15 | $50-100M | $1-10B | 5-7 yrs. | 3 |
| High | IF-2, WR&T-2a & b | Improved methods to detect/repair leaks for storage tanks | Develop improved methods to detect degradation in Hanford tank farm DSTs and develop techniques to repair damaged areas of the tanks. | Demonstration | Risk Mitigation | 0-10 | $100-300M | $1-10B | 5-7 yrs. | 83 |
| High | WT-9 | Improved sampling methods for double shell tanks | Develop better sampling methods for retrieval, staging and transport to the WTP in the DST system for waste feed qualification. The sampling method must address both the representativeness of the sample as well as the efficiency of taking the required samples. | Concept / Demonstration | Incremental | 0-10 | $100-300M | $1-10B | 5-7 yrs. | 45 |
| Medium | TC-4, TC-5, WR&T-8 | Advanced in-situ characterization methods coupled with improved performance assessment models | Optimization of the extent of waste removal from the tanks can be performed using improved characterization methods to include in-situ techniques and improved performance assessments (PA) to quantify the residual risk and uncertainty of the materials remaining. Advances in both techniques could help better quantify the residual concentrations of constituents of concern and the volumes of the material remaining. | Characterization techniques - Demonstrated on lab scale. PA demonstrated on a pilot/prototype scale | Transformational | 0-15 | $10-50M | $1-10B | 5-7 yrs. | 10 |

| Priority | Concept ID | Prioritized Research Area | Concept | R&D Investment | | | | Estimated Savings | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Technical Maturity | Technology Type | Timeframe (years) | Total Cost | ROM Cost Savings | Schedule Acceleration | Estimated ROI* |
| *Waste Pretreatment* | | | | | | | | | | |
| Top | PS-4 | In-tank pretreatment of HLW sludge | Evaluation of in-tank sludge pretreatment methodologies could help with acceleration of the HLW mission. The required mixing equipment including mixer type and operations need to be determined. The settling time required for efficient operations must also be determined and could involve the evaluation of additives to act as settling aids or the use of filtration technologies. | Full scale demo – elsewhere | Transformational | 0-5 | $10-50M | >$25B | >10 yrs. | 556 |
| Top | PS-2 | At-tank pretreatment of HLW sludge | Provide a skid-based approach similar to Tank Side Cesium Removal (TSCR) to achieve sludge processing. Perform washing of sludge and concentration. | Prototype | Transformational | 0-5 | $100-300M | >$25B | >10 yrs. | 156 |
| High | PL-5 | RCRA organics removal from tank supernate | Develop technologies to remove the RCRA organics that have been identified in the tank supernatants. | Lab demonstration | Transformational | 0-10 | $10-50M | >$25B | >10 yrs. | 7 |
| High | PS-6 | Increased solids concentration during waste processing with water management | Provide a skid-based approach similar to TSCR to achieve sludge concentration near the HLW facility. This skid would be located near the HLW facility to avoid long transfers of high solids loading material and to avoid flush high-water volumes in WTP. | Pilot/Prototype | Transformational | 0-5 | $100-300M | >$25B | >10 yrs. | 161 |
| High | PS-3 | Improved understanding of aluminum chemistry to optimize sludge processing | Improved chemical understanding and predictive models are needed to better optimize sludge retrieval, transport, and washing and to alter target amount removed. | Concept | Long-range | 0-5 | $0-10M | $250M-1B | >10 yrs. | 500 |
| Medium | PL-1 | Improved supernate filtration processes | Develop or modify filtration technologies to improve filtration performance. Deploy in a skid mounted system potentially. | Pilot/prototype, full-scale demo for similar problem | Risk Mitigation | 0-5 | $0-10M | $0-250M | 0-3 yrs. | 250 |
| Medium | PL-2 | Additives to optimize filtration | Improve the overall filter performance through the addition of filter aids. | Lab Demonstrations | Incremental | 0-10 | $0-10M | $0-250M | 0-3 yrs. | 250 |
| Medium | PL-8 | Sodium nitrate separation or destruction technologies | Develop technologies to remove/separate the sodium nitrate found in the tank waste. An example would be destruction of the sodium nitrate such that it no longer poses the current burden on the off-gas treatment systems. | Pilot/Prototype | Transformational | 0-15 | $10-50M | $0-250M | 0-3 yrs. | 100 |
| Medium | PL-10 | Plutonium/actinide removal from supernate | Methods for actinide pretreatment, such as a monosodium titanate (MST) strike, may be helpful in reducing potential for actinide loading on CST. Remove actinides prior to Cs removal with CST. | Pilot/Prototype | Transformational | 0-5 | $50-100M | $0-250M | 0-3 yrs. | 3 |
| *Waste Immobilization & Disposal* | | | | | | | | | | |
| Top | IM-13 | Cementitious materials development to improve long-term performance | Need to develop improved containerized grout formulations as well as to validate their durability and long-term performance. This development would be necessary to implement Supplemental Treatment of LAW using a grout waste form for on-site disposal; however, grout waste forms could also be amenable to offsite disposal. | Concept/Demonstration | Transformational | 0-10 | $10-50M | >$25B | >10 yrs. | 500 |
| Top | IM-1b | Improved high level waste glass formulations | Expand HLW glass processing envelope to improve waste loading and allow flexibility for a range of potential flowsheet options. Original compositions were developed over a fully leached and washed tank sludge with modest glass waste loading. Data and models are needed over expanded glass property-composition space. | Concept/Demonstration | Incremental | 0-10 | $10-50M | >$25B | 5-7 yrs. | 500 |

| Priority | Concept ID | Prioritized Research Area | Concept | R&D Investment | | | | Estimated Savings | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Technical Maturity | Technology Type | Timeframe (years) | Total Cost | ROM Cost Savings | Schedule Acceleration | Estimated ROI* |
| Top | IM-4 | $NO_x$ management through sludge washing or offgas abatement | Develop methods and technologies to reduce nitrogen-based emissions from HLW and LAW vitrification processes. Explore alternative reductants that may react more completely with nitric acid feeds to reduce additional NOx formation or acetonitrile. New reductants and processing strategies could help reduce the risks and hazards of NOx and $NH_3$ and would need ways to direct feed waste with minimal treatment. | Lab Demonstration, Pilot/Prototype | Incremental | 0-10 | $50-100M | $1-10B | 5-7 yrs. | 333 |
| Top | DL-3 | Improved transport models/ performance assessments for waste forms | Evaluate assumptions for performance assessments for excessive conservatism and develop better transport and performance assessment models for multiple waste forms to increase waste loadings at disposal sites. | Pilot/Prototype | Transformational | 0-10 | $0-10M | $250M-1B | 5-7 yrs. | 500 |
| High | IM-2c | Improvement to high level waste glass melter design & throughput | A rigorous evaluation of the limiting steps based on current feed assumptions is required. The results of this evaluation would lead to a prioritized list of design modifications to optimize facility throughput. | Concept, Laboratory Demonstration, Pilot/Prototype, Full-scale Demonstration | Incremental | 0-10 | $100-300M | >$25B | >10 yrs. | 111 |
| Medium | IM-12 | Waste dewatering/dried waste form | Assess and implement tank waste dewatering options with consideration of scale-up, cost, and safety. | Lab Demonstration, Pilot/Prototype | Transformational | 0-10 | $300-600M | $10-25B | >10 yrs. | 41 |
| *Secondary Waste Treatment* | | | | | | | | | | |
| High | SW-1 | Improved grout waste forms | A cementitious waste form is the baseline technology, but retention of some species is a concern by regulators and may represent a significant contribution to release from the IDF, dependent on partitioning within WTP and waste form performance. New grouting compositions or lithified aggregate mixtures (for liquid and solid SW) with getters may present a viable option. | Lab Demonstration, Full scale demonstration in use elsewhere, Commercially available off the shelf | Incremental | 0-5 | $10-50M | $0-250M | 0-3 yrs. | 333 |
| Medium | PL-6 | Iodine separation in liquid phase | Develop and implement iodine separation technologies effective for alkaline tank waste and secondary liquid waste streams from thermal treatment off gases. | Concept to Pilot/prototype | Risk Mitigation | 0-5 | $0-10M | $0-250M | 0-3 yrs. | 250 |
| Medium | SW-9 | Iodine separation in gas phase | Remove the iodine post melter in the gas phase to reduce processing and waste disposition risks. | Concept | Risk Mitigation | 0-10 | $0-10M | $0-250M | 0-3 yrs. | 250 |
| Medium | SW-10 | Technetium separation technologies | Develop Tc separation techniques for SBS condensate allowing disposition of other constituents in offgas stream elsewhere and Tc to be incorporated in glass. | Lab demonstration | Incremental | 0-10 | $10-50M | $0-250M | 0-3 yrs. | 50 |
| Medium | IF-7 & 12 | Process intensification/ automation of Effluent Treatment Facility | Evaluation of process intensification of LERF-ETF process to include automation and unit operation upgrades to increase capacity of the ETF process. | Concept | Incremental | 0-10 | $100-300M | $0-250M | 0-3 yrs. | 47 |
| *Mission Enablers* | | | | | | | | | | |
| Top | WR&T-9 | Improved equipment decontamination/ disposal options | Evaluate new waste retrieval and infrastructure equipment decontamination and disposal options. | Commercially available off the shelf for some items, Pilot/Prototype for others | Incremental | 0-5 | $0-10M | >$25B | 7-10 yrs. | 50 |
| Top | WR&T-10b | Real time monitoring for liquid process feeds | Develop new Real time monitoring capabilities for liquid process feeds to reduce sampling time and minimize waste. Measure physical and chemical properties of liquid samples. | Pilot/Prototype, Full-scale demonstration | Incremental | 0-5 | $0-10M | $250M-1B | 5-7 yrs. | 313 |

| Priority | Concept ID | Prioritized Research Area | Concept | R&D Investment | | | | Estimated Savings | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **Technical Maturity** | **Technology Type** | **Timeframe (years)** | **Total Cost** | **ROM Cost Savings** | **Schedule Acceleration** | **Estimated ROI*** |
| High | Hanford-1 | Develop system model for infrastructure & technology cost evaluation | In order to evaluate cost, schedule, and risk management improvements a new system model for tank farm and WTP operations needs to be developed. Using this new system model, a cost benefit/engineering analysis of tank farm and the Hanford tank waste mission operations can be completed. | Deployable COTS/GOTS for the platform | Transformational | 0-5 | $10-50M | >$25B | 7-10 yrs. | 1250 |
| High | DL-6 | Alternative disposal options for crystalline silicotitanate ion exchange media | Evaluate and implement alternative disposal options to vitrification for disposal of CST. | Concept | Transformational | 0-10 | $10-50M | $250M-1B | 0-3 yrs. | 125 |
| Medium | PL-3 | Optimize cesium loading on crystalline silicotitanate ion exchange media | The current operating scheme for the CST columns has not been optimized to achieve the maximum possible loading. Alternative operating schemes (relying on available process parameters) would be explored to evaluate whether higher column utility could be achieved. | Lab demonstration | Incremental | 0-10 | $0-10M | $250M-1B | 0-3 yrs. | 40 |
| Medium | PS-9 | Improved offgas treatment/ abatement for key air toxics | Waste treatment or offgas abatement methods to reduce impacts of key air toxics that are limiting waste processing operations | Pilot/Prototype | Incremental | 0-5 | $10-50M | $0-250M | 0-3 yrs. | 125 |
| Medium | IF-14 | Remote/automated systems | Develop or adapt robotic systems to assist or replace hands-on work at Hanford. Robotic systems could be used to remove workers from hazardous environments for selected tasks or could be used to assist workers for tasks that are not completely automated. Systems to be evaluated include autonomous systems that could perform rounds and other simple tasks to wearable devices that augment worker reality. | Concept | Incremental | 0-5 | $100-300M | $1-10B | 0-3 yrs. | 1 |

Note: 1. Colors in the first two columns correspond to the corresponding color on the tracks of the railway map in

Figure 6.

2. Estimated ROI - During the analysis, the Costs and Schedule Modeling team developed the cost savings as a range, and the schedule savings in years. The total savings were then calculated as a range over the life cycle of the project. The total saving ranges were assigned scaling factors to make comparisons. The scaled savings were then divided by the estimated investment costs to generate a scaled ROI. The nominal unit for ROI is the scaled savings estimate per million dollars in investment ($).

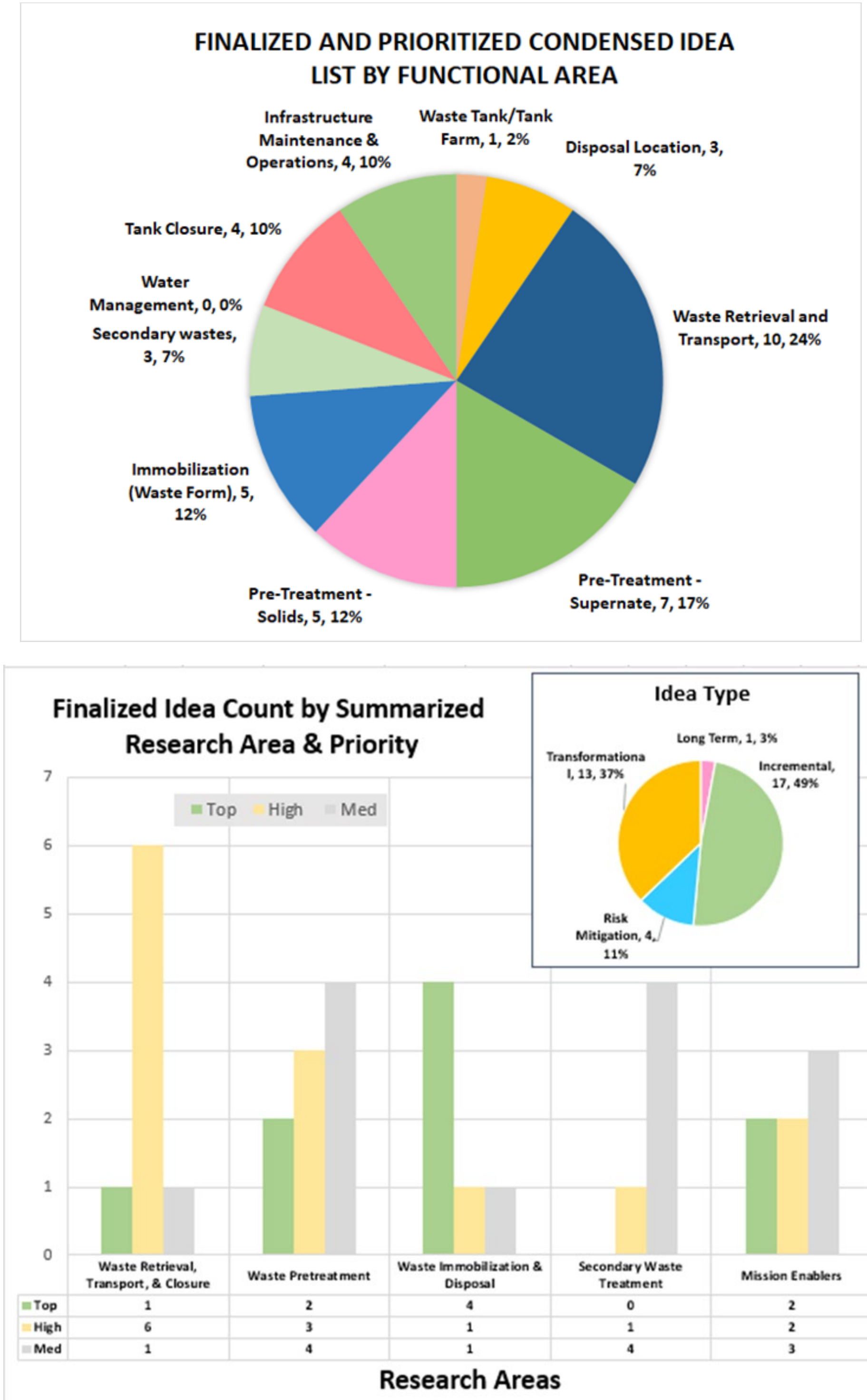


**Figure 4. Charts of the Count and Percent by Functional Area, Technology Type, and Priority for the Proposed Investment Portfolio**

Ultimately, several paths can be taken to complete the Hanford tank waste mission. The team envisions the treatment path for a specific tank or tank farm would consider the process paths depicted in Figure 5. The critical DOE decisions outlined in Figure 5 and discussed in Table 1 would provide ORP with the paths available to treat waste based on the selected disposition path. The team envisions this specific decision tree becoming less complicated as waste treatment begins and the critical DOE decisions are made. The R&D areas that have been identified would inform these decision paths. Although the NNLEMS team expects the need for technical and programmatic challenging decisions to diminish as critical DOE decisions are made, it recognizes that emerging issues and unanticipated results could further complicate the tank waste cleanup mission. As the Hanford tank waste mission is the most complicated and expensive component of the EM mission, flexibility in the ability to allocate resources to target emerging challenges will be important. The NNELMS team could continue to be involved to advise DOE to facilitate DOE's response to emerging situations.

To generate the NNLEMS recommended enhanced R&D roadmap, the team selected a path that follows the DOE Manual 435-1.1 waste determination process for selecting the treatment and disposition paths, as shown in the baseline and enhanced Hanford Tank Waste mission roadmaps shown in

Figure 6. The baseline is a very high-level depiction of the current Hanford tank waste mission. The team envisions the R&D roadmap as a “railway station” map with sets of “tracks”. The “tracks” lead from the Hanford tanks in their current state to completion of the Hanford tank waste mission with closed tanks and the waste processed for disposal sites (as depicted by the “engine barn” at the top of the figure). The multiple colored “tracks” represent the multiple types of waste that must be processed to complete the mission. The thickness of the tracks in

Figure 6 is a relative representation of the amount of the material processed via that disposal route compared to the baseline quantities. The number of dollar signs depicted at the end of each waste track indicate the relative magnitude of the cost for that pathway (i.e., the sum of the waste volume times the costs of processing and disposal). The mission level decisions are represented by “switching stations” (represented by the symbol) with alternative paths to reach the mission endpoints. These mission level decision points impact the amount of waste generated, as well as the types and sizes of the waste processing facilities needed. Pre-decisional R&D can be used to inform the decisions and the mix of R&D required to enable waste disposal along the “tracks”. Each of these mission level decision points is informed by an R&D portfolio containing key R&D areas (shown as “train stops” depicted by ○) which inform the mission decision. In a number of cases, further improvements to an individual waste track will be provided by additional R&D initiatives, following the mission decision point, and depicted by the “train stops”, displayed as solid circles, ●. As discussed above, some of these research areas support multiple waste tracks reflected by multiple-colored circles (and multiple colors in Table 4).

Multiple paths can be taken, and varying amounts of each waste type can be considered, to complete the Hanford tank waste mission. These will be dependent on DOE’s decision on the technology R&D portfolio to implement; the success of the R&D projects; and the mission level decisions that DOE chooses to pursue.

Figure 6 represents the NNLEMS team ‘s recommended R&D portfolio. The location of the mission level decision in the roadmap are not meant to reflect the timing of the decisions but rather depict how the R&D areas inform the decisions.

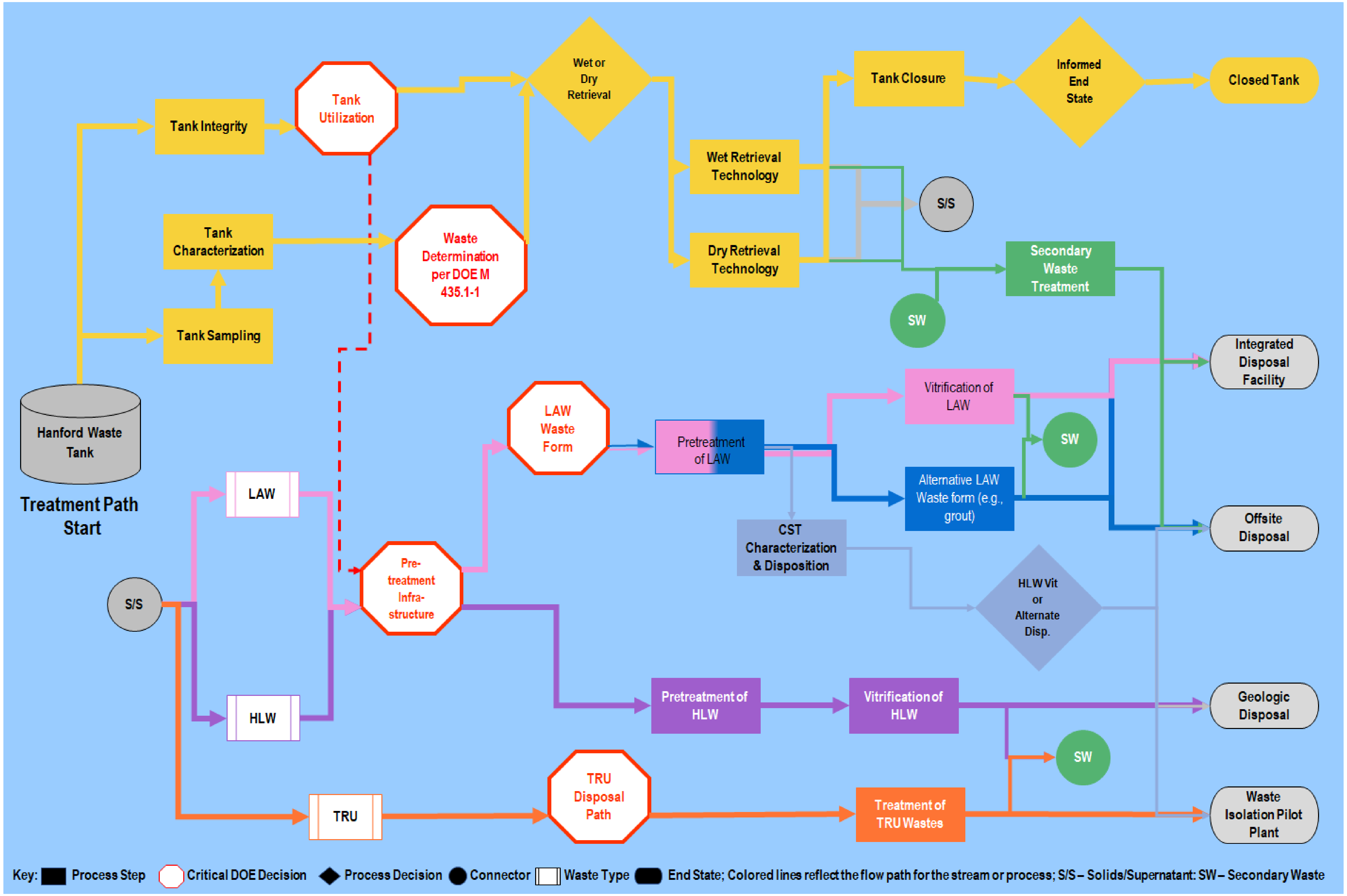


**Figure 5. Treatment Paths for Hanford Tank Waste Mission**

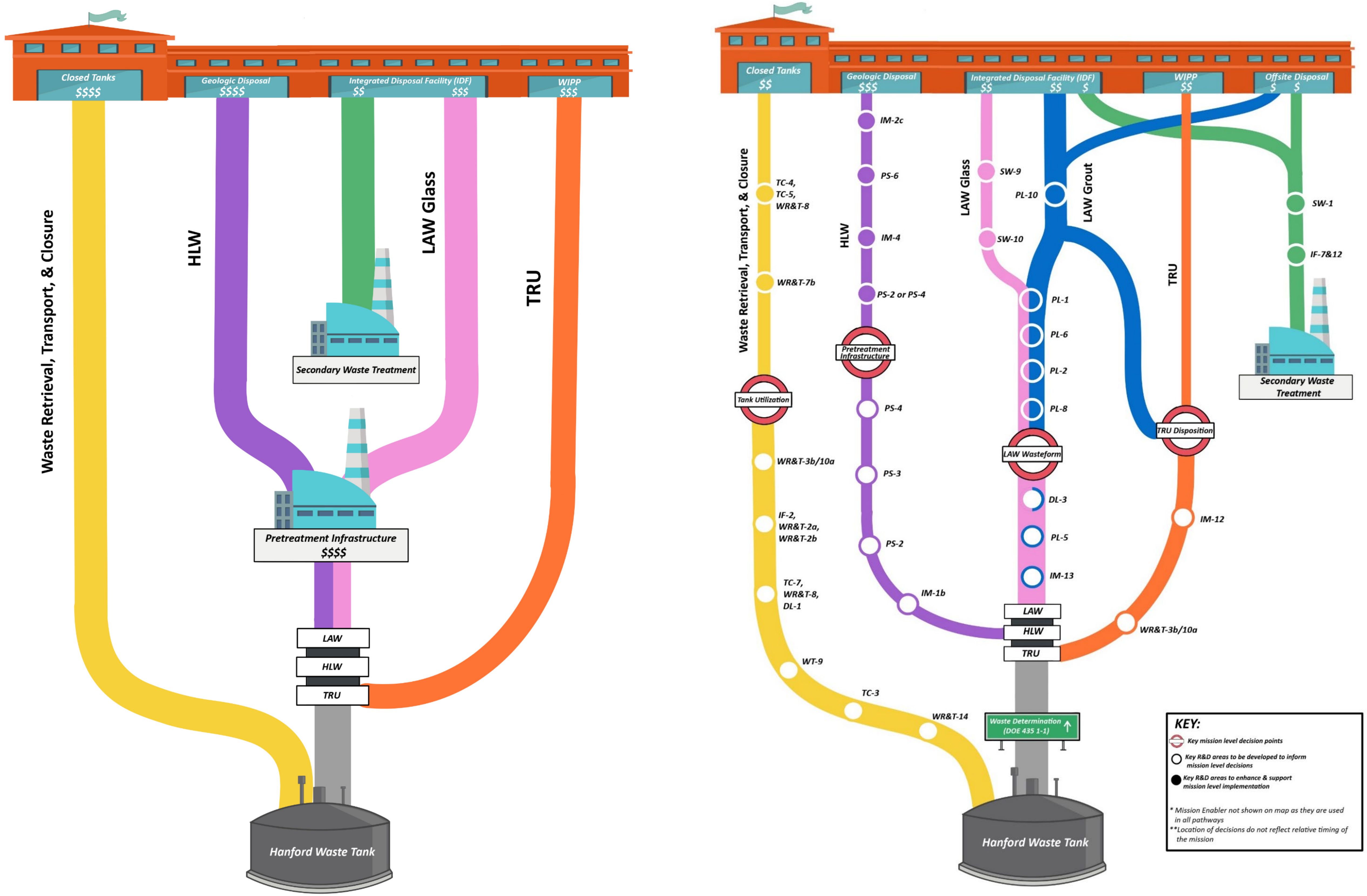


Figure 6. Baseline and NNLEMS Team Recommended R&D Enhanced Hanford Tank Waste Mission Roadmaps

Each concept has an estimated R&D funding requirement and timeframe, as well as estimated cost and schedule savings. Figure 7 depicts a few of the paths that could be pursued with the identified improvement areas representing assumptions on the result of the critical decisions. These paths do not represent all of the viable options but rather provide some of the paths that might be pursued for illustrative purposes. As an example, if Figure 5 is followed, and the Waste Determination process determines that the material is HLW, then a Pretreatment Infrastructure decision needs to be made and one option would be pretreatment in the tank using R&D developed by PS-4 concepts. Figure 6 shows this path along the purple tract, while HLW Route Path 1 in Figure 7 also reflects this path and the multiple R&D areas that could be pursued to optimize processing following this path.

Also included in Figure 7 are the projected savings in costs and schedule that might be realized should these prioritized research areas be pursued and prove successful, as well as the R&D investment range and the team's estimate on the probability of success. The team recognizes the finances noted are truly rough order of magnitude estimates given that this initiative was not a rigorous cost and schedule analysis and in light of the nature of the interdependencies of the concepts upon each other. The savings are not likely to be fully additive because they are not all mutually exclusive. More rigorous modeling of the preferred flow paths would be needed to determine the potential savings with higher certainty. However, the data does indicate that treatment paths that maximize the volume of lower radionuclide content waste through LAW processing and use grout as the LAW waste form should result in significant schedule savings and life cycle costs, as well as mitigate some of the peak funding levels required to support infrastructure construction.

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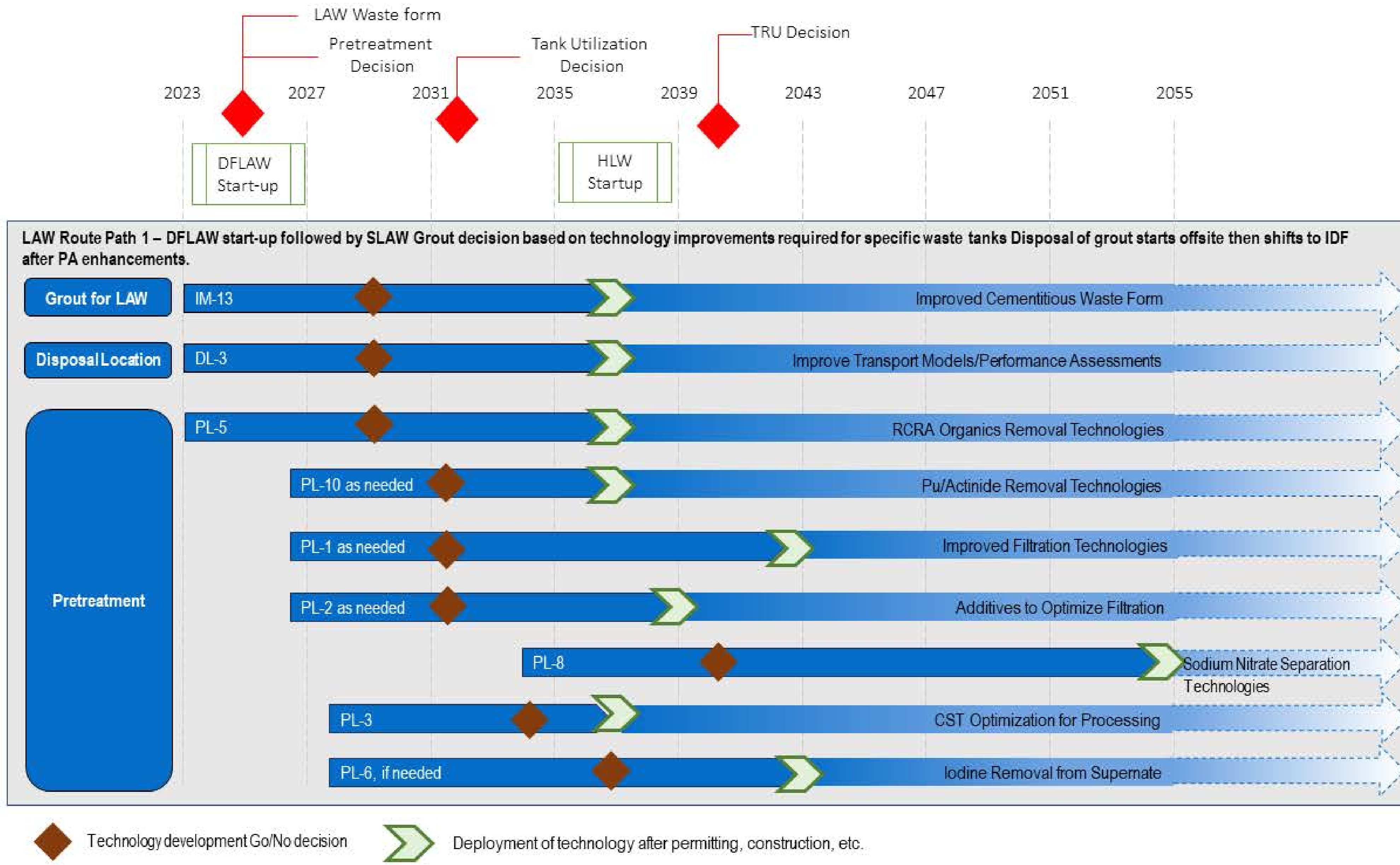
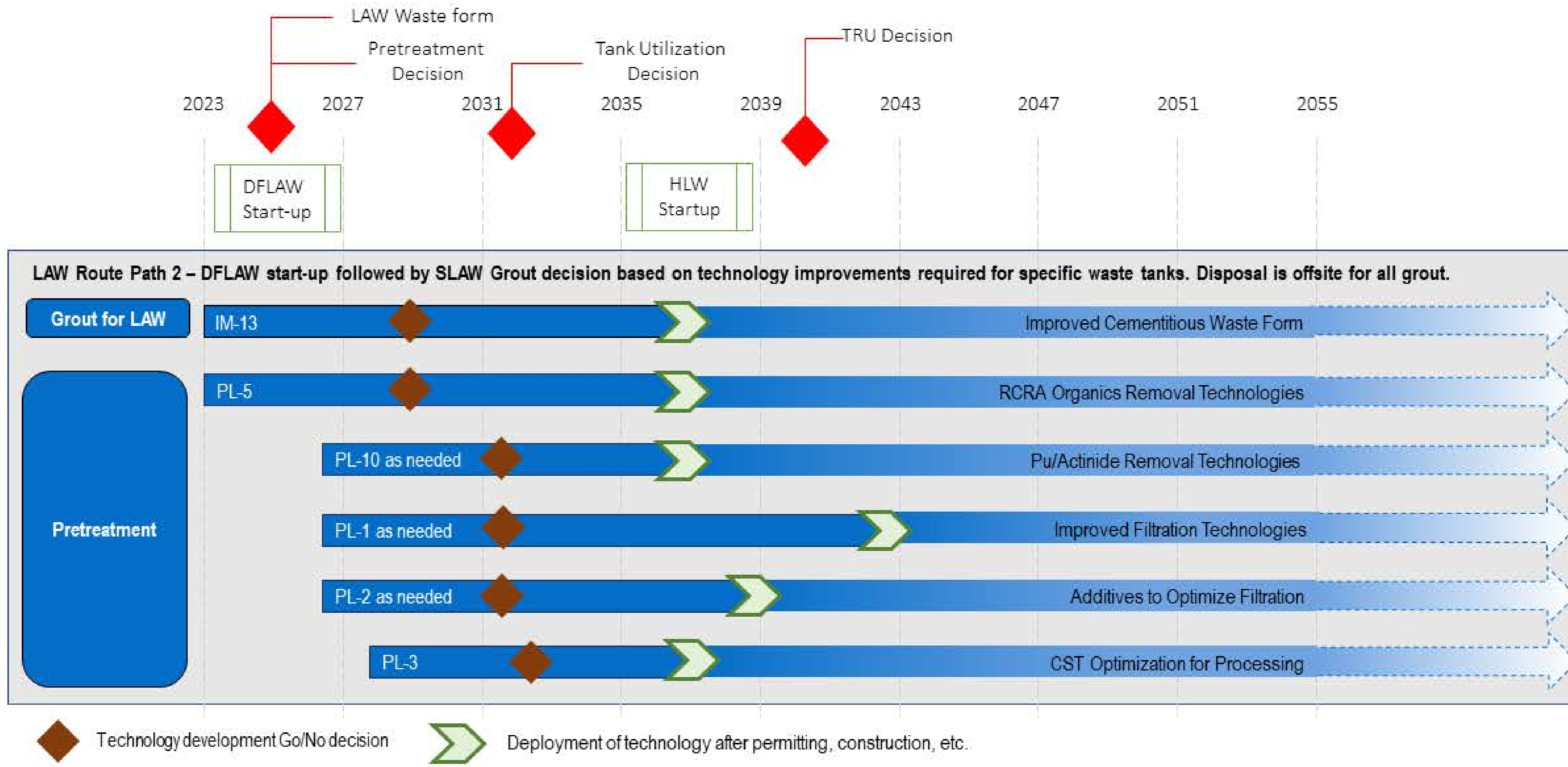
**Figure 7. Potential R&D Roadmap Paths Based on Critical Mission Decisions and Implementation of R&D Areas**


**Figure 7 continued. Potential R&D Roadmap Paths Based on Critical Mission Decisions and Implementation of R&D Areas**




| | R&D Investment Range ($M) | Cost Savings Range ($M) | Schedule Savings Range (yrs.) | Probability of Success |
|---|---|---|---|---|
| IM-13 Improved Cementitious Waste Form | 10-50 | ≥25000 | >10 | 80% |
| DL-3 Improve Transport Models/Performance Assessments | 0-10 | 250-1000 | 5-7 | 95% |
| PL-5 RCRA Organics Removal Technologies | 100-300 | ≥25000 | >10 | 75% |
| PL-10 Pu/Actinide Removal Technologies | 50-100 | 0-250 | 0-3 | 95% |
| PL-1 Improved Filtration Technologies | 1-10 | 0-250 | 0-3 | 95% |
| PL-2 Additives to Optimize Filtration | 0-10 | 0-250 | 0-3 | 50% |
| PL-8 Sodium Nitrate Separation Technologies | 10-50 | 0-250 | 0-3 | 70% |
| PL-3 CST Optimization for Processing | 0-10 | 250-1000 | 0-3 | 90% |
| PL-6 Iodine Removal from Supernate | 0-10 | 0-250 | 0-3 | 70% |

**Figure 7 continued. Potential R&D Roadmap Paths Based on Critical Mission Decisions and Implementation of R&D Areas**




| | R&D Investment Range ($M) | Cost Savings Range ($M) | Schedule Savings Range (yrs.) | Probability of Success |
|---|---|---|---|---|
| IM-13 Improved Cementitious Waste Form | 10-50 | ≥25000 | >10 | 80% |
| PL-5 RCRA Organics Removal Technologies | 100-300 | ≥25000 | >10 | 75% |
| PL-10 Pu/Actinide Removal Technologies | 50-100 | 0-250 | 0-3 | 95% |
| PL-1 Improved Filtration Technologies | 1-10 | 0-250 | 0-3 | 95% |
| PL-2 Additives to Optimize Filtration | 0-10 | 0-250 | 0-3 | 50% |
| PL-3 CST Optimization for Processing | 0-10 | 250-1000 | 0-3 | 90% |

**Figure 7 continued. Potential R&D Roadmap Paths Based on Critical Mission Decisions and Implementation of R&D Areas**

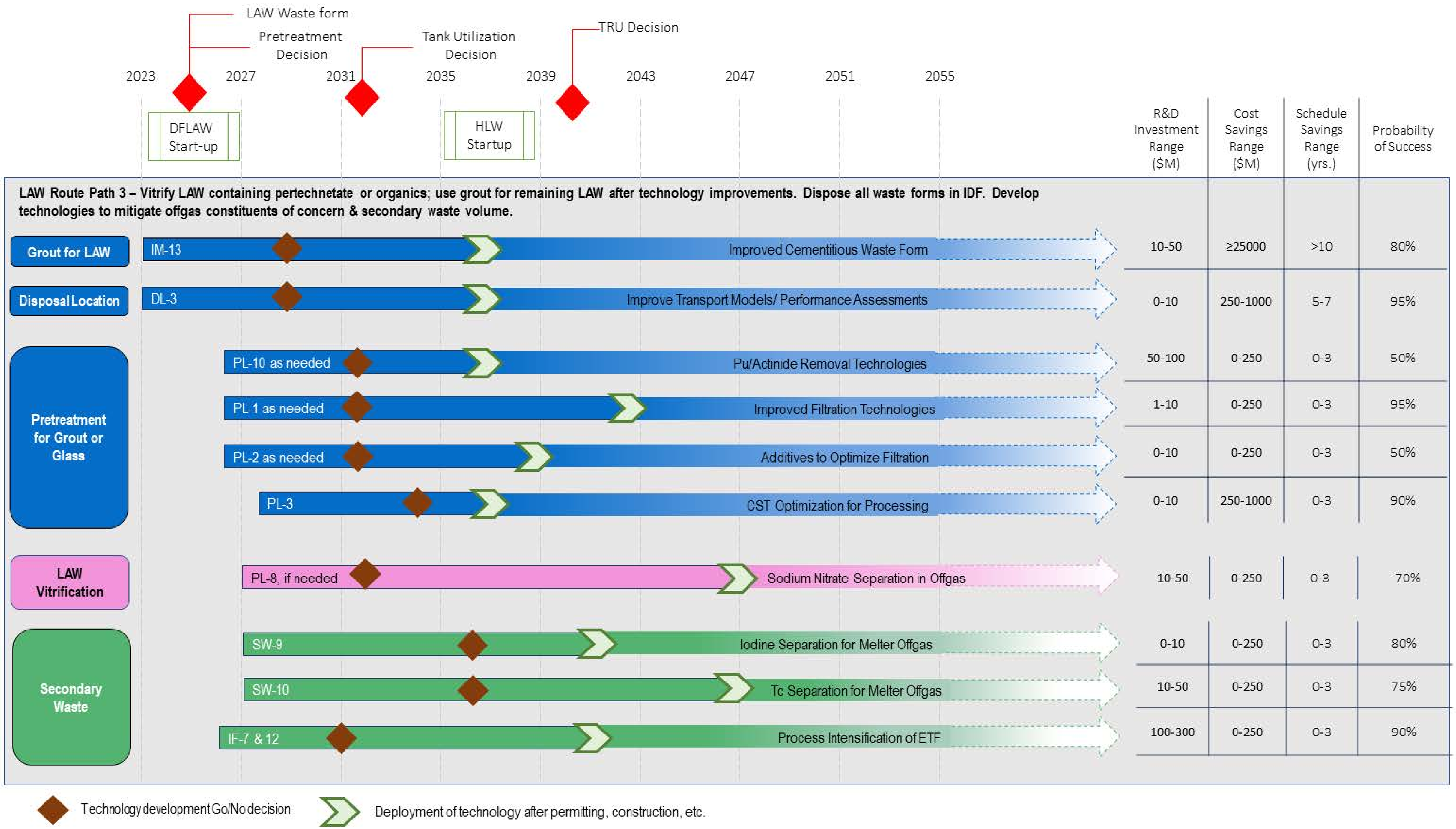



**Figure 7 continued. Potential R&D Roadmap Paths Based on Critical Mission Decisions and Implementation of R&D Areas**

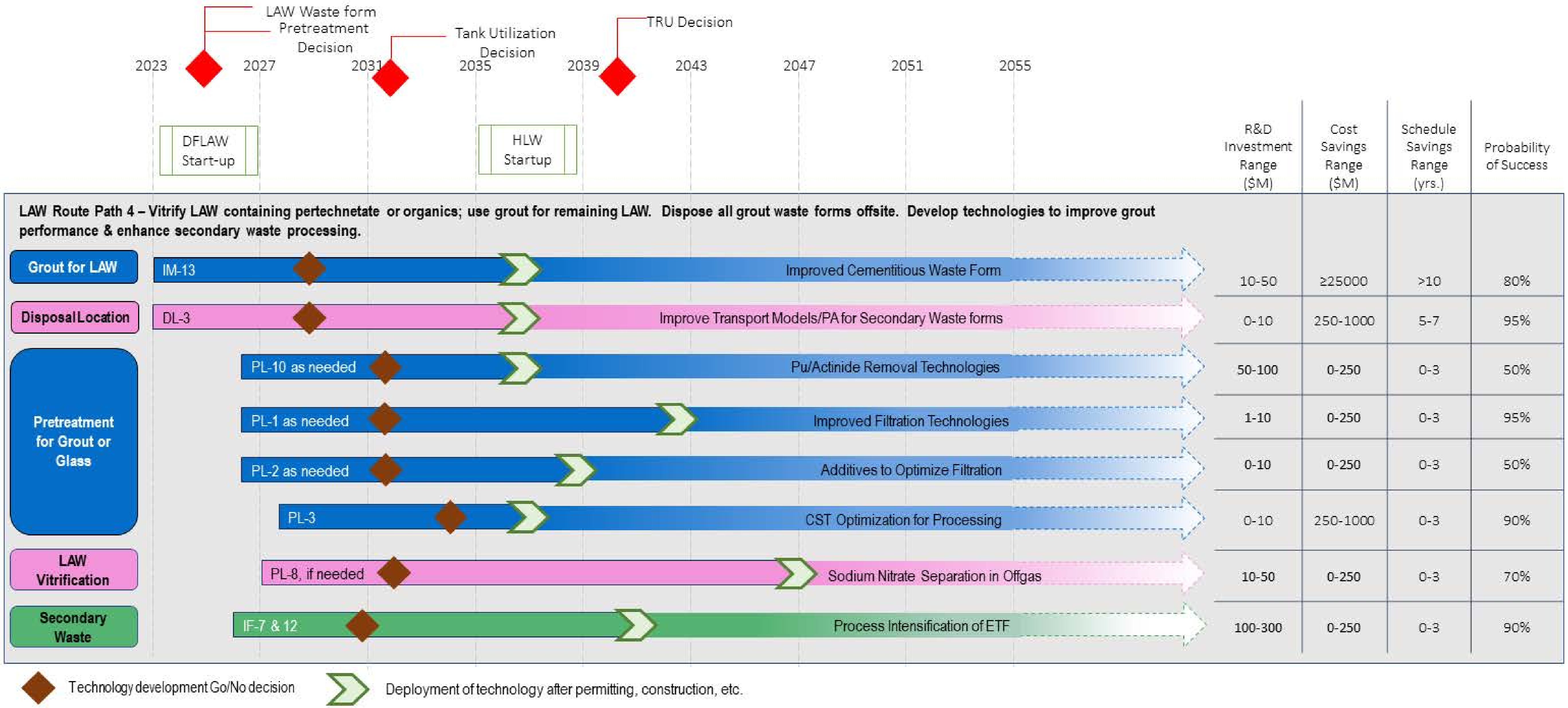



**Figure 7 continued. Potential R&D Roadmap Paths Based on Critical Mission Decisions and Implementation of R&D Areas**

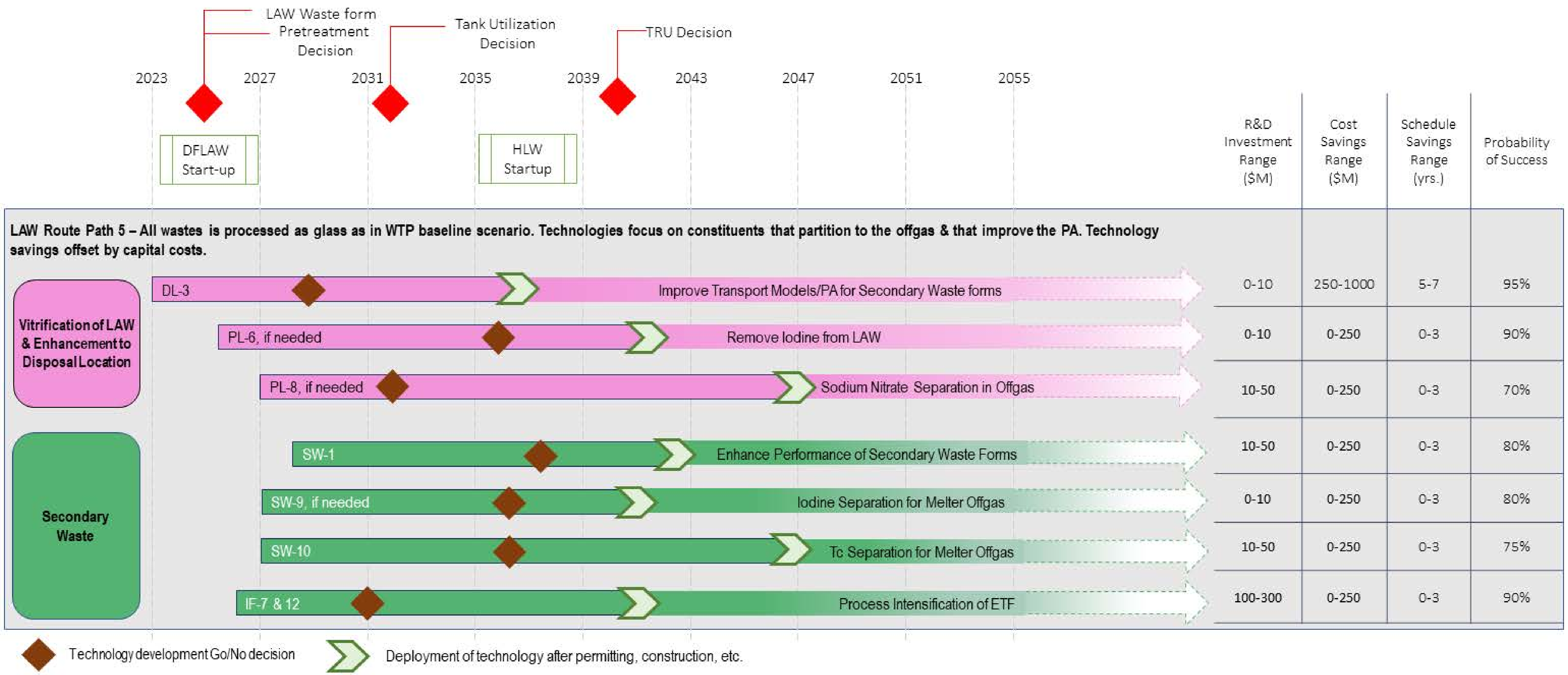



**Figure 7 continued. Potential R&D Roadmap Paths Based on Critical Mission Decisions and Implementation of R&D Areas**

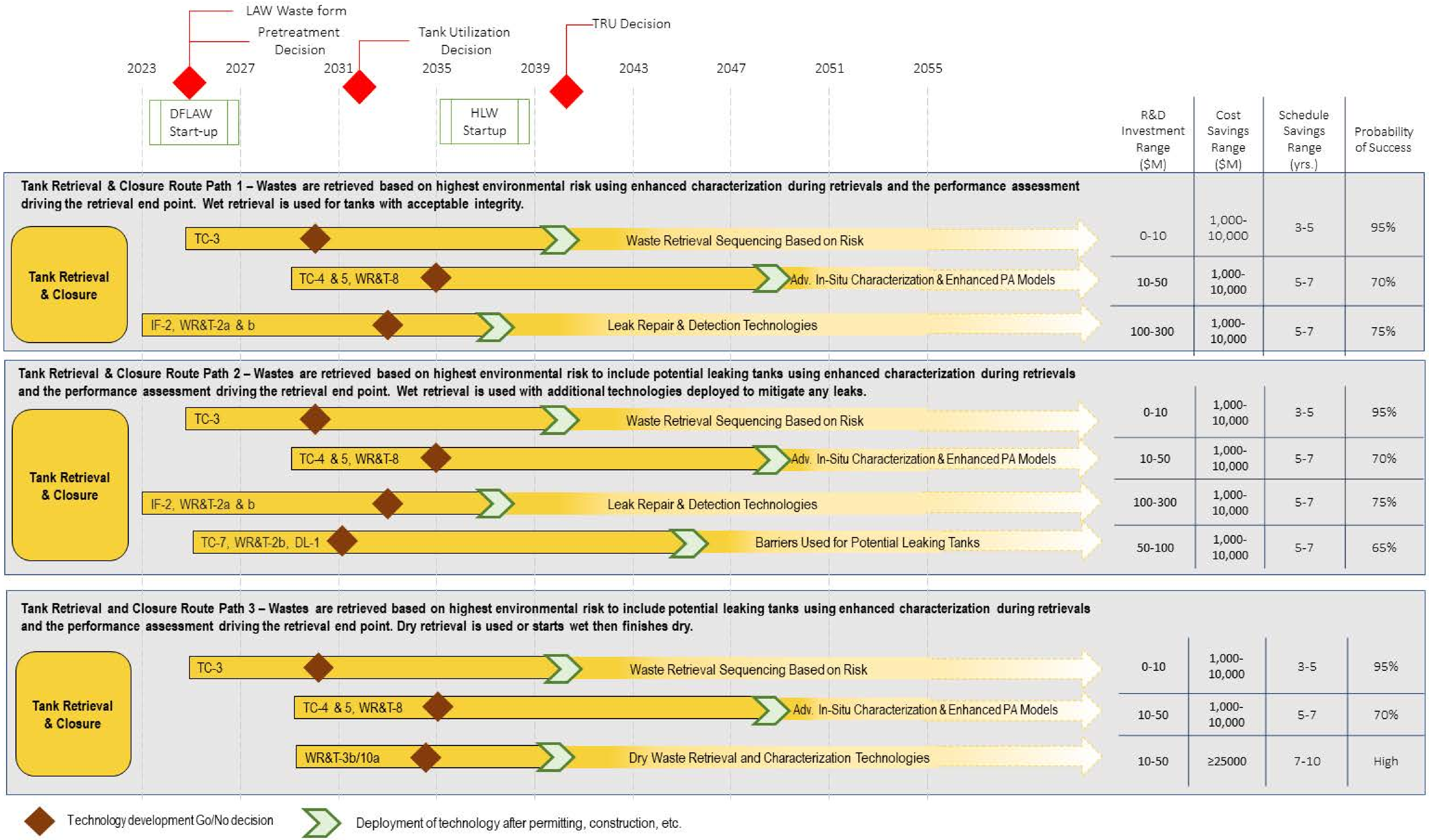



**Figure 7 continued. Potential R&D Roadmap Paths Based on Critical Mission Decisions and Implementation of R&D Areas**

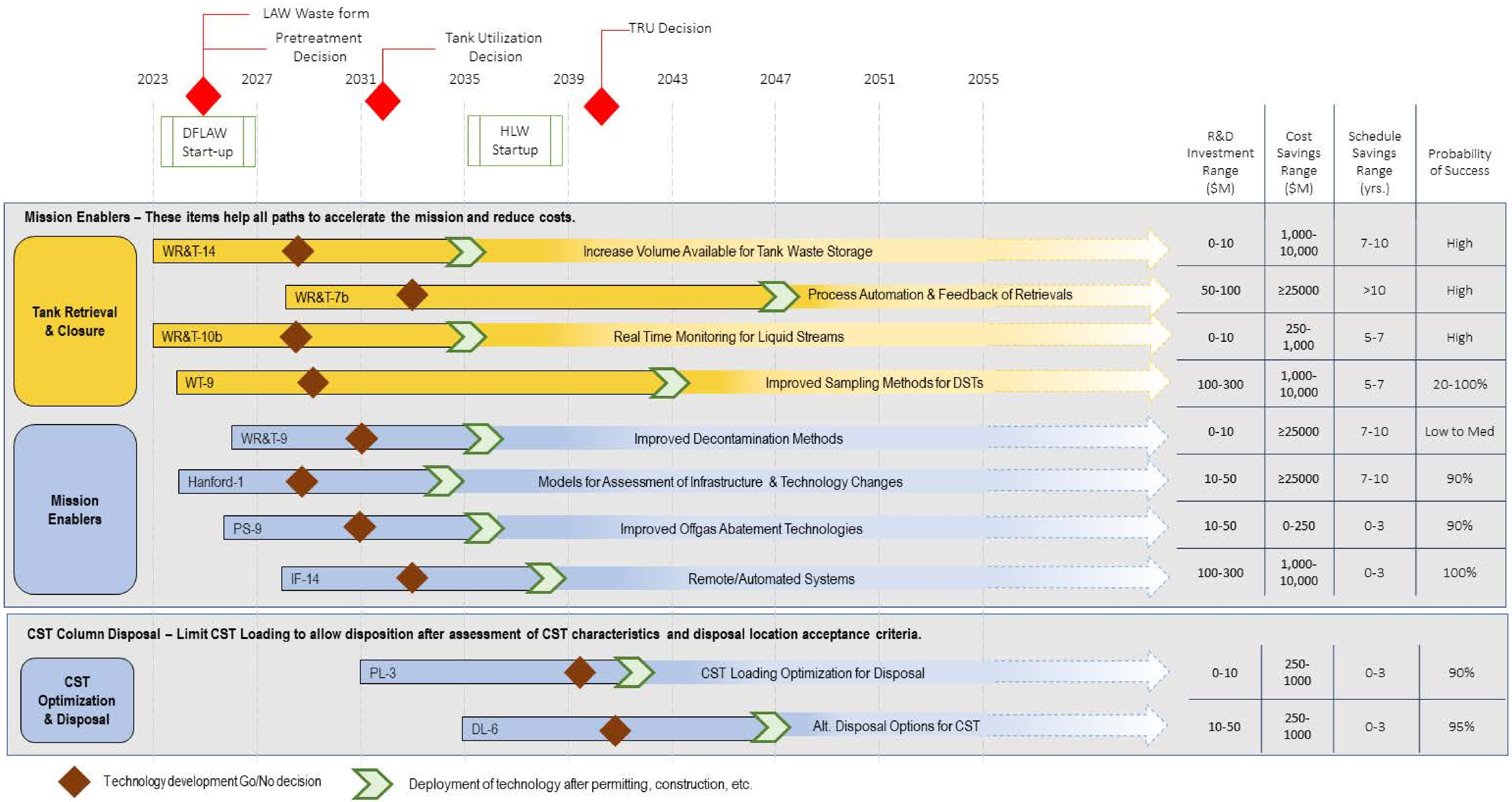



**Figure 7 continued. Potential R&D Roadmap Paths Based on Critical Mission Decisions and Implementation of R&D Areas**

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## Recommended Competitive Technology Development Program (CTDP) Process

Directed work scope to the national laboratories to execute Hanford Tank Waste Acceleration R&D is expected to continue, particularly where these laboratories have unique capabilities and facilities to execute the R&D recommendations in this Roadmap. The following is a set of recommendations for the creation, implementation and execution of a competitive program to engage the broader R&D community to meet all of the research challenges identified above.

As outlined in the EM Technology Development Framework[1], the DOE-EM Technology Development program seeks flexibility in an evolving technology development environment, as well as the desire to include a balance of long-term and short-term projects for DOE-EM, and a process for competitively awarding proposals to meet these needs.

Key high-level recommendations for the implementation of the CTDP include the following:

- DOE HQ and the Office of River Protection would assemble an implementation team that includes members from the Hanford site contractors, subject matter experts from the national laboratories, other DOE offices (e.g., Office of Science, BER, ARPA-E, etc.), universities and industry (as warranted).
- The team would evaluate this roadmap in the context of current and anticipated site mission needs as defined by the Technology Roadmap prepared for DOE Hanford by the Tank Farms operating contractor (RPP-PLAN-43988, current version) to finalize, and if necessary, revise, scope and research priorities. Recognizing that a number of the technology research needs identified in this roadmap have been and/or are being pursued by the site under the WRPS Technology and Innovation Roadmap, successful technology development and delivery will require a high-level of integration to avoid duplications of effort and assure efficient execution of all future Technology Development and Deployment activities.
- The team would assess R&D activities outside of EM that could benefit the Hanford site and mission acceleration. For example, on-going cementitious materials research for the Office of Nuclear Energy may have applicability to the recommended 'Grout for LAW' R&D work in IM-13. The Advanced Research Projects Agency – Energy's (ARPA-E) sensor development efforts under GEMINA for the interrogation of harsh environments could potentially be adapted to waste tank analysis and process monitoring.
- The team would conduct regular (e.g., semi-annual or annual) evaluations of R&D progress in the execution of this R&D Roadmap to assure technologies are being delivered to meet mission need dates as defined in the System Plan.
- The team would also assess real-time feedback from operational systems and newly identified operating issues that may arise. Such real-time feedback may impact R&D priorities and/or technology development elements of this roadmap necessitating a revision of priority and research direction.

[1] Office of Environmental Management, *Technology Development,* January 2021

## Research Programs Evaluated for the CTDP

The NNLEMS team evaluated the competitive processes of several DOE R&D programs (described below) to develop recommendations for implementing the R&D areas recommended in the roadmap process.

The DOE Office of Basic Energy Sciences (BES) and Energy Frontier Research Centers (EFRC) implement well developed proposal processes and established review criteria for selecting and awarding proposals.

The Basic Research Needs Environmental Management research and development program and its Basic Research Needs report also provides valuable experience. The Basic Research Needs report, itself, defines priority research directions (PRDs) most likely to have a dramatic future impact on cleanup and long-term storage of nuclear waste and has been drawn upon in the development of research priorities for this roadmap.

The Laboratory Directed Research and Development (LDRD) research program instituted by the National Laboratories has several operational components that are relevant to how the competitive proposal process could be managed for the roadmap portfolio. First, all concepts are submitted as pre-proposals that are evaluated for merit and impact. From these pre-proposals, a few are down selected to prepare a full proposal on the concept. This review and evaluation process is used by all the National Laboratories and is a proven process that would be easily transferable for use in implementing the roadmap portfolio. An important element of this process is the selection of nonbiased review teams for these reviews, which is a well-documented process that could also be implemented to avoid conflicts of interest.

DOE Hubs, particularly the National Alliance for Water Innovation (NAWI), have competitive process elements that could be beneficial to the Hanford tank waste RD&D program including: (1) requests for information and advanced communication of upcoming RFPs, (2) matchmaking to facilitate the development of multi-institutional teams and (3) a proposal review process that includes a post review-lessons-learned process for continued process improvement.

Based on our evaluation of these R&D programs, the following recommendations are presented for consideration:

1. The first and future RFPs should be developed by a team led by DOE HQ and ORP with appropriate tank waste technical and technology development and deployment expertise and NNLEMS technical and roadmap expertise. Ad hoc members with relevant expertise that are not fixed members of the review team would rotate through to provide an independent perspective may also be added at DOE's discretion. The team would develop, and sequence RFPs based on priorities identified in the roadmaps with consideration of unexpected or emerging issues that may have impact on site schedule and mission. The RFPs would be developed with consideration of recommended quick wins (above), recommended priority site needs and longer term, strategic investments that reduce cost and/or shorten mission time.
2. With respect to communication of RPF opportunities, we recommend a web-based information session in advance of each RFP to inform prospective respondents on the details of the upcoming RFP including clearly defined expectations, review process and associated review criteria. (The session will be recorded and posted on an easily accessed website.) We recommend matchmaking

support to those potential respondents who are looking for / in need of collaborators (this is likely to be particularly important to small businesses and minority serving universities or institutions within disadvantaged communities). Several docents selected by DOE, perhaps from the NNLEMS team and/or other ad hoc experts, would be responsible for facilitating matchmaking requests.

3. RFPs should encourage the participation of: (1) small businesses, minority owned small businesses, and minority serving and disadvantaged community research institutions; and (2) the formation of multi-institutional teams that include national labs, industry (including small businesses), and universities.
4. The RFP process would request interested respondents to begin by submitting a pre-proposal with a description of the team, its qualifications, the proposed research, impact to mission acceleration and a one-page CV for the principal investigator. DOE commonly requests 5-page pre-proposals across their programs but here a custom length (shorter or longer) may be chosen to enable effective down selection for full proposal requests. A 1 to 3-page appendix to allow respondents to include relevant data, images and other information could also be included in the RFP as warranted (similar to the process used by SERDP). The pre-proposals would then be subjected to independent peer-review. Reviewers would evaluate and score submissions using these recommended criteria: (i) responsiveness to the objectives and requirements of the RFP; (ii) scientific and technical merit; (iii) appropriateness of the proposed research; and (iv) likelihood of impact to mission acceleration. Applicants with the highest rated pre-applications could be encouraged to submit full proposals while those lower rated pre-applications could be discouraged for full submission. Succinct feedback to all pre-application respondents should be considered. This can be done efficiently by developing a predetermined matrix of feedback comments (e.g., "the submission is not fully responsive to the defined needs in the RFP because …" etc.). DOE would make the final decision on the selection of pre-proposals and the nature of feedback provided to respondents.
5. Requested full proposals would again be subjected to independent technical peer review. The reviewers would evaluate proposals against seven recommended criteria: (i) scientific and technical merit; (ii) appropriateness of proposed method or approach; (iii) strength of management plan; (iv) synergy among principal investigators, including cohesion and integration of research activities; (v) competency of applicant's personnel, proposal performance history, and adequacy of proposed resources; (vi) reasonableness and appropriateness of the proposed budget; (vii) development and/or utilization of unique facilities, capabilities or approaches and (viii) likelihood of impact to mission acceleration. Upon the completion of the proposal reviews, DOE would bring the review team together to discuss scoring, review outcomes and make recommendations to break scoring ties, when necessary. DOE would then make the final decision on selection and funding of full proposals.
6. Upon completion of the review and selection process DOE should consider hosting internal lessons-learned sessions with the independent technical review team to discuss observation and outcomes with a focus on process improvement for future RFP development and the review process.
7. Organizational and individual conflicts of interest (COI) would be carefully considered and mitigated by DOE throughout the entire review and selection process. DOE would have the option to involve site contractors, NNLEMS team members and/or technical experts from the national labs or universities to assist in the development of RFPs where specific expertise is required. However, the selection of proposal review team members would require some level of COI mitigation. To the extent possible, reviewers should not be selected from institutions that respond to a specific RFP.

The assignment of multiple reviewers, a minimum of three, to each proposal would also significantly mitigate the bias of an individual reviewer. DOE could also choose to develop and require a documented COI acknowledgement. For example, the NAWI proposal review process requires that each reviewer document and acknowledge in advance that they have no known or possible COI before reviewer selection is finalized. Alternatively, in R&D areas where the majority of SMEs are at the national laboratories, and the RFP is likely to have significant national laboratory response, the COI processes used by the Office of Science could be implemented. Process aside, individuals are expected to document COI and recuse themselves from participation as warranted. Ultimately, DOE would have the final decision in reviewer selection when COI is in evidence.

8. The procurement process for funding R&D proposals would be consistent with and meet federal acquisition guidelines.

## CTDP Proposal Review Team

We recommend identifying a group of technical experts with knowledge and expertise across the R&D needs defined in the roadmap. Overall coordination and project selection would be led by DOE The review team members selected by DOE do not have a standing membership, but rather are ad hoc teams assembled on an as-needed basis to review proposals in their specific area of expertise. It may be comprised of representatives from the DOE, the National Laboratories, academia, Hanford site contractors, or consultants with expertise in the relevant proposal area. These review teams would make selection and funding recommendations for DOE consideration. However, final decisions on the selection and funding of proposals rest solely with DOE.

## CTDP Portfolio Management Recommendations

As previously discussed, the NNLEMS team used a multiple step process to identify technologies that could reduce mission costs or accelerate completion of the tank waste mission schedule. The team identified a portfolio that would provide short-term improvements necessary to address immediate pinch-points or improve processes in the mission flowsheet from a technology or cost standpoint. The process also encouraged the identification of technologies that would be transformational in nature. It is important to note that transformational technologies may frequently require multi-year investments by DOE, and portions of this research would likely require increases in funding beyond the amounts typically available in existing technology investments.

During the technology evaluation process, specific criteria were included for the NNLEMS team to determine whether a candidate technology represented an incremental or transformational improvement. Other factors considered in evaluating the merits of a technology included such items as costs to develop or mature a technology, costs to implement the technology, probability of success, projected mission savings, and number of years in schedule improvement. As previously discussed, the methodology allowed for screening out potential transformational technologies that did not yield a meaningful “return on investment”, i.e., high savings relative to development/deployment costs, or appreciable schedule acceleration. Approximately 40% of the technologies that passed our screening process and were subsequently evaluated against a similar set of criteria, were determined to represent transformational approaches across the Top, High, and Medium categories.

A balanced approach to funding technologies that provide incremental improvements to baselines, as well as technologies that require longer-term investments, is consistent with other technology development programs. In the late 1990's, EM implemented a technology development program that was organized along cleanup functional lines using a Focus Area concept. One of these was a Tanks Focus Area (TFA) that responded to site-generated gaps or needs for technologies by working with entities, primarily within the DOE system, to develop technologies to address the needs. Initially, many of these were to improve baseline approaches; however, as the TFA process matured, it established a goal to fund longer-term activities. One of the successful applications of this was the maturation of candidate technologies for pretreating tank supernate or salt wastes at the Savannah River Site, in which funding over several years led to a decision to select the technology (actinide removal and caustic-side solvent extraction) that has been successfully employed in the Salt Waste Processing Facility. After technology selection, continued funding by EM in the solvent extraction technology led to development of a solvent that further increased cesium (and strontium) decontamination factors, enabling a projected shortening of the tank waste mission at SRS.

Based on portfolio management strategies typically employed by industry[2], the following additional recommendations are included for consideration:

1. Develop clear guidance and expectations for the research and development portfolio based on a strong and transparent link to EM's strategy for accelerated Hanford clean-up.
2. Review the existing research portfolio managed under the DOE Hanford site offices with consideration of research recommendations from this roadmap. Integration of efforts when applicable should be considered.
3. Regular portfolio reviews should be used to evaluate progress of technology maturation and review for likelihood of implementation success, and as a process to support alignment of research activities within the overall EM strategy.
4. Communicate successes and challenges across the Hanford Site Clean-Up program with a focus on building consensus with internal and key external stakeholders and regulators.
5. Upon selecting new projects, evaluate the current (and past) portfolio investments for balance, renewal and emerging RD&D challenges.
6. Portfolio management could be shared across the Hanford Tank Waste Management Program and involve the EM-HQ and the Office of River Protection with the support of their contractors.

[2] Arthur D. Little. Finding your balance: Insights into world class portfolio management. https://www.adlittle.com/sites/default/files/viewpoints/ADL_R_D_BestPractice_Finding_your_balance_Portfolio_Management_01.pdf

## Summary

An evaluation of the Hanford tank waste treatment mission has been performed and a R&D Roadmap for accelerating the mission has been developed. This roadmap was developed by SMEs from the NNLEMS, academia, and industry familiar with the EM tank waste mission or with developing innovative R&D roadmaps. The information provided can be used by DOE-EM to inform the EM budget request for technology development initiatives for fiscal year 2024.

Key observations and assumptions made by the team during the development of the R&D Roadmap include:

- The continuing escalation of cost and time to complete tank waste treatment and closure necessitates new technology improvements to deliver timely risk reduction for the surrounding Hanford communities, site workers, the nation, and the environment. Pursuing technological advances will give decision makers more options, some potentially game changing.
- Alternate technical approaches may appear to be beneficial without increasing the technical risk but may require significant regulatory negotiations and stakeholder engagement. Several mission level decisions have been identified that have the potential to have a substantial impact on the lifecycle costs if the technical maturity of the concepts can be advanced and identified concerns can be resolved.
- The NNLEMS team assumes that DOE Manual 435.1-1, *Radioactive Waste Management Manual*, and subsequent DOE Directives will be applied to selecting disposition paths for the Hanford tank farm's wastes.
- Given the remaining duration of the mission (>50 yrs.), the R&D program should have a diversified investment portfolio that includes opportunities to reduce the risk of achieving the existing baseline without additional escalation of costs and schedule; incremental improvements to the existing baseline that could have significant impacts on the schedule, and transformational technologies that would require additional time to mature, including fundamental research to develop potentially game changing technologies that are presently unknown.
- Flexibility in the treatment options or flowsheet is needed, including consideration for treatment strategies by tank farm, matching the hazards of the constituents of concern with potential at-tank or modular options to avoid the need for cross-site transfers to the WTP facilities. This would have the secondary benefit of mitigating throughput impacts on these facilities that have been predicted to occur throughout the Hanford mission.
- New right-sized blending/staging tanks could improve throughput and lessen the reliability on existing DSTs, which is currently a regulator concern.
- Based on operational experience at the SRS, the Hanford System Plan evaluations, and the limited evaporative capacity for the tank waste mission, additional evaporator capability will be needed for the mission.

The strategy used for the Roadmap development is to provide a R&D program that can begin to implement options in the near term that should allow waste removal from tanks and treatment to proceed while solutions for more technically challenging wastes are pursued.

The Roadmap provides a recommended portfolio of investments to enable technology development through facility deployment (RD&D) with supporting documentation outlining the process for technology selection, a preliminary cost/benefit analyses of the proposed concepts, and a proposal for a competitive technology development program to implement the roadmap. The R&D Roadmap also identifies potential flowsheet changes and key DOE decisions that if implemented could facilitate the acceleration. The key mission-level decisions identified by the team include:

- Selection of waste forms for LAW
- Pretreatment infrastructure to efficiently meet mission needs
- Tank Utilization
- Disposition of TRU waste

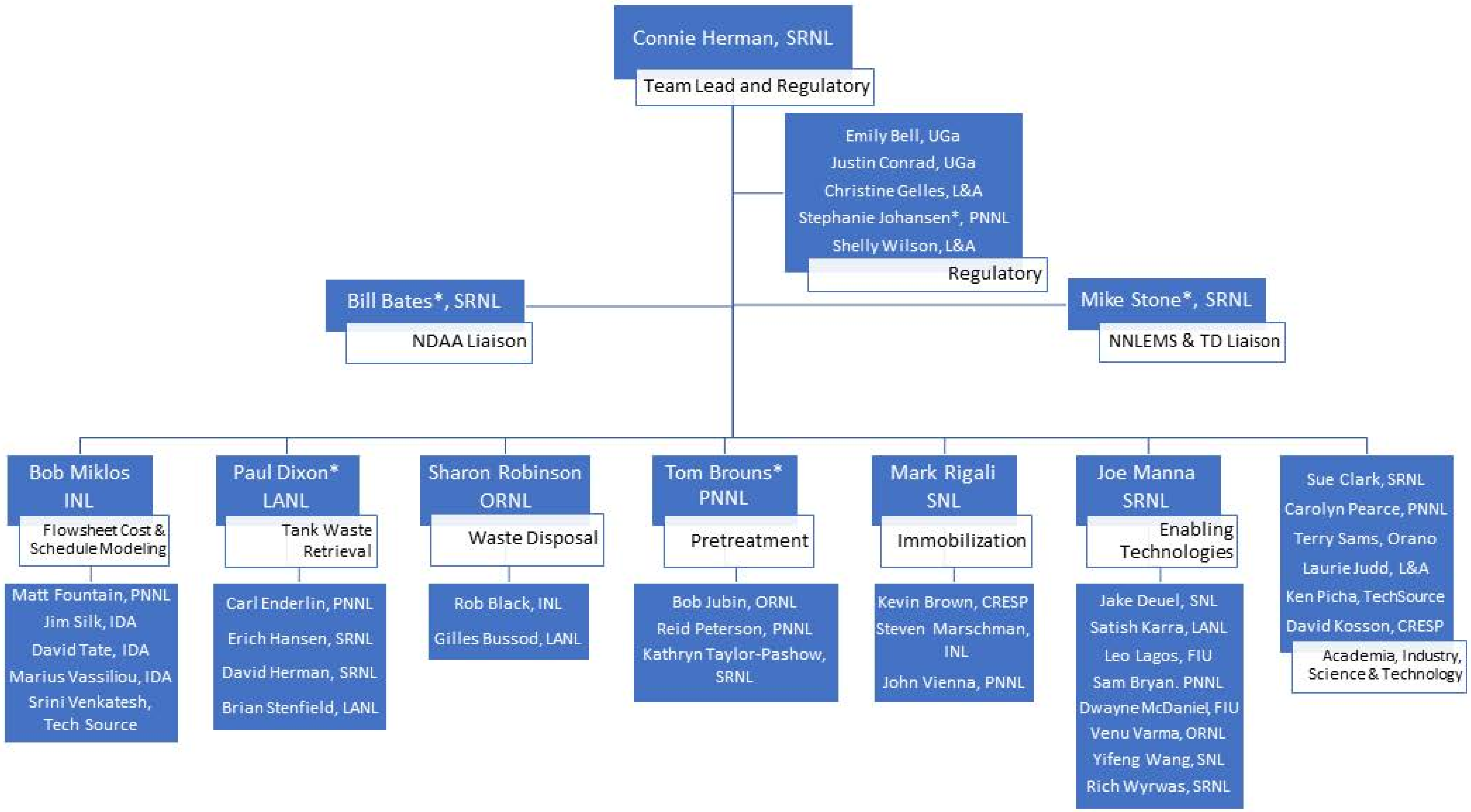
These key decisions impact the amount of waste generated for each disposal facility, as well as the types and sizes of waste processing facilities needed for each waste stream, and the R&D portfolio mix needed to support the program. Therefore, a flexible, multi-pronged approach has been taken for the Hanford tank waste R&D Roadmap. The team recommends that near-term (pre-decisional) R&D be pursued to provide decision makers with data to make informed mission-level decisions and increase stakeholder acceptance of those decisions. R&D that will likely be beneficial in most of the scenarios should also be pursued early in the RD&D program. The mix of R&D required to support waste processing and disposition long term will evolve over time as key mission level decisions are made, information from RD&D projects become available, and the Hanford cleanup activities progress.

Implementation of this roadmap, led by the DOE HQ and the Office of River Protection, would involve: (1) integration with the WRPS roadmap and ongoing and planned site closure activities; (2) development and sequencing of R&D priorities via a detailed RFP process; (3) regular evaluations of R&D progress; and (4) revision of research priorities as needed based on feedback from operational systems and rising operational issues.

To facilitate transparency and an understanding of the future goals of DOE with the R&D Roadmap, it is recommended that an initial open discussion of the R&D Roadmap be held for the public, either in person or virtual and recorded for further dissemination, with annual public discussions of updates thereafter. A website could also be established with R&D Roadmap information and updates for access by the public to include a contact for those with access restrictions.

# Attachments

# Attachment 1: Team Members and Structure




*NDAA SLAW Team

# Attachment 2: NNLEMS Team Charter

# Development of the Network of National Laboratories for Environmental Management and Stewardship Research and Development Roadmap for Accelerating the Hanford Tank Waste Cleanup Mission Charter

## 1. Purpose

The Department of Energy (DOE)'s Hanford Site in southeastern Washington State has 56 million gallons of radioactive and chemical waste stored in 177 underground tanks—the result of more than four decades of plutonium production. The mission of the Office of River Protection includes the retrieval, treatment, and disposal of this waste in a safe, efficient manner, reducing any threat it may pose to the Columbia River. It is prudent to continually identify research and development (R&D) opportunities to provide cutting-edge technologies that can be used for improving efficiency, along with cost savings and schedule acceleration for the Hanford tank waste cleanup program.

For these reasons, the Acting Assistant Secretary for Environmental Management (EM-1) will commission the Network of National Laboratories for environmental Management and Stewardship (NNLEMS) to conduct an evaluation of the tank waste mission at the Hanford Site and develop a R&D Roadmap for accelerating the mission. The R&D Roadmap, when developed in the Spring of 2022, will be used to inform the EM budget request for fiscal year (FY) 2024 concerning technology development initiatives.

## 2. Roles and Responsibilities

### 2.1 Federal Stewardship

Development of the R&D Roadmap will be managed, approved, and maintained by a Federal Steering Committee that reports to EM-1. The EM Senior Advisor for Laboratory Policy will be responsible for leading the Federal Steering Committee. Members of Federal Steering Committee include the Assistant Manager of the Tank Farm Project; the Director of the EM Technology Development Office; the Director of Office of Budget and Planning; and other EM program offices that may be added at a later time, if needed. The Assistant Manager of the

Tank Farm Project will be responsible for coordination with the Hanford Site, including supplying site data and other information that the NNLEMS Team may request. The Director of the EM Technology Development Office will ensure the proposed Roadmap is consistent with and will complement the integrated technology development program for the EM complex.

The Federal Steering Committee will coordinate with e.g., the Office of Science and Advanced Research Projects Agency-Energy, as necessary during the development and implementation of the Roadmap to ensure that the Roadmap is consistent with current and planned basic research and innovation initiatives sponsored by other DOE programs or other Federal agencies.

Any update to the leadership and membership of the Federal Steering Committee will be approved by EM-1.

## 2.2 NNLEMS Team

The NNLEMS Team will support development of R&D focus areas (including but not limited to retrieval, treatment, and disposal). The NNLEMS Team will include, but not be limited to, the Savannah River National Laboratory (SRNL), Pacific Northwest National Laboratory (PNNL), Oak Ridge National Laboratory (ORNL), Los Alamos National Laboratory (LANL), Idaho National Laboratory (INL), and the Sandia National Laboratories (SNL). The team of labs will be led by SRNL. The NNLEMS Team may consult with subject matter experts in industry, academia or other stakeholders as the Team deems appropriate and necessary. DOE will have no role in the selection of such experts to work with the NNLEMS Team, and DOE will not exercise management and control of any groups of experts created by the NNLEMS Team.

Any pre-decisional documents to which the DOE labs have access may be shared with technical experts in accordance with applicable law. Members of the NNLEMS Team will be required to sign a Non-Disclosure Agreement to gain access to pre-decisional documents that will be supplied by DOE for this effort. NNLEMS will follow their own processes and procedures to manage access to such documents by any non-DOE Laboratory participants they may consult with. Participation of industry experts in consultations with the NNLEMS Team does not disqualify their company from participating in future procurement activities at the Hanford Site.

# 3. Scope of Work

Over the next 12 months beginning in May 2021, the NNLEMS Team will review the current baseline for completing the tank waste mission, and develop the R&D Roadmap to identify focus areas. Key documents for the review will be provided by the DOE Office of River Protection.

The NNLEMS Team will evaluate the existing tank waste program, as well as past proposals for program acceleration, in addition to developing independent proposals to accelerate the process. Recommendations will include proposals to more efficiently retrieve and treat the tank waste, efficiently implement various immobilization technologies, and efficiently disposition the treated waste. The alternative approaches must account for regulatory requirements and agreements. The team will also consider alternative classifications of tank waste currently managed as "high level waste". The evaluation will focus on technologies.

In addition, the evaluation will track the progress and status of the NNLEMS Team-led FFRDC study on treatment of supplemental low-activity waste to ensure that applicable strategies developed during that review are considered during the development of the Roadmap.

Based on the evaluation, the NNLEMS Team will provide a draft Roadmap to EM-1 for approval containing the recommended focus areas developed during the evaluation. The Roadmap will identify the proposed methods for tank waste acceleration and a preliminary cost/benefit analysis of any recommended proposals. The evaluation will also include a proposal for how to manage a competitive technology development program to implement the Roadmap.

In the near term, the draft Roadmap will be used to inform the EM budget request for FY2024. The Roadmap will be updated with NNLEMS' support with technology development and management directives on a regular basis. The Roadmap will be used to guide the investment in breakthrough technologies that can be implemented to improve efficiencies in the Hanford tank waste mission. A Laboratory Directed Research and Development (LDRD)-like program may be developed for implementation of the Roadmap.

## 4. Funding

Funding for the NNLEMS Team study will be allocated to each of the participating National Laboratories by the EM Laboratory Policy Office, in consultation with EM-1, Office of River Protection and Office of Technology Development.

## 5. Reporting and Documentation

The Federal Steering Committee, and the NNLEMS Team, when necessary, will provide regular briefings to EM senior leadership at least quarterly on the status of the preparation of the Roadmap. Key milestones and schedule include:

NNLEMS proposal due to EM-1 by May 31, 2021.
Draft R&D Roadmap due to EM-1 by April 30, 2022.
Final R&D Roadmap due for public release by August 31, 2022.

Additional interim milestones/deliverables will be developed and identified in the NNLEMS Team proposal.

Development of the R&D Roadmap will be documented in MAX.gov for transparency and traceability.

**Concurrence:**

Ming Zhu — Digitally signed by Ming Zhu Date: 2021.06.01 17:50:02 -04'00' — 6/1/2021

Ming Zhu, Senior Advisor for Laboratory Policy — Date

Delmar L. Noyes — Digitally signed by Delmar L. Noyes Date: 2021.06.01 13:30:33 -07'00' — 6/1/2021

Delmar Noyes, Assistant Manager, Tank Farm Project — Date

Kurt D. Gerdes — Digitally signed by Kurt D. Gerdes Date: 2021.06.01 16:16:37 -04'00' — 6/1/2021

Kurt Gerdes, Director, Office of Technology Development — Date

Charles S. (Steve) Trischman — Digitally signed by Charles S. (Steve) Trischman Date: 2021.06.01 17:45:26 -04'00' — 6/1/2021

Steve Trischman, Director, Office of Budget and Planning — Date

Nicole Nelson-Jean — Digitally signed by Nicole Nelson-Jean Date: 2021.06.02 14:54:16 -04'00' — 6/2/2021

Nicole Nelson-Jean, Associate Principal Deputy Assistant Secretary for Field Operations — Date

Mark Gilbertson — Digitally signed by Mark Gilbertson Date: 2021.06.02 15:59:58 -04'00' — 6/2/21

Mark Gilbertson, Associate Principal Deputy Assistant Secretary for Regulatory and Policy Affairs — Date

Dae Y. Chung — Digitally signed by Dae Y. Chung Date: 2021.06.02 15:02:43 -04'00' — 06/02/21

Dae Chung, Associate Principal Deputy Assistant Secretary for Corporate Services — Date

**Approval:**

07/15/2021

William I. White, Acting Assistant Secretary for Environmental Management — Date

# Attachment 3: Quick Win Ideas for Hanford Tank Waste Mission

**Quick Win #1 - R&D Focus** – LDR Organics Characterization and Removal/Destruction

**Description (Original Background):**
LDR organics must be removed or destroyed to sufficient levels to meet the disposal requirements for Hanford tank waste. Establishing a firm removal/treatment requirement for LDR organics is problematic based on the current level of underlying characterization estimates for non-HLW or vitrification disposal options under consideration. This proposal would 1) develop a better understanding of the LDR organic content in the Hanford tank waste and 2) evaluate removal/destruction technologies for their potential treatment. The study would build on recent WRPS, PNNL, and SRNL efforts in these areas and proposed NNLEMS projects for in-line monitoring. The LDR characterization tasks include: 1) obtaining and evaluating tank waste characterization data to define data gaps and technology limitations associated with LDR constituent measurement in either the sample/analyze approach or in-line monitoring and 2) comparing actual sample data for selected tanks to estimates of LDR constituents obtained from Henry's Law based on tank headspace and exhauster data. Studies to reduce the LDR organic content of the waste stream include separation via evaporation targeting the more volatile compounds and chemical destruction technology for the residual LDR organic compounds. Testing and verification would be accomplished with a suite of LDR organics that have been verified to be present in the Hanford tanks with the purpose of determining the limits / extent of reduction that can be achieved with the available technology to address key problem contaminants of concern. A follow-on study would involve pursuing development/scale up of both the confirmatory analysis and treatment methods to support future deployment.

**R&D ROM** – $2-5 M per year for 3 - 4 years

**Roadmap Tie, Existing Program Ties, and Near-Term Plan**
PL-5: RCRA Organics removal from Tank Supernate
WT-1 through 4: In situ characterization methods
*LAW Waste Form* decision

**Proposed Work Scope**

These activities are recommended for evaluating analysis and destruction of regulated organics that may be present above disposal limits in some Hanford tank wastes and impact the supplemental Low Activity Waste (LAW) stream. The objectives are to improve the analysis procedures to ensure regulatory limits are met and to develop a method to destroy organics, if present, in the decontaminated LAW solution, and to ensure potential grout materials from the Supplemental LAW (SLAW) stream meet the WAC. A decision on SLAW treatment has not been made.

1. <u>Measurement of Radioactive Waste Samples for LDR Organics</u>: This task would improve understanding of the LDR content in the Hanford tank waste by establishing methods to decontaminate radioactive samples to enable their analysis for LDR organic constituents and performing analysis on actual samples. Current EPA methods for analysis of samples to measure regulated organics require larger amounts of liquid to enable reaching

detection limits than are practical with the limited size and radiation dose rates common to tank waste samples. There are multiple potential methods to achieve low detection limits with limited sample sizes, such as by preconcentration on a sorbent. The sorbent method being pursued by WRPS and 222-S laboratory involves using a special polymer-coated stir-bar to sorb the organics, followed by thermal desorption. (This work is currently supported by WRPS at the 222-S lab). These special stir-bars would not extract most of the radionuclides, so they can be used with large volumes of highly radioactive liquid inside a shielded environment, and then be removed to be analyzed in a radiological fume hood with minimal dose. This method may be effective, but also may have matrix stability problems with the polymer and/or is not effective with all organics that must be analyzed. Another method that should be considered is to modify existing sorbents with doping material, such as ethylene glycol or silicone to significantly increase the range of $K_{o/w}$ that can be extracted.

Existing data on organics in tank waste is derived from different sources, with some liquid sample results and some from tank vapor samples. The vapor samples are used to calculate the possible tank liquid concentrations, but these data points are possibly suspect.

The analysis methods used at Hanford's 222-S laboratory are based on EPA methods. Those methods may not be compatible with the waste tank matrix, largely because the EPA methods require acidification of the liquid. During acidification, the nitrite in tank waste becomes highly reactive and may form nitrated organics that were not actually present in the original sample. SRNL has previously developed a method using a buffer solution to minimize the unintended production of nitrated organics, but it is not EPA-method certified. Similarly, phthalates are often claimed present in Hanford waste based on analysis of tank vapor samples. This is likely in error because phthalates are non-volatile but are suspected to be present in sampling and analysis equipment. Resolving the potential formation of nitrated organics and presence of phthalates during analysis may impact the requirements for disposal of a grout waste form.

- Subtask A will focus on developing alternate stir-bar sorbents that are stable in the waste matrix and effective for the expected organics.
- Subtask B will focus on establishing whether CST can be used to decontaminate the sample without removing the organics so larger amounts can be handled by laboratory personnel to reduce dose rates when handling sample volumes specified by EPA methods, and as an alternative if the sorbent on the stir-bars method is found incompatible with the chemical environment.
- Subtask C will focus on mining existing date and evaluating tank waste characterization data to define data gaps and technology limitations associated with LDR constituent measurement in either the sample/analyze approach or in-line monitoring and comparing actual sample data for selected tanks to estimates of LDR constituents obtained from Henry's Law based on tank headspace and exhauster data. (Potentially tied to Quick Win #5)

- Subtask D will focus on modifying the 222-S Procedures for analysis of samples to avoid nitration of organics and the presence of phthalates. Testing would be needed to examine the analysis method and potential presence of phthalates from background equipment. Work in FY22 will be initial investigations, limited primarily to literature studies, with simulant testing to commence in FY23. Method development and finalization will be performed in FY24, along with real waste testing in FY24 and FY25. Activities will be coordinated with Hanford Laboratory Management and Integration (HLMI) personnel at 222-S laboratory

| **Task** | **Description** | **ROM FY22 ($K)** | **ROM FY23 ($K)** | **ROM FY24 ($K)** |
|---|---|---|---|---|
| 1A | Measurement of Radioactive Waste Samples for LDR Organics – Alternate Sorbents | 125 | 500 | 0 |
| 1B | Measurement of Radioactive Waste Samples for LDR Organics – Decontamination Studies | 0 | 300 | 200 |
| 1C | Obtaining and evaluating tank sample and vapor results to define gaps and limitations of data | 0 | 250 | 0 |
| 1D | Modifying procedures and examining production of nitrated organics and presence of phthalate contamination | | 400 | 400 |

2. <u>Develop Methods to Destroy Organics in Tank Waste</u>: This task would expand on and supplement initial laboratory studies currently underway at SRNL. Initial studies are examining stability of organics in tank waste simulants and are identifying evaporation methods to remove them and chemical oxidation methods to destroy them. There are other methods to destroy organics that may be applicable. These methods include Wet Air Oxidation (WAO), pressurized thermolysis, electron beam radiation, and ozonation. Initial evaluations are needed to determine if these methods are practical.

   To augment initial chemical oxidation laboratory studies that are currently underway, the methods found effective will be scaled up and expanded. For example, if initial testing indicates that hydrogen peroxide oxidation is effective, testing will be needed to search for catalytic additives that can enhance hydrogen peroxide oxidation efficacy. Similarly, testing will be needed to optimize hydrogen peroxide oxidation such as through elevated temperature, concentrations, etc. Kinetic studies of the destruction rates of regulated organic compounds will be needed to establish conditions and residence times for a process.

   To mature the technologies used for removal or destruction of organics, actual waste testing will be needed. Evaporation, and potentially oxidation, of actual waste samples that contain regulated organics is a key step in proving the viability of the process.

Once an oxidation method is established, testing will be needed to determine if residual oxidant or secondary oxidizers will impact the behavior of a grout waste form (Supplemental LAW). A key function of the slag used in grout waste form is its reduction potential which is the mechanism for sequestration of Tc and some hazardous metals. The oxidation step will change the composition of the waste and may produce secondary solids. Testing would be needed to determine if residual oxidant or secondary oxidizers produced by the oxidation step will impact the reduction potential of the slag used for grout, and to develop a formulation and mixing process to handle insoluble solids. Ultimately, the grout waste form will need to meet the WAC requirements for the disposal location.

- Subtask A will evaluate the practicality of applying other oxidation methods to destroy organics through literature studies and engineering estimates. These methods will include Wet Air Oxidation (WAO), pressurized thermolysis, electron beam radiation, and ozonation. If any of these methods are projected to be practical, a proposal will be prepared that will scope out testing and maturation of that organic destruction method.
- Subtask B will be an expansion of the initial laboratory studies that are currently underway by augmenting the chemical oxidation methods that are found effective. For example, if initial testing indicates that hydrogen peroxide oxidation is effective, this subtask will examine catalytic additives that can enhance hydrogen peroxide oxidation, and optimizing hydrogen peroxide oxidation such as through elevated temperature, concentrations, etc. FY23 activities for subtask B will involve fabricating and initial run-in of a scaled-up destruction system and kinetic studies of the destruction rates of regulated organic compounds that are thought to be present in the tank waste.
- Subtask C will involve initial set up and testing of rigs for evaporation and oxidation that can be used with small amounts of radioactive tank waste, followed by actual waste demonstrations.
- Subtask D will involve evaluating the impact of chemically oxidized LAW on grout performance against likely Waste Acceptance Criteria. Testing would be needed to determine if residual oxidant or secondary oxidizers produced by the oxidation step will impact the reduction potential of the slag used for grout, and to develop a formulation and mixing process to handle insoluble solids. Testing will examine performance, homogeneity, and regulatory compliance (e.g., reduction capacity, leaching, TCLP). This task will not initiate until the flowsheet is better defined.

| Task | Description | ROM FY22 ($K) | ROM FY23 ($K) | ROM FY24 ($K) |
|---|---|---|---|---|
| 2A | Develop Methods to Destroy Organics in Tank Waste – Initial Technology Evaluation | 125 | TBD (only required if current work is not fully effective in organic destruction) | 0 |
| 2B | Develop Methods to Destroy Organics in Tank Waste – Laboratory Studies Expansion | 0 | 800 | 800 |
| 2C | Evaporation/oxidation of actual Hanford tank waste samples | 0 | 350 | 800 |
| 2D | Demonstrations of grout formation with oxidized LAW samples | 0 | 300 | 500 |

Contributors: C.A. Nash, D.J. McCabe, A.J. Boggess, (SRNL) and M. Asmussen (PNNL)

**References:**

Duarte, C.L., Geraldo, L.L., de Aquino P., O. Jr., Borrely, S.I., Sato, I.M., de Oliveira Sampa, M.H., Radiation Physics and Chemistry, 71 (2004) 443-447

Englande, A.J. Jr., Krenkel, P., Shamas, J., Wastewater Treatment and Water Reclamation, Elsevier, Inc., 2015; http://dx.doi.org/10.1016/B978-0-12-409548-9.09508-7

TWRSPP93-064; PNL-SA-23181, Second IPM Technology Selection Meeting (June 27-29, 1994) Final Report, July 21, 1994

**Quick Win #2 - R&D Focus** – Development of Sludge Preparation Tanks At or In-Tank

**Description**
The baseline WTP HLW feed preparation strategy relies upon the Pretreatment Facility to wash the HLW to remove constituents of concern, perform any necessary Al dissolution or Cr leaching, and to concentrate the HLW sludge to maximize waste loading and waste throughput. Due to safety and technical issues, the construction of the Pretreatment Facility has been significantly delayed and a Tank Waste Characterization and Staging (TWCS) facility was proposed to ensure HLW feeds to the Pretreatment Facility meet the required WAC.

At the Savannah River Site (SRS), these functions have been performed in the DSTs when needed and a sequenced approach has been utilized to allow interim technologies or facilities to be deployed to continue the waste treatment mission while technical issues with the baseline facilities are being resolved. To mitigate the risk that staging and pretreatment of HLW sludge may not be ready to support the HLW Facility, technology evaluations and demonstrations are proposed to determine feasible technologies for at-tank or in-tank sludge preparation. These technologies could also be deployed in the design of the TWCS facility should it be determined to be necessary and could be coupled with monitoring technologies to mitigate concerns with use of existing DSTs for sludge preparation. The initial focus should be on sludges resulting from PUREX processing due to the similarity with HLW sludges that have already been processed at SRS. The waste tanks storing PUREX sludge are in close proximity to the HLW facility and the 242-A evaporator, mitigating the need for near-term operations of the cross-site transfer lines.

Potential technologies or areas to be considered in no particular order include: 1) evaluation of the current state of the art for mixing technologies to obtain the necessary homogeneity of the HLW sludge, 2) additives to improve in-tank settling rates or enable solids suspension for sludge with consideration of their potential downstream impacts, 3) at-tank modular type systems for filtration, leaching, size reduction, and washing, 4) in-tank systems for filtration such as rotary filters that have been evaluated for both Hanford and SRS sludge, 5) evaluation of potential aluminum dissolution parameters and impacts on the safety basis based on recent performance data and the Office of Science EFRC efforts, and 6) evaluation of the HLW facility design and potential glass formulations to understand and update the waste acceptance criteria related to HLW sludge properties for the HLW Interface Control Document (ICD).

**R&D ROM** – $1.5-6 M per year for 3 - 5 years with the initial focus on the data gathering for the current state of the art in these areas and to ready for out-year testing and the following years focused on demonstration and scale-up.

**Roadmap Tie, Existing Program Ties, and Near-Term Plan**
PS-4: In-tank pretreatment of high-level waste sludge
PS-2: At-tank pretreatment of high-level waste sludge
PS-3: Improved understanding of aluminum chemistry to optimize sludge processing
PL-2: Additives to optimize filtration
IM-1b: Improved high level waste glass formulations
IM-2c: Improvement to high level waste glass melter design & throughput
*Pretreatment Infrastructure* decision
*Tank Utilization & Waste Receipt Facilities* decision

Some efforts have been initiated through ORP and its contractors in this area. Existing programs include the following:

- A contractor led effort under the Integrated Flowsheet program has begun evaluation of Direct Feed HLW (DFHLW) options. The Integrated Flowsheet has embedded support from both PNNL and SRNL as well as reach-back support from VSL. The Integrated Flowsheet study has prepared a list of gaps for a DFHLW flowsheet using the existing DST system assuming that caustic leaching is not performed. As part of the Integrated Flowsheet effort, SRNL has prepared a draft summary of tank mixing experiences during sludge batch preparation at SRS.
- An evaluation of the feasibility of using *in situ* analysis for a DFHLW option has been discussed with ORP and its contractors and was also described in the Quick Win "Sample Reduction using Material Balance and Real-Time, In-Line Monitoring Approaches for HLW Applications". The timing for advancing this project is now given WTP is finalizing the design for the HLW facility.
- Al-leaching is not currently being evaluated under the contractor led effort because it would be pursued in the next phase of the treatment plan but is part of an Office of Science EFRC effort (PS-3 in the Roadmap). The program goal is to develop an improved understanding of aluminum chemistry that can be leveraged to support enhanced models and strategies for leaching.
- HLW glass formulation work could lessen the need for washing, Cr-leaching, and Al-leaching to achieve high waste loadings and throughput. These efforts have historically been funded by ORP but may require additional funding for testing of new approaches envisioned for HLW glass production.
- ORP chartered an External Expert Review to evaluate the current design and processing strategies for the HLW facility to include processing through the Pretreatment Facility and with consideration of DFHLW processing. As part of the charter, the team is to recommend potential testing to support the advancement of the design and construction, as well as the overall flowsheet.
- The DNFSB has previously identified concerns with the transfer of liquids containing solids (sludges or slurries) to include concerns with deposition and piping wear. Both WRPS and BNI have addressed these concerns through their design and engineering programs. Assessment of the resolution in light of any changes to processing plans should be considered.

**Proposed Work Scope**

Based on the known work scope, the following activities are proposed for funding to advance the sludge process for HLW production.

1. Sludge Preparation and Staging - HLW feed campaign staging may have multiple waste preparation needs (e.g., washing, leaching, filtration, blending, size reduction) depending on the specific tank or type of waste being processed. For the initial phases of HLW processing, limited ability to wash, filter, and blend the tanks is anticipated with other sludge preparation functions likely being delayed until later phases. Predicting the composition of the tanks to prepare for processing of the sludge campaign in the facility is further complicated by limited sample information on each of the tanks especially in representative retrieved conditions. The ability to accurately and reliably predict compliance with the HLW Waste Acceptance Criteria (WAC) limits will be greatly improved through sampling during the retrieval process and will be essential in maintaining sufficient feed and HLW facility throughput. The Hanford integrated DFHLW team will be assessing sludge retrieval technologies for implementation in the tank farm, as well as the design needs for any staging tanks for the HLW sludge to the HLW facility. This effort could

be furthered by a review of existing sludge sample characterization data to help predict sludge inventory compositions and retrieval performance using C-farm retrieval experience. Additionally, understanding the waste compliance strategy and the potential use of in-situ sampling methods will be integral in the sludge preparation process. For purposes of this quick win, it is assumed that the contractor will be funding assessment of sludge retrieval technologies and the waste compliance strategy.

   a. Proposed Activity - estimated $200K cost to evaluate current sample data relative to planned HLW sludge staging.

2. Glass Formulation - The current analysis supporting DOE's External Expert Review for HLW treatment is identifying key gaps in formulation data that would enable the initial phases of HLW processing to include potentially less washed and concentrated sludge. Development of data to address these gaps will be needed, and the glass data base efforts already funded by DOE-EM TD will be helpful in assessing these gaps. This work will be coordinated with current ORP glass program priorities and BNI scope to determine where this effort can be supported as well as the needed timing of this evolution.

3. Sludge Preparation/Filtration – For the initial phases of HLW processing, limited filtration capability is anticipated to assist with washing and concentrating of the sludge. As with the SRS HLW processing, settle/decant operations will occur to concentrate the HLW sludge and the duration will pace the ability to prepare the sludge campaign. Much like the SRS efforts, the build-up of hydrogen through radiolysis or thermolysis will need to be considered and mixing of the sludge may be required to release hydrogen before it builds up to flammable concentrations; therefore, the number of days of settling (or Q-time between mixing) may be limited. If insufficient solids settling rates are observed, delays in waste feed staging and concentration operations will occur. Different technical solutions could be applied to mitigate this potential concern and could involve the use of deployed filtration systems or additives to help with settling. These technologies may not be necessary to start processing but may prove beneficial after start-up and as problems are encountered. Conceptually, near-tank or at-tank filtration systems to support washing and decanting operations could be deployed.

   a. Proposed Activity #1 - estimated $100-400K cost. Evaluate existing settling data to determine the extent of settling issues with the proposed operating conditions for HLW processing. If needed, perform testing with tank waste suspected of having low settling rates using selected core segments or representative tank waste samples at multiple solids loadings in as received (retrieved and transferred) and a washed solution matrix.
   b. Proposed Activity #2 – estimated $200K cost. Evaluate available technologies for at-tank or in-tank filtration with consideration of the potential vault location for staging of HLW sludge. Technologies need to consider required footprint and disposition of the effluent in addition to potential processing times.
   c. Proposed Activity #3 to be started upon completion of Activity #2 - estimated $500K cost. Develop the simulant for filtration testing and perform simulant testing to develop the process parameters for the selected filtration system.
   d. Proposed Activity #4 – estimated $100K cost. Evaluate the current state of the art for additives to enhance or inhibit settling as needed for sludge preparation. This

evaluation needs to consider the potential downstream impacts and will result in a deliverable on recommended additives for testing should additives prove necessary.

4. Zr Cladding Simulant Development – Currently, the simulants that have been developed are not believed to be representative of the Zr cladding wastes. These wastes are envisioned to be processed during the initial phases of HLW processing and process parameters may need to be adjusted to enable the preparation, transfer, and vitrification of this waste stream.

   Proposed Activity - Develop a simulant for Zr cladding waste to enable process development testing with simulants. This work would be done in conjunction with the AW-105 core characterization utilizing data as it becomes available to develop a simulant for this type of waste to enable further process development testing.

5. Sludge Transfers – The target solids concentrations for slurries or sludges are likely to be different if prepared in the tank farm than what is possible through the WTP Pretreatment facility due to constraints potentially caused by the lengths of transfers and safely achievable transfer line pressures.

   The Hanford integrated DFHLW team will be assessing the transfer requirements based on potential impacts to the tank farm and to the HLW facility. This will require consideration of the location for any staging tanks and transfer pump and piping design requirement. Ultimately, these assessments or consideration will help define the Waste Acceptance Criteria for the HLW facility. After the evaluation of the impact of the operational requirements, testing may be required to demonstrate acceptable transfer with mitigated solids deposition, abrasive wear, and pipeline plugging. The testing program will be defined based on this assessment.

**Quick Win #3 - R&D Focus -** Tank Life Extension, Repair and Leak Containment to Support Mission Acceleration and Completion

**Description**

The double-shell tanks at Hanford serve a critical mission need for storing wastes, receiving retrieved wastes from single-shell tanks, and staging wastes for pretreatment and feeding the WTP. They may also provide a critical capability for sludge processing, especially for direct-feed HLW in lieu of sludge preparation in the PT facility. Unfortunately, many of the DSTs have exceeded their design life, the remaining are fast approaching their design life, and one DST (AY-102) has been removed from service due to a leak through the primary liner into the annulus. In addition, the available capacity of the DSTs limits the pace at which waste can be retrieved, transported, and staged for treatment. Any loss of DST capacity resulting from future DST leaks or failures would severely impact the Hanford tank waste mission. The estimated cost of replacing a DST is >> $250M, which, if required, would likely have an associated lengthy permitting timeline and, thus, added adverse schedule impact. It would also reduce available funding to support treatment and final waste disposition. Tank life extension – a robust program to maintain and integrate effective structural analysis, corrosion control, inspection, repair and return to service – consistent with multiple analogous industry sector best practice programs, is critical to maintaining the existing fleet of DSTs and enable mission completion. Currently, there is no program in place to be able to repair and return a DST to service after a leak or out-of-spec condition is discovered.

Several Hanford programs currently exist in DST structural analysis, routine DST tank wall and accessible tank floor inspection and analysis, and overall corrosion monitoring and control. In addition, R&D efforts are underway for under-tank and knuckle region NDE inspection with several promising technologies being developed and tested. Evaluations of potentially promising tank repair methods have also recently been initiated. This proposal would expand, accelerate, and integrate the structural analysis, corrosion control, full (wall-knuckle-bottom plate) DST NDE inspection and analysis, and tank repair methods to enable robust maintenance and return to service for DSTs experiencing primary liner through wall failure or wall thinning. The proposed near-term activities critical to advancement of a robust life extension program include 1) develop and qualify advanced volumetric bottom plate NDE inspection methods, deployment equipment, and machine-learning-based data analysis/interpretation methods for all DSTs, 2) develop, test, and qualify tank repair materials and deployment methods for in-annulus (e.g., wall thinning) and in-tank (thinning and through-plate defects) repair including validation, and 3) develop the technical basis including testing, analysis, requirements (e.g., inspection methods and frequency) to enable a repair and return-to-service program to be accepted and implemented.

**Proposed Work Scope**

In this quick win area, there are three areas proposed for pursuit:

A. Tank life extension of the in-service double-shell tanks at Hanford.
B. Leak repair or leak abatement during retrieval of the single shell tanks.

C. Leak containment at a tank or tank farm through the use of both reactive and impermeable barriers.

***A.*** *Tank life extension of the in-service double-shell tanks at Hanford to augment existing WRPS work and further evaluate both DST tank life extension and potential reuse technologies.*

As discussed above, existing programs are underway to inspect and extend the life of the DSTs at Hanford. These efforts will benefit from implementation of WR&T-14 and evaluation of optimal tank storage scenarios through an integrated modeling effort that includes cost benefit, schedule, various tank utilization scenarios, and associated enterprise risk elements (e.g., digital twin of plant configurations, tankage alternatives, utilization scenarios/CONOPS, flow sheet impact assessments, managed risk decision analysis, etc.). Washington River Protection Solutions (WRPS) has funded extensive evaluation and development of tethered robotic devices to perform visual inspections and position ultrasonic sensors in the annular space and in the cooling channeling underneath the DST liners for monitoring DST integrity (Denslow et. al 2019, Cree et al 2020).

In 2020, PNNL completed an assessment of a range of technical approaches for infrastructure tank repair (Enderlin, PNNL-SA-150668). From this paper assessment, a range of repair technologies were evaluated to identify a method to pursue for repairing and extending the service life of nuclear storage tanks of other DOE infrastructures. The top two concepts from the semi-quantitative assessment were Solid-state coating (Cold Spray) and Friction stir welding/ processing. The Cold Spray approach has been extensively explored for tank repair and life extension, but the Friction stir welding/processing was not. According to the paper technical assessment, the major area of difference was the ability of Cold Spray to be deployed remotely versus the Friction stir welding/processing.

1. There are industrial entities that have developed approaches for robotic deployment of the Friction stir welding that should be engaged to determine the utility in nuclear applications, to repair waste storage tanks. For example, Kuka (https://www.kuka.com/en-us/company/press/news/2021/07/cell4_fsw) has extensive literature on the use of Friction stir welding/processing in conjunction with a robotic system. Kuka should be engaged to determine the applicability of their technology and automation setups to the specific requirements defined for Hanford waste tanks.

   **Funding to initiate research:** $250k to collaborate with Kuku corporation (or other qualified vendor) to assess the Friction stir welding application performance relative to traditional repair methods and to cold-spray under relevant environmental conditions.

As noted above, WRPS has also conducted development work for utilizing cold spray as an additive manufacturing technique for life extension and potentially as a repair technique for DSTs and other critical infrastructure (Grant et al 2019, Enderlin et al 2020, Johnson et. al 2022). The following tasks are proposed for furthering the application of cold spray as a life extension and potential repair technology for DSTs.

2. Evaluation of galvanic potential and further assessment of induced corrosion and corrosion resistance associated with cold spray and candidate deposits. While mild steel deposits have yielded acceptable adhesion, porosity, and hardness and provide a significantly low galvanic potential, the application of mild steel has required the use of helium gas to generate sound adhesive bonding. Other candidate deposit materials have been successfully deposited using nitrogen as the carrier gas. With helium being significantly higher in cost and prone to supply issues, other candidate deposit materials should be fully assessed and compared to mild-steel deposits to determine if acceptable corrosion resistance is obtained. Powders for generating cold spray deposits can be tuned to aid in increasing corrosion resistance.

   **Funding to initiate research:** $220k to generate deposits for candidate materials, measure galvanic potential, and conduct head-to-head comparative corrosion testing for applicable environmental conditions.

3. Determination of cold-spray deposit geometries and associated requirements to allow in situ verification of deposit soundness and future monitoring of tank integrity. Development of ultrasonic techniques to monitor the DST liner wall thickness utilizing long-range volumetric measurements to interrogate wall volumes significantly larger than the sensor footprint. This approach allows the DST liner to be assessed by applying the sensor and taking measurements at a limited number of points as opposed to traversing sensors over the entire liner surface using discrete volumetric techniques that interrogate only the approximate area of the sensor footprint. The long-range techniques integrate the results of overlapping long-range scans to generate spatial assessments of the tank liner. The profile/gradients associated with changes in material thickness/configuration can impact the ability of the ultrasonic techniques to yield meaningful results.

   **Funding to initiate research:** $400k to determine impact of cold spray thickness and geometry on long-range ultrasonic measurement techniques being developed for DST monitoring and provide requirements for generating deposits on the tank liner. The effort would include determining limits of detection and ability to detect unsound deposits for verification purposes.

   **Funding to initiate research:** $250k to assess the size, thickness, and aspect ratio of deposits that may impact residual stresses associated with cold spray patches (deposit applied to a limited region of a surface) and the associated adhesion of a deposit. The effort would utilize the requirements associated with ultrasonic verification and monitoring to provide final requirements for generating deposits for application to a DST liner.

4. Current efforts for tank repair are investigating performing permanent repairs to the exterior of the DST liner based on identified flaws (e.g., wall thinning, pitting). To address active leaks or repurpose a DST that has experienced leaking (e.g., AY-102), in-tank bladders provide a potential method to repurpose a previous leaking DST to allow

for LAW supernatant or liquid lag storage. Smaller in-tank bladders also provide a means to displace waste in the region of a leak and provide a seal to mitigate an existing leak without having to pinpoint the exact location of the leak. The use of in-tank bladders for leak mitigation could provide a near-term response to a leak until more permanent repairs could be made. For repurposing a previously leaking tank, in-tank bladder(s) can make use of the existing DST structure while minimizing the impact of additional corrosion to provide storage for liquid waste. The proposed task would evaluate commercial options, evaluate workable sizes, deployment, and potential materials for application in the hazardous environment.

**Funding to initiate research:** $230k – $280k to assemble a decision matrix for technology assessment, and $80k material testing and characterization. The documentation will include:

a. Key references on prior assessments/reviews previously completed by WRPS.
b. Search OSTI for relevant ideas and papers.
c. Cross reference the UK Database for related concepts.
d. Search CAS and other citations databases in relevant space
e. Status of the current WRPS program results.

**Long –Term R&D ROM** – $5-11 M per year for 3- 5 years to qualify tank bottom volumetric inspection methods (nearest term deployment), develop/demonstrate viable tank repair methods for out-year testing, and develop technical basis for integrated life extension program.

**Roadmap Tie, Existing Program Ties, and Near-Term Plan**
WT&T-14: Increase volume available for tank storage
IF-2, WR&T-2a & b: Improved methods to detect/repair leaks for storage tanks
IF-14: Remote/automated systems
*Key Decision - Tank Utilization & Waste Receipt Facilities*

### *B. Leak repair or leak abatement during retrieval of the single shell tanks.*

Single-shell tanks (SST) have been found to leak and are limited in water additions, which creates challenges and makes retrieval of solids waste inefficient.

1. Potential enhancement for retrieval operations is to make use of expandable/flexible basins that could be inserted through existing risers and expanded to create an open top basin. The basin would allow dry/low water content solids to be retrieved from the tank floor into the basin where the material could be made into a slurry for transport out of the tank. Proposed task would evaluate commercial options, evaluate workable sizes, deployment, and potential materials for application in the hazardous environment.

   **Funding to initiate research:** $230k – $280k to assemble a decision matrix for technology assessment, and $80k material testing and characterization. The documentation will include:

a. Key references on prior assessments/reviews previously completed by WRPS.
b. Search OSTI for relevant ideas and papers.
c. Cross reference the UK Database for related concepts.
d. Search CAS and other citations databases in relevant space
e. Status of the current WRPS program results.

2. Evaluate the use of small in-tank bladders as a means to displace waste in the region of a leak and provide a seal to mitigate an existing leak without having to pinpoint the exact location of the leak. The use of in-tank bladders for leak mitigation could provide a near-term response to a leak and allow continued retrieval with less leak risk.

   **Funding to initiate research:** $100k to assemble a decision matrix for technology assessment, and $100k material testing and characterization. The documentation will include:
   a. Key references on prior assessments/reviews previously completed by WRPS.
   b. Search OSTI for relevant ideas and papers.
   c. Cross reference the UK Database for related concepts.
   d. Search CAS and other citations databases in relevant space

### C. ***Leak containment at a tank or tank farm through the use of both reactive and impermeable barriers***

There is a substantial gap in the knowledge base of the current state of the art in barrier technology that may be applicable to current and future mission needs at Hanford to deal with leaking and suspected leaking tanks during retrieval. The utilization of barrier technology as a means of defense in depth, as well as an enabling technology in support of both new and conventional retrieval methods, has not progressed past the planning stage with utilization currently not foreseen until 10-15 years into the future. In addition, there has not been any comprehensive analysis of available barrier technology, as a whole, conducted by the DOE nor the EPA – with a few exceptions of site specific and unique applications - since the mid to late 1990's.

Upon cursory review, the latest 'comprehensive' assessment for the time consisted of a limited (in comparison to today's opportunity) set of technologies that were reviewed by the DOE and a similar effort by the EPA. These reviews did not consider what we now know today as being important beyond the drilling and barrier materials in and of itself. These studies were largely based upon recent experience in the use of permeable reactive barriers. Additional aspects must be included in a more up to date study, inclusive of drilling/material placement methods, barrier materials, performance monitoring methods and metrics, best technology candidates for a given site's soil conditions, morphology, or geochemistry versus barrier material versus contaminant, etc.

Since the time of those earlier study reports, there have been significant advances in

- drilling methods and capabilities (e.g. ultra-short radial directional drilling; use of direct push rig angle drilling, etc.);

- materials (e.g., engineered cellular magmatics, advanced cementitious materials, permeable and impermeable barrier materials and the contaminants they are capable of managing, miscibility gap alloys and compounds, in-situ vitrification methods and processes, etc.);
- improvement in various processes associated with barrier design, deployment/ emplacement (e.g., vertical walls, slanted walls, sub-grade and surface in-situ horizontal barriers, conical/circumferential slanted walls, etc.); and
- verification and performance monitoring, imaging, and NDA/NDE of the barriers and/or the tanks being skirted.

**R&D ROM:** Can be completed in 3 phases for less than $15M

1. Phase 1 cost is <$1.5M over a 3-6 month period to develop the Structured Analysis of Alternatives Barrier Systems dBase.
2. In Phase II, the advanced 3D environmental and system performance modeling and digital twin integration effort as part of the Phase 2 component is likely less than $3M and only a year to 1.5 years, or so, in development, testing, V&V, and operational use.
3. Phase III will consist of pilot/prototype and full-scale demonstration with a cost of $10M - $15M. The range for full scale field testing will depend upon the technologies identified for further pursuit during the Strategic Analysis of Alternatives knowledge base research and development effort and whether the emplacement soils are clean or contaminated.

**Roadmap Tie, Existing Program Ties, and Near-Term Plan:**
Barrier technology use, and/or barrier chemistry has been identified in the NNLEMS R&D Roadmap for Hanford Tank Waste Mission Acceleration Draft in more than 50 locations, with more than a dozen specifically citing barrier walls technology. Specific Concept IDs include: DL-1, DL-6, IF-2, IM-13, SW-1, TC-3, TC-7, TD-1, TD-2, TC-3, TC-7, and WR&T-2a & 2b. In addition, unfunded RTW-52 identified this potential technology application, which is located in Appendix C of the WRPS Roadmap.

Of particular note, relative to advanced materials that may be substantial candidates as barrier technology, several aspects are currently funded but not yet tied to these efforts. Their current funding is via the ARPA-E and similar programs and specifically address advanced cementitious / ‘roman’ cement materials, engineered cellular magmatics, and other similar products.

In addition, Los Alamos National Laboratory has an extensive barrier and cap testing program with **LITHTEC™ EARTH BARRIERS**. The testing of reactive and liner barrier technologies is currently ongoing with this company. Sandia National Laboratory also has reactive barrier technology described in their 2014 Grand Challenge titled “proposed in-situ permeable reactive barrier to mitigate Hanford single- and double-shell underground tank leaks”. The Sandia technology is currently being deployed and tested at several DOE-LM sites with Lawrence Berkeley National Laboratory. Commercial vendors are also available to deploy the technology.

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RTW-52 found in Appendix C of the WRPS Roadmap

Grand Challenge 2014 “PROPOSED IN-SITU PERMEABLE REACTIVE BARRIER TO MITIGATE HANFORD SINGLE- AND DOUBLE-SHELL UNDERGROUND TANK LEAKS”

**Quick Win #4 - R&D Focus** – SST Retrieval Infrastructure to Enable Flexible, Timely Waste Mobilization

**Description**

Of the 149 single-shell tanks (SSTs) at Hanford, 133 store more than 28 million gallons of saltcake, sludge, and interstitial liquids. The majority of the tanks and corresponding tank farms do not yet have the necessary infrastructure in-place to support waste retrieval. The first tank farm retrieved - C-Farm- provided lessons learned on retrieval technology performance, application of temporary and portable infrastructure (e.g., transfer lines, exhausters, etc.), and operational challenges. For the A complex and specifically AX tank farm retrievals currently underway, significant infrastructure investments were made to address some limitations noted with C-Farm. Approximately $1B in infrastructure upgrades were made to support the A complex. SST retrieval from the North East (B complex), South West (S, SX, U complexes) and North West (T complex) tanks will also require infrastructure to support retrieval operations. Investments of the same magnitude as the A complex for the remaining tank farms would be costly, time consuming, and limit flexibility and responsiveness to support waste mobilization and processing needs. With the increasing risk of additional SST leaks over time and increasing demand for SST retrievals as waste treatment begins, lower cost and more flexible SST retrieval infrastructure is needed. In addition, if another SST was found to be leaking and waste retrieval was determined to be an appropriate and necessary corrective action, there is no readily available infrastructure and proven systems available to mobilize for an individual waste mobilization operation.

The approach and primary systems needed for effective SST retrieval depend on the leak integrity of the individual SST, as well as the primary objectives of waste mobilization. For example, the objective may be to substantially eliminate the driving force for a leak or maximum waste removal to support both LAW and HLW processing. Regardless of objectives, infrastructure needs for SST retrieval include power, transfer lines, ventilation and emissions control, waste receipt capacity via available DST or other vessels (e.g., Waste Retrieval Facilities), leak detection, and possible leak mitigation methods. For B and T complexes, the absence of nearby DSTs or currently available waste receipt facilities make SST retrieval from these farms more difficult. The purpose of this proposal is to identify and develop viable waste retrieval and infrastructure options for individual SSTs across the Hanford site.

Proposed activities include 1) assessing and selecting best retrieval options for SSTs, 2) identifying economically viable infrastructure to support waste retrieval, and 3) developing, testing, and resolving critical technical gaps in both the retrieval technology or enabling infrastructure to enable procurement and demonstration of flexible SST retrieval systems. The scope could also include development of the technology or equipment to allow immobilization of the retrieved wastes, so the waste is permanently stabilized particularly when emergency tank space is not available or sufficient. Lessons learned from C and AX-farm retrievals, other Hanford SST retrieval operations and plans (e.g., salt well pumping, selective dissolution), and complex-wide retrieval activities will be reviewed to define and evaluate the priority retrieval technology options and their corresponding S&T needs. The infrastructure focus of this effort will be on identifying temporary, modular, and lower cost but effective systems that can enable SST retrieval without large investments and major tank farm upgrades. For example, options may include low volume saltcake dissolution retrieval with adjacent smaller TSCR capability that could enable waste mobilization and transfer to WTP or direct immobilization without adjacent DSTs or WRFs. The priority technology options will be tested and demonstrated to the level necessary to support retrieval project decisions on deployment.

**R&D ROM** – $2-4 M per year for 3-5 year, starting with assessment of lessons learned from past retrievals, critical infrastructure needs and advancements options, and leading up to scaled testing to address feasibility gaps. Assumes results of other programmatic efforts to address issues such as tank ventilation/vapors abatement will also support this infrastructure assessment efforts.

**Roadmap Tie, Existing Program Ties, and Near-Term Plan**
IM-13: Cementitious materials development to improve long-term performance
IF-2, WR&T-2a & b: Improved methods to detect/repair leaks for storage tanks
TC-7, WR&T-2b, DL-1: Formulate and install barriers targeted for constituents of concern at tanks or disposal site with active monitoring
WR&T-14: Increase volume available for tank storage
PS-9: Improved offgas treatment/abatement for key air toxics
*Tank Utilization & Waste Receipt Facilities* decision

**Proposed Work Scope**
Work scope in this effort would be performed in parallel with efforts identified in the Quick Win for **"**Tank Life Extension to Support Mission Acceleration and Completion" since it is considering methods to mitigate leaks and perform temporary repairs to allow limited service.

**1.** Single-shell tanks (SST) have been found to leak and are limited in water additions, which creates challenges and makes retrieval of waste inefficient, especially given limited infrastructure existing in most SST farms. In addition, much of the saltcake waste will require dissolution in order to process through Cs ion exchange (i.e., TSCR like system) before final disposition as LLW. A potential solution is to deploy low water retrieval methods, such as saltwell pumping, with locally-controlled dissolution. Potential enhancement for retrieval operations could employ dry retrieval methods, with use of expandable/flexible basins that could be inserted through existing risers and expanded to create an open top basin within the tank. The basin would allow dry/low water content saltcake solids to be retrieved into the basin where the material could be slurried for dissolution and/or transport out of the tank. The proposed task would evaluate commercial options, evaluate workable sizes, deployment, and potential materials for application in the hazardous environment.
   a. \$200k – \$250 k study and write up
   b. \$80k material testing and characterization

**2.** An initial study focusing on tanks that do not require treatment prior to disposal (e.g., tanks designated as CH-TRU tanks) could allow an early start for disposition of these tanks as well as provide a test bed for retrieval methods with tank waste that can be contact-handled. The initial evaluation would propose technologies to be evaluated and an initial plan and cost estimate for a test bed using the technology at one of the CH-TRU tanks. The study would cost \$150K and require 5-6 months.

**3.** Perform an analysis of the chemical information on the tanks in B-farm and T-farm in TWINS to identify complexities that could be challenging for direct grouting of the retrieved wastes. The study would focus on the CH-TRU tanks and opportunistic tanks. The initial estimate is \$125K and 6 months. Based on this first phase, follow on work would include grout testing to assess the ability to grout the retrieved wastes.

**Quick Win #5 - R&D Focus** –Sample Reduction using Material Balance and Real-Time, In-Line Monitoring Approaches for HLW Applications

**Description**

The use of Material Balance Approaches (MBA) and Real-Time, In-Line Monitoring (RTIM) for HLW processing has the potential to reduce feed preparation time and analytical turnaround time regardless of the facility to be used to perform the HLW sludge preparation (e.g., Pretreatment Facility or Direct Feed HLW), which in turn can reduce the overall Hanford mission schedule and costs. For processing scenarios that would include the Pretreatment Facility, the assessment would not be able to rely as heavily on a material balance approach because of the recycle streams and other blending of streams that occur within the facility post sludge retrieval from the tank farm. However, some improvements in sampling times could be realized through RTIM and, if this option is considered viable, the assessment will focus on sampling requirements and potential analytical techniques that could be evaluated and deployed.

In a Direct Feed HLW (DFHLW) scenario, the HLW feed preparation process could be similar to the process used at the Savannah River Site (SRS) to prepare HLW for vitrification. An assessment of the technical feasibility of the SRS DWPF feed qualification and sampling approach will be performed to evaluate the necessary sampling points and required analyses. For example, the analysis of radionuclides for DWPF canister reporting utilizes samples taken from the tank farm "macro batch" versus the individual melter feed batches as the DWPF process does not change the ratios of radionuclides to iron during processing after the HLW sludge has completed in-tank feed preparation. The evaluation will: 1) consider where and why samples are taken to include the purpose and need for each sample in context of a DFHLW flowsheet; 2) propose methods to allow elimination of each sample to include an evaluation of whether a material balance approach or a real-time monitoring instrument could be utilized to replace each sample; 3) expand the Hanford DFLAW multi-lab and CRESP RTIM program to include DFHLW evaluations.

Potential technologies that could be tested for applicability include ATR-FTIR (currently being used for DWPF laboratory scale tests), LIBS for tank waste, and Raman for selected secondary effluent streams. The studies would include an initial paper study using the expected sample matrixes to determine if the instruments are capable of performing the analysis followed by proof-of-concept testing to validate that feasibility of the measurements. Samples of non-radioactive simulants on hand at SRNL, PNNL, or VSL would be shipped to the laboratories currently performing work for the DFLAW RTIM for evaluation. The goal would be to demonstrate feasibility of the RTIM instrument for the HLW sampling needs using the instruments and test setup currently being used for the DFLAW RTIM.

**Roadmap Tie, Existing Program Ties, and Near-Term Plan**

WT-1 through WT-4: In-situ characterization

DOE-ORP has an existing program (DOE-ORP Real-Time In-Line Monitoring Program) to evaluate RTIM for WTP facilities in the DFLAW flowsheet.

WRPS has funded work to evaluate Raman instruments for measurements of anions in the DFLAW feed and tank waste supernatant streams.

**Proposed Work Scope**

Phase I: Identify analytes and locations to target for RTIM in a DFHLW flowsheet.

Phase II: Identify instruments available to perform targeted analysis and perform initial feasibility tests

Phase III: Select instruments for additional testing and perform testing to develop quantitative methods for the instrument in the expected process composition matrix.

**R&D ROM** – $2.5M over a 3-year period

**Update:**

SRNL will be performing the Phase I evaluation described above as part of the currently funded DOE-ORP RTIM program. The evaluation will determine the applicability of *in situ* analysis for each unit operation in a DFHLW flowsheet. This analysis would also identify gaps in the in-situ capability and develop a roadmap specific to in-situ analysis technology development for Hanford DFHLW applications. The deliverable would be a report describing the approaches deemed feasible for application of RTIM to the DFHLW process and a downselect of instruments to be evaluated in Phase II of the program.

Proposed Quick Win Initial Scope

1. The installation of a LIBS instrument at LANL is nearing completion from evaluation of Hanford WTP-LAW simulants. A small amount of funding would allow testing of the instrument with samples of Hanford non-radioactive simulants of sludge streams to include untreated sludge, washed/leached sludges, and HLW melter feed. These tests would demonstrate the feasibility of elemental analysis of sludge waste slurries with LIBS. It should be noted that a CRESP funded task at Georgia Tech has been supporting anion measurements of non-radioactive simulants DWPF process slurries in support of SRNL testing of the SRS process using an ATR-FTIR instrument. The CRESP program has also performed testing using simulants of Hanford WTP-LAW streams. Providing Hanford sludge simulants could expand the CRESP program to Hanford sludge streams.

   It is estimated that $200,000 in funding with allow initial feasibility tests with simulants of the Hanford sludge waste streams and would require 6-9 months. This testing would provide an early indication of the applicability of the LIBS and ATR-FTIR instruments for DFHLW applications. The deliverable would be a report indicating whether additional development of the LIBS and ATR-FTIR instruments should be pursued.

2. The Raman system designed and tested at PNNL has been demonstrated on moderately turbid solutions. The next phase is to extend this development into extended flow regimes and turbidity ranges, utilizing Raman probes developed by small business partners and SBIR grants. We will test and compare various probe designs specifically to measure different flow regimes and turbidity ranges. We will assess the ability and potential limitations of measurements that extend into 5-10 wt%+ solids concentrations expected for sludge feed to HLW facility. We will be generating initial chemometric models for the automated quantification of two key Hanford tank constituents, nitrate and phosphate, and assessing ability to extend quantification to a majority of feed constituents most important to time-critical waste formulation decisions.

   The estimated cost would be $200,000 for initial feasibility studies using simulants of the Hanford sludge waste streams and would require 9-12 months. The deliverable would be a report indicating whether additional development of a Raman system for high solids applications is practical.

# Attachment 4: Idea Sheets for Portfolio of Proposed Investment

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** WR&T – 14 Increase Volume Available for Tank Storage (Tank Retrieval, Characterization & Closure)

**Gap or Opportunity Addressed:** Available tank storage and staging capacity is a challenge for increased processing of tanks wastes. Evaluate needed tank storage volume through a cost benefit analysis of building new tanks, creating a modular/mobile tank system or evaluate reuse of single shell tanks (SST's) for staging.

**Technology Idea or Concept:** Evaluate through a cost benefit analysis the options of building new tanks, developing a modular/mobile tank system and the reuse of sound SSTs for temporary storage of treated and untreated waste. The lack of temporary storage near single shell tank farms limits flexibility for waste treatment options, specifically mobile and modular systems. The inability to return material to sound single shell tanks and the lack of temporary storage near single shell tank farms makes the use of modular at-tank systems impractical thus limiting treatment options. Single shell tanks are currently in use as feed and treated waste receipt tanks at SRS for operations of Tank Closure Cs-Removal (TCCR). The ability to use modular/mobile tankage or reuse of sound SSTs allows for treatment at-tank avoiding a significant number of waste transfers between tank farms.

**Existing Funded Program:** None identified

**Connectivity to other Gap, Opportunity, or Concept:** Concept ID C61, C69, C70, C79

**Proposed Technology – Technical Maturity/Process Simplicity:** Proposal does not directly involve technology development. The implementation of the results of the study would likely require the use of additional existing leak detection technologies.

**Complexity:** The initial deliverable is an evaluation; implementation could impact waste tanks or integration of modular storage systems into existing infrastructure.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** It is expected that the evaluation will be completed within 5 years.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** The recommendation will be completed in the initial evaluation stage and result in the deployment decision, no additional funding required for decision phase.

**Deployment Costs (required funding):** Evaluation will provide cost estimate for implementation of the evaluated options, including the estimate of the recommendation.

**Additional investment over life cycle of Hanford mission:** The evaluation will provide implementation costs for the recommended option.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years), Deployment is expected to be less than 5 years from the decision to proceed.

**WR&T-14**

**ROM net Cost Savings over the life cycle***:* Potential costs savings are realized by accelerating treatment and potentially significantly reducing inter-area transfers. Additionally, potential exists to utilize existing infrastructure and avoid building new process vessels.

**Schedule Acceleration of the Hanford Mission***:* Schedule acceleration will be determined as part of the evaluation with a risk informed approach.

**Net impact on Safety/Environment:** Implementation of sound temporary storage may result is accelerated retrievals and treatment of waste, thus reducing the risk of aging tanks. By enabling mobile/modular at-tank treatment, the tanks of greatest integrity concern could be targeted thus allowing targeted risk reduction.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Probability of successful deployment is very high, technology is very high, similar concepts are currently in operation at SRS (TCCR, DWPF returns).

Utilization of additional mobile tankage is low risk; reutilization of SSTs is likely a high regulatory but low safety risk.

**Regulatory Permitting/Licensing changes required:** If the cost benefit analysis shows a positive impact, then a potential major regulatory change may be needed (e.g., for tank reuse).

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** N/A

**Potential Applicability to Other Sites:** SSTs are currently being used in the waste treatment system at SRS.

**Does the technology help buy down a Mission Risk?** Implementation has the potential to accelerate retrievals and waste treatment, thereby reducing risk of the continually aging infrastructure.

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid range cost. This study will identify potential transformational systems operations (Could lead to risk informed changes in the baseline and life-cycle costs when implemented.) e.g., reuse of tanks for temporary storage and staging, enables use of portable modular treatment/ temporary storage/transportation systems etc.

**Technology Insertion Time Frame:** Implementation timeline to be determined in the study. It is expected that reuse of SSTs would require facility upgrades. Upgrade to existing facilities or construction of modules is expected to require less than 5 years once decision to process is received.

**References:** N/A

**Contact:** David Herman - SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** WR&T – 3 Dry Waste Retrieval Technologies (Waste Retrieval, Transport & Closure)

**Gap or Opportunity Addressed:** Evaluate dry or minimal liquid retrieval technologies for known leaker tanks to mitigate potential release to the environment. Utilize National Lab experiences and commercial vendor literature review required for existing technologies.

**Technology Idea or Concept:** The purpose is to develop dry retrieval equipment and techniques to remove waste from the waste tanks and transport it to the treatment or disposal facilities. Dry mining technologies are very well developed, and commercially available systems would be adopted for dry retrieval of tank waste. By using dry mining techniques, substantial amounts of water currently required for waste retrieval will be avoided. This reduces the probability of waste leaking from a tank during retrieval. Additionally, the need to evaporate any additional water needed for retrievals is eliminated and maximizes the tank space available during retrievals. Depending on the waste and disposal site, dry retrieved waste may be viable for direct disposal (e.g., TRU waste) thus eliminating multiple processing steps.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | *2016_23 Application of Commercial Mining Technology for Waste Retrieval of TRU for Disposal at WIPP;* | 2016_23_Application of Commercial Mininc |
| *RTW-08 - Dry Sludge Retrieval System RTW-12: Development of New Riser Installation System* | *RTW-03: Remote Tank Farm Above Ground Inspections, RTW-23; RTW-34: Extended Reach Sluicing System Modifications* | *2014_17_Salt Cake Waterless Retrieval System for Moving Slurry SRNL* | 2014_17_Salt%20Cake%20Waterless%20Re |
| | *RTW-34 RTW-55* | *2016_12 Reducing Liquid Introduction to SST Retrieval by Scarification;* | 2016_12_Reducing Liquid Introduction tc |
| | | *2018_17 Methods to minimize introduction of liquids to Hanford waste tanks during retrieval and treatment or other methods to conserve double-shell tank (DST) space* | 2018_17_Methods%20to%20minimize%2( |

**WR&T-3**

*Also: Nitrocision commercial technology - Liquid Nitrogen (not funded/listed):*
*https://www.linkedin.com/company/nitrocision-llc*

**Connectivity to other Gap, Opportunity, or Concept:** WR&T-10a for analytical monitoring/ characterization, C11, C20, C23, C31, C59, C64, C80, C81

**Proposed Technology – Technical Maturity/Process Simplicity:** Technology for dry retrievals is very mature in the commercial indust*ry* (Full-scale demonstration in use elsewhere for similar problem). The available equipment will likely need modification to operate in the waste environment. An evaluation would be conducted to recommend the appropriate technologies for a pilot scale demonstration.

**Complexity:** The system will consist of two primary units, the mining equipment to retrieve the waste and the transport unit to transport the waste out of the tank. It is anticipated the commercially available equipment may need modifications to deploy in the waste environment.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** It is expected that dry retrieval techniques and equipment could be evaluated and demonstrated at pilot scale within 5 years.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M), Costs to perform the evaluation and pilot scale demonstration is expected to be less than $10M.

**Deployment Costs (required funding):** Once demonstrated at pilot-scale it is estimated that an additional $10M would be required to deploy the technology in the field.

**Additional investment over life cycle of Hanford mission:** Additional investment of the project lifetime would include replacement equipment or decontamination for redeployment. Disposal costs for the equipment are expected to be minor.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years), Deployment is expected to be less than 5 years from the decision to proceed.

**ROM net Cost Savings over the life cycle***:* Potential costs savings are estimated to be up to 40% of tank retrieval costs ($40M-$50M/tank). Life cycle cost savings of ~$2.5B could be realized if 50 suspected leaker tanks are retrieved by dry technologies.

**Schedule Acceleration of the Hanford Mission***:* Schedule acceleration is estimated to be between 10 and 15 years. The schedule savings are in tank retrievals and the potential for direct disposal and not in waste treatment.

**Net impact on Safety/Environment:** Dry retrieval has the potential for a major positive environmental impact. Eliminating or reducing water reduces the potential for leaks to the environment during the retrieval process. Accelerated retrievals reduces the time that waste tanks are required to be in service thus reducing the risk of tank integrity failure.

**WR&T-3**

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Probability of successful deployment is very high, technology is very mature, commercially available and readily adaptable.

Risk to permission to deploy is the perceived risk that the equipment could compromise tank wall integrity during operation.

**Regulatory Permitting/Licensing changes required:** Depending on the type of equipment changes involved, approval of a Class 2 or Class 3 RCRA permit modification request would be required prior to equipment installation. This is anticipated to take 2-3 years. Regulatory change required to implement direct disposal onsite of dry retrieved waste will require a Class 3 RCRA permit mod.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** Deployment of dry retrieval technology helps mitigate risks of leaks in single shell tanks or tanks with potential integrity issues.

**Potential Applicability to Other Sites:** Dry retrieval may have similar benefits at other DOE sites, specifically SRS.

**Does the technology help buy down a Mission Risk?** Dry retrieval will reduce the risk of waste reaching the environment.

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet

**Technology Insertion Time Frame:** Technology is ready for immediate implementation. Insertion as soon as possible could mitigate the impact of introducing new sources of liquids in the tank farm, which have to be dispositioned.

**References:** N/A

**Contact:** David Herman – SRNL, Paul Dixon - LANL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** WR&T-10a Dry Waste Characterization Monitoring (Enabling Technologies)

**Gap or Opportunity Addressed:** Develop new real time monitoring capabilities for dry/bulk process feeds to reduce sampling time and minimize waste, applicable to TRU for offsite disposition.

**Technology Idea or Concept:** The utilization of commercially available instrumentation and/or technologies that are in the development stage to support measuring the physical (density, water moisture, strength of dry/bulk material) and chemical properties (including TRU). In-situ measurement of physicochemical properties will mitigate the need to sample and accelerate the retrieval preparation process, hence reducing the cost. Technology developed can be utilized for other DOE processes. Vendors: DOE laboratories, Humboldt, Agilent, Icpmslasers, Teledyne Ceta Technologies, Stellarnet, Spectrum, Metrohm, etc.

**Existing Funded Program:** No.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| *None identified* | MTW-36<br>MTW-37<br>MTW-40<br>RTW-44<br>MTW-76 | *2015_35_Eliminate Regulated Organics from LAWPS-WTP Waste acceptance Criteria WRPS;* | 2015_35_Eliminate%20Regulated%20Orga |
| | | *2015_1_Alternative Engineering Strategy for WTP;* | 2015_1_Alternative%20Engineering%20Str |
| | | *2018_12_HLW LAW Processing Strategy based on Rad Operations;* | 2018_12_HLW%20LAW%20Processing%2 |
| | | *2018_19_Accelerating SST Retrieval and Closure by Combined In-Tank Character.* | 2018_19_Acceleratin g%20SST%20Retrieva |

**Connectivity to other Gap, Opportunity, or Concept:** Technology can be shared with IM-6, IM-12, WR&T 3, and WR&T Hanford-1

**Proposed Technology – Technical Maturity/Process Simplicity:** Pilot/prototype to Full-scale demonstration. Technology to be verified prior to use.

**Complexity:** a) Used at each tank requiring dry/bulk mobilization/transfer. b) Standalone instrumentation. Could potentially be integrated with retrieval equipment.

**WR&T-10a**

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M) for COTS/GOTS, Low to Medium ($10M - $50M) for full integration with Hanford-1

**Deployment Costs (required funding):** $1M to $2M for bench/pilot/prototype scale testing, $1M to $10M for full scale.

**Additional investment over life cycle of Hanford mission:** a) deployed for each tank that will use dry/bulk material retrieval and transport, $1M to $2M b) Operating costs would be part of existing annual operating cost c) Disposal of instrumentation would be part of existing annual operating cost.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle***:* Savings to be obtained by not sampling, $30M per year plus the life-cycle savings of over $500M.

**Schedule Acceleration of the Hanford Mission***:* 5 to 10 years

**Net impact on Safety/Environment:** Minor and Positive, robust implementation of WR&T 7b and Hanford-1.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** High successful deployment based on maturity of technology. Employed where dry/bulk material retrieval will be performed.

**Regulatory Permitting/Licensing changes required:** Minor, Class 2 or 3 RCRA permit mod, 2 to 3 years to obtain.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** Performing this activity makes WR&T-7b and Hanford-1 better.

**Potential Applicability to Other Sites:** Idaho

**Does the technology help buy down a Mission Risk?** Yes, optimization of waste form through forward processing and reduce mission schedule. Potential identification and minimization of system disruptions.

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet

**Technology Insertion Time Frame:** Can be implemented into any process where dry/bulk material characterization is required.

**References:**

- W. O. Heath, "Procedure for Measuring Sludge Shear Strength Using Shear Vane", WHO-86-1
- R. R. Russo and at el., "Laser Ablation in Analytical Chemistry – A Review", Lawrence Berkeley National Laboratory', LBNL-48521, 2001

**Contact:** Erich Hansen - SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** WR&T-7b Process Automation & Feedback of Monitoring and Retrieval Technologies (Tank Retrieval, Characterization & Closure)

**Gap or Opportunity Addressed:** Develop process feedback systems to address operational challenges and effectiveness. Use Artificial Intelligence (AI) and edge computing to optimize productivity and give feedback. Create better predictive capabilities to evaluate the effectiveness of retrieval technologies (modeling, sensor or visual)

**Technology Idea or Concept:** Process Automation and Feedback

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| | *RTW-15: Evaluate Back-Up Options for HLW Delivery from Tank*<br><br>*RTW-16: Develop Integrated HLW Feed Qualification Plan*<br><br>*RTW-21: Improve ESP – A Thermodynamic Modeling Program*<br><br>*MTW-96: Exoskeleton* | *2018_5 Waste Incidental to Reprocessing: West Area Opportunities for Low-Activity Feed (WIR-WOLF)* | 2018_5_Waste Incidental to Reproces |

**Connectivity to other Gap, Opportunity, or Concept:** Concept C2, C3, C30. Ties to other programs such as Fossil Energy, Nuclear Energy, and ARPA-E.

**Proposed Technology – Technical Maturity/Process Simplicity:** Range - COTS mature deployable. Enhancement to artificial intelligence and machine learning requires RDT&E. Will be enhanced by development of Hanford-1 model.

**Complexity:** a) Supports all retrieval and transfer unit operations b) Low-High

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years to initiate

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M), Medium ($10M - $50M), Low/Medium range of $10M-$25M depending what parts of the system are chosen for deployment.

**Deployment Costs (required funding):**

a) Incremental $5M-$15M based on technology and extent of implementation. With the development of a successful model (Physical plant items e.g., integrated control, RAMAN, Digital Twin, and Radionuclide speciation)
b) If Hanford-1 digital twin exists and efforts focused on supervisory control/operator assisted implementation, then initial FULL-SCALE demonstration will cost $25M to $100M for integrated mission unit operations implementation

**Additional investment over life cycle of Hanford mission:**

a) Tied to Hanford-1 and emerging issues the maintenance and upkeep costs <$1M/year
b) Tied to Hanford-1 model which is modular and cost to add modules is complexity driven, estimate in the range of $1M-$5M.
c) N/A

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 yrs) full scale; Quick (1- 5 yrs) for incremental modular deployment

**ROM net Cost Savings over the life cycle***:*

a) Dependent on where deployed, implementation level and level of integration ($30M-$50M/yr)
b) Dependent on where deployed, implementation level and level of integration ($30M-$50M/yr)
c) Combined with Hanford 1 model a lifetime cost savings of ~$2B can be realized over a 40-year mission

**Schedule Acceleration of the Hanford Mission***:* >10 years

**Net impact on Safety/Environment:** Major (Optimization of waste form through forward-feed processing and reduce mission schedule)

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - High (Based on implementation of current & emerging industry practices i.e., Industry 4.0)

**Regulatory Permitting/Licensing changes required:** None anticipated unless permitted systems are changed/modified

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - N/A
b) Positive reinforcement - Direct tie to Hanford 1 model and ties to other external programs such as FE, NE, ARPA-E.
c) Mutually exclusive - N/A

**Potential Applicability to Other Sites:** Yes

**WR&T-7b**

**Does the technology help buy down a Mission Risk?** Optimization of waste form through forward-feed processing & reduce mission schedule

**Identify the category of the potential concept:** As automation is added: 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet. As automation is added: 1) Risk Mitigation – not schedule driven but helps the project schedule by reducing risk

**Technology Insertion Time Frame:** Prior to start of HLW vitrification facility.

**References:** N/A

**Contact:** Carl Enderlin - PNNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** TC-3 Risk Based Waste Retrieval Sequencing (Tank Retrieval, Characterization & Closure)

**Gap or Opportunity Addressed:** The current tank closure retrieval sequencing, as documented in the *Integrated Waste Feed Delivery Plan,* considers the needs of commissioning, near-term, and long-term operations; necessary infrastructure installation; projected waste transfer operations; and programmatic and regulatory commitments. It doesn't necessarily prioritize the retrieval or tank closure sequence with consideration of the constituents of concern and their associated risk to the environment.

**Technology Idea or Concept:** Work with the Regulators and Stakeholders to prioritize retrieval sequencing and timing of tank closures to address the highest risk to the environment. This practice is currently performed at the Savannah River Site with tank retrievals sequenced to coincide with environmental risk. Retrieval and closure costs for tanks with minimal remaining constituents of concern could be deferred to allow for enhanced retrieval or closure technologies to be developed or to allow funding to be applied to mitigate higher risk concerns (i.e., constituents being released, or personnel being exposed to constituents that have radiological or chemical hazards).

**Existing Funded Program:** Does not appear to be funded on the WRPS roadmap and some correlation to previous Grand Challenge.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| | *RTW-56 Technology to Support Risk-Based Retrieval & Closure* | *2017_35_Technology to Support Risk Based Retrieval and Closure of Hanford Tanks* | 2017_35_Technology to Support Risk Basec |

**Connectivity to other Gap, Opportunity, or Concept:** Concept WR&T-7 would develop process automation feedback through in-line or real-time measurements to identify the optimal endpoint for retrieval, which would help identify the residual risk to closure for a specific tank. WR&T-8 proposes the use of performance assessment (PA) modeling, chemistry models, or engineering practices to understand the residual risk during retrieval. This approach is also in-line with item, K-16, to revisit the end state for waste retrievals based on risk versus the use of 3 technologies.

**Proposed Technology – Technical Maturity/Process Simplicity:** The proposed sequencing and addressing of risk is used at the Savannah River Site for its tank waste program; therefore, this has been demonstrated at full scale elsewhere for a similar problem (4a). Therefore, feasibility of the concept has been previously demonstrated.

**TC-3**

**Complexity:** a) Unit operations affected by this concept include tank retrieval, tank closure, and the Tank Farm Operations Contractors Integrated Waste Feed Delivery Plan b) Sequencing does not require a lot of integration with other unit operations; however, moving retrieval or closure equipment from tank farm to tank farm may incur additional costs versus completing these activities for an individual tank farm.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years to update the planning tools to determine if changes would help reduce the risk. Additional benefits could be realized if sequencing allows additional decay and technologies to be pursued to close a tank without much retrieval. It does, however, drive inefficiencies if risk variation is within a tank farm and equipment is moved from tank farm to tank farm when sequencing.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M)

**Deployment Costs (required funding):** $1M to deploy the planning tool which will be at full scale

**Additional investment over life cycle of Hanford mission:** Repeated deployment costs should be negligible since updating of the waste feed delivery plan is part of the baseline.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 years); estimated 8 years to implement assuming negotiations will be needed with regulators.

**ROM net Cost Savings over the life cycle**: Estimated cost savings are $45-90M annually assuming average retrieval savings of $36M and closure savings of $9M based on System Plan 9 funding numbers for tank retrieval and closure. Potentially two evolutions could be saved a year. No peaks in funding are typically associated with retrievals. The total potential savings is estimated at $7-12B based on 3 to 5 years of schedule savings for a baseline budget of $2.5B/year. There are potentially some system inefficiencies with moving retrieval equipment that could impact the overall savings.

**Schedule Acceleration of the Hanford Mission**: Estimated schedule acceleration of 3-5 years

**Net impact on Safety/Environment:** The proposed concept can have minor positive impact on the potential safety envelope and environmental risk since higher risk constituents are being addressed. If the sequencing targets potential leaking tanks that are releasing constituents of concern to the environment, then the concept could have a major positive impact on safety and the environment.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** 95% estimated probability of successful deployment based on the approach being used at Savannah River Site already.

**Regulatory Permitting/Licensing changes required:** Tri-Party Agreement negotiations may be needed if the tank farm closure dates are shifted by targeting specific tanks of concern. Permit modifications may also be required and could take up to 5 years.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** This concept is closely tied to the effectiveness of the selected retrieval technology and the analyses performed during retrieval. The use of barriers as proposed in concept TC-7 could make this concept better because it would help mitigate the impact of any material that leaks from the tank.

**Potential Applicability to Other Sites:** The Savannah River Site already uses this concept.

**Does the technology help buy down a Mission Risk?** The concept helps buy down risk of tanks with higher concentrations of constituents of concern being released to the environment.

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet

**Technology Insertion Time Frame:** The most benefit comes from inserting the concept early, and once the overall Hanford Tank Mission processing strategy and flowsheet is confirmed.

**References:** N/A

**Contact:** John Vienna, Tom Brouns – PNNL, Connie Herman - SRNL

## NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** TC-7, WR&T-2b, DL-1 Formulate & Install Barriers Targeted for Constituents of Concern (Tank Retrieval, Characterization & Closure)

**Gap or Opportunity Addressed:** The current tank closure end-state is based on achieving specific volume removal targets and the number of retrieval methods used, if unable to achieve volume targets, versus the actual risk of the constituents remaining. Barriers can potentially be utilized on the outside of the tank or at disposal sites to mitigate the impact of any migration of residual contaminants that would allow reduction in volume of contents removed. These barriers could also be used to isolate potential leaking tanks and allow for more aggressive retrieval techniques to remove larger volumes of wastes.

**Technology Idea or Concept:** Develop barriers or caps (e.g., cementitious or lithified rock aggregate systems) with additives targeting contaminants of concern for the outside of tanks or for disposal sites and demonstrate deployment strategies. The addition of specific additives to slow the release rates of the contaminants of concern could drive long term risk assessment in a positive manner. At the disposal location, this could mitigate potential performance concerns for the primary or secondary waste form and respective constituents of concern. These barrier technologies could improve added systems that monitor for any migration of contaminants with responsive systems for mitigating the contaminants also possible as done with the SRS F-area funnel and gate technology.

**Existing Funded Program:** Previous Grand Challenges have contained elements of this concept. The current Roadmap also contains an element of this proposal.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| | *RTW-52 Barrier Technology Research– written as a study with different approaches than proposed)* | *2014-37: Proposed In-situ Permeable Reactive Barrier to Mitigate Hanford Single- and Double-Shell Underground Tank Leaks (apatite based injections for Tc and other constituent immobilization subsurface)* | |
| | | *2018-2: Mitigation Wall to Accelerate the Closure of SST Tank Farm* | |

**Connectivity to other Gap, Opportunity, or Concept:** The concept proposed could help make immobilization concepts targeting grout formulation constituents of concern more viable as cementitious aggregates can also be made into slurries that cure into hard caps after reasonable curing times in air. These concepts include WT-6 and IF-2. In turn, these combined concepts could enable Supplemental LAW as a grout waste form or minimize the need for Tc/I removal and accelerate tank retrievals.

Similarly, this concept could be used in conjunction with proposals to better understand the performance of the glass waste form in the IDF environment.

Finally, if used as a barrier for a tank to be retrieved, the barrier could mitigate the impacts to the environment for a potential leaking tank.

**Proposed Technology – Technical Maturity/Process Simplicity:** The proposed barrier technology has been demonstrated on a Pilot/prototype scale (3) as a barrier and at a Full-scale demonstration for closely related problem. As cementitious aggregates can also be made into slurries that cure into hard caps after reasonable curing times in air. The novelty may be the use of the specific additives needed for the targeted constituents of concern.

**Complexity:** a) The number of Unit Operations affected include the barrier formulation, barrier injection technology, monitoring system, and the PA/system performance models. b) The complexity of the required system integration to implement the technology is low when the barriers are deployed with monitoring. Complexity increases to medium if a feedback system is involved in the monitoring to remediate any problem constituents over time.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years required to make the Go/No-Go decision based on deployment of barrier technology elsewhere.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M), assume $20M.

**Deployment Costs (required funding):** Estimated costs to get to deployment are captured in the go/no-go decision. The initial full-scale demonstration will depend on how many barriers have to be constructed - per farm or per tank. This may also depend on where the go/no-go deployment occurs, but estimated costs are $40M. One option could use the Hanford MUST as a pilot.

**Additional investment over life cycle of Hanford mission:** Repeated deployment costs would be incurred at each farm. It is estimated that 10 farms could use this technology. Operating costs would need to include the difference in monitoring costs that are potentially negligible since most tank farms had $65M in management costs for closure. No other costs are expected to be incurred above baseline technology for implementation.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Slow (>10 years), assume 15 years because of permitting requirements. Cementitious aggregates and slurries already exist and are used in conjunction with (i) their strength for roads (UCS>10 MPa), (ii) their chemistry for capping AUM tailings and mitigating aqueous uranyl migration via sorption, and (iii) their range of existing hydrologic properties (from hydraulically conductive to impermeable). The aspect that could take longer is in engineering their specific use for mitigating other actinide mobility.

**TC-7 (WR&T-2B and DL-1)**

**ROM net Cost Savings over the life cycle**: Estimated cost savings are $12-15M annually assuming a savings of $20-80M per tank in retrieval and closure. At most, 2 tanks per year are processed and assume there are 10 tanks/farm. Cost savings are offset by deployment costs. Note that the aggregate materials used are mostly derived from local soils in the southwest and are lithified in place so that the transportation greenhouse gas footprint is low (unlike OPC grouts and cements). This technology also does not contribute to greenhouse gas emissions. No peaks in funding are typically associated with closures. The total potential savings are estimated at $9.5-14.5B based on 4-6 years of schedule savings for a baseline budget of $2.5B/year and expenses of roughly $460M.

**Schedule Acceleration of the Hanford Mission***:* Estimated schedule acceleration of 4-6 years with additional potential retrieval time savings if you are able to move the retrieval equipment sooner to start the next tank retrieval.

**Net impact on Safety/Environment:** The proposed concept can have major positive impacts on the potential safety envelope and environmental risk by controlling migration of water into the tank and constituents out of the tank. Aggregate systems also have a potential positive environmental ("green") impact.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** 65% estimated probability of successful deployment given the need for targeted formulations to go after constituents of concern.

**Regulatory Permitting/Licensing changes required:** PA updates including regulator reviews and permit modifications are likely to be required, and potentially NEPA analyses. These efforts could take up to 10 years.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** This concept (TC-7) could make concept TC-4 better. This concept will aid the overall tank retrieval time if you stop earlier and could accelerate tank retrievals if harder to retrieve/low hazard material can be left behind. This concept could also aid in disposal of grout waste forms (Concept IM-13).

**Potential Applicability to Other Sites:** SRS uses similar barrier technologies for soil and ground water remediation applications. This could have potential applicability to tank confinements throughout the complex.

**Does the technology help buy down a Mission Risk?** The concept helps reduce the risk of closed tank infiltration from the surrounding soil and groundwater.

**Identify the category of the potential concept:** Primarily 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet. Could be "3) Transformational – change in the baseline and has a mid-range costs" with real time contaminant response systems added.

**Technology Insertion Time Frame:** The most benefit comes from inserting the concept early for tank retrieval and closure.

**References:** N/A

**Contact:** Gilles Bussod – LANL, Mark Rigali – SNL, Connie Herman - SRNL

## NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** IF-2 & WR&T-2a and 2b Improved Methods to Detect/Repair Leaks for Storage Tanks (Waste Retrieval, Transport, & Closure)

**Gap or Opportunity Addressed:** The physical arrangement of the waste tanks and transfer lines makes non-destructive analysis (e.g., ultrasonic wall thickness measurements) difficult. An automated process to perform these measurements would provide additional assurances and information for the tank integrity programs.

Development of methods to repair degraded areas or leak sites in the DSTs or the transfer lines could prevent development of leak sites and allow repairs of leak sites. This technology could extend the life of existing Double Shell Tanks (DSTs).

**Technology Idea or Concept:** Develop improved methods to detect degradation in Hanford tank farm DSTs and develop techniques to repair damaged areas of the tanks.
- NDA and robotic systems for tank inspection and repair
- Patching systems to repair leaks

**Existing Funded Program:** The existing Hanford TD program has made and continues to invest in technologies to improve inspection methods and develop repair techniques. Small tethered robotic inspection tools have been developed and tested using mockups of the DST anulus. A cold-spray repair technique has been tested on coupons representing the tanks.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | *2018_8_DST Leak Repair Method* | 2018_8_DST%20Leak %20Repair%20Metho |
| *MTW-92* | *RTW-52*<br>*MTW-81* | *2014_37_Proposed IN-SITU Permeable Reactive Barrier to Mitigate Hanford Single- and Double-Shell Und* | 2014_37_Proposed IN-SITU Permeable Re |

**Connectivity to other Gap, Opportunity, or Concept:** Concept IDs J-8, J-9, WR&T-12

Methods to inspect and repair the tanks and/or transfer lines would allow greater confidence in utilization of existing resources for HLW preparation processes as well as the potential to avoid building new facilities if existing facilities can be utilized. Technologies for deployment both before and during retrieval to mitigate potential release to the environment

**Proposed Technology – Technical Maturity/Process Simplicity:** Demonstration

Small tethered robotic inspection tools have been developed and tested using mockups of the DST anulus. A cold-spray repair technique has been tested on coupons representing the tanks.

**IF-2, WR&T-2a and 2b**

**Complexity:** a) Unit operations - Waste Tanks b) Medium

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** 5-10 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M)

**Deployment Costs (required funding):** a) Pilot scale /demonstration - 10-50M b) Initial full-scale demonstration - $25-300M

**Additional investment over life cycle of Hanford mission:**

a) $1-5M to repair a tank side, $10-50M each time a repair is performed for tank bottom
b) Operating costs - N/A
c) Enhanced cleaning required for a tank bottom repair would generate secondary waste

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:**

External sides, Quick <5 years
Internal tank, Medium 5-10 years

**ROM net Cost Savings over the life cycle**: a) Annual costs (range) - N/A b) Peak cost – N/A c) Total potential savings - $250-500M per tank repaired of cost avoidance

**Schedule Acceleration of the Hanford Mission**: Not acceleration, risk mitigator of 2-5 years unless the technology is needed to allow use of existing DSTs for a HLW preparation, staging, and characterization processes.

**Net impact on Safety/Environment:** Major Positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 75%

**Regulatory Permitting/Licensing changes required:** Assuming operation under final status RCRA permit, this requires class 2 permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - N/A
b) Positive reinforcement - Helps with WT-9, PS-2, 3, 4 and potentially WR&T
c) Mutually exclusive - N/A

**Potential Applicability to Other Sites:** SRS

**Does the technology help buy down a Mission Risk?** Tank leaking or failure

**Identify the category of the potential concept:**

1) risk mitigation-not schedule driven but protect the schedule

3) transformational –change in the baseline and mid-range costs

**Technology Insertion Time Frame:** 5-7 years

**References:** N/A

**Contact:** Carl Enderlin - PNNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** WT-9 Improved Sampling Methods for Double Shell Tanks (Waste Retrieval, Transport, & Closure)

**Gap or Opportunity Addressed:** Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. In addition, these samples may not be representative of the bulk waste in the tank, particularly for samples with significant amounts of sludge solids. Current evaluations of High Level Waste (HLW) sludge retrieval options by Washington River Protection Solutions (WRPS) have identified this issue as a gap to be addressed for mixing and sampling the existing Double Shell Tanks (DSTs) that could be utilized for HLW staging and characterization.

Improving the sampling methods would reduce the costs for a HLW option that does not involve the Pretreatment Facility and would also reduce the time and dose required for processing the tank waste.

**Technology Idea or Concept:** Better sampling methods for retrieval, staging and transport to the Waste Treatment Plant (WTP) in the DST system for waste feed qualification. The sampling method must address both the representativeness of the sample as well as the efficiency of taking the required samples.

Effective ways to mix the existing DSTs or other vessels that would be utilized for waste feed staging and characterization as well as improved sampling methods for bulk waste sampling and sampling of heels.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| *RTW-01*<br>*MTW-77*<br>*PTW-54*<br>*MTW-73*<br>*MTW-83* | *MTW-24*<br>*MTW-76*<br>*MTW-37* | *2018_19_Accelerating SST Retrieval and Closure by Combined In-Tank Character...;* | 2018_19_Acceleratin g SST Retrieval and Cl |
| | | *2014_25_Continuous Sludge Leaching in WTP Pretreatment Facility;* | 2014_25_Continuous Sludge Leaching in W |
| | | *2014_41_In-Line Solids Classification;* | 2014_41_In-Line Solids Classification.pc |
| | | *2018_12_HLW LAW Processing Strategy based on Rad Operations* | 2018_12_HLW%20L AW%20Processing%2 |

**WT-9**

Evaluations of tank mixing and flow loops for sampling have been evaluated in the past for a two mixing pump scenario using pilot scale demonstrations and physical simulants of the tank waste. These evaluations indicated significant issues in sample representativeness for selected simulants.

The WRPS TD roadmap states, "To help prevent the risk of mission delays, all future project and mission elements need to be assessed as soon as possible for any potential waste sampling technology gaps." but only MTW-77, Large Volume Supernatant Sampler and Transportation System and RTW-01, Retrieval and Closure Solid Waste Sampling Tools have been selected for near term funding. MTW-77 evaluates increasing the size of the current grab sample method for supernatants from 0.5L to 1.0L while RTW-01 involves improving the core sampling technique. Neither address tank homogeneity issues or methods needed to allow a DST to be used as a staging or characterization tank for HLW.

**Connectivity to other Gap, Opportunity, or Concept:** Idea A34, A3

The ability to take a representative sludge sample from the existing DSTs would allow HLW vitrification options without the Pretreatment Facility to utilize these existing tanks to stage and characterize waste and reduce the required costs to achieve a viable HLW flowsheet.

**Proposed Technology – Technical Maturity/Process Simplicity:** 2. Concept / Demonstration

As stated above, pilot scale demonstrations with physical simulants have been performed for a 2-pump configuration. It is expected that evaluation of different mixing pump and/or sampling systems would start with modelling and then proceed to additional pilot-scale tests.

**Complexity:** Impacted Unit ops a) Waste tank unit ops, pumping processes, tank superstructure. b) Medium - In general, updating the mixing systems for the existing DSTs would impact all of the processes utilizing the tank as well as potentially requiring upgrades to the tank superstructure.

The addition of a flow-loop sampling method would also impact some of the tank processes.

The mixing and sampling samples to handle a wide range of rheological properties and particle size distributions. Integration of the efforts with expected HLW feed profiles would be required.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** >5 years - It is expected that evaluation of different mixing pump and/or sampling systems would start with modelling and then proceed to additional pilot-scale tests using physical simulants of the tank waste. Development work is likely needed on the simulants as well as the mixing/sampling equipment to be utilized.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M) - Modelling efforts to evaluate tank mixing system needs would be expected to require 1-2 years and approximately $1 million in funding. Setting up the pilot scale demonstrations and performing the range of tests needed to evaluate the vessel mixing and sampling is expected to take 4-6 years and require $10-25M.

**Deployment Costs (required funding):** a) $10-50M to get to deployment b) $50-500M for full-scale demonstration

If a system can be developed that deploys into existing tank risers, then deployment costs would be limited to the purchase and installation of equipment. However, it is likely that additional risers would be needed, and deployment would require additional risers and other infrastructure, which would result in increased deployment costs.

**Additional investment over life cycle of Hanford mission:** a) Repeated deployment costs - $500k/year b) Operating costs - $500k/year c) Other costs incurred above baseline technology - $250k/year

Additional costs were assumed to be limited to modeling or testing to ensure that the next projected batch of HLW would not exceed the operational limits of the mixing/sampling systems as well as maintenance costs to replace spent equipment.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Depends on tank configuration: Medium 5-10 years for 4 pumps, Quick <5 years for 2 pumps

**ROM net Cost Savings over the life cycle***:*

a) $400-500M avoidance per year during tank farm HLW preparation facility construction Saving in operations cost for DST versus tank farm HLW prep facility are likely minimal
b) $400-500M avoidance per year during tank farm HLW preparation facility construction Saving in operations cost for DST versus tank farm HLW prep facility are likely minimal
c) $1-4B if existing DSTs can be utilized versus new construction for a HLW direct feed pretreatment/staging/characterization function.

**Schedule Acceleration of the Hanford Mission***:* Assuming a direct feed HLW option in the DSTs can process waste at rates that avoid feed breaks in the HLW mission, a 4-5 year mission acceleration would be achieved versus feeding HLW at rate provided by the WTP-PT facility.

**Net impact on Safety/Environment:** None

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:**

2 pumps, 20% Estimated probability of successful deployment
4 pumps, 90% Estimated probability of successful deployment
Flow loop, 100% Estimated probability of successful deployment

**Regulatory Permitting/Licensing changes required:** Assuming operation under final status RCRA permit, this requires class 2 permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - This activity is required for use of existing DSTs for HLW characterization/staging without the Pretreatment Facility but could benefit the baseline WTP flowsheet as well

b) Positive reinforcement - Makes pretreatment, in tank and at tank qualification better
c) Mutually exclusive - N/A

**Potential Applicability to Other Sites:** SRS utilizes slurry-mixing pumps and grab samples for HLW pretreatment, staging, and characterization. Improvements in this type of process could apply to the SRS processes.

**Does the technology help buy down a Mission Risk?** Non representativeness of samples pulled in tank farm - process delays. Potential to decrease uncertainty in waste loading/product compliance

**Identify the category of the potential concept:** 2) incremental –some fit existing baseline/flowsheet but maybe not all 3) transformational –change in the baseline and mid-range costs if existing DSTs are used for DFHLW pretreatment, staging, and characterization

**Technology Insertion Time Frame:** 5-7 years

**References:**

- RPP-RPT-58361, Rev. 00A, One System Waste Feed Delivery Remote Sampler Accuracy Test Report, March 2015

**Contact:** Michael E Stone, SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** TC-4, TC-5, WR&T-8 Advanced In-Situ Characterization Methods Coupled with Improved Performance Assessment Models (Waste Retrieval, Transport & Closure)

**Gap or Opportunity Addressed:** The current tank closure end-states are based on achieving specific volume removal targets[1] and using a minimum number of retrieval methods, if unable to achieve volume targets, versus the potential risk of the residual constituents. The residuals may not contain constituents of concern at levels that pose unacceptable risks; a previous evaluation indicated that removing approximately 50% of the tank waste would result in an approximate 90% long-term risk reduction[2] - that is, that the long-term risk reduction is not proportional to the waste volume retrieved. Additionally, the assumptions used for contaminant release and transport may be inaccurate or intentionally bounding (to address model and other uncertainties), driving the need for more material removal than would be required from a risk standpoint.

**Technology Idea or Concept:** Optimization of the extent of waste removal from the tanks can be performed using improved characterization methods to include in-situ techniques and improved performance assessments (PA) to quantify the residual risk and uncertainty of the materials remaining. Advances in both in-situ and remote characterization techniques could help better quantify the residual concentrations of constituents of concern and the volumes of the material remaining. Potential characterization technologies include:

- 3D Mapper and Laser to determine the surface area for the volume remaining. Deployment through multiple risers to minimize the "shadow" effect of tank obstacles.
- Recirculation in-situ characterization methods to understand the components being retrieved in real time during retrieval
- New statistical methods to evaluate waste stratification when sampling is unrealistic or development of new ways to get representative samples from stratified waste tanks to reduce uncertainty
- Real-time tank heel analysis to confirm inert residuals.
- Cone Penetrometer measurements to determine rheological data of the waste.

By improving PA models (including implementing more realistic release and transport mechanisms) and parameterizing with data obtained from improved characterization methods (above), more realistic predictions of contaminant release and transport behavior and more certain quantification of risks of the residual material can be determined. These improved PA models could allow for additional low-risk materials to remain in the waste tanks when coupled with long-term monitoring protocols and monitored natural attenuation approaches.

[1] According to the Hanford Tri-Party Agreement (TPA), the retrieval limits are 360 $ft^3$ and 30 $ft^3$ for 100-Series and 200-Series tanks, respectively (Ecology, EPA, and DOE 1996, Appendix H, p. H-5). TPA Appendix H also defines the process to be taken if retrieval targets cannot be satisfied. Further, note that the retrieval targets are applied to each individual waste tank and not the aggregate either by tank farm or over all tanks.
[2] EMAB Report, Draft Final Phase II Report: Review of Life Cycle and Technology Applications of the Office of Environmental Management's Tank (energy.gov)

## Existing Funded Program:

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | *2014_13 Develop Basis to Support Future Risk-Informed Retrieval, Cleanup and Closure Decision Making* | |
| *MTW-77: Large-Volume Supernatant Sampler & Transportation System* | *RTW-39: Risk-Informed Tank Retrieval Modeling Optimization* | *2014_29 Risk-Based Tank Retrieval and Closure of Hanford Waste Tanks* | |
| *RTW-02: Residual Volume Measurement System* | *RTW-07: Post Waste Retrieval Updates to WMA C PA Maintenance* | *2014_22 Geochemical Testing and Model Development – Residual Tank Waste* | 2014_22_Geochemical Testing and Model |
| | *MTW-13: Improve Liquid Observation Well Data Acquisition* | *2014_41 In-Line Solids Classification* | 2014_41_In-Line Solids Classification.pc |
| | *RTW-33: Instrumentation for Detecting Plutonium Accumulations in Tanks* | *2014_29 Risk-Based Tank Retrieval and Closure of Hanford Waste Tanks* | |
| | *RTW-53 Three-Dimensional Flash LIDAR* | *2015_14 3-Domensional Flash LIDAR to Map Waste Tanks* | |
| | *RTW-56: Technology to Support Risk-Based Retrieval & Closure* | *2015_8 Use of Sonar and Ultrasound to Quantify Solids in Double-Shell Tanks;* | 2015_8_ Use of Sonar and Ultrasound |
| | | *2015_16 In-Situ Radiological Characterization of HLW Tank Residues* | 2015_16_In-Situ%20 Radiological%20Chara |
| | | *2017_2 Risk Informed Retrieval and Closure Strategy* | 2017_2_Risk Informed Retrieval an |
| | | *2017_18 3-Domensional Flash LIDAR to Map Waste Tanks* | |
| | | *2017_35 Technology to Support Risk Based Retrieval and Closure of Hanford Tanks* | 2017_35_Technology to Support Risk Based |

Not currently funded. Hanford Roadmap contains similar items - RTW-02 is funded to help quantify tank residuals. RTW-07, RTW-39, and RTW-53 are unfunded and have similar concepts for modeling and residual characterization methods. Past Grand Challenges have considered performance modeling of the residuals to help determine the retrieval end point.

The Consortium for Risk Evaluation and Stakeholder Participation (CRESP) has proposed scope to improve PA models and support their use in risk-based retrieval estimates in their work plan.

**Connectivity to other Gap, Opportunity, or Concept:** Concept TC-2 proposed real-time tank heel analysis to confirm inert or low-risk residuals to allow further retrieval to stop based on radiological content, phase characterization, and predicted risk remaining for closure. This concept would allow for additional residual material if it can be shown to be inert or present acceptable risk. Technology to be developed would allow for 1) characterization of concentrations of residuals in place, 2) leachability assessment method to support heel retrieval decisions and performance assessment, and 3) method that provides 3D mapping of residuals in the tank so total volume of material is better quantified. These data would drive the risk analysis and could result in more efficient retrievals.

Concept TC-5 is similar to this one and assumes that the tank cleaning end-state may be based on outdated assumptions on contaminant transport behavior that may drive the removal of more material than required from a risk standpoint. The proposed concept in TC-5 will use existing models and data to understand the transport of contaminants from earlier environmental releases or intentional discharges.

Concept WR&T-8 will be evaluated through the use of PA models, chemistry models or other engineering practices where the maximization of risk-based retrieval of tank waste was combined with this concept for evaluation.

Concepts WT-1, WT-2, WT-3, and WT-4 propose the development of in-situ characterization techniques for measurement of chemical composition, physical properties, radiological properties, mineralogy, and organic content of tank waste material. These technologies can be leveraged to improve understanding of the materials remaining during and after waste retrieval.

Concepts such as WR&T-4 would evaluate the practicality of minimal water additions for hard heel removal. When coupled with concepts to better quantify the constituents remaining and understand the predicted long-term behavior of these constituents, the total volume of waste to be treated in a processing facility would be reduced while not increasing residual risk.

**Proposed Technology – Technical Maturity/Process Simplicity:** The proposed characterization techniques have been demonstrated on a lab scale (2). The PA and its updates have been demonstrated on a pilot/prototype scale (3) but the practicality of short turn around will need to be demonstrated.

**Complexity:** a) The number of Unit Operations affected by this concept include tank characterization and sampling, tank retrieval, and PA modeling for closure. b) The complexity is considered medium due to the ties with the PA and the required system integration.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years required for characterization method development go/no go and to determine whether updates to PA assumptions will be beneficial.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M), assume $10M

**Deployment Costs (required funding):** Estimated costs is $10M to deploy the characterization technology and $10M to update the PA models and assumptions for tank closure.

**Additional investment over life cycle of Hanford mission:** Repeated deployment costs of $10M are likely for each tank where technology is deployed, and PA update costs may be realized for each tank farm. Assume 80 tanks for implementation and 10 tank farms. The in-situ characterization costs may be equivalent to the baseline costs because you have to perform ex-situ characterization and potentially need new equipment each time. The PA cost may increase slightly due to need to look at different scenarios so $2M for each farm.

Operating costs are assumed to be similar to the baseline for characterization and PA modeling. The costs of avoiding additional retrieval would be avoided in operating costs.

No other costs are anticipated to be incurred for the implementation of this concept above the baseline technology.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Slow (>10 years), assume 15 years with a 2040 start.

**ROM net Cost Savings over the life cycle**: Estimated cost savings are $20-160M annually assuming that the last part of retrieval can be reduced and some of closure management costs are saved. Based on System Plan 9 budgets, $20-80M per tank will be saved during retrieval and 1-2 tanks a year would be impacted. No peaks in funding are typically associated with retrievals. The potential total potential savings are $10-15B based on 4-6 years of schedule acceleration at a baseline budget of $2.5B/year.

**Schedule Acceleration of the Hanford Mission**: Estimated schedule acceleration of 4-6 years

**Net impact on Safety/Environment:** The proposed concept can have minor positive impact on the potential safety envelope and environmental risk because the constituents of concern would be better characterized and quantified. Additional pathway analysis could be beneficial in determining direction and magnitude of any contaminant plumes.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** 70% estimated probability of successful deployment due to rad remote deployment challenges and the modeling required.

**Regulatory Permitting/Licensing changes required:** Tri-Party Agreement negotiations may be needed followed by PA updates including regulator reviews and permit modifications. These efforts could take up to 10 years.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** Concept TC-7 could make this concept better. This concept will aid the overall tank retrieval time if you stop earlier but the mission needs to have capacity to treat the waste (e.g., glass or grout).

**Potential Applicability to Other Sites:** The Savannah River Site could benefit from the characterization technologies if developed soon enough.

**Does the technology help buy down a Mission Risk?** The concept helps implement risk-based closures through improved characterization and modeling to assess residual risk.

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid-range cost.

**Technology Insertion Time Frame:** The most benefit comes from inserting the concept early and once the overall Hanford Tank Mission processing strategy and flowsheet is confirmed.

**References:** N/A

**Contact:** Kevin Brown – CRESP, Connie Herman and Erich Hansen - SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PS-4 In-tank Pretreatment of HLW Sludge (Waste Pretreatment)

**Gap or Opportunity Addressed:** Sludge washing, settling, and concentration is needed to remove problematic species such as Al, $PO_4^{3-}$, $SO_4^{2-}$, $NO_3^-$ and halides that can significantly impact HLW vitrification and transfer them to the LAW stream for immobilization. In-tank sludge processing is the primary option for sludge preparation without completion/operation of the Pretreatment (PT) facility. In-DST processing may have difficulty meeting washing or throughput requirements due to sludge properties. Improved methods for in-tank sludge processing are needed to ensure successful pretreatment.

**Technology Idea or Concept:** Optimization of in-tank sludge pretreatment is needed to ensure success. Variables such as washing fluid, composition, time, temperature, and selected endpoints need to be considered and evaluated. In addition, required mixing necessary including mixer type and operation is to be determined. The settling time required for efficient operations must also be determined and could involve the evaluation of additives to act as settling aids or the use of filtration technologies.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | *2016_34_Optimization of Sodium Concentration in DFLAW Feed (perhaps a bit of a stretch)* | 2016_34_Optimization of Sodium Concentr |
| | *PTW-40, High-Level Waste Phased Approach* | | |
| | *RTW-15 Evaluate Back-Up Options for HLW Delivery from Tank Farms* | | |
| | *RTW-19 TRU/Sr-90 Precipitation in Double-Shell Tanks* | | |
| | *PTW-52 DFLAW Pretreatment Operations Technology Maturation (retired Idea)* | | |
| | *PTW-42* | | |

**Connectivity to other Gap, Opportunity, or Concept:** Related to PS-2 which also deals with sludge pretreatment, but at-tank versus in-tank. PS-2 and PS-4 could both be utilized, with PS-2 being used for challenging wastes that are not easily dealt with using in-tank washing/ pretreatment methods. Also related to PS-3, improved understanding of aluminum chemistry, which could provide useful knowledge for optimizing an in-tank aluminum dissolution processes. Additional connectivity to E25.

**Proposed Technology – Technical Maturity/Process Simplicity:** Full scale demo. In-tank aluminum dissolution and sludge washing are currently performed at SRS for preparing sludge batches to feed the vitrification facility. Applicability of those technologies/processes to Hanford tanks and sludge should be evaluated.

**Complexity:**

a) Several unit operations within a waste tank – mixing, washing, leaching (temperature control), settling/filtration, decanting, Filter flush
b) High required integration

**Projected Time Line for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M)

**Deployment Costs (required funding):**

a) $15M for demonstration

b) $30 M for initial full-scale deployment. The initial full-scale costs are based upon incremental costs beyond mixer/transfer pumps already included in baseline for sludge retrieval. Additional costs are for supporting measurement and control of in-tank washing and settling/decant operations.

**Additional investment over life cycle of Hanford mission:**

a) $780 M for repeat of initial deployment in other DSTs after the initial full-scale deployment. It is not envisioned that the operations would be performed in every DST.
b) Modest increase in operational costs over baseline sludge retrieval ($10M).
c) Other costs incurred above baseline technology - None.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle***:*

a) Annual costs - Estimated cost savings of $47M (avoidance of $57M annual operating costs for PT facility minus the additional $10M in operational costs over baseline sludge retrieval.)
b) Estimate of $6-8B in peak costs savings due to avoidance of completion of PT facility for sludge processing.
c) Total potential savings estimated at $16B based on savings of $47M/year in operational costs and $14.8B savings from elimination of PT capital costs.

**Schedule Acceleration of the Hanford Mission***:* 15-20 years based on the assumption PT would not start until 2050 due to funding constraints.

**PS-4**

**Net impact on Safety/Environment:** Major positive due to accelerated timeline for sludge processing; potential minor negative if DST integrity fails

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 95%

**Regulatory Permitting/Licensing changes required:** Class 2 or 3 RCRA permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) PS-4 or PS-2 or PT needed for HLW vitrification if the PT facility is not completed.
b) PS-3 (improved understanding of aluminum chemistry) makes PS-4 better. PS-2 could also benefit this concept if both are pursued and PS-2 is used to handle wastes that present challenges to the in-tank treatment process.
c) Mutually exclusive - N/A

**Potential Applicability to Other Sites:** SRS

**Does the technology help buy down a Mission Risk?** Risk reduction in having a method for preparing feed to the HLW vitrification facility if the PT facility is not completed.

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid-range costs 4) Long range program - Transformational technology with potential big payoff in the 10-15 year time frame

**Technology Insertion Time Frame:** 10-15 years with DFHLW start-up

**References:** N/A

**Contact:** Kathryn Tayor-Pashow - SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID**: PS-2 At Tank Sludge Processing (Waste Pretreatment)

**Gap or Opportunity Addressed:** The baseline Pretreatment (PT) facility will require significant additional capital funding to complete and performing sludge processing in tank may not be able to achieve all the functions that are currently intended for the PT facility. Therefore, an option that achieves most of the PT functionality without the large expense of completing the PT facility could be beneficial.

**Technology Idea or Concept:** Provide a skid-based approach similar to Tank Side Cesium Removal (TSCR) to achieve sludge processing. Objective of the skid would be at a minimum to wash sludge and concentrate it, it could include aluminum dissolution if that option was desirable.

**Existing Funded Program:** No. There are no currently funded activities for a skid-based approach. There were previous DOE funded activities looking at skid mounted sludge pretreatment (ART program from the early 2010s).

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| *RTW-08* | *RTW-44- Use of Sonar & Ultrasound to Quantify Solids in DSTs* | *2014_21_GC cross flow filtration and caustic side solvent extraction* | 2014_21_GC%20cross%20flow%20filtration |
| | *RTW-15 Evaluate Back-Up Options for HLW Delivery from Tank Farms* | *2016_34_Optimization of Sodium Concentration in DFLAW Feed (perhaps a bit of a stretch)* | 2016_34_Optimization of Sodium Concentr |
| | *PTW-40- High-Level Waste Phased Approach* | *2015_8_ Use of Sonar and Ultrasound to Quantify Solids in Double-Shell Tanks (quantification not filtration)* | 2015_8_ Use of Sonar and Ultrasound |
| | | *2014_21_GC cross flow filtration and caustic side solvent extraction* | 2014_21_GC%20cross%20flow%20filtration |

**Connectivity to other Gap, Opportunity, or Concept:** Concepts E1, E19, E29, E44, E45

This links with PS-6 as they share some of the same functionality. Also, this is related to PS-4 as they share some of the same objectives. PS-3 requires implementation of either PS-4 or PS-2 for its benefit to be realized.

**PS-2**

**Proposed Technology – Technical Maturity/Process Simplicity:** 3 – this basic approach has been demonstrated through the pilot scale (from the ART projects). However, there would be some modifications from the prior project based on current objectives.

**Complexity:** Medium integration: Includes washing, filtration, solids collection and filter flushing at a minimum, could also include leaching.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years as this has already been developed to pilot scale. As indicated above, it would need to be updated to meet current objectives, but the basic concept has been validated.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low <$10M. This would require some limited technology development to support a go-no go decision but would not require an extensive technology development program to support a go/no-go decision.

**Deployment Costs (required funding):** High estimate for a full-scale demonstration is $150M. Most of those costs would be on the tank farm side developing the infrastructure and any authorization basis documents to support this concept. The equipment costs themselves would be only a fraction of that total, as the equipment is all of the shelf and could be designed today.

**Additional investment over life cycle of Hanford mission:** None – the assumption is that one skid would be sufficient to support the HLW processing requirements.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years), The assumption is that this could be deployed in a similar timeframe as TSCR – 4 years.

**ROM net Cost Savings over the life cycle***:* From AoA Table 77, total WTP annual operating costs estimated at $452M in 2018 dollars. PT alone is $57M (HLW $99M; BOF $85M; LAW $159M; LAB $52M). In System Plan 9, TSCR annual operating costs average $48.8M over 49 yrs of operation. Assume tank side sludge processing annual costs will be similar to TSCR for savings of ~$8M annually (57-49).

This option enables omitting the PT facility from the system, resulting in approximately $15B in savings.

**Schedule Acceleration of the Hanford Mission***:* 15-20 years. This is based on the delay in start-up of the PT facility due to funding constraints.

**Net impact on Safety/Environment:** Major positive in that this enables a much earlier start of sludge processing.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 90%

**Regulatory Permitting/Licensing changes required:** Would require some additional Class 2 or Class 3 permitting, likely 2-3 years to complete.

**PS-2**

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** PS-3 makes this item better.

**Potential Applicability to Other Sites:** Some potential that if a tank side sludge pretreatment system were developed that it could be applied to SRS sludge pretreatment.

**Does the technology help buy down a Mission Risk?** Risk reduction in having a method for preparing feed to the HLW vitrification facility if the PT facility is not completed.

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid range costs. This approach is transformational as it opens up a new route for sludge pretreatment and eliminates a 15-20 year lag in the schedule as the PT facility is completed.

**Technology Insertion Time Frame:** This technology would need to be deployed in sequence with HLW vitrification. It may be needed ahead of HLW start-up to enable preparation of some feed for the vitrification facility depending on the properties of the sludge.

**References:**

- M.K. Edwards, Russell, R.L., Shimskey, R.W. and Peterson, R.A, "Bench Scale Testing of the Continuous Sludge Leaching Process", August 2010, Separation Science and Technology, 45:1807-1813.

**Contact:** Reid Peterson - PNNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PL-5 RCRA Organic Removal from Tank Supernate (Waste Pretreatment)

**Gap or Opportunity Addressed:** Tank waste supernate containing Resource Conservation & Recovery Act (RCRA) organics may need to be treated for the organics to meet RCRA Land Disposal Restriction (LDR) standards for non-vitrification or other thermal options for Low-Activity Waste (LAW) immobilization. Evaporation may be effective for many LDR organics but needs to be verified for the range of constituents of concern expected in Hanford tanks and may require supplemental treatment methods to assure LDR compliance.

**Technology Idea or Concept:** The concept is to develop technologies to remove the RCRA organics that have been identified in the tank supernatants. Such technologies could include:

- oxidation/destruction
- volatilization/evaporation
- extraction (e.g., solvent/supercritical)
- capture evaporator concerns with ammonia abatement from IF-17

The organic removal may require a combination of multiple methods to address the range of organics and combination of organics present in the tanks.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | *2015_35_Eliminate Regulated Organics from LAWPS-WTP Waste acceptance Criteria WRPS* | 2015_35_Eliminate%20Regulated%20Orga |
| PTW-23 | MW-08 ETF Organic Destruction Unit Operation (Retired TEDS Sheet) | *2015_1_Alternative Engineering Strategy for WTP* | 2015_1_Alternative Engineering Strategy |
| | | *2018_12_HLW LAW Processing Strategy based on Rad Operations* | 2018_12_HLW%20LAW%20Processing%2 |
| | | *2018_19_Accelerating SST Retrieval and Closure by Combined In* | 2018_19_Accelerating SST Retrieval and Cl |
| | | *2017_24_GC Ammonia Remediation Supporting Hanford WTP Secondary Waste Processing* | 2017_24_GC%20ammonia%20remediatio |

**PL-5**

**Connectivity to other Gap, Opportunity, or Concept:** This concept / gap is directly connected to IM-13 in that IM-13 may not be implementable without addressing this technology gap. There is also connectivity to the following additional concepts/gaps: D24, D28, D51, D66, D73, A62 and condensed concepts WT-10 and PS-5.

**Proposed Technology – Technical Maturity/Process Simplicity:** 2. lab demonstration for developing and testing of efficiencies / effectiveness of the methods to remove the various RCRA organics.

**Complexity:**

a) Unit operations include evaporator, condensation, GAC filtration, condensate to the Effluent Treatment Facility (ETF) for treatment and/or GAC treatment for organics destruction, reuse or disposal of GAC, immobilization/disposal of any secondary waste/non-liquid residues
b) Medium technical complexity. The number of RCRA organics present a number of challenges to finding a single low temperature process that would adequately remove/destroy the full suit that might be present. It is currently believed that multiple processes might need to be applied depending on the specific organics present. Potentially the treatment could use something like the modular concept of the Tank Side Cesium Removal (TSCR).

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** Optimization of specific destruction processes could be achieved in < 5 years.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M), This has a relatively low cost for technology development. This cost would be well below the low ($10M) threshold.

**Deployment Costs (required funding):** A number of the organic destruction approaches are relatively mature technologies, and thus no pilot scale costs are anticipated. However, real waste testing is believed to be necessary at small scale for select, representative tank wastes. Cost for small scale hot testing and initial full-scale deployment would be ~$30M.

**Additional investment over life cycle of Hanford mission:**

a) Repeated deployment costs - $25-50M (assuming up to 3 units associated with TSCR units in east/west areas). This also assumes evaporation for estimating this item
b) Operating costs - No significant increase over TSCR operating costs
c) Other costs incurred above baseline technology - No significant increase in secondary wastes beyond that estimated from downstream evaporators (e.g., Effluent Management Facility).

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 years)

**ROM net Cost Savings over the life cycle***:* This activity coupled with IM-13 is estimated to achieve:

**PL-5**

a) Annual cost savings of $320M to $380M
b) Peak cost savings of – $380M
c) Total potential savings of $15.5B (unescalated) to $50.6B (escalated)

**Schedule Acceleration of the Hanford Mission***:* This activity coupled with IM-13 is estimated to accelerate the mission by 10-20 years

**Net impact on Safety/Environment:** This activity will have a minor positive impact.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 75%

**Regulatory Permitting/Licensing changes required:** NEPA (for non-vitrification technologies), Class 3 RCRA permit mod, 10 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - This is enabling technology for IM-13 and must be done to allow IM-13 to be successful.
b) Positive reinforcement - None
c) Mutually exclusive - None

**Potential Applicability to Other Sites:** Minimal, if any, applicability to other sites has been identified.

**Does the technology help buy down a Mission Risk?** Inability to dispose of grouted LAW m if it exceeds the LDR treatment standards should it be selected as the Supplemental LAW waste for.

**Identify the category of the potential concept:** Primary category is 3) transformational – change in the baseline and mid-range costs (enabling grouting of LAW and offsite disposal).

The secondary is 4) Long-range transformational which would be enabling onsite disposal of grouted LAW.

**Technology Insertion Time Frame:** 5 - 10 years

**References:** N/A

**Contact:** R. T. Jubin – ORNL, Dan McCabe - SRNL

**NNLEMS Hanford Tank Waste Mission Acceleration Team**

**Concept ID:** PS-6 Sludge Concentration (Waste Pretreatment)

**Gap or Opportunity Addressed:** The baseline Pretreatment (PT) facility will likely be too expensive to complete and performing sludge processing in-tank may not be able to achieve all the functions that are currently intended for the PT facility. One of the key functions is to concentrate the sludge to 15 to 20 wt% prior to transfer to the HLW facility. Settle-decant operations in DSTs may require much longer settle times than needed to meet throughput requirements. In addition, concentrating at tank increases risk of solids settling and potential line plugging in long transfer line from farm to the HLW facility. Therefore, an option that achieves this PT functionality without the large expense of completing the PT facility and reduced risk of in-line sludge settling would be beneficial.

**Technology Idea or Concept:** Provide a skid-based approach similar to Tank Side Cesium Removal (TSCR) to achieve sludge concentration near the HLW facility. This skid would be located near the HLW facility to avoid long transfers of high solids loading material and to avoid flush high flush water volumes in WTP.

**Existing Funded Program:** No. There are no currently funded activities. There were previous DOE funded activities looking at skid mounted sludge pretreatment (ART program from the early 2010s). There was also an extensive program at SRS to look at sludge washing and concentration using rotary microfiltration at tank.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| | *MTW-91, Tank-Side Waste Evaporation* | *N/A* | |

**Connectivity to other Gap, Opportunity, or Concept:** Concept E15. This links with PS-2 as they share some of the same functionality. Also, this is related to PS-4 as they share some of the same objectives.

**Proposed Technology – Technical Maturity/Process Simplicity:** Pilot/prototype – an approach has been demonstrated through the pilot scale (from the ART projects). However, there would be some modifications from the prior project based on current objectives. An alternative approach would be to deploy something similar to the SRS slurry mix evaporator (SME) to evaporate and concentrate the sludge. That concept has been deployed, but not in a skid mounted approach, so some development would be required. Pilot/prototype with rotary microfilter was performed at SRNL for sludge washing and concentration for SRS sludge.

**Complexity:** Medium: Includes sludge transport from feed tank or post sludge preparation vessel, evaporation or physical dewatering, water recycle to tank farms/evaporator/or the Effluent Treatment Facility, concentrated sludge mixing and transport to treatment unit (e.g., HLW VIT).

**PS-6**

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years as this has already been developed to pilot scale. As indicated above, it would need to be updated to meet current objectives, but the basic concept has been validated.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision***:* Low <$10M. This would require some limited technology development to support a go-no go decision but would not require an extensive technology development program to support a go/no-go decision.

**Deployment Costs (required funding):** High estimate for a full scale demonstration is $150M. Most of those costs would be on the tank farm side developing the infrastructure and any authorization basis documents to support this concept. The equipment costs themselves would be only a fraction of that total, as the equipment is all off the shelf and could be designed today.

**Additional investment over life cycle of Hanford mission:** None – the assumption is that one skid would be sufficient to support the HLW processing requirements.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years), The assumption is that this could be deployed in a similar timeframe as TSCR – 4 years.

**ROM net Cost Savings over the life cycle***:* From AoA Table 77, total WTP annual operating costs estimated at $452M in 2018 dollars. PT alone is $57M (HLW $99M; BOF $85M; LAW $159M; LAB $52M). in System Plan 9, TSCR annual operating costs average $48.8M over 49 yrs of operation. Assume tank side sludge processing annual costs will be similar to TSCR for savings of ~$8M annually (57-49).

This option enables omitting the PT facility from the system, resulting in approximately $15B in savings.

**Schedule Acceleration of the Hanford Mission***:* 15-20 years. This is based on the delay in start-up of the PT facility due to funding constraints.

**Net impact on Safety/Environment:** Minor positive in that this avoids line plugging issues between tank farms and this skid.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 90%

**Regulatory Permitting/Licensing changes required:** Would require some additional Class 2 or Class 3 RCRA permitting, likely 2-3 year to complete.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** PS-6 may make IM-12 better.

**Potential Applicability to Other Sites:** Could build upon SRS SME experience. May have some applicability to SRS sludge washing.

**Does the technology help buy down a Mission Risk?** Reduces risk of sludge processing TOE reduction with use of in-tank settle decant only and reduce risk of solids settling in transfer line from tank farms to HLW Vit facility.

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid-range costs. This approach is transformational as it opens up a new route for sludge pretreatment and eliminates a 15-20 year lag in the schedule as the PT facility is completed.

**Technology Insertion Time Frame:** This technology would need to be deployed in sequence with HLW vitrification. It could be deployed slightly ahead of HLW to enable preparation of some feed but the need will depend on the specific HLW sludge.

**References:**

- M.K. Edwards, Russell, R.L., Shimskey, R.W. and Peterson, R.A, "Bench Scale Testing of the Continuous Sludge Leaching Process", August 2010, Separation Science and Technology, 45:1807-1813.

**Contact:** Reid Peterson – PNNL, Mike Stone and David Herman - SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PS-3 Improved Understanding of Aluminum Chemistry to Optimize Sludge Processing (Waste Pretreatment)

**Gap or Opportunity Addressed:** Aluminum is a key constituent of HLW sludges and is manifested in different chemical forms with varying solubility and processing difficulty. Improved chemical understanding and predictive models are needed to better optimize sludge retrieval, transport, and washing and to alter target amount removed/compound.

**Technology Idea or Concept:** New knowledge of aluminum chemistry in alkaline, concentrated electrolytes is required to accelerate waste processing. Examples of new understanding that would lead to major improvements in waste processing and cost reductions include: (i) reducing uncertainty associated with precipitation kinetics of aluminum hydroxides; (ii) determining mechanisms of hard crust formation on the waste surface and improving strategies to break it up; (iii) quantifying the effect of co-anions on aluminum solubility (solubility studies required in the presence of nitrite, nitrate, carbonate, and key species pertinent to tank waste); and (iv) determining the influence of solution composition on particle aggregation and settling behavior. This work will provide a new physical interpretation of why aluminum behaves the way it does, an interpretation that could accelerate the tank waste mission by providing a parameterized model that describes effects of tank waste constituents.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | *2014_22_Geochemical Testing and Model Development – Residual Tank Waste (perhaps a bit of a stretch)* | 2014_22_Geochemical Testing and Model |
| | *RTW-21 IMPROVE ESP – A Thermodynamic Modeling Program*<br><br>*RTW-27, Improved Solubility Modeling of Aluminum*<br><br>*RTW-28, Solubility Modeling of Oxalate, Fluoride & Other Simple Mixtures*<br><br>*RTW-29, Improved Solubility Modeling of Phosphate* | *2018_1_Hanford Waste Chemistry Book Project* | 2018_1_Hanford Waste Chemistry Boo |

| | | | |
|---|---|---|---|
| | *PTW-51, Nitrite-Hydroxide Solubility to Determine Aluminum Solubility in DFLAW* | | |
| | *DOE-BES funded Energy Frontier Research Center: Interfacial Dynamics in Radioactive Environments and Materials (IDREAM). Scope is not funded as part of existing TD roadmap.* | | |

**Connectivity to other Gap, Opportunity, or Concept:** PS-3 enables and underpins contribution to other concepts (PT, PS-2, PS-4 and retrieval). Connections to other gap/ opportunities include: E32, E36, and WT-8

**Proposed Technology – Technical Maturity/Process Simplicity:** 1. Concept – basic science required

**Complexity:**

a) High. Aluminum is a major constituent in the waste and aluminum solubility has a big impact on where aluminum goes in the flowsheet, yet there is high uncertainty in its solubility under different conditions.
b) This concept intersects and engages multiple unit operations in the flowsheet. An urgent flowsheet gap is related to PT (filtration) and the retrieval/dilution of DFLAW feeds, because adding water to waste can cause aluminum to precipitate. Improved understanding of aluminum solubility will allow sludges to be washed effectively to remove aluminum (and other problematic constituents) with a DST (PS-4) or skid-based system (PS-2). The concept is also a high priority for HLW retrieval, with the science supporting improved sludge washing, which affects the feed to the HLW facility.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years - Benefitting from Office of Science funded research, empirical evidence on new mechanisms that play a role in aluminum solubility can improve speciation-based solubility models. Data obtained can immediately start to improve accuracy in estimation of aluminate solubility in tank waste.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M)

**Deployment Costs (required funding):** <$5M. Deployment costs will involve incorporation of the data produced in this concept into a parameterized model to *support all subsequent processing*, including sludge pretreatment, washing fluid composition, time, temperature, improving filtration and filter performance with high solids. Actual processing will be covered by other concepts (PS-2, PS-4, etc.). Hot cell confirmation with actual wastes may be necessary for confirming models with real tank waste ~ $10M.

**PS-3**

**Additional investment over life cycle of Hanford mission:**

a) Repeated deployment costs - None – the assumption is that investment in fundamental aluminum chemistry would support all subsequent processing requirements.
b) Operating costs - None
c) Other costs incurred above baseline technology - None

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle**

a) Annual costs - N/A
b) Peak cost - N/A
c) Total potential savings - The goal of this concept is to develop a low capital cost way to reduce the volume of aluminum-bearing sludge by an order of tens of percent that will reduce the HLW mission by tens of years (assuming a 50-year mission life). Every year that HLW processing is reduced will reduce costs by ~$400-$500M minimum.

**Schedule Acceleration of the Hanford Mission***:* >10 years potentially. Based on advancement in the fundamental understanding of waste behavior

**Net impact on Safety/Environment:** Minor Positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 90%

**Regulatory Permitting/Licensing changes required:** None

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - None
b) Positive reinforcement - PS-3 enables and underpins contribution to other concepts (PT, PS-2, PS-4 and retrieval)
c) Mutually exclusive - N/A

**Potential Applicability to Other Sites:** SRS

**Does the technology help buy down a Mission Risk?** E2: Al Leaching/Partitioning, and in WR&T – dealing with aluminum solubility including waste dissolution and unwanted reprecipitation.

**Identify the category of the potential concept:** 4) Long range program - Transformational technology with potential big payoff in the 10-15 year time frame

**Technology Insertion Time Frame:** Immediate impact could be up to 10 years. Immediate benefits from improved dilution of DFLAW feeds. Intermediate term impacts through improved sludge retrieval and washing strategies for HLW processing. Longer term impacts to the mission by accelerating HLW sludge processing, including more complex sludges could be >10 years.

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**Contact:** Carolyn Pearce, Reid Peterson, Matthew Fountain - PNNL, Jacob Reynolds, Michael Britton - WRPS

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PL-1: Improved LAW Filtration (Waste Pretreatment)

**Gap or Opportunity Addressed:** Tank Side Cesium Removal (TSCR) currently relies on dead end filtration with a relatively small filter area available. Testing to date has shown that the presence of even a nominal amount of solids will challenge the ability of TSCR to maintain process throughput. However, to date, there appear to have been minimal solids charged to the TSCR filter. Should that situation change in the future, there will be a need for improved LAW filtration capacity.

**Technology Idea or Concept:** There have been a number of strategies in the past to make the solids less susceptible to fouling. These generally involve increasing the shear at the surface of the filter media, either through rotation (rotary microfilter), cross flow, or through an alternative backpulse such as ultrasonic. Some of these concepts are more mature (cross flow has been demonstrated at full scale in the Salt Waste Processing Facility (SWPF) at SRS) than others (ultrasonic has limited bench scale testing). The proposed technology would be deployed on a skid like system.

**Existing Funded Program:** Yes. There is no currently funded contractor scope looking at alternative filtration methods as defined in the concept above. However, there is a limited amount of funding currently supporting a MSIPP project at Howard University looking at fouling mechanisms.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| *None* | *RTW-44* | *2014_21-GC cross flow filtration and caustic side solvent extraction* | 2014_21_GC%20cross%20flow%20filtratior |
| | | *2014_16_RMF for washing SRNL* | 2014_16_RMF%20for%20washing%20SRNl |
| | | *2014_40-Separation and Vitrification of Cesium and Strontium in a Pretreatment Process* | 2014_40_Separation and Vitrification of Ce |

**Connectivity to other Gap, Opportunity, or Concept:** Linked to D21, D49, D74

PL-2 proposes improving filtration through introduction of a filter aid. A filter aid could also be used in conjunction with the concepts provided in this task.

**PL-1**

**Proposed Technology – Technical Maturity/Process Simplicity:** Depending upon which approach is employed, this technology would range from 2 (lab demonstration for ultrasonic) to 4 for cross flow filtration (using SWPF as an example of a full-scale demonstration). Cross flow filtration is also the simplest technology to deploy but may require a slightly larger skid for deployment.

**Complexity:** Unit Operation activities include: Pumping, filtration, solids return to tank farm and supernate feed to ion exchange.

Medium complexity. Would replace or augment current dead-end filter. May require change in pumping pressures and configuration of solids return. Additional TSCR skid or change to future TSCR units.

The concept for this is to deploy a stand alone skid. The largest concept – cross flow filtration – would likely occupy the space roughly equivalent to one TSCR enclosure. None of these approaches could be retro fitted into TSCR, and thus they would all likely require a new skid of some sort.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** Again, this would depend on the technology selected. Cross flow filtration is ready to go now and would require little technology development to support a deployment decision. In contrast, the other technologies would require additional time. Based on the fastest timeline, this should be <5 years.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:**
This has a relatively low cost for technology development as the data is already available to support the primary options. This cost would be well below the low ($10M) threshold.

**Deployment Costs (required funding):** This is a relatively mature technology, and thus no pilot scale costs are anticipated. Cost for initial full-scale deployment would be $10M.

**Additional investment over life cycle of Hanford mission:** If required, this system would be needed to support the replacement TSCR units. Assuming at least two additional TSCR replacements, the additional lifecycle deployment cost would be $20M.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** This technology could be deployed on a similar time frame as TSCR (~ 4 years) thus, a quick (<5 years) post Go/No Go decision is expected.

**ROM net Cost Savings over the life cycle***:* The benefit to this activity is in the avoidance of additional costs associated with the lower TOE associated with TSCR if the current dead end filtration approach has lower than anticipated performance.

The low end of the range is $0 if filtration for TSCR continues as planned. However, if TSCR filtration begins to see challenges from solids present in the filter feed, the costs could quickly escalate and TSCR would be effectively shut down by a filter failure. Since it is reasonable to re-deploy this technology within 4 years, the effective cost avoidance would be $1B (assuming $0.25B/year of added operations due to the delay).

**PL-1**

**Schedule Acceleration of the Hanford Mission***:* This is primarily a risk avoidance activity, and as such does not accelerate the mission timeline, but rather avoids a 4 year delay in the schedule if the risk associated with TSCR filtration is realized.

**Net impact on Safety/Environment:** None – the skid mounted system is anticipated to pose roughly the same risk as the current TSCR system.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 95% - this is a relatively low risk deployment.

**Regulatory Permitting/Licensing changes required:** Would require a similar permitting strategy as the current TSCR units, likely involving a Class 2 or 3 RCRA permit modification. This would require some time (2-3 years to complete) but should be relatively straight forward.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** None

**Potential Applicability to Other Sites:** This has the potential for some applicability for SRS in supplement to both Tank Closure Cesium Removal (TCCR) and SWPF filtration.

**Does the technology help buy down a Mission Risk?** Yes – this element is primarily focused on risk reduction associated with potential TSCR utility.

**Identify the category of the potential concept:** 1) Risk Mitigation – not schedule driven but helps the project schedule by reducing risk

**Technology Insertion Time Frame:** This may need to be deployed before DFLAW if TSCR filter risks are realized in the very near term, more likely would be deployed after DFLAW as TSCR can likely make it through supporting DFLAW start-up.

**References:**


- Geeting, Allred, Rovira, Shimskey, Burns and Peterson, "Cross Flow Filtration of Hanford tank AP-105 Supernatant", January 2018, PNNL-27085.
- Poirier, Herman and Bhave, "Evaluation of Alternative Filter Media for the Rotary Microfilter", November 9, 2011, SRNL-STI-2011-00690.


**Contact:** Reid Peterson – PNNL, David Herman - SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PL-2 Additives to Optimize Filtration (Waste Pretreatment)

**Gap or Opportunity Addressed:** Supernate filtration is required to meet Waste Incidental to Reprocessing (WIR) requirements for removal of entrained solids that may contain insoluble radionuclide complexes, and to protect downstream pretreatment processing such as ion exchange that would be negatively impacted by solids fouling or plugging. Dead-end filtration is currently used in the Tank Side Cesium Removal (TSCR) and Tank Closure Cesium Removal (TCCR) system, and requires frequent backflushing to maintain effective operations, reducing the overall TOE. Improvements to existing filtration processes that increase TOE are needed.

**Technology Idea or Concept:** The concept is to improve the overall filter performance through the addition of filter aids. There are two primary objectives for the addition of filter aids. The first is to form a layer that will protects the basic filter media in the system. The second objective of the filter aid is to then improve the flow rate of the liquid through the filter by decreasing compressibility of the solid cake and increasing filter cake permeability.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | *2014_21-GC Cross Flow Filtration and Caustic Side Solvent Extraction* | 2014_21_GC%20cros<br>s%20flow%20filtratior |
| | *RTW-44* | *2014_40-Separation and Vitrification of Cesium and Strontium in a Pretreatment Process* | 2014_40_Separation<br>and Vitrification of Ce |
| | | *2016_26-AT-Tank Cesium Removal* | 2016_26_AT-Tank<br>Cesium Removal.pdf |
| | | *2015_15_Tank Waste Radionuclide Removal and Immob Options* | 2015_15_Tank%20W<br>aste%20Radionuclide |
| | | *2014_16_RMF for Washing* | 2014_16_RMF%20for<br>%20washing%20SRNl |

**Connectivity to other Gap, Opportunity, or Concept:** This is connected to PL-1 in that PL-1 is also focused on improving filtration via alternate filtration concepts.

**PL-2**

**Proposed Technology – Technical Maturity/Process Simplicity:** 2 - lab demonstration for developing / testing of filter aid.

**Complexity:** a) Unit Operations include filtration, ion exchange, transfer, vitrification. b) Medium technical complexity. Would replace or augment current dead-end filter. May require change in pumping pressures and configuration of solids return. Additional TSCR skid or change to future TSCR units

High integration complexity. Must assure that all downstream impacts of additives are assessed. Compatibility of filtration additives with downstream filtration, ion exchange, waste transfer and vitrification would be needed.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** Optimization of a filter aid could be achieved in < 5 years.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M), This has a relatively low cost for technology development. This cost would be well below the low ($10M) threshold.

**Deployment Costs (required funding):**

a) This is a relatively mature technology, and thus no pilot scale costs are anticipated.
b) Real waste testing is believed to be necessary at small scale; may need to test with range of tank waste feeds (simulant or real wastes) to assure compatibility as mission progresses. Cost for small scale hot testing and initial full-scale deployment would be $20M.

**Additional investment over life cycle of Hanford mission:**

a) No repeat deployment costs except for compatibility verification as feeds change.
b) Operating costs - $1-$5M (additives costs and compatibility verification as feeds change).
c) Other costs incurred above baseline technology - None.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium, 5-10 years

**ROM net Cost Savings over the life cycle***:* The benefit to this activity is in the avoidance of additional costs associated with the lower TOE associated with TSCR if the current dead end filtration approach has lower than anticipated performance.

**Schedule Acceleration of the Hanford Mission***:* This is primarily a risk avoidance activity, and as such does not accelerate the mission timeline, but rather avoids a 4-year delay in the schedule if the risk associated with TSCR filtration is realized.

**Net impact on Safety/Environment:** This activity is not expected to have any significant impact on safety or environment.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 50%

**PL-2**

**Regulatory Permitting/Licensing changes required:** Class 2 RCRA permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - None
b) Positive reinforcement – PL-1
c) Mutually exclusive - None

**Potential Applicability to Other Sites:** TCCR at SRS would benefit directly from this activity if filtration issues occurred.

**Does the technology help buy down a Mission Risk?** D1: Solid-Liquid Separation TOE reduction

**Identify the category of the potential concept:** Primary - 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet. Secondary - 1) Risk Mitigation – not schedule driven but helps the project schedule by reducing risk

**Technology Insertion Time Frame:** 5 - 10 years. This may need to be deployed before DFLAW if TSCR filter risks are realized in the very near term, more likely would be deployed after DFLAW as TSCR can likely make it through supporting DFLAW start-up

**References:** N/A

**Contact:** R. T. Jubin - ORNL, Kathryn Taylor-Pashow and Erich Hansen – SRNL, Reid Peterson - PNNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PL-8 Sodium Nitrate Separation or Destruction Technologies (Waste Pretreatment)

**Gap or Opportunity Addressed:** Sodium nitrate represents a significant fraction of the waste requiring treatment. Nitrates/$NO_X$ abatement represents a significant cost and risk for thermal waste treatment such as vitrification, and a potential long-term groundwater risk for most low-temperature treatment processes such as waste grouting. Methods for safe destruction of nitrates or separation of sodium nitrate from tank wastes.

**Technology Idea or Concept:** The concept is to develop technologies to remove / separate the sodium nitrate found in the tank waste. An alternative to the separation would be destruction of the sodium nitrate such that it no longer poses the current burden on the off-gas treatment systems of the high temperature operations or poses long-terms risks arising from the waste forms from low-temperature processes. Such technologies could include:

- fractional crystallization
- clean salt
- denitrification (biological, NAC)

**Existing Funded Program:**

| *WRPS Programs* | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | *2016_18_Techno-economic Assessment of Nitrate Destruction Options for Hanford Tank Waste* | 2016_18_Techno-eco nomic Assessment of |
| | *PTW-49*<br>*MTW-59*<br>*PTW-49* | | |

**Connectivity to other Gap, Opportunity, or Concept:** E43, E46, D53

**Proposed Technology – Technical Maturity/Process Simplicity:** 3. Pilot/prototype. Several of these concepts have been demonstrated at laboratory-scale, some on actual wastes, and/or piloted at large scale for similar waste streams.

**Complexity:**

a) Activities include filtration, chemical, electrochemical and/or membrane separation of sodium salts, treatment/immobilization of sodium salt stream and disposal, transfer of low sodium/nitrate stream with to LAW immobilization.
b) Medium technical complexity.

**PL-8**

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** Optimization of a process could be achieved in < 5 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M), This has a relatively low cost for technology development. This cost would be well below the low ($10M) threshold.

**Deployment Costs (required funding):**

a) For caustic recycle, system was demonstrated at small pilot scale. No additional pilot testing expected unless significantly different waste application.
b) The deployment costs were estimated using the caustic recycle Hanford Case 2 estimates from a 1999 reference (DOE/EM-0494). Cost for small scale hot testing and initial full-scale deployment would be ~$90M in 2022 dollars based on 1999 estimates.

**Additional investment over life cycle of Hanford mission:**

a) Repeated deployment costs (escalated to 2022 $'s) - $275M. Assumed a 13-year operating life facility. Needed 3 such facilities to cover the 40-year operational period. Cost per facility was $55.6M. This covers the costs of the second and third facility (the first was covered under deployment costs. Assumes repeat investments to reach ~40-year operations. Operating costs were assumed to be $52M/13 years for each facility.
b) Operating costs - None
c) Other costs incurred above baseline technology - None

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Slow (<15 years), anticipated to be 10-15 years

**ROM net Cost Savings over the life cycle**:

a) Annual costs - N/A
b) Peak cost - N/A
c) Total potential savings - An estimated cost savings of $394M ($680M in 2022 $'s) is based on Ref. Cost savings for Hanford Case 2, reduction in MT of LAW glass produced of ~120,000 MT. based on 1998 estimates for LAW immobilization. $1609/MT and disposal $1784/MT).

**Schedule Acceleration of the Hanford Mission**: While cost savings are expected, this concept is not expected to significantly shorten the Hanford Project

**Net impact on Safety/Environment:** Positive (if it reduces LAW fraction being vitrified).

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 70%

**Regulatory Permitting/Licensing changes required:** For vitrification, class 3 RCRA permit mod, 2-3 years. For non-vitrification, NEPA, class 3 RCRA permit mod, 10 years.

**PL-8**

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - None
b) Positive reinforcement - None
c) Mutually exclusive - None

**Potential Applicability to Other Sites:** None

**Does the technology help buy down a Mission Risk?** E7: Water Management. Also, depending on technology, this could reduce nitrate to LAW offgas. Note that most of the mature options are focused on recycling NaOH and/or reducing LAW volume.

**Identify the category of the potential concept:** The primary category 3) Transformational – change in the baseline and has a mid-range cost. Secondary category 4) Long range program - Transformational technology with potential big payoff in the 10-15 year time frame based on reducing LAW, recycle caustic for sludge processing, and retrieval impacts

**Technology Insertion Time Frame:** 10-15 years (dependent on SLAW and HLW sludge processing decisions).

**References:** DOE/EM-0494

**Contact:** R. T. Jubin, ORNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PL-10 Plutonium/Actinide Removal from Supernate (Waste Pretreatment)

**Gap or Opportunity Addressed:** The baseline disposal path for loaded CST is vitrification; however, alternative disposition paths either on-site or off-site could reduce costs. It is known that Pu and other actinides in tank waste supernate will be removed to some degree during pretreatment using CST, increasing the potential that the loaded CST columns are classified as TRU waste, and complicating ultimate disposition of the CST canisters. Lab scale column testing with actual tank waste from AP-107 showed TRU loadings of greater than 100 nCi/g.[1] Methods for actinide pretreatment, such as a monosodium titanate (MST) strike, may be helpful in reducing potential for actinide loading on the CST.

**Technology Idea or Concept:** Methods to remove actinides prior to Cs removal with CST. Monosodium titanate (MST) is currently used at the Salt Waste Processing Facility at SRS to remove Sr and actinides prior to the Cs removal (solvent extraction) process. A similar process could be performed on the Hanford waste to reduce actinide (and $^{90}$Sr) loading on the CST to expand the potential disposal paths available for the spent CST.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | *2014_4-Simplified Disposition of Direct Feed Low Activity Waste Effluent.pdf* | 2014_04_Simplified Disposition of Direct F |
| | *PTW-46*<br>*RTW-19* | | |

**Connectivity to other Gap, Opportunity, or Concept:** Related to DL-6 which is to evaluate direct disposal (versus vitrification) options for the loaded CST. PL-10 would expand options available for consideration under DL-6. Also connected to concept E15.

**Proposed Technology – Technical Maturity/Process Simplicity:** Full scale demonstration – in use elsewhere for closely related problem (i.e., currently being used at SRS).

**Complexity:**

a) Several unit operations including a strike tank and filtration for removing the MST post-strike. Facilities will also be needed for transferring used MST to the HLW feed for vitrification.
b) Requires integration with downstream Cs removal (e.g., TSCR) and HLW Vitrification. Depending on technology for actinide removal, may require integration with filtration prior to actinide processing similar to filtration in the TSCR system.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years for go/no-go decision.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M)

**Deployment Costs (required funding):**

a) $5M for hot cell demonstration with actual waste
b) $10-15M for initial full-scale deployment assuming modular type system similar to TSCR

**Additional investment over life cycle of Hanford mission:**

a) Repeated deployment costs - $30M (assuming three replicate system integrated with expansion to three TSCR facilities)
b) Estimated $10M in additional operational costs over life cycle for replacement MST.
c) Disposition of loaded MST in HLW vitrification assumed to not extend operating life of HLW mission. However, load out/in capability that would have been needed for baseline CST-disposition through HLW Vit would now be required for MST.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle***:*

a) Annual costs - $0. Assume no net reduction in HLW Vitrification costs as vitrification of all loaded MST could be blended into planned sludge treatment campaigns with minimal increase in duration.
b) Peak cost - $0. No reduction in need for resin load out/load in capability at HLW facility (not currently in baseline)
c) Total potential savings - $0 to low reduction in total costs due to offsite CST disposal cost in addition to MST disposition in HLW vitrification

**Schedule Acceleration of the Hanford Mission***:* Potential small avoidance of cost and schedule delay to install spent resin load out/load in station at HLW that can accommodate both Cs-loaded CST and alpha-loaded MST.

**Net impact on Safety/Environment:** Minor positive due to reduction in TRU content in CST and LAW

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 95%

**Regulatory Permitting/Licensing changes required:** Class 3 RCRA permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - None

b) Positive reinforcement - Would provide benefit to DL-6 which is related to direct disposal (versus vitrification) options for the loaded CST. PL-10 would expand options available for consideration under DL-6.
c) Mutually exclusive - None

**Potential Applicability to Other Sites:** SRS

**Does the technology help buy down a Mission Risk?** Reduces/eliminates risk of CST columns being designated as TRU waste. May be needed to support alternate CST disposition options.

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid-range cost.

**Technology Insertion Time Frame:** 5-10 years

**References:**


- Campbell, E.L., Rovira, A.M., Colon-Cintron, F., Boglaienko, D., Levitskaia, T.G., Peterson, R.A., Characterization of Cs-Loaded CST Used for Treatment of Hanford Tank Waste in Support of Tank-Side Cesium Removal, PNNL-28945, Rev.0/RPT-TCT-005, Rev.0., August 2019.


**Contact:** Kathryn Taylor-Pashow, SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** IM-13, Cementitious Materials Development, Performance and Durability for LAW (Immobilization & Waste Disposal)

**Gap or Opportunity Addressed:** There is a need to develop improved containerized grout formulations as well as to validate their durability and long-term performance. This development will be necessary to implement Supplemental Treatment of Low Activity Waste (LAW) should a grout waste form be selected for on-site disposal; however, these grout waste forms could also be amenable to offsite disposal.

**Technology Idea or Concept:** In 2020 a National Academies of Sciences, Engineering and Medicine (NAS) report evaluated possible approaches to provide supplemental treatment capacity for Hanford LAW (NAS, 2019). This report was supported by a study evaluating different immobilization technologies, including grout, and showed that a grouted inventory of SLAW could meet disposal performance requirements at Hanford if the standard grout properties are retained or further improvements are made (Bates et al. 2019). An assessment of technologies to enhance the performance of a grouted waste form for the LAW inventory should Supplemental Treatment for on-site disposal be selected by DOE was recently completed (Skeen et al.). The technologies evaluated ranged in technology readiness and possible impact. The assessment document presents a roadmap to enhancing a grouted SLAW inventory, but since 2020 several other items have appeared, including the recent Section 3125 2022 National Defense Authorization Act (NDAA) study *Review of the Continued Analysis of Supplemental Treatment of Low-Activity Waste at the Hanford Nuclear Reservation* (which itself was a follow-on study from the original 2019 that could also enhance the performance of this system).

*Real Waste Demonstration of SLAW Grout* – Extensive testing of real Hanford waste in grout has not occurred since the 1990's. With the current operations of the Tank Side Cs-Removal (TSCR) system, a demonstration of grouting of treated LAW (beyond the Test Bed Initiative) would allow comparisons to laboratory data to date. This would include a pre-treatment evaporation step for Land Disposal Restriction (LDR) organics removal, leach testing, fresh and cured properties, and Toxic Characteristic Leaching Procedure (TCLP) measurement. The demonstration would also support identifying future areas for development.

*Stability of Getter/Immobilization Methods* – Laboratory studies have shown the ability to improve the retention of contaminants/radionuclides in grout waste forms. However, the data are limited to standard laboratory tests. Demonstrating the stability of these technologies against relevant disposal variables (redox, chemical) would build the technical defensibility of the approach.

*Reoxidation of Grout Waste Forms in IDF* – The primary variable of interest for grout disposal in the IDF is the ingress of oxygen (both liquid and gas phase transport) leading to reoxidation and mobilization of redox sensitive contaminants. Laboratory tests have been performed previously, and a large-scale field test is ongoing, but targeted studies to understand the rate limiting step in the process or ways to remediate reoxidation (e.g., reactive barriers, iron inclusion in grout) would build defense in depth and ensure accurate projections of grout performance in the IDF.

*Define Processing Requirements for Containerized Grout* – The "baseline" and most widely studied grout formulation for Hanford LAW is Cast Stone, based on the saltstone from the Savannah River Site. This formulation is designed to be pumpable and flowable to fill large disposal units and is not an optimized formulation for containerization. Defining processing requirements for a containerized grout would facilitate evaluation and maturation of alternate formulations (including geopolymers) for LAW that meet performance requirements upon disposal and ensure efficient processing.

*Farm Specific Formulations* – A blended LAW from multiple tanks/farms requiring supplemental treatment is the common projected feed vector. The remote farms (e.g., B farm) appear in the feed late in the mission and are the most expensive and with significant technical challenges (e.g., lack of infrastructure for retrieval/transfers). These wastes have unique chemistry compared with the blended LAW requiring Supplemental Treatment. Demonstrating grout formulations for the retrieved wastes from these farms could present a significant mission benefit by local grout production (containerized) at these farms.

**Existing Funded Program:** Yes, funding for specific problems within this Concept have been funded in the past and some funding is currently provided by DOE's Office of River Protection.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| *MW-02*<br>*DTW-02*<br>*DTW-07* | *DTW-12*<br>*DTW-13*<br>*DTW-14*<br>*RTW-25*<br>*RTW-07*<br>*PTW-45* | *2018_25_Chemically bonded phosphate ceramics for encapsulation of secondary solid waste* | 2018_25_Chemically bonded phosphate ce |
| | | *2017_32_Ammonia Getters for Liquid Secondary Waste Grout Formulations* | 2017_32_Ammonia Getters for Liquid Sec |
| | | *2018_26_Petrographic Laboratory to Support Cast Stone Development Incorporating Cesium-Loaded CST from TSCR* | 2018_26_Petrographi c%20Laboratory%20t |
| | | *2017_22_At-tank Tc and Iodine Removal and Disposition* | 2017_22_At-tank%2 0Tc%20and%20iodine |

| | | | |
|---|---|---|---|
| | | *2018_20_Cementitious Immobilization of Treated LAW* | 2018_20_Cementitio us Immobilization of 1 |

**Connectivity to other Gap, Opportunity, or Concept:** SW-1, PS-2, PS-3, PS-4, and IM-2.

**Proposed Technology – Technical Maturity/Process Simplicity:** Aspects of this technology range from 2 (laboratory demonstration) to 4 (full-scale demonstration). Many grout technologies have been demonstrated in the laboratory to some degree, including all those listed above. However, grout has been extensively used in the DOE mission (e.g., Saltstone at SRS) and in the international waste community with minimal challenges in scale up of processes/ technologies. Much of the technology need above is focused on building defense in depth.

**Complexity:** **T**his concept area affects several unit operations including Pretreatment, Formulations, Mixing, Transport, Containerization and Disposal Location.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** It is expected the work needed could be completed within 5 years.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Costs to reach a technology deployment decision of the recommended methods and technologies is expected to be Medium, $10M -$25M.

**Deployment Costs (required funding):** Deployment costs are estimated to be $50M including pilot/demonstration activities.

**Additional investment over life cycle of Hanford mission:** Additional investment of the project lifetime would include any replacement equipment and maintenance needed ~$1M/year. Disposal costs for any equipment are expected to be minor.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Deployment of methods or technologies would coincide with pretreatment and vitrification schedules is estimated to be Quick (<5 years) for off-site disposal and Medium (5-10 years) for on-site disposal.

**ROM net Cost Savings over the life cycle***:* We estimate that this will reduce the overall Hanford Mission cost by $30B.

**Schedule Acceleration of the Hanford Mission***:* We estimate a schedule reduction of 10 years.

**Net impact on Safety/Environment:** The environmental risk will largely depend on the decision to dispose on-site versus off-site.

**IM-13**

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Probability of successful deployment is estimated at 80% with unique risks for both on-site or off-site treatment and disposal.

**Regulatory Permitting/Licensing changes required:** For off-site disposal, NEPA modification, a non-HLW determination under DOE Manual 435.1-1 (e.g., WIR) are required and estimated at 5 years. Onsite disposal would require NEPA modification, a non-HLW determination under DOE Manual 435.1-1, e.g. WIR, a performance assessment, and permit modification would be required estimated at10 years.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** There are no dependencies or synergies with other proposals. However, there is positive reinforcement between this proposal and SW-1 "New Grouting Compositions or Lithified Aggregate Mixtures". In addition, most LLW processes could also benefit from improved grout formulations.

**Potential Applicability to Other Sites:** Some methods might be deployed at the OREM sludge build up project and/or SRS, although the latter is further ahead in their efforts.

**Does the technology help buy down a Mission Risk?** This would depend largely on the decision to dispose of the waste form on-site or off-site.

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid-range cost 4) Long range program - Transformational technology with potential big payoff in the 10-15 year time frame.

**Technology Insertion Time Frame:** Time frame for insertion is estimated to be 5-10 years and would require a change in mission flowsheet (DOE LAW Wasteform decision).

**References:**


- Bates WF, ME Stone, TM Brouns, CA Langton, RT Jubin, AD Cozzi, NR Soelberg, GD Guthrie, and JR Cochran. 2019. *Report of Analysis of Approaches to Supplemental Treatment of Low-Activity Waste at the Hanford Nuclear Reservation*. SRNL-RP-2018-00687, Savannah River National Laboratory, Aiken, SC.
- Skeen, RS, CA Langton, DJ McCabe, C Nash, RM Asmussen, S Saslow, IL Pegg, and AG Mishko. 2020. *Evaluation of Technologies for Enhancing Grout for Immobilizing Hanford Supplemental Low-Activity Waste (SLAW)*. SRNL-STI-2020-00228. Rev.0, Savannah River National Laboratory, Aiken, SC.
- National Academies of Sciences, Engineering, and Medicine. "Final Review of the Study on Supplemental Treatment Approaches of Low-Activity Waste at the Hanford Nuclear Reservation: Review# 4." (2020).


**Contact:** Matt Asmussen – PNNL, Mark J. Rigali – SNL, Christine Langton - SRNL.

**NNLEMS Hanford Tank Waste Mission Acceleration Team**

**Concept ID:** IM-1b -- Improvements in HLW Glass Waste Form (Immobilization & Waste Disposal)

**Gap or Opportunity Addressed:** Expand high-level waste (HLW) glass processing envelop to improve waste loading and allow flexibility for a range of potential flowsheet options. Increase glass property-composition database through systematic testing and reduce conservatism in current glass property and composition constraints.

**Technology Idea or Concept:** Baseline glass compositions have been developed and demonstrated for successful immobilization of HLWs. In the case of Hanford, HLW the baseline compositions were developed over a narrow range of waste compositions based on fully leached and washed tank sludges with modest waste loading. More recent efforts have shown promise to increase the loading of pretreated sludge compositions from a broader range of HLW feeds and proof-of-principle test were performed for immobilization of HLW sludges without significant washing or leaching. To improve the efficiency of HLW treatment, data and models are needed over expanded glass property-composition space. These data are needed for wastes covering a broader range of sludge compositions with minimal treatment. This expansion in composition range in combination with a reduction of conservatism in glass composition and property constraint will allow for more flexible and efficient tank waste treatment.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| *DTW-02*<br>*DTW-07*<br>*DTW-08*<br>*PTW-23* | *RTW-07*<br>*DTW-12*<br>*RTW-56*<br>*DTW-13*<br>*MTW-59*<br>*PTW-49*<br>*MW-15*<br>*PTW-40* | *2015_12_HLW Direct Vitrification* | 2015_12_HLW Direct Vitrification.pdf |
| | | *2014_26_DF_HLW* | 2014_26_DF_HLW.pdf |

**Connectivity to other Gap, Opportunity, or Concept:** PS-2, PS-3, PS-4, and IM-2c. Ideas F15, F17, F22, F49, F65, F67, F75, F77, F78, F86

**Proposed Technology – Technical Maturity/Process Simplicity:** Aspects of this technology range from 2 (laboratory demonstration) to 4 (full-scale demonstration). HLW glass design is a mature technology currently practiced at industrial scale and demonstrated at pilot scale for Hanford pretreated sludge simulants and at laboratory scale for Hanford pretreated sludge samples. General expansion of the glass composition envelope is demonstrated with simulants at bench-scale. The design and testing of glasses for minimally treated Hanford sludge has been demonstrated at laboratory scale along with relaxation of current conservative constraints. This is also similar to the technology used at SRS and West Valley for HLW vitrification.

**IM-1B**

**Complexity:** This technology is implemented within one process function: melter feed preparation. However, several unit operations are significantly impacted, including sludge washing, sludge leaching, melter operation, and melter off-gas treatment.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** It is expected that glass property-composition data collection, process testing, and constraint evaluation would be performed over the next 10 years with an improved approach ready in time for Hanford HLW vitrification start.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Costs to perform the scope including scaled demonstrations is estimated at $50M.

**Deployment Costs (required funding):** Once demonstrated at pilot-scale its deployment in the plant requires only modest budget (e.g., $5M).

**Additional investment over life cycle of Hanford mission:** Previous experience in the US and abroad suggests that continuous improvements will be beneficial for most of the mission life. An assumed budget of roughly $1-2M/y after initial deployment.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Deployment is expected to begin with startup of the Hanford HLW facility. One such estimate is 2033.

**ROM net Cost Savings over the life cycle***:* Potential costs savings are estimated to be mission schedule reduction of between 5 and 10 years. At a conservative $2.5B/y of mission that would indicate a range of $12.5-25B.

**Schedule Acceleration of the Hanford Mission***:* Potential costs savings are estimated to be mission schedule reduction of between 5 and 10 years.

**Net impact on Safety/Environment:** If mission life is reduced by 5 to 10 years, then there is a major impact on potential safety and environmental risks. The environmental risks associated with failure of tanks and the safety risks due to operations of the mission. This program is trying to minimize toxic air emissions and will continue to explore alternatives that help reduce emissions that contribute to global climate change

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Probability of successful deployment is estimated at 85% assuming a net reduction in glass over 10% and 100% for some improvements in flexibility, robustness, and cost.

**Regulatory Permitting/Licensing changes required:** Implementation of new glass formulations would require evaluation against the HLW waste form product specifications. Potential glass former chemical changes and their associated emissions may require permit modifications, 5 years.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** There are complementary synergies with sludge pretreatment technologies PS-3, -4, and -5. More robust HLW glass compositions can reduce the demands of sludge pretreatment processes making those technologies easier to be implemented. There is also a complementary synergy with HLW vitrification facility improvement (IM-2c). Higher waste loading can be one method of improving waste throughput. Increased waste loading may also impact the corrosion rates of plant components including melter refractories, electrodes, thermowells, bubblers, level probes and off-gas treatment components due to higher salt component concentrations.

**IM-1B**

**Potential Applicability to Other Sites:** Improved HLW glasses may have similar benefits at other DOE sites, specifically SRS and ID.

**Does the technology help buy down a Mission Risk?** Improved HLW glass will reduce the risk of waste reaching the environment and reduce the risk associated with poorer performance from sludge pretreatment processes and HLW vitrification facility throughput challenges.

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet 4) Long range program - Transformational technology with potential big payoff in the 10-15 year time frame

**Technology Insertion Time Frame:** Implementation is most advantageous at the time of HLW vitrification facility startup. Startup will occur far from waste loading and process rate boundaries and operations will gradually progress to an optimized process including rate and waste loading. However, full assessment of the potential could be advantageous prior to HLW facility startup to support systems evaluations and decisions using potential HLW facility capabilities.

**References:**

- Peeler, D.K., J.D. Vienna, M.J. Schweiger, and K.M. Fox. 2015. *Advanced High-Level Waste Glass Research and Development Plan,* PNNL-24450, Pacific Northwest National Laboratory, Richland, WA.
- Vienna, J.D., G.F. Piepel, D.S. Kim, J.V. Crum, C.E. Lonergan, B.A. Stanfill, B.J. Riley, S.K. Cooley, and T. Jin. 2016. *2016 Update of Hanford Glass Property Models and Constraints for Use in Estimating the Glass Mass to Be Produced at Hanford by Implementing Current Enhanced Glass Formulation Efforts,* PNNL-25835, Pacific Northwest National Laboratory, Richland, WA.

**Contact:** John Vienna, PNNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** IM-4, $NO_X$ Management (HLW System Off-Gas Design and Washing Endpoint) - (Immobilization & Waste Disposal)

**Gap or Opportunity Addressed:** This concept area is focused on identifying and development methods and/or technologies that will reduce nitrogen-based gaseous emissions from vitrification processes and reduce the risk of exposure from these compounds to workers.

- Vitrification of HLW should be capable of handling the waste feed by direct feeding without significant washing.
- Vitrification of LAW shall minimize products of incomplete combustion (PICS) impact by using other reductants than sugar.
- Reduce the safety risk of ammonia from LAW and HLW processing

**Technology Idea or Concept:** Develop methods and technologies to reduce nitrogen-based emissions from HLW and LAW vitrification processes. NOx and $NH_3$ emissions released in facilities can be fatal due to asphyxiation. $NH_3$, found in high concentrations in some waste tanks, if released, can cause blindness, lung damage and/or death. Nitrate, the predominant anion found in waste tanks, was added during process and is also generated by radiolysis of water. During vitrification, nitrates and nitrites are also formed by the incomplete reaction of sugar with $HNO_3$. Additionally, acetonitrile ($CH_3CN$) is formed by the reaction of nitrates with sugar in the LAW melters. Although sugar is the selected reductant for glass formulation at Hanford, it is beneficial to explore alternative reductants that may react more completely with nitric acid feeds to reduce additional NOx formation or acetonitrile. There is also a benefit to reducing the amount of pretreatment (i.e., washing) of tank sludges to reduce water consumption that must be subsequently treated for disposition. Being able to direct feed wastes to the glass melters, while safely managing NOx, would reduce the reliance on washing and help reduce waste volumes. Note that multiple studies and Grand Challenges have yielded improvements in treating and processing HLW and LAW waste streams. For example, methods for acetonitrile destruction have been proposed and tested for use at ETF. To improve the efficiency of HLW and LAW treatment, additional methods and technologies need to be developed over expanded pretreatment and glass processing space. These methods and technologies are needed to evaluate new reductants and processing strategies to reduce the risks and hazards of NOx and $NH_3$ (and associated nitrogen-bearing compounds) and to develop ways to direct feed waste to melters with minimal treatment. Successful implementation of these methods and technologies will allow for more flexible and efficient tank waste treatment.

**Existing Funded Program:** Yes, specific problems within this Concept were funded about 10 years ago and some are beginning to be funded depending on their priority (e.g., acetonitrile destruction) by DOE's Office of River Protection.

**IM-4**

| *WRPS Programs* | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| *PTW-23* | *MTW-57*<br>*PTW-45*<br>*PTW-49* | *2016_18_Techno-economic Assessment of Nitrate Destruction Options for Hanford Tank Waste* | 2016_18_Techno-eco nomic Assessment of |

**Connectivity to other Gap, Opportunity, or Concept:** F-35, F-68, F-69, F-83, PS-2, PS-3, PS-4, and IM-2.

**Proposed Technology – Technical Maturity/Process Simplicity:** 2. Lab demonstration and 3. Pilot/prototype. Note that this Concept has crosscuts in several technical areas including pretreatment to LAW and HLW vitrification. The common element is the nitrogen compounds that must be managed. A strategy for each area needs to be developed so there can be agreement on technical direction. Then, methods/technologies need to be solicited, evaluated, and developed. Once methods and technologies are recommended, funding for development can be prioritized.

**Complexity:** This Concept area affects several unit operations. Pretreatment methods would be affected. Vitrification methods, both LAW and HLW would be affected. Off-gas handling and treatment (e.g., at ETF) may also be affected.

**Projected Time Line for Go/No-Go Technology Deployment Decision (technology-specific):** It is expected the work needed could be completed within 5 years.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M), Costs to perform demonstration of recommended methods and technologies is expected to be about $25M.

**Deployment Costs (required funding):** Once demonstrated at pilot-scale it is estimated that deployment in the plant is within current operating budget estimates. No additional deployment costs are anticipated.

**Additional investment over life cycle of Hanford mission:** Additional investment of the project lifetime would include any replacement equipment and maintenance needed. Disposal costs for any equipment are expected to be minor. An assumed budget of roughly $1-2 M/y after initial deployment.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 years), Deployment of any methods or technologies would coincide with pretreatment and vitrification schedules.

**IM-4**

**ROM net Cost Savings over the life cycle***:* Potential costs savings are estimated to be $150M annually with $3B in cost savings over the life cycle.

**Schedule Acceleration of the Hanford Mission***:* Schedule acceleration is estimated to be 5 years or less.

**Net impact on Safety/Environment:** Eliminating or substantially reducing $NH_3$ and NOx emissions greatly improves worker safety. Implementation would have a major, positive safety impact.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Probability of successful deployment is estimated at 50% for the successful reduction in $NH_3$ and NOx emissions. The need for significant washing of the waste is also reduced.

**Regulatory Permitting/Licensing changes required:** Regulatory change required to implement modifications to pretreatment and vitrification processes. Class 2 or Class 3 RCRA permit modification required (2-3 year effort).

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** There are complementary synergies with activities PS-2, PS-3, PS-4, IM-2c.

**Potential Applicability to Other Sites:** Some methods might be deployed at SRS, although they are further ahead in their efforts.

**Does the technology help buy down a Mission Risk?** Improved pretreatment methods and HLW and LAW vitrification processes will improve worker safety and assure plant schedule will not be impacted by process upsets due to NOx or $NH_3$ releases.

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet.

**Technology Insertion Time Frame:** New methods and technology would have to meet the existing plant schedule to be most effective. Thus, the technology should be developed for insertion within the current schedule. However, positive impacts can still be had even if insertion can be done as part of ongoing activities at a later date.

**References:**

- *Technical Review of the Waste Treatment and Immobilization Plant Low-Activity Waste Facility*, 15-WTP-0151, U.S. Department of Energy, Office of River Protection, Richland, Washington, 2015.
- K.S. Matlack, et al. *Final Report: Regulatory Off-Gas Emissions Testing on the DM1200 Melter System Using HLW and LAW Simulants,* Vitreous State Laboratory, The Catholic University of America, Washington, D.C., 2005.
- R.T. Pabalan, et al. *Hanford Tank Waste Remediation System Pretreatment Chemistry and Technology,* NUREG/CR-6714, U.S. Nuclear Regulatory Commission, Washington, D.C., 2001.

**IM-4**

- A. Goel, et al. *Challenges with Vitrification of Hanford High-Level Waste (HLW) to Borosilicate Glass – An Overview,* Journal of Non-Crystalline Solids, X 4 (2019).

**Contact:** Steven C. Marschman-INL

**NNLEMS Hanford Tank Waste Mission Acceleration Team**

**Concept ID:** DL-3 Improved transport models/performance assessment for waste forms (Immobilization and Waste Disposal)

**Gap or Opportunity Addressed:** Better transport and performance assessment models are needed to reduce the conservatism in performance models. High performance computing may need to be applied to performance assessments, particularly for alternative waste forms.

**Technology Idea or Concept:** Evaluate assumptions for performance assessments for excessive conservatism and develop better transport and performance assessment models for multiple waste forms to increase waste loadings at disposal sites.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | *2018_20_Cementitious Immobilization of Treated LAW.pdf;* | 2018_20_Cementitious Immobilization of T |
| *DTW-08*<br>*DTW-02* | *RTW-39*<br>*DTW-14* | *2018_25_Chemically bonded phosphate ceramics for encapsulation of secondary solid waste.pdf;* | 2018_25_Chemically bonded phosphate ce |
| | | *2018_5_Waste Incidental to Reprocessing- West Area Opportunities for Low-Act....pdf* | 2018_5_Waste Incidental to Reproces |
| | | *2017_2_Risk Informed Retrieval and Closure Strategy.pdf* | 2017_2_Risk Informed Retrieval an |
| | | *2017_35_Technology to Support Risk Based Retrieval and Closure of Hanford Tanks* | 2017_35_Technology to Support Risk Basec |
| | | *2014_22_Geochemical Testing and Model Development – Residual Tank Waste* | 2014_22_Geochemical Testing and Model |
| | | *2018_3_Treatment and Disposal of WTP solid secondary waste* | 2018_3_Treatment%20and%20Disposal%2 |

| | | | |
|---|---|---|---|
| | | *2017-08, Siloxane Polymer Alternatives for Stabilization of High Salt Content Low Activity Wastes* | |
| | | *2018-20, Cementitious Immobilization of Treated LAW and Ancillary Benefits to Risk Reduction in Cross-Site Transfer* | |

**Connectivity to other Gap, Opportunity, or Concept:** B21, B34, B44, B57, B60, TC-7.

**Proposed Technology – Technical Maturity/Process Simplicity:** Pilot/prototype

**Complexity:** a) Number of Unit Operations affected: 1 - Performance assessment (includes waste form and the disposal site. b) Required system integration to implement the technology: Medium

**Projected Time Line for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low - $10M

**Deployment Costs (required funding):** Negligible incremental costs over baseline performance assessment activities

**Additional investment over life cycle of Hanford mission:** Negligible incremental costs over baseline performance assessment activities

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 years)

**ROM net Cost Savings over the life cycle***:* Estimate cost savings from a) Annual costs ($4M – 170M) b) Peak cost – does this get flattened for are there any peaks? ($4M – 170M) c) Total potential savings ($250M – 10B)

**Schedule Acceleration of the Hanford Mission***:* Estimated number of years saved (5 – 10 years)

**Net impact on Safety/Environment:** Minor Positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** 40%

**Regulatory Permitting/Licensing changes required:** Major – Performance Assessment update and permit mods requiring ~10 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** NA

**DL-3**

**Potential Applicability to Other Sites:** Hanford specific

**Does the technology help buy down a Mission Risk?** NA

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid range costs

**Technology Insertion Time Frame:** Any time but maximum impact will be achieved if/when a grout waste form is considered for on-site disposal

**References:** N/A

**Contact:** Sharon Robinson - ORNL

**NNLEMS Hanford Tank Waste Mission Acceleration Team**

**Concept ID:** IM-2c Improvements on HLW Vitrification Facility and Melter Technology (Waste Immobilization & Disposal)

**Gap or Opportunity Addressed:** Significantly improve the Hanford High-Level Waste (HLW) Vitrification facility throughput by improving the rate limiting system components.

**Technology Idea or Concept:** Estimates of Hanford's tank waste treatment mission duration indicate that HLW vitrification is likely the rate limiting component (assuming supplemental low-activity waste (LAW) treatment has sufficient capacity). Therefore, improvements in HLW process rate would reduce mission duration, saving operating costs and reducing risks (e.g., from tanks leaking into the surrounding environment). The rate of HLW processing through the HLW vitrification facility is determined by a host of different potentially rate-limiting steps, the importance of which differ with changes in waste feed and glass assumptions. Known rate-limiting steps include: 1) melter feed batch time (including waste receipt, mixing, sampling, analysis, glass formulation, and glass former delivery); 2) heat management; 3) melter processing rate (including cold cap reactions and power); 4) canister handling, storage, and cooling; 5) offgas treatment (including submerged bed scrubber (SBS) quench duty, selective catalytic reduction (SCR) unit NOX destruction, thermal catalytic oxidation (TCO) unit organics/products of incomplete combustion (PICs) destruction); 6) secondary waste management (including bubbler changeout, melter changeout, liquid waste returns, and filter change out) requiring an improved understanding of erosion/corrosion to extend the life of process equipment (e.g., melters and bubblers) to reduce downtime and improve facility total operating efficiency (TOE). Each of the above steps was designed for operation with fully leached and washed sludge received at 20 wt% undissolved solids and operation at 7.5 MT glass per day with a 70% TOE and relatively low waste loading; whereas, changes in feed makeup may reduce plant throughput. A rigorous evaluation of the limiting steps based on current feed assumptions is required. The results of this evaluation would lead to a prioritized list of design modifications to optimize facility throughput. Implementation of the design modifications would significantly increase HLW Vitrification facility throughput.

**Existing Funded Program:** Yes, partially. Limited efforts currently underway to support development of HLW waste acceptance criteria.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| ***Funded*** | ***Unfunded*** | | |
| *DTW-02* | *DTW-12*<br>*RTW-44*<br>*MTW-36*<br>*PTW-49* | *2017_26_ Comprehensive, Enhanced LAW/HLW Melter Offgas System Support for Improved Performance, Start-up, Operation and Design* | |

| | | | |
|---|---|---|---|
| | | *2016_12_Reducing Liquid Introduction to SST Retrieval by Scarification* | 2016_12_Reducing Liquid Introduction to |
| | | *2017_28_ Real-Time, In-Line Monitoring for Direct Feed HLW (DFHLW)* | |
| | | *2018_9_Real-Time, In-Line Monitoring for Direct Feed HLW (DFHLW)* | |
| | | *2014_26_DF_HLW* | 2014_26_DF_HLW.pdf |
| | | *2015_12_HLW Direct Vitrification* | 2015_12_HLW Direct Vitrification.pdf |

**Connectivity to other Gap, Opportunity, or Concept:** PS-2, PS-3, PS-4, and IM-1b.

**Proposed Technology – Technical Maturity/Process Simplicity:** Aspects of the likely required technologies to significantly improve HLW Vitrification facility throughput include 1 (Concept); 2 (Laboratory demonstration); 3 (Pilot/prototype); and 4 (Full-scale demonstration). For example, HLW vitrification is a mature technology currently practiced at industrial scale, implemented at DOE's Savannah River Site and West Valley Demonstration Project for HLW vitrification, and demonstrated at pilot scale for Hanford pretreated sludge simulants and at laboratory scale for Hanford pretreated sludge samples. Early evaluations have identified that the facility throughput could be increased from 6 MT glass per day to 7.5 MT glass per day based on fully washed and leached sludge delivered at 20 wt% solids. Small scale tests were performed for unleached and mildly washed sludge simulants with higher waste loading that showed promise.

**Complexity:** Necessary technology improvements would be implemented within four process functions: feed preparation, melter operation, off-gas treatment, and canister handling with significant system integration required for implementation. Furthermore, glass formulation, sludge washing, and sludge leaching would also be influenced by expected technology improvements.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** The decision to perform the process rate limitations study would need to be made within the next year and the study within the next 3-5 years to support final facility design followed by system modification testing and qualification and pilot demonstrations prior to construction completion (i.e., one example schedule for construction completion is 2031). Information on the HLW system performance will also be gained once treatment is initiated. This processing knowledge will inform the direction of the program.

**IM-2c**

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M), An initial, detailed evaluation of the rate-limiting steps would require <$10M in the first year. System modification and small-scale demonstration may require an additional $10M. The total of these cost results in a medium score.

**Deployment Costs (required funding):** Pilot system demonstrations and equipment procurement for the plant will require >$50M with $75M being an initial ROM estimate.

**Additional investment over life cycle of Hanford mission:** Previous experience in the US and abroad suggests that continuous improvements would be beneficial for at least the first 10 years of operation. An assumed, estimated budget would be roughly $2M/y after initial deployment of technology improvements.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 years), Deployment is expected to begin with startup of the Hanford HLW Vitrification facility. One such estimate is 2033 resulting in a medium score.

**ROM net Cost Savings over the life cycle***:* Using the baseline schedule as a reference, potential technology improvements and increased efficiency are estimated to result in a mission schedule reduction of between 5 and 10 years. Assuming baseline funding of $2.5B/year of mission, the technology improvements quickly add up to real savings (e.g., $12.5-25B total over the mission life), especially relative to the estimated decision and deployment costs (~$95M assuming decision costs of ~$20M and deployment costs of ~$75M) as indicated above.

**Schedule Acceleration of the Hanford Mission***:* Using the baseline schedule as a reference, potential technology improvements and increased efficiency are estimated to result in a mission reduction of between 5 and 10 years.

**Net impact on Safety/Environment:** Major Positive. If mission life is reduced by 5 to 10 years, then there would be a major impact on potential safety and environmental risks. The environmental risks associated with failure of tanks and the safety risks due to operations of the mission would both be significantly reduced resulting in a major positive score. Note that this program is working to assure that any emissions would stay within regulatory limits (e.g., technologies or controls) and that waste tank repair methods are being developed and tank waste retrievals are accelerated to reduce the risk of future tank leaks.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Probability of successful deployment (i.e., significantly increasing HLW Vitrification facility throughput) is estimated at 60%. There is likely a 100% probability for some improvements in rate when compared to a no action approach.

**Regulatory Permitting/Licensing changes required:** Minor. There would likely be a modification needed to the Class 3 RCRA permit that is assumed to require 2-3 years.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** There are synergies with sludge pretreatment technologies PS-3, -4, and -2. Increased HLW throughput could reduce the demands of the sludge pretreatment processes making implementation of those technologies easier. There would also synergy with HLW glass improvement (IM-1b). To achieve the increased throughput, tank waste retrieval efforts and secondary waste treatment efforts will need to be optimized for the HLW throughput as well.

**Potential Applicability to Other Sites:** No immediate applicability to other sites. There may be future applicability to HLW vitrification operations at the Savannah River Site.

**Does the technology help buy down a Mission Risk?** Increased HLW vitrification throughput would reduce the risk of waste leaking from tanks and reaching the environment and would also reduce the risk associated with poorer than expected performance from sludge pretreatment processes and HLW vitrification facility throughput challenges.

**Identify the category of the potential concept:** The primary solution (grouping) would be 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet – where some technology improvements fit the existing baseline/flowsheet; however, some may not. The secondary solution (grouping) would be 4) Long range program - Transformational technology with potential big payoff in the 10-15 year *time frame* - and would protect the baseline schedule (but not be schedule driven in nature).

**Technology Insertion Time Frame:** Implementation is most advantageous at or before the time of the HLW Vitrification facility final design or 5-10 years (based on an example schedule for construction completion by 2031).

**References:**

- Chapman, C.C. 2007. High Level Waste Vitrification Plant Capacity Enhancement Study, 24590-HLW-RPT-PE-07-001, River Protection Project, Waste Treatment Plant, Richland, WA.
- Matlack, K.S., H. Gan, W. Gong, I.L. Pegg, C.C. Chapman, and I. Joseph. 2007. High Level Waste Vitrification System Improvements: VSL-07R1010-1, ORP-56297, Vitreous State Laboratory, the Catholic University of America, Washington, D.C.

**Contact:** John D. Vienna - PNNL; Kevin G. Brown - CRESP and Vanderbilt University

## NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** IM-12 -- Waste Dewatering and Dried Waste Form(s) - (Waste Immobilization & Disposal)

**Gap or Opportunity Addressed:** Assess and implement tank waste dewatering options with consideration of scale-up, cost, and safety. It is technically possible to remove tank sludge, dry it, and then dispose of it as low-level waste (LLW) or transuranic (TRU) waste. TRU waste then can be immobilized in grout, and there are potential disposal pathways as LAW/LLW. Disposal of some Hanford tank waste as TRU or LLW would require a non-HLW determination under DOE M 435.1-1.

**Technology Idea or Concept:** Past projects have been conducted to dewater Hanford tank waste for supplemental treatment to further technology development of the Demonstration Bulk Vitrification System (DBVS) project and selected Hanford tank waste for disposition at WIPP. Both projects tested a vacuum dryer dewatering technology in a modular/mobile system to disposition water in the retrieved tank waste. For disposal at WIPP, the dried waste can be grouted/cemented depending on the waste characteristics, and then packaged. Because of their technical and economic effectiveness, solidification/ stabilization (S/S) methods, using cement and other additives either alone or in conjunction with other types of treatment such as incineration, are the recommended Best Demonstrated Available Technology (BDAT) for at least 57 RCRA-listed wastes, including metals.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| | *RTW-19*<br>*PTW-46*<br>*MTW-91* | *2014-17, Salt Cake Waterless Retrieval System for Moving Slurry Across Site* | |
| | | *2015-11, Using a High Pressure, Low Flow Rate Scarifier to Fragment Solids Coupled with Pneumatic Conveyance to Retrieve the Solids and Cutting Fluid Slurry with Reduced Fluid Use and Reduced Solids Dissolution in Leak prone SSTs* | |
| | | *2015-26, Application of Commercial Mining Technology for Waste Retrievals* | |
| | | *2015-28, MARS-V Alternative and Dry Method for Waste Gathering* | |

**IM-12**

| | | | |
|---|---|---|---|
| | | *2016-12, Reducing Liquid Introduction to SST Retrieval by Scarification* | |
| | | *2016-23, Application of Commercial Mining Technology for Waste Retrieval of TRU for Disposal at WIPP* | |
| | | *2017-05, Waste Retrieval Using Auger Technology* | |
| | | *2017-11, Flowsheet Development to Support Dry Retrievals for Hanford Transuranic (TRU) Tanks* | |
| | | *2017-37, Waste Gathering System for removing hard packed wastes in suspected "leaker" SSTs using no introduced liquids* | |

**Connectivity to other Gap, Opportunity, or Concept:** PS-2, PS-3, PS-4, and IM-2c. Idea F44 .

**Proposed Technology – Technical Maturity/Process Simplicity:** This technology requires additional (2) Lab demonstration followed by (3) Pilot/prototype demonstration. The results of these additional tests in light of current requirements and conditions would be used to perform a (4) Full-scale demonstration.

**Complexity:** Unit operations affected include: waste retrieval; drying; condensate capture, treatment, and disposal; containerization, treatment / immobilization; shipping; and disposal with significant system integration required for implementation.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** It is expected that assessment and laboratory/pilot scale demonstration evaluation would be performed over a 5-year period to reach a go/no-go decision for a full-scale demonstration.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M), Medium ($10M - $50M), Costs to perform the scope to reach laboratory/pilot demonstration is estimated at $10M.

**Deployment Costs (required funding):** Demonstration at laboratory/pilot-scale is estimated at $10M while deployment costs to achieve full-scale demonstration and initial full-scale deployment in the plant is estimated at $600M.

**Additional investment over life cycle of Hanford mission:** An additional $5M/year in costs is estimated to account for varying waste types and qualification processes.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 years), Full-scale demonstration and deployment are expected to take 5 to 10 years (medium) after go/no-go decision.

# IM-12

**ROM net Cost Savings over the life cycle***:* Potential costs savings are estimated to be $150M annually and $3B over the project lifecycle.

**Schedule Acceleration of the Hanford Mission***:* A mission schedule reduction of between 5 and 10 years is anticipated at a cost savings of $2.5B/year from the baseline operations.

**Net impact on Safety/Environment:** Safety and environmental impacts are expected to be neutral or positive depending on the choice of disposal site.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Probability of successful deployment is estimated at 85%.

**Regulatory Permitting/Licensing changes required:** For offsite disposal, NEPA analysis and non-HLW determination under DOE M 435.1-1 would be required and it is considered possible for the necessary modification to be completed within 5 years. For onsite disposal, NEPA analysis and non-HLW determination under DOE M 435.1-1 would also be needed with a performance assessment and permit modifications estimated at 10 years.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** The drying and disposal of TRU offsite would have synergy with IM-13 (*Cementitious Materials Development, Performance and Durability for LAW*).

**Potential Applicability to Other Sites:** Idaho calcine.

**Does the technology help buy down a Mission Risk?** Increased rate of waste retrieval and treatment via dewatering (and disposal) would reduce the risk of waste leaking from tanks and reaching the environment.

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid-range costs 4) Long range program - Transformational technology with potential big payoff in the 10-15 year time frame

**Technology Insertion Time Frame:** The technology is transformational necessitates a change to the mission flowsheet. The insertion time frame is anticipated to be 10 years.

**References:**


- A.R. Tedeschi, T.H. May, and W.E. Bryan, 2008, "Dewatering Treatment Scale-up Testing Results of Hanford Tank Wastes – 8259," WM2008 Conference, February 24-28, Phoenix, AZ.
- A. R. Tedeschi and M. Wheeler, 2014 "Hanford Tank Waste to WIPP – Maximizing the Value of our National Repository Asset – 14230," WM2014 Conference, March 2 – 6, 2014, Phoenix, Arizona, USA.
- Adaska, W.S., Tresouthick, S.W., West, P.B.: Solidification and stabilization of wastes using portland cement. Report Number: EB071.02 W, Portland Cement Association (1991)


**Contact:** Mark J. Rigali - Sandia National Laboratories; Kevin G. Brown - Vanderbilt University & CRESP

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** SW-1 Improved Grout Waste Forms (Secondary Waste Treatment)

**Gap or Opportunity Addressed:** The secondary-low level wastes (LLW) represents a potentially large volume to be dispositioned and will contain constituents of concern for long-term disposal. A cementitious waste form is the baseline technology, but retention of some species is a concern by regulators and may represent a significant contribution to release from the Integrated Disposal Facility (IDF), dependent on partitioning within WTP and waste form performance.

**Technology Idea or Concept:** The handling and disposal of secondary wastes is a baseline requirement in the Hanford mission for both liquid secondary waste (LSW) and solid secondary wastes (SSW). In consideration of all the components of secondary wastes there are three technology areas that can be realized: (1) those that can lead to mission acceleration, (2) those that won't accelerate the mission but also will not slow the mission and (3) those which could hinder operations if realized.

New grouting compositions or lithified aggregate mixtures (for LSW and SSW) with getters may present a viable option for improved contaminant retention. The species of concern include ammonia, I-129, and Tc-99.

Opportunistic Secondary Waste Treatment Giving Mission Acceleration

Two liquid secondary waste streams generated from WTP operations: (1) Effluent Management Facility (EMF) evaporator bottoms and (2) Caustic Scrubber effluents from WTP that could be decoupled from the baseline WTP-LAW flowsheet and be treated/solidified via grout. The EMF evaporator bottoms account for ~10% of the LAW feed and can limit waste loading by returning halides and sulfate to WTP. The caustic scrubber effluents account for a significant volume of liquid to be handled by the aging Effluent Treatment Facility (ETF).

Development and testing of grout for these waste streams has been scoped previously (PNNL-26750) and work to optimize the flowsheet and formulations (for both on-site and off-site disposal) are needed to complete technology development for the decoupled options. Such an effort would entail

- Flowsheet description
- Identify requirements for on/off-site disposal

Optimization testing based on prior work - No Acceleration but Would Facilitate Sustained Operations

Utilization of an off-site disposal (or immobilization and disposal) pathway would ensure sustained operations by providing a stable pathway for the secondary wastes. Off-site disposal pathways for the grouted secondary wastes (or direct transport of spent solid secondary waste) should be considered as disposal of similar materials is regularly performed in the nuclear industry. The relative volume to be disposed of over the mission duration is small, and it would move the contaminants to a location without a pathway to potable water. This approach would avoid potential mission delays for a minor cost increase associated with off-site disposal.

No Acceleration but Could Limit Sustained Operations

If the secondary wastes are disposed of on-site, a risk appears in that waste form performance may limit disposal and therefore directly impact the mission. The required performance of the waste form for on-site disposal will be dictated by the inventory of contaminants in the secondary waste (higher inventory, potential for larger source term contribution, higher performance required).

The release from the waste forms can be controlled by the long-term aging of the material and a recent review by PNNL and SRNL covered possible mechanisms for SSW grout (PNNL-32458).

Several concepts for secondary waste grout improvement for on-site disposal have been identified and are dependent on the waste stream.

Liquid Secondary Waste (LSW) General

*Baseline Optimization of ETF Brine LSW*

*(Struvite precipitation, solidification for IDF):*

- *Cost and risk comparison of ETF brine* – ETF brine wastes will have high ammonium content that could lead to ammonia release. While ammonia-tolerant grouts are undergoing R&D there is a risk of continued ammonia evolution from the waste forms in storage or in the IDF. Whereas traditional formulations would generate the ammonia during mixing and the ammonia would be abated within the facility. A cost and risk comparison between approaches should be undertaken to define the ideal grouting approach for the ETF brine.
- *Ammonia Destruction/Release at ETF* - to avoid mitigation in the grout formulation, ammonium can be destroyed through a process step or released by conversion to alkaline conditions (could be during solidification). Ammonium destruction methods should be considered and testing performed to develop process flow sheets.

*Risk Mitigation for On-site Disposal for Alternates to Baseline (High $SO_4$/Higher Tc/Higher I at ETF)*

- *Optimizing high-sulphate tolerant waste forms* – The ETF brine also contains high amounts of sulfate that can lead to post-curing cracking. WRPS/PNNL/SRNL developed hydrated lime containing formulations that can handle the high sulphate and provided best-to-date Tc retention. However, formulations are not optimized for processing/ performance. Additional development and testing could lead to "getter-free" improvements.
- *Amended Grout for Secondary Wastes* – If partitioning of Tc or I is higher than current projections, use of an amended grout can slow release. The use of redox getters for Tc (e.g., using simple materials) or Ag-free getters for I would be preferable. Additional development and testing are required for enhanced getters.

Solid Secondary Waste (SSW) General

- A demonstration at scale of the candidate immobilization pathways for SSW is required to gather processing information and confirm waste form properties, i.e., advance the TRL to the point of implementation.
- A study to define and evaluate the various packaging, transport and disposal scenarios for the various SSW streams is lacking. This study would allow decision makers to confirm SSW (and LSW) disposal options and waste form requirements. Again, the objective is to advance the TRL for implementation.

Suitability for IDF Disposal - Non-debris SSW

- *Use of a macro-encapsulation/barrier grout for debris waste* – Instead of solidifying/blending of the non-debris (particulate) SSW, the spent material could be placed within a precast, low-permeability contains lined with stabilizing grout liners and then grouted to reduce exposed surface area within the package and disposed. The low-permeability grout would prevent ingress of water and subsequent migration of contaminants.
- *Amended Grout for Activated Carbon* – Iodine is not retained well on grouted GAC. The encapsulating grout can be amended through a getter or use of a low permeability formulation to minimize iodine release.
- *Long-term stability of Iodine on Ag-mordenite* – Leach studies (PNNL-28545, Rev 1) have shown that grouted Ag-mordenite, especially in a non-reducing grout, has very low iodine release in short-term lab tests. Testing this waste form's stability in other disposal variable in the IDF would build defense in depth for the performance.

Suitability for IDF Disposal - Debris SSW

- *Use of a macro-encapsulation/barrier grout for debris waste* – Instead of a single macroencapsulation of debris SSW, the spent material could be placed within a precast, low-permeability grout liner, then grouted within the package and disposed in the IDF. The low-permeability grout would prevent ingress of water and subsequent dissolution and transport (migration) of contaminants.
- *Predicting contaminant release from Ultra-high-performance grout (UHPG)* – UHPG has been evaluated for macroencapsulation of HEPA filters, and the low-permeability of the grout is promising. However, implementation and performance have not been demonstrated at scale, nor has the transport rates from a macro-encapsulated core of waste been measured. Scale-up is needed to strengthen the defense in depth for this promising approach and advance the TRL to the point of implementation

It should be noted that performance of a waste form in the IDF can also be enhanced through improvements to the IDF near field. A summary of possible improvements to the near field was recently summarized (Skeen et al. SRNL-STI-2020-00228)

**Existing Funded Programs:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| ***Funded*** | ***Unfunded*** | | |
| *MW-02*<br>*DTW-02*<br>*DTW-07*<br>*DTW-08* | *DTW-12*<br>*DTW-13*<br>*DTW-14*<br>*MW-15* | *2018_25_Chemically bonded phosphate ceramics for encapsulation of secondary solid waste* | 2018_25_Chemically bonded phosphate ce |
| | | *2017_32_Ammonia Getters for Liquid Secondary Waste Grout Formulations* | 2017_32_Ammonia Getters for Liquid Sec |
| | | *2018_26_Petrographic Laboratory to Support Cast Stone Development Incorporating Cesium-Loaded CST from TSCR* | 2018_26_Petrographic%20Laboratory%20t |
| | | *2017_22_At-tank Tc and iodine removal and disposition* | 2017_22_At-tank%20Tc%20and%20iodine |
| | | *2018_20_Cementitious Immobilization of Treated LAW* | 2018_20_Cementitious Immobilization of T |

**Connectivity to other Gap, Opportunity, or Concept:** Concept G4. Related to SW-10; SW-9; PL-6; IM-13.

**Proposed Technology – Technical Maturity/Process Simplicity:** 2. Lab demonstration and 4. Full-scale demonstration a) in use elsewhere for similar problem b) in use elsewhere for closely related problem to 5. Commercially available/ off the shelf/ service for SSW.

**Complexity:** Medium complexity: Depends on disposal location - Separations/ size reduction, Formulation, Mixing, transport - container or disposal location

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 yr except for tasks that require long term performance evaluation which is 5-10 yr.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M)

**Deployment Costs (required funding):** Estimated costs to get to deployment

- Pilot Demonstration. $10 Million
- Initial Full Scale: $5 Million

**Additional investment over life cycle of Hanford mission:**

- Repeated deployment costs: $0 Million
- Operating costs: Incremental; Some Risk for specific getters. For example, in the use of Silver, for Iodine. Depends on I release and silver to I ratio needed. Estimate of ~$1M/year for processing secondary waste.
- Other (Secondary Waste Disposition): trivial above baseline

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle***:* This concept reduces risk of secondary waste onsite disposal performance and represents cost avoidance only.

**Schedule Acceleration of the Hanford Mission***:* Risk avoidance not a schedule savings.

**Net impact on Safety/Environment:** Minor Positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 80%

**Regulatory Permitting/Licensing changes required:** Require PA update and permit modifications (minor)

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** Positive reinforcement. This SW-1 program will make IM-13 better.

**Potential Applicability to Other Sites:** None identified.

**Does the technology help buy down a Mission Risk?** IDF PA risks from Tc, I, and possibly Ammonia.

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet

**Technology Insertion Time Frame:** Need in < 5 years

**References:** Same programs from WRPS Technology Roadmap (Funded/Unfunded)

**Contact(s):** Joseph Manna, Michael Stone, Christine Langton - SRNL; Tom Brouns and Matt Asmussen - PNNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PL-6 Iodine Separation in Liquid Phase (Secondary Waste Treatment)

**Gap or Opportunity Addressed:** Iodine, despite low total inventory in tank waste, is the primary risk driver to groundwater due to its high volatility within the vitrification process and substantial transfer to secondary waste streams, and high mobility in the subsurface. There are limited current technologies for iodine separation from either high ionic strength alkaline tank waste or liquid secondary waste streams from vitrification offgas systems. Effective iodine IX resins or sorbents that can enable separation from primary and secondary liquid waste streams are needed.

**Technology Idea or Concept:** Iodine separation technologies effective for alkaline tank waste and secondary liquid waste streams from thermal treatment off gases. This can be used in combination with SW-9.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | *2017_22-At-tank Tc and Iodine Removal and disposition.docx* | 2017_22_At-tank%20Tc%20and%20iodine |
| *PTW-23*<br>*DTW-07* | *RTW-56*<br>*MW-15*<br>*DTW-12* | | |

Current 2021-2022 WRPS program work is focused on Iodine removal using ion exchange column technologies.

**Connectivity to other Gap, Opportunity, or Concept:** Concept IDs D17, D18, D31, D56, D75 and condensed gap IM-5

**Proposed Technology – Technical Maturity/Process Simplicity:** Concept to Pilot/prototype

**Complexity:** a) Unit operations - Separation/scrub from offgas or media in offgas to capture; immobilization; disposal b) Medium complexity: Melter and offgas system ties; potential new process incorporation

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** 5-10 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M)

**Deployment Costs (required funding):** a) $5M for Pilot scale /demonstration b) $5M for Initial full-scale demonstration

**PL-6**

**Additional investment over life cycle of Hanford mission:**

a) Repeated deployment costs – N/A
b) Operating costs - $5M
c) Other costs incurred above baseline technology - $5M

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle***:*

a) NA - cost avoidance
b) NA - cost avoidance. A replacement media or guard bed for GAC may avoid cost of new unit operation or additional liquid waste stream
c) NA - cost avoidance

**Schedule Acceleration of the Hanford Mission***:* N/A - no schedule acceleration. Avoidance of cost and/or schedule slippage

**Net impact on Safety/Environment:** Minor positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 80%

**Regulatory Permitting/Licensing changes required:** Class 2 or 3 RCRA permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - N/A
b) Positive reinforcement - If this is pursued, this will reduce load on LERF-ETF, potentially
c) Mutually exclusive - if iodine removal is performed, not likely to be on site disposal

**Potential Applicability to Other Sites:** N/A

**Does the technology help buy down a Mission Risk?** IDF PA, IDF Disposal authorization, and LERF HAZCAT. Avoidance of costs of non-compliant secondary wastes that must be disposed offsite.

**Identify the category of the potential concept:** 1) Risk Mitigation – not schedule driven but helps the project schedule by reducing risk 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet

**Technology Insertion Time Frame:** N/A

**References:** N/A

**Contact:** Tom Brouns - PNNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** SW-9 Iodine Separation in Gas Phase (Secondary Waste Treatment)

**Gap or Opportunity Addressed:** Uncertainty in partitioning of iodine in the melter and offgas system causes process and disposition risks. Grouting of the spent granulated activated carbon (GAC) may be problematic because of the iodine captured on the media which causes Integrated Disposal Facility (IDF) risks (performance issues) and Hazard Categorization issues for the Liquid Effluent Retention Facility (LERF)/Effluent Treatment Facility (ETF).

**Technology Idea or Concept:** Remove the iodine post melter in the gas phase**.** Potential concepts:

a. Potential abatement of iodine by opportunistic adsorption on WTP LAW secondary off-gas system thermal catalytic oxidizer (TCO) platinum-based catalyst. This behavior is predicted in literature and postulated by PNNL. A simple test with this TCO catalyst at prototypic conditions would demonstrate this behavior and possible mitigation from reaching the caustic scrubber solution. No active work conducted on this concept, but test scope has been proposed by PNNL.
b. Modify pH or remove caustic scrubber to reduce iodine partitioning to the liquid phase and allow higher concentrations of iodine and other residual gas constituents to exit the WTP LAW stack. No active work conducted on this concept. Estimated air permit limits would be challenged and would need approval. WTP design and operations impacts need to be assessed.

Note, the ideas c, d, and e below have overlap with PL-6 concepts. Thus, before these ideas are pursued, they should be coordinated with PL-6 to ensure there is not a duplication of R&D efforts.

c. Identify and implement a new iodine sorbent media tolerant of high-NOx conditions and provides sufficient retention efficiency for I-129 to abate downstream iodine impacts at LERF/ETF and WTP LAW air permit. Focus on commercially available media, consider modified commercial media, and also include sorbent material in development if a commercially available media is not readily available. PNNL has a relatively mature (TRL 4) silver functionalized aerogel media developed for the nuclear industry to remove iodine, but ideally a commercially produced media is desired. Nothing is currently being evaluated or developed in this area.
d. Recycle the caustic scrubber stream periodically to the EMF Evaporator feed tank to mitigate iodine concentrations exceeding acceptance to LERF/ETF. WRPS is currently considering this flowsheet change, PNNL is assessing impacts on glass quantities and sampling strategy to identify and monitor possible intermittent iodine concentration. SRNL is assessing impacts of this flowsheet change on the LAW offgas operations.
e. Conduct liquid-phase iodine removal on EMF process condensate effluent prior to receipt in LERF. WRPS CTO has been funding development work in this area for approximately 2 years. PNNL has screened solid sorbent materials for liquid phase iodine removal and reported findings in PNNL-31794. Follow-on lab-scale flowthrough iodine removal work was conducted at PNNL based on down selected set of viable iodine sorbent

materials. Iodine removal using a rotating bed reactor (RBR) was conducted by VSL and reported in VSL-21R5040-1.  Additional work in planned for larger-scale testing of the RBR by VSL.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| ***Funded*** | ***Unfunded*** | | |
| PTW-23<br>DTW-07 | RTW-56<br>MW-15<br>DTW-12 | *2018_25_Chemically Bonded Phosphate Ceramics for Encapsulation of Secondary Solid Waste* | 2018_25_Chemically bonded phosphate ce |
| | | *2017_22_At-tank Tc and Iodine Removal and Disposition* | 2017_22_At-tank%20Tc%20and%20iodine |

**Connectivity to other Gap, Opportunity, or Concept:** Concept G47.  Related to SW-1; PL-6; IM-13.

**Proposed Technology – Technical Maturity/Process Simplicity:** 1. Concept – basic science required.

**Complexity:** A. Separation/scrub from off-gas or media in off-gas to capture; immobilization; disposal. Medium: B. Melter and offgas system ties; potential new process incorporation.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** 5-10 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M)

**Deployment Costs (required funding):**

- Pilot Demonstration. $5 Million
- Initial Full Scale: $5 Million

**Additional investment over life cycle of Hanford mission:**

- Example a. would require thermal catalytic oxidizer (TCO) platinum-based catalyst, which may be part of the current off-gas baseline. But iodine capture would likely result in a need for more frequent replacement of the catalyst and added operating cost for some maintenance downtime, as well as dealing with spent catalyst.

- Repeated deployment costs: ~$250K for replacement of catalyst annually with new materials. This is just a rough estimate at this stage. Would depend on how much Iodine partitions to the TCO.
- Additional Investment required over life cycle: Operating costs: Incremental; $5 Million, This would depend on the approach. For example a above, the more frequent replacement of the TCO system with Pt catalyst would add cost long term for maintenance down time and to install new catalyst bed. Estimated at $250K annual for catalyst needs, in addition to other maintenance replacement costs.
- Additional Investment required over life cycle: Other (Secondary Waste Disposition): $5 million.  Disposal cost of the spent Pt catalysts waste path (grouting or disposition at WIPP).

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle***:*

- Annual costs (range): Cost avoidance
- Peak cost – cost avoidance. A replacement media or guard bed for GAC may avoid cost of new unit operation or additional liquid waste stream
- Total potential savings (range) - Cost avoidance

**Schedule Acceleration of the Hanford Mission**:  Dependent on whether stream is recycled - not baseline currently?  More likely a schedule slip avoidance of 1-2 years.

**Net impact on Safety/Environment:**  Minor positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 80%

**Regulatory Permitting/Licensing changes required:**  Class 2 or 3 RCRA permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** Positive reinforcement.  If we do, this will reduce load on LERF-ETF, potentially.  This SW-9 program will make IM-13 & SW-1 better.  If we complete removal of gaseous iodine through the use of a sorbent or catalyst, then the disposition path is likely not to be on site disposal.  Sorbent material could be dispositioned off-site versus the baseline primary disposition in the glass form. Thus, the option for off-site exists and this would avoid I-129 PA impacts on-site.

**Potential Applicability to Other Sites:**  None identified for EM sites.  Potential issues with Iodine production from advanced reactors and how to handle.

**Does the technology help buy down a Mission Risk?**  IDF PA and LERF HAZCAT. Avoidance of costs of non-compliant secondary wastes that must be disposed offsite.

**Identify the category of the potential concept:**  1) Risk Mitigation – not schedule driven but helps the project schedule by reducing risk

**SW-9**

**Technology Insertion Time Frame:** Need in < 5 years, as tied to the startup of DFLAW.

**References:** Same programs from WRPS Technology Roadmap (Funded/Unfunded), see above.

**Contact(s):** Joseph Manna, Michael Stone - SRNL; Tom Brouns, Matt Fountain - PNNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** SW-10 Technetium Separation Technologies (Secondary Waste Treatment)

**Gap or Opportunity Addressed:** Submerged Bed Scrubber (SBS) condensate is predicted to have a high concentration of $^{99}Tc$ (as well as $Cl^-$, S, and $F^-$.). In the baseline, this stream would be recycled to the melter but the $Cl^-$, $F^-$, and S are only marginally soluble in glass and could limit waste loading. Recycling the $^{99}Tc$ without the $Cl^-$, $F^-$, and S would reduce potential negative impact on melter operations and performance. The $Cl^-$, $F^-$, and S would then be dispositioned as secondary waste.

The LAW caustic scrubber solution is currently sent directly to the Effluent Management Facility (EMF) condensate system for transfer to the Liquid Effluent Retention Facility (LERF)/ Effluent Treatment Facility (ETF). If iodine-129 levels in the scrubber solutions exceed the limits for transfer to LERF/ETF, then the stream will instead be sent to the EMF evaporator. The volume of this stream could exceed the capacity of the EMF evaporator when combined with the SBS condensate and flushes already planned for evaporation in the EMF facility. In order to prevent accumulation of water in the WTP LAW process, an alternative disposition for the recycle stream may be needed which could be provided by removing the Tc from the stream. It is noted that iodine removal could also be needed if the caustic scrub solution is added to the EMF evaporator feed.

**Technology Idea or Concept:** Develop Tc separation techniques for SBS condensate allowing disposition of other constituents in offgas stream elsewhere and Tc to be incorporated in glass. Potential concepts include:

- Reductive precipitation (e.g., stannous chloride) – Prior work by D. McCabe (SRNL in this area)
- Ion exchange (e.g., Purolite® A-530E)
- Novel sorbents (e.g., LDHs, porous materials (MOFs, COFs, PCPs, etc.) – See the Grand Challenges below

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | *2014_4_Simplified disposition of direct feed low activity waste effluent* | 2014_04_Simplified Disposition of Direct F |
| | *PTW-45*<br>*MW-15*<br>*RTW-56*<br>*DTW-12* | *2017_7_Development of a reductive separations process for Tc from the LAW Off-Gas Condensate via ZVI* | 2017_7_Development of a reductive separ |

**SW-10**

| | | | |
|---|---|---|---|
| | | *2014_28_Metal Organic Frameworks for Selective Removal of TcO4- from Low-Level Nuclear Waste* | 2014_28_Metal Organic Frameworks f |
| | | *2014_36_Maturation of Technetium Separation Technology* | 2014_36_Maturation of Technetium Separa |
| | | *2017_22_At-tank Tc and iodine removal and disposition* | 2017_22_At-tank%20Tc%20and%20iodine |

**Connectivity to other Gap, Opportunity, or Concept:** Concept G50. Related to SW-1 & IM-13.

**Proposed Technology – Technical Maturity/Process Simplicity:** 2. Lab demonstration

**Complexity:** Add unit operations to remove Tc from Condensate prior to evaporations and send evaporated bottoms off site. Recycle Tc back to LAW. Sending different solids (Sn) to LAW Melter, so feed integration will be required. Should be straightforward to tie in liquid stream to ETF. Need to understand Rad levels.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** 5-10 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision*:*** Medium ($10M - $50M)

**Deployment Costs (required funding):**

- Pilot Demonstration. <$10 Million
- Initial Full Scale: $40 Million

**Additional investment over life cycle of Hanford mission:**

- Repeated deployment costs: $0 Million
- Additional Investment required over life cycle - Operating costs: Incremental; $5 Million
- Additional Investment required over life cycle - Other (Secondary Waste Disposition): $30 million.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 years)

**ROM net Cost Savings over the life cycle***:*

- Annual costs (range): Cost avoidance

- Peak cost: Cost avoidance.
- Total potential savings (range); Cost avoidance. Could reduce impact of having higher than expected S, Cl, and F in the recycle stream.

**Schedule Acceleration of the Hanford Mission***:* Would expect more supplemental LAW

**Net impact on Safety/Environment:** Minor positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 75%

**Regulatory Permitting/Licensing changes required:** Class 2 or 3 RCRA permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

- Dependency with other - None identified.
- Positive reinforcement. N/A
- Mutually exclusive: N/A

**Potential Applicability to Other Sites:** None identified for DOE sites.

**Does the technology help buy down a Mission Risk?** Will allow some materials to not be recycled.

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet

**Technology Insertion Time Frame:** Does not need to start at the beginning of mission. Need in 5-25 years

**References:**


- Same programs from WRPS Technology Roadmap (Funded/Unfunded), see above.
- K. M. L. Taylor-Pashow, D. J. McCabe, and J. M. Pareizs, "Investigation of Variable Compositions on the Removal of Technetium from Hanford Waste treatment Plan Low Activity Waste Melter Off-Gas Condensate Simulant", SRNL-STI-2017-00087, Rev. 0, March 2017.
- J. B. Duncan, "The Removal of Technetium-99 from the Effluent Treatment Facility Basin 44 Waste Using Purolite A-530E®, Reillex HPQ®, and Sybron IONAC SR-7® Ion Exchange Resins", RPP-RPT-23199, Rev. 0, October 2004.
- D. Banerjee, D. Kim, M. J. Schweiger, A. A. Kruger, and P. K. Thallapally, Removal of $TcO_4^-$ ions from solution: materials and future outlook", Chem. Soc. Rev., 2016, 45, 2724-2739.


**Contact(s):** Joseph Manna, Michael Stone, Kathryn Taylor-Pashow - SRNL; Tom Brouns (PNNL)

## NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** IF-7 & IF-12 Process Intensification/ Automation of Effluent Treatment Facility (Secondary Waste Treatment)

**Gap or Opportunity Addressed:** Effluent Treatment Facility *(*ETF) treatment capacity improvements are needed to process effluents from vitrification processes. If a LAW supplemental treatment facility utilizes vitrification, then the existing ETF treatment capacity will be inadequate.

**Technology Idea or Concept:** Evaluation of process intensification of LERF-ETF process to include automation and unit operation upgrades to increase capacity of the ETF process. A review of the process would need to be performed to determine process bottlenecks and suggestions developed for process improvements, but initial assessment should evaluate filtration, ultraviolet oxidization, and evaporation process improvements.

**Existing Funded Program:** None. However, facility upgrades to allow processing of Waste Treatment Plant (WTP) effluents during the Direct Feed Low Activity Waste (DFLAW) portion of the WTP mission have recently been completed.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| | *MW-10 – Unfunded- Remotely Operated or Automated ETF Internal Tank Cleaning Device* | | |

**Connectivity to other Gap, Opportunity, or Concept:** Concepts J-16

Improving the ETF capacity would reduce the cost of implementing a vitrification option for LAW supplemental treatment and could decrease costs of treating effluents from the WTP-LAW facility.

**Proposed Technology – Technical Maturity/Process Simplicity:** Concept – basic science required

**Complexity:** a) Unit operations - All of LERF/ETF – several b) Complexity - High integration required

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M)

**IF-7 and IF-12**

**Deployment Costs (required funding):** a) Pilot scale /demonstration: $5-10M b) Initial full-scale demonstration: $50-150M

**Additional investment over life cycle of Hanford mission:**

a) Repeated deployment costs $500K/year
b) Operating costs - N/A
c) Other costs N /A

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 years)

**ROM net Cost Savings over the life cycle***:*

a) Annual costs $25M
b) Peak cost $25M
c) Total potential savings $500M

**Schedule Acceleration of the Hanford Mission***:* None

**Net impact on Safety/Environment:** Minor Positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 90%

**Regulatory Permitting/Licensing changes required:** Already operating under final status Resource Conservation & Recovery Act (RCRA) permit, this requires class 3 permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - N/A
b) Positive reinforcement - Makes Supplemental LAW vitrification less expensive (needed capacity upgrades) and would improve existing effluent handling from existing WTP facilities.
c) Mutually exclusive - N/A

**Potential Applicability to Other Sites:** Other rad effluent treatment facilities (SRS, others)

**Does the technology help buy down a Mission Risk?** Process throughput

**Identify the category of the potential concept:**

2) incremental solution –some fit existing baseline/flowsheet but maybe not all

1) risk mitigation-not schedule driven but protect the schedule

**Technology Insertion Time Frame:** 5 years

**References:** N/A

**Contact:** Matt Fountain - PNNL

## NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** WR&T-9, Equipment Decontamination and Disposal (Mission Enablers)

**Gap or Opportunity Addressed:** Evaluate new waste retrieval and infrastructure equipment decontamination and disposal options (could be used to address concerns with Tc/I disposition in IDF and open release of cleaned equipment). Some of the identified technologies may also be suitable for enhancing dry retrieval operations.

**Technology Idea or Concept:** The bulk of our current suite of technologies, processes, and procedures associated with D4 activities, and in particular decontamination and surface prep, stem from methods, tools, and materials developed decades ago. Significant advances in material science, fabrication and bonding methods, Non-Destructive Evaluation (NDE)/ NOn-Destructive Inspection (NDI) methods, remote systems and sensor suite capabilities, and physical & chemical cleaning methods, processes, and tooling have been realized within the last decade. This has been more evident and put into practice in the private sector than in the federal.

Several of these, alone and/or in combination, will likely provide significant benefit to the DOE EM and LM missions, as well as other DOE and/or federal agency conops and D4 activities. There is a high likelihood of success in identifying COTS, GOTS, and commercial technology and best practices from analogous and unrelated industry and operational market sectors and fields (i.e., cross-theater technology transfer) that will better meet our needs and the needs of sister agencies. Some of these will be ready to use as is, some with minor to modest modifications (applied engineering / RDDT&E), and others may yet require basic research followed by the full 413.3 and NQA-1 dictated RDDT&E / TRA / TRL / TMP processes to realize their potential. Any applied or developmental technology, process, or methods identified will require screening and pilot testing to determine efficacy in our theaters of operation and the unique environmental and procedural conditions associated with them.

Examples for consideration that are likely to be directly applicable with little or no development of significance include but are not limited to the following four examples of technology, process and procedure currently in use in several commercial market sectors. In some cases, there has been limited application in the federal sector, principally in the defense and aerospace industries. Commercial Market Sectors and/or Applications common to each of the following technology examples include, but are not limited to:

- Aircraft Maintenance
- Ship Maintenance
- Hexavalent Chrome Conversion - Convert toxic hexavalent chrome to benign forms of chrome as you strip paints and coatings that contain hexavalent chrome.
- Composite (CFRP, fiberglass, etc.) Manufacturing
- Infrastructure Maintenance and Architectural Restoration
- Corrosion Removal - Remove corrosion quickly and cleanly, restoring substrate to original, pre-paint condition.
- NDE/NDI surface preparation
- Decontamination and cleaning of NPP SSCs and some government facility EM cleanup programs, domestic and foreign
- Bridge Maintenance
- Fire Restoration

- General surface cleaning / prep
- Historic Restoration
- Lead Abatement
- Marine and Offshore
- Mold Remediation
- Oil and Gas
- Petrochemical
- Power Generation
- Pulp & Paper
- Water Treatment

Laser / Photo ablation

a) Description:
SUMMARY: In recent years, photo (laser) ablation has emerged as a practical alternative solution for many types of surface preparation applications. The development of reliable, solid-state lasers with closed-loop beam delivery systems enables the use of laser energy for selective and controlled removal of corrosion products and coating materials without damage to the underlying substrate material. The energy absorption characteristics of metal-oxide compounds make the laser exceptionally effective in removing corrosion products such as rust, when operated with appropriate process parameters.

Decontamination using active, closed-loop control, the Q-switched laser ablation processes has been tested and confirmed in collaboration with the Electric Power Research Institute (EPRI), Framatome (now Areva,) and the Tennessee Valley Authority (TVA) during the 1990's and early 2000's. The observations, issues, concerns, and baseline comparisons of the early efforts were relevant at the time, however, are likely outdated as there has been reported significant improvement in the sponge media and process equipment since the late 1990's. An updated pilot / full scale test should be conducted to update the comparative performance and costs against current alternative processes, as this decontamination method is still viable and in use in the commercial sector NPPs, with potential significant application within the DOE Complex.

LIKELY PRIMARY BENEFITS: This technology offers the least amount of secondary / tertiary waste generation during the decontamination evolution.

Photoablation stripping has been reputed to generate about 12% (by weight) as much waste as does media blast, and about 0.3% as much as solvent stripping. In many cases the waste volumes are literally one or more orders of magnitude smaller with photoablation in comparison to other stripping methods and processes.

It has also been reported that photoablation enables capturing the waste in easy-to-handle, dry paper filters / HEPA filter cartridges, making proper waste disposal far simpler and less expensive.

b) MATURITY: This is a relatively mature technology that is COTS available technology and has been in use since the early 1990's. There has been limited and no recent demonstration within the National Lab and/or DOE theaters.

c) References: TBD

2) Dry Ice Blasting

a) Description:
SUMMARY: Dry-ice blasting is a form of carbon dioxide cleaning, where dry ice, the solid form of carbon dioxide, is accelerated in a pressurized air stream and directed at a surface in order to clean it. The method is similar to other forms of media blasting such as sand blasting, plastic bead blasting, or soda blasting in that it cleans surfaces using a media accelerated in a pressurized air stream, but dry-ice blasting uses dry ice as the blasting medium. Dry-ice blasting is nonabrasive, non-conductive, nonflammable, and non-toxic.

Dry ice is made of reclaimed carbon dioxide that is produced from other industrial processes, and is an approved media by the EPA, FDA and USDA. It also reduces or eliminates employee exposure to the use of chemical cleaning agents.

Compared to other media blasting methods, dry-ice blasting does not create secondary waste or chemical residues as dry ice sublimates, or converts back to a gaseous state, when it hits the surface that is being cleaned. Dry-ice blasting does not require clean-up of a blasting medium. The waste products, which includes just the dislodged media, can be swept up, vacuumed, or washed away depending on the containment.

The dry ice used can be in solid pellet form or shaved from a larger block of ice. The shaved ice block produces a less dense ice medium and is more delicate than the solid pellet system. In addition, pellets may be made by either compressing dry ice snow, or using tanks of liquid $CO_2$ to form solid pellets.

LIKELY PRIMARY BENEFITS: The Dry Ice Blasting technology offers a near non-existent amount of secondary / tertiary waste generation during the decontamination evolution, second only to the Photo Ablation methods. As the dry ice $CO_2$ sublimes after it has removed the surface contaminants and coatings via surface blasting, there is left only the particulate matter removed.

A modest downside in comparison to the photoablation method, there is more particulate matter than seen in photoablation as there has been no very rapid heating of the coating forcing coating compounds to vaporize and chemically dissociate. Nor are the $CO_2$ pellet impingement forces sufficient to generate gas phase pressure waves that drive material from the surface at explosive speed. Nor will there be pressure waves that eject condensed phase reaction products and non-volatile components of coatings from the surface. There will be, however, the removed surface coating(s) and oxide layers as debris and particulate matter.

b) MATURITY: This is a relatively mature technology that is COTS available and has been in use since the early 1990's. It has been demonstrated and utilized in the NPP and National Lab theaters, as well as in the DoD, aerospace, and maritime sectors, to name a few.

The observations, issues, concerns, and baseline comparisons of the report were relevant at the time, however, are likely outdated as there has been reported significant improvement in the sponge media and process equipment since the 1990's.

An updated pilot / full scale test should be conducted to update the comparative performance and costs against current alternative processes, as this decontamination method is still viable and in use in the commercial sector NPPs, with potential significant application within the DOE Complex.

c) References: TBD

**3)** Sponge Blasting

a) Description:
SUMMARY: The Sponge Blasting process is a highly specialized form / advancement of the Vapor Blasting set of technologies. There are several companies that produce the product and process equipment, with Sponge-Jet, both an American company and product trade name, as the most prominent. In 1999, as part of the Innovative Technology program, the DOE tested the process and product in an early version identified as Soft Media Blast Technology (SPONGE BLASTING PROCESS) that was manufactured and patented by a firm that has since been sold three times and is now a technology from a British owned firm (NuVison Engineering). A report, DOE/EM-0463, "Soft Media Blast Cleaning", Deactivation and Decommissioning Focus Area; OST Reference #1899 was issued in August of 1999.

The Sponge Blasting process propels a soft blast media against the surface to be decontaminated, using mechanical abrasion and contaminant absorption to clean the surface. Compressed air is used to propel soft blast media, which is ejected through a hose and nozzle arrangement. The soft blast media is propelled against the surface being cleaned by a portable pneumatically powered Feed Unit. The soft blast media can be recycled by collecting it from the work area and feeding it through a separate (vibratory) Classifier Unit, which mechanically removes large debris and powder residues from the cleaning media after use. The unit vibrates, causing the media to fall downward through a series of separation screens that separate the debris from the reusable media. In the past, the media must be manually collected and loaded into the Classifier Unit for separation, then the recycled media must be manually returned to the Feed Unit for reuse. It is understood, but must be confirmed, that the current process is one that makes use of an auger style air feed system via a portable pneumatically powered feed unit.

This technology appears to be somewhat unique in that the soft sponge-like media, unlike normal abrasive media, reputedly can absorb contamination, reducing the quantities of airborne contaminants and waste generated. The media breaks down after being reused several times and is then separated from the recyclable media by the Classifier Unit.

LIKELY PRIMARY BENEFITS: The primary benefits identified in the 1999 DOE testing are included to capture early observations, but it is noted that current testing would be necessary should this technology be chosen as part of a suite of technologies to further evaluate. The early reported observations include but are not limited to:

- The Sponge Blasting media permits the cleaning of materials contaminated with enriched uranium, thereby providing a substantial cost savings by reducing the quantity of material disposed of offsite, e.g., at the NTS.
- The Sponge Blasting media can be recycled, reducing the overall cost of using this technology.
- The baseline technology waste stream is a liquid, while the Sponge Blasting waste stream is of a solid matrix and therefore easier to contain, which substantially reduces operational and cleanup costs. Liquid waste streams are typically more difficult to contain, generate more volume per unit of containment, and are therefore more expensive to dispose of.
- The aggressiveness of this cleaning technology can be controlled through the selection of the blast media. Furthermore, the cleaning intensity achieved with the selected blast media can be controlled by varying the blast air pressure.
- Sponge Blasting clearly improved cleaning effectiveness by successfully decontaminating materials for disposal locally / onsite
- Sponge Blasting also required less PPE for operation, except for double hearing protection due to the increased noise, which also decreased stay times in the work zone.

Some notable challenges include but are not limited to:

- The use of a dry ablative medium means that a secondary and/or tertiary waste stream will be produced, though there is significantly less of it than in other dry ablative medium systems [e.g., sand, garnet, ceramics frit, etc.]

- When used for radiological decontamination, the use of the recycled ablative medium runs a risk of contaminating the operable units in the Sponge Blasting system, as well as the release of airborne contaminants due to the dry 'dust' / fines generated during the decon impact events and the recycling and vibratory recycler and auger transport subsystem elements.

b) MATURITY: This is a COTS available technology that has been in use since the early 1990's and one that has also been demonstrated and utilized in the NPP and National Lab theaters. The observations, issues, concerns, and baseline comparisons of the report were relevant at the time, however, are likely outdated as there has been reported significant improvement in the sponge media and process equipment since the 1990's.

An updated pilot / full scale test should be conducted to update the comparative performance and costs against current alternative processes, as this decontamination method is still viable and in use in the commercial sector NPPs, with potential significant application within the DOE Complex.

c) References: TBD other than as noted above

4) Electrochemical Cleaning

a) Description:
SUMMARY: Researchers at Los Alamos have developed a novel electrochemical technology consisting of several components in a system that provides a self-contained, efficient, semi- or fully automated, and flexible decontamination system for metals and metal alloys. Any number of novel system configurations are possible such as: 1) a recirculating bath to clean contaminated parts, 2) a recirculating solution through a suction head for larger parts or surfaces, and 3) injecting and removing the solution in/out of large containment tanks. The System is integrated with a proprietary contactor for separation of radioactive components. The decontamination system can also be used to etch steel alloys for increased adhesion of coatings. Coatings embedded with nanoparticles have also been developed and tested on these etched surfaces. The project team is seeking input from potential users or interested parties regarding the further development and application of the technology.

MARKET APPLICATION: This technology could be used to decontaminate containment tanks, enclosures and parts in nuclear facilities or other industrial facilities (e.g., oil and gas) either as regular maintenance or for decommissioning. The system can be sized or scaled up or down as needed. There are many DOE operated or commercial nuclear facilities worldwide that have large scale decommissioning activities, which require decontamination.

PRIMARY BENEFITS: Other systems exist for decontaminating surfaces; however, the Los Alamos system is ideal for difficult 2D and 3D surfaces and spaces. The technology could also be used in the coatings industry to prepare difficult to coat surfaces by etching them prior to coating. The coatings that have been developed could be used to protect against corrosion, biofouling, or other wear intensive applications.

b) MATURITY: LANL already has pilot scale prototypes that are planned to test soon in the Lab’s nuclear facility and are currently assessed as TRL 6-7.

c) References:
i) LA-UR-20-28163, INTEGRATED ELECTROCHEMICAL DECONTAMINATION AND ETCHING SYSTEM
ii) LA-UR-22-22416, DOE Emerging Technology Meeting, 2022-03-17 (Santa Fe, New Mexico, United States)
iii) “High Efficiency Automated Leaching of Glove Boxes “, Rodriguez, David Anthony Tyler ; Karmiol, Benjamin ; Stritzinger, Jared Tyler ; Walsh, Sean Peter ; Monreal, Marisa Jennifer ; et al. Prepared for : JOWOG 22-2 ; 2019-07-15; Los Alamos, New Mexico, 2019-07-3
iv) "Electrochemical approach to metal decontamination", Karmiol, Benjamin; Stritzinger, Jared Tyler; Rodriguez, David Anthony Tyler; Walsh, Sean Peter; Monreal, Marisa Jennifer; Monroe, Jeremy Jacob; Xu, Ning; Mckee, Steven Douglas. Prepared for : American Chemical Society Southwest & Rocky Mountain Regional Meeting, El Paso, TX, 2019-11-

13, LA-UR-19-31321 Provisional Patent: DOE Reference: S-133,812.00

**Existing Funded Program:** Technologies 1, Photonic Ablation; 2, Dry Ice Blasting; and 3, Sponge Blasting as noted above, are not known to have any existing funded programs within the DOE complex at this time.

Technology 4, Electrochemical Cleaning is currently funded for the work being conducted by Mr. Benjamin Karmiol, LANL, AMPP-4: MATERIALS RECOVERY AND RECYCLING

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| *RTW-01: Retrieval and Closure Solid Waste Sampling Tools* | *RTW-25: Highly Flowable Grout* | *2017_33 Borehole Miner (BHM) Extendible-Nozzle System for Cleaning Tank Walls, In-Tank Hardware, and Floor Integrated with Optical Sensing to Identify Areas to Clean* | 2017_33_Borehole Miner (BHM) Extendib |
| | *RTW-54: Tank Waste Modular Treatment Study* | *2015_20_Phased Deployment of NitroJet Technology with Columbia Energy's MARS for Hanford HLW Tank Hard Heel Removal* | 2015_20_Phased Deployment of NitroJ |
| | *MTW-82 Tank Annulus Floor Cleaning (Retired sheet)* | *2014_19_TC Chemistry in Tanks and Impact on Waste Transfer and Supplemental Treatment* | 2014_19_TC Chemistry in Tanks ar |
| | | | *Also, look at Savannah River P and R reactor decommissioning* |

**Connectivity to other Gap, Opportunity, or Concept:** DL-5, Develop capture media packaging to allow disposal of I, Tc, $NH_4$ and $NO_3$ for on-site and off-site disposal options

DL6, Evaluate direct disposal options versus vitrification for disposal of CST for on-site and off-site disposal options

IM-3, Technetium and Iodine Management (Excluding Glass Waste Forms, combined with IM-5)

IM-5, Mercury Management

**Proposed Technology – Technical Maturity/Process Simplicity:** Technologies 1, Photonic Ablation; 2, Dry Ice Blasting; 3, Sponge Blasting as noted above, are Commercially available/ off the shelf/ service; have had some documented history of Full-scale demonstration a) in use elsewhere for similar problem AND b) in use elsewhere for closely related problem in the commercial NPP sector; AND Pilot/prototype testing has been completed at DOE and/or commercial NPP facilities in the past (1990's – 2000's for all but Technology 4, Electrochemical Cleaning). It should also be noted that recent advances that are significant and germane to current envisaged needs for Technologies 1,2, and 4 have NOT been tested at DOE facilities, but have had engineering scale and full-scale testing and/or deployment within the commercial sector (NPPs (including TMI for some), aerospace, other power generation and fabrication facilities, as well as for DoD and NASA.

Technology 4, Electrochemical Cleaning is currently in development / in an RDDT&E environment at LANL (see prior notes for Technology 4)

**Complexity:** Supports all retrieval, transfer, characterization, and disposal unit operations

System integration requirements will be dependent upon the deployment mission profile (e.g., in tank decontamination efforts versus decon efforts for removed SSCs and/or size reduced for disposal SSCs) and location(s) as well as the particular technology or technologies deployed.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** < 5 years for any / all of the technologies proposed

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M total cost) with $500K - $3M per technology under consideration based upon use of initial Pilot to determine best operating parameters followed by full-scale demonstration with surrogate material.

Medium $10M - $50M if using actual debris and/or contaminated SSCs with a full-scale (hot) demonstration.

**Deployment Costs (required funding):** This activity can be the same as / simultaneous to the "Go/No-Go" pilots and/or full-scale demonstrations, therefore costs are the same:

Low (<$10M total cost) with $500K - $3M per technology under consideration based upon use of initial Pilot to determine best operating parameters followed by full-scale demonstration with surrogate material.

Medium $10M - $50M if using actual debris and/or contaminated SSCs with a full-scale (hot) demonstration.

**Additional investment over life cycle of Hanford mission:** It is anticipated that most of the costs will be associated with initial equipment acquisition and then by consumables and maintenance costs. These costs are in turn dictated by use rate, area decontaminated, and other deployment factors. Consumables and Maintenance are estimated at approximately $1M - $2M depending upon the number of fiber bundles and laser scanning heads needed in the case of Technology 1; and by the amount of ablative material / medium needed for Technologies 2 & 3. Technology 4 is as of yet to be determined and will be reported during the planned development efforts at LANL under the current RDDT&E program with supplemental funding from this effort for any additional RDDT&E that is specific to our needs versus current development program needs under the existing program.

Due to the nature of the D&D support efforts that these technologies will provide, all other costs are anticipated to be part of existing annual operating costs.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick, within the initial "<5 years" allocated for initial deployment / full-scale testing and demonstration. First operation can begin immediately after formal RR / ORR as may or may not be deemed necessary.

**ROM net Cost Savings over the life cycle***:* Unknown / TBD as it depends upon which technology / technologies are deployed, how and where they are deployed and when they are deployed [Technology insertion time frame].

During the course of testing and full-scale deployment and utilization in commercial NPP and other nuclear facility programs, as well as some [very] early DOE specific testing, DFs have ranged from a factor of 10 to 100 reduction – often to free release levels; and cost savings have ranged from a savings of 25% - 70% of costs that would have been incurred via conventional decontamination methods. ALARA savings have been consistent with these measures.

**Schedule Acceleration of the Hanford Mission***:* The exact amount of schedule acceleration will depend upon which technology/ technologies are deployed, how and where they are deployed, and when they are deployed. With those caveats, time savings of up to year over the life of the tank farms operation should be realized. The technology can be inserted at the start of tank farm retrieval operations.

**Net impact on Safety/Environment:** For technologies 1 – 3, substantial personnel / work safety, ALARA, and environmental (waste reduction) beneficial impacts have been observed and measured when deployed at NPPs, other nuclear facilities, and other hazardous commercial facilities.

It is expected that similar Positive results will be observed and measured, with Minor to Major [positive] impact, depending upon which technology / technologies are deployed, how and where they are deployed, and when they are deployed [Technology insertion time frame].

Technology 4 impacts are expected to be similar and will be better quantified and qualified during the completion of the RDDT&E cycle for the existing program and any added elements introduced by this program thus leveraging assets and multiple program dollars.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** 75% - 99% successful deployment is anticipated, based upon the success achieved in the private and some government sectors. The lower end (75%) is suggested due to unforeseen circumstances that may come out of any HAZOP and / or USQ reviews, as well as the challenges of deployment at some [secure] sites where site security requirements preclude optimal deployment for demonstration [let alone full deployment and routine use] at the site (e.g., Paducah).

**Regulatory Permitting/Licensing changes required:** None, unless PA changes are driven by reduced technetium, iodine, mercury, and other regulated constituents. If we are impacting the final tank closure permits, then this technology insertion might require Class 2 permit mod and 2-3 years implementation.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** We do not foresee any Dependency with other circumstances. Successful utilization of the D&D technologies would allow more robust implementation of WR&T-10a/b, WR&T-3, and Hard Heal removal. We do not foresee any Mutually exclusive circumstances.

**Potential Applicability to Other Sites:** All nuclear and non-nuclear sites within the DOE Complex that have 'contaminated' facilities and SSCs; or facilities that have SSCs requiring coatings maintenance and /or NDI/NDE requirements whereby conventional coatings removal methods pose O&M and/or environmental / sustainability challenges; as well as many facilities and SSCs of most other federal agencies [e.g., DoD, NASA, etc.]

**Does the technology help buy down a Mission Risk?** Personal and Environmental Safety; ALARA; equipment use, reuse, and disposal; waste minimization and disposal volume reduction, as well as special wastes of concern management and removal from routine waste streams and volumes.

**Identify the category of the potential concept:** When deployed: 2) Incremental – some fit to existing baseline / flowsheet, but maybe not all. Too early to tell at this juncture as there may be significant short-, mid- and long-term program benefits if special wastes can be isolated and individually addressed at Hanford and/or at other sites within the Complex.

**Technology Insertion Time Frame:** There are ongoing operational and program objective needs for enhanced D&D technologies. [Cross Complex] Benefit would start to be realized early after technology insertion at Hanford where Tank Farm operations and other cleanup mission objectives could immediately benefit.

**References:** References are provided in the "Technology Idea or Concept" section for each of the recommended technologies to be vetted and deployed.

**Contact:** Paul Dixon - LANL

## NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** WR&T-10b Real Time Monitoring for Liquid Process Feeds (Enabling Technologies)

**Gap or Opportunity Addressed:** Develop new real-time monitoring capabilities for liquid process feeds to reduce sampling time and minimize waste.

**Technology Idea or Concept:** The utilization of commercially available instrumentation and/or technologies that are in the development stage to support measuring the physical (rheology, density, particle size distribution, solids and liquid fractions, and critical velocity) and chemical properties (composition of total, liquid, and solids, and pH). In-situ or at tank measurement of physicochemical properties will mitigate the need to sample and accelerate the retrieval preparation process, hence reducing the cost. Technology developed can be utilized for other DOE processes. Vendors: Emerson, Endress+Hauser, Krohne, pulsar measurements, Rhosomics, Malvern Panalytical, Lasentec, and multiple others. Electrical resistance tomography has great potential to assess velocity profile, critical velocity, and rheological properties.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| MTW-93<br>PTW-54 | MTW-36<br>MTW-37<br>MTW-40<br>MTW-76 | *2015_35_Eliminate Regulated Organics from LAWPS-WTP Waste acceptance Criteria WRPS;* | 2015_35_Eliminate%20Regulated%20Orga |
| | | *2015_1_Alternative Engineering Strategy for WTP;* | 2015_1_Alternative%20Engineering%20Str |
| | | *2018_12_HLW LAW Processing Strategy based on Rad Operations;* | 2018_12_HLW%20LAW%20Processing%2 |
| | | *2018_19_Accelerating SST Retrieval and Closure by Combined In-Tank Character.* | 2018_19_Acceleratin g%20SST%20Retrieva |

**Connectivity to other Gap, Opportunity, or Concept:** Technology can be shared with IF-1, WT-1, WT-2, WT-3, WR&T-7b and Hanford-1

**Proposed Technology – Technical Maturity/Process Simplicity:** Pilot/prototype to Full-scale demonstration. Technology to be verified prior to use.

**WR&T-10b**

**Complexity:** a) Used at each tank requiring liquid mobilization/transfer. b) Integrated into a recirculation loop that could be coupled with the transfer pumping system.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M) for COTS/GOTS, Low to Medium ($10M - $50M) for full integration with Hanford-1

**Deployment Costs (required funding):** $1M to $2M for pilot/prototype scale testing, $1M to $10M for full scale.

**Additional investment over life cycle of Hanford mission:** a) deployed for each tank that will use liquid retrieval and transport, $1M to $2M b) Operating costs would be part of existing annual operating cost c) Disposal of instrumentation would be part of existing annual operating cost.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle***:* Savings to be obtained by not sampling, $30M per year with a lifecycle cost savings of $12.5-$25B

**Schedule Acceleration of the Hanford Mission***:* 5 to 10 years acceleration

**Net impact on Safety/Environment:** Minor and Positive, robust implementation of WR&T-7b and Hanford-1.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** High successful deployment based on maturity of technology. Employed where liquid retrieval will be performed.

**Regulatory Permitting/Licensing changes required:** Minor, Class 2 or 3 RCRA permit mod, 2 to 3 years to obtain.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** Performing this activity makes WR&T-7b and WR&T Hanford-1 better, as well as synergy with the proposed WT-9 technologies.

**Potential Applicability to Other Sites:** SRS and Oak Ridge.

**Does the technology help buy down a Mission Risk?** Yes, optimization of waste form through forward processing and reduce mission schedule. Potential identification and minimization of system disruptions.

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet

**Technology Insertion Time Frame:** Can be implemented into any process where liquid characterization is required.

**References:**

- S.E. Kelly, "Remote Sampler Demonstration Isolok Configuration Test", RPP-RPT-59332, Rev. 0, June 2016
- R. Y. Sulaiman, "Mobilization Measurement Instrumentation Test Specification", SLPFB-SPEC-026, 2018
- A.P.N. Sutherland and et al., "Determining concentration and velocity profiles of non-Newtonian settling slurries using electrical resistance tomography", The Journal of the Southern African Institute of Mining and Metallurgy", October 2008
- T. D. Machin and et al., "In-pipe rheology and mixing characterization using electric resistance sensing", Chemical Engineering Science, 2018

Additional references can be provided as well as vendor literature.

**Contact:** Erich Hansen - SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** Hanford-1, Infrastructure Cost Evaluation through development of a System Model (Enabling Technologies)

**Gap or Opportunity Addressed:** Waste retrieval and infrastructure cost reductions (Superstructure improvements, reduced shielding and support infrastructure). In order to evaluate cost, schedule and risk management improvements a new system model for tank farm and WTP operations needs to be developed. Using this new system model a cost benefit/ engineering analysis of tank farm and the Hanford tank waste mission operations can be completed.

**Technology Idea or Concept:** Development, in a phased and integrated modular approach, of a fully integrated system model that takes into account to the maximum extent practicable the full set of legacy systems and efforts to date to model plant design, process, flow sheet, performance / operations research, risk, cost and schedule. The goal is to move to a fully current state of art integrated risk modeling inclusive of digital risk modeling, process modeling, design modeling, decision analysis, and digital twins / IIoT / Industry 4.0 model integration. The digital twin elements will take into account not only the physical plant, but also the flow sheet and process engineering, as well as plant operations (e.g., predictive and preventative maintenance, changes in chemistry and waste forms, regulatory changes, etc.).

The key principles and relationships between the models, benefits, and Industry 4.0 plant automation stack and digital twins are illustrated in Figure 1.

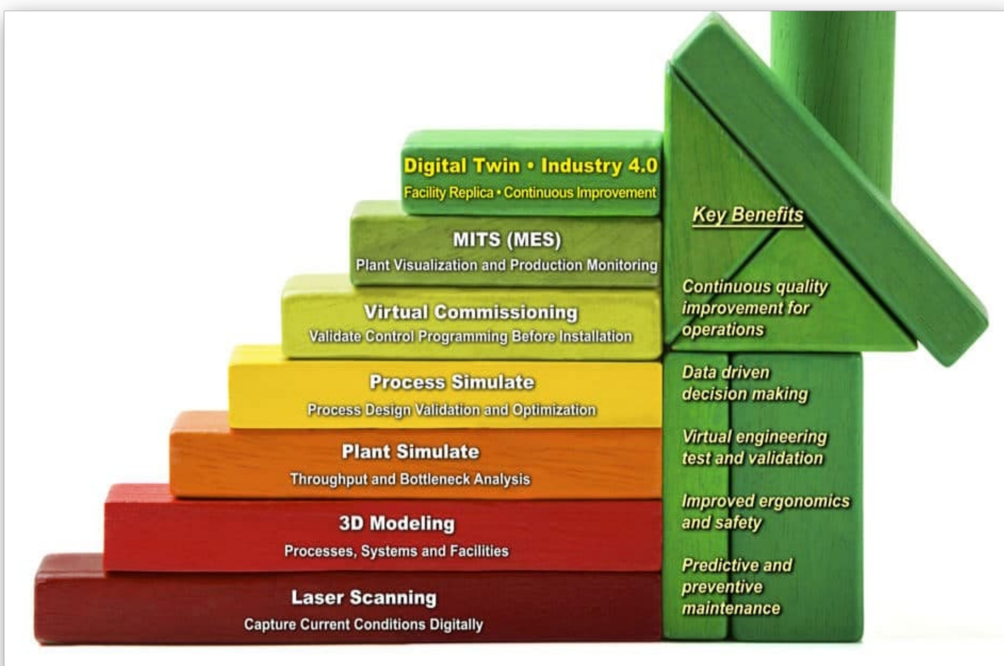


**Figure 1: Key Principles and Relationships Between the Models, Benefits, and Industry 4.0 Plant Automation Stack and Digital Twins**

**Hanford - 1**

Generally speaking, a digital twin (DT) is a “live”, learning virtual representation of a physical world entity, service, or process. There are three types of digital twin – Product, Production/Process, and Performance. The combination and integration of the three digital twins as they evolve together is known as the digital thread.

The power and capabilities of new technologies are helping to accelerate the realization and benefits of DTs. The advanced engineering & design modeling, process and flow sheet modeling, operations modeling, decision analysis and impact driver assessment modeling and digital risk modeling; as well as the advanced virtual and physical prototyping technologies (think simulation modeling, 3D printing, etc.) enable an organization to visualize end-to-end processes in real-time vis-à-vis empowering them to understand what will and what is happening at every stage of the process – whether built yet or only existing in the virtual world.

DT empowers the engineers, construction teams, operations teams, and risk management teams to simulate and run ‘what-if’ scenarios to understand how a product or a process will behave in the real world. It also gives businesses an unprecedented view of how their product or service performs in real conditions. When you further peel the concept, one would realize that it is empowered by all-new aged technologies like AR, VR, AI, Automation, IoT/IIoT, Industry 4.x, Edge Computing, Open Process Automation (OPA) systems, Cloud & Fog enterprises, Big Data, Data Modelling, Data Engineering, Blockchain, and NFT to name a few.

According to a few studies, better control reduces the time, effort, and money spent on the projects by up to 30%. This opportunity is much bigger than the opportunities which existed during Dot Com and the ongoing Digitalization era. Integral to this will be the use of Digital Risk Models. Critical will be the compliance with CMMI (Capability Maturity Model Integration) and CMMC (Cybersecurity Maturity Model Certification).

Many of the tools, software, firmware, and operating systems are COTS / GOTS and available for purchase at this time. There are more than two dozen available and ranked very highly by major end users, both commercial and governmental. Some of these packages are in the final stages of IP protection and will be ‘off the shelf’ available within the next quarter or two.

Early in the effort we will need to take stock of what we have now, conduct a gap analysis of what we need and what we would like to be able to do, assess the success of others that have gone before us (build on their success without repeating their mistakes) and then down select to those tools needed and determine when they will be needed so that technology injection points can be timed and programmed accordingly.

Specific early emphasis will focus on risk enabled approaches and decision analysis integration relative to waste retrieval and treatment; the flow sheet; improved integrated OR modeling to better evaluate the superstructure and retrieval technology improvement queuing as they relate to process and production of waste form product.

**Existing Funded Program:** There are several aspects of this that are already funded to an extent. There are elements that are funding the ‘right’ intent, but the wrong tool. This will be another of the early activities to sort out. New funding will be needed.

**Hanford - 1**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| | *RTW-07: Post Waste Retrieval Updates to WMA C PA Maintenance* | *2016_18 Techno-economic Assessment of Nitrate Destruction Options for Hanford Tank Waste;* | 2016_18_Techno-economic Assessment of |
| | | *2014_13 Develop Basis to Support Future Risk-Informed Retrieval, Cleanup and Closure Decision Making* | |
| | | *2014_22 Geochemical Testing and Model Development – Residual Tank Waste* | |
| | | *2014_29 Risk-Based Tank Retrieval and Closure of Hanford Waste Tanks* | |
| | | *2018_5 Waste Incidental to Reprocessing: West Area Opportunities for Low-Activity Feed (WIR-WOLF)* | 2018_5_Waste Incidental to Reproces |
| | | *2018_19_Accelerating SST Retrieval and Closure by Combined In-Tank Character...* | 2018_19_Accelerating SST Retrieval and Cl |
| | | *2015_10_ A Virtual Workbench for Waste Processing* | |
| | | *2015_15_Tank Waste Radionuclide Removal and Immobilization Options Evaluation* | |
| | | *2015_19_Task Modeling, Simulation, and Skill in Tank Retrieval Operations* | |
| | | *2016_15_A Virtual Workbench for Waste Processing* | |
| | | *2017_2_Risk Informed Retrieval and Closure Strategy* | 2017_2_Risk Informed Retrieval an |
| | | *2017_35_Technology to Support Risk Based Retrieval and Closure of Hanford Tanks* | 2017_35_Technology to Support Risk Based |

**Connectivity to other Gap, Opportunity, or Concept:** Model ties to WR&T-1, WR&T-7a/7b, WR&T-8, WR&T-13, WR&T-14, WM-1, WM-2, WM-3/SW-6, WM-5, and likely a substantial number of other Concept IDs when taking into account full integrated risk modeling, process modeling, design modeling, decision analysis, and digital twin / IIoT / Industry 4.0 model integration

**Proposed Technology – Technical Maturity/Process Simplicity:** Deployable COTS/GOTS for the platform. Site specific modeling will be required.

**Complexity:** All Unit Operations will be affected (7 or 8 modules). Required systems integration complexity will be High as all software, processes, and eventually physical plant will need to be integrated in order to gain the greatest benefit. However, system enhancements can occur along the way to initiate the process and to refine fidelity.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years to initiate

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium: $10M-$15M, Full Benefit - Bayesian Model, Non-Bayesian Model, GoldSim, Digital Twins (integrated OR, design, flow sheet, chemistry and digital risk modeling and analysis)

Low: $5M-$7M if Incremental Benefit approach is taken, e.g., decision analysis using Bayesian, Non-Bayesian, and GoldSim models; discreet OR models; and possibly DT Flow Sheet Models

**Deployment Costs (required funding):** Medium: $10M-$15M Full Benefit - Bayesian Model, Non-Bayesian Model, GoldSim, Digital Twins (integrated OR, design, flow sheet, chemistry and digital risk modeling and analysis)

Low: $5M-$7M if Incremental Benefit approach is taken, e.g., decision analysis using Bayesian, Non-Bayesian, and GoldSim models; discreet OR models; and possibly DT Flow Sheet Models

**Additional investment over life cycle of Hanford mission:** Taking into account hotel load, ($1.5M-$3M/yr) $15M-$30M life cycle to address configuration management, bench marking, version control, out year modelling etc.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle***:* Annual Cost savings of up to $200M/yr. Annualized over full life cycle operation could lead to the full benefit ($25B based on 25% cost savings lifetime) allows uninterrupted retrieval and transport operations that provide input feed to a plant 24/7.

Incremental Implementation Benefit (focus on retrieval timing and required infrastructure optimization to reduce mission life (i.e., melters needed)

**Schedule Acceleration of the Hanford Mission***:* Potentially 10 years if integration and optimization of the tank waste system can be obtained

**Net impact on Safety/Environment:** Minor-Major depending upon the level and extent of implementation

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 90% to implement successfully; breadth of model may be a question or uncertain

**Regulatory Permitting/Licensing changes required:** None for the modeling and DT efforts in and of itself. Potential major if model suggested changes / impacts are considered and acted upon and these regulatory impacts will have been considered and integral to the model analysis.

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** We do not foresee any Dependency with other circumstances. Positive reinforcement to All Unit Operations benefiting. We do not foresee any Mutually exclusive circumstances.

**Potential Applicability to Other Sites:** Platform is usable at all sites but must be made site specific with tailored modules.

**Does the technology help buy down a Mission Risk?** Numerous areas of cost, schedule, and process risk identified across the entire program for its full lifecycle

**Identify the category of the potential concept:** With full implementation of concept: 3) Transformational – change in the baseline and has a mid-range cost.

With partial implementation of concept. Develop a model framework and add modules as necessary: 2) Incremental –some fit existing baseline/flowsheet but maybe not all

**Technology Insertion Time Frame:** With full implementation, work needs to be initiated ASAP to minimize negative impacts to past and ongoing efforts. With partial implementation of concept. Develop a model framework and add modules as necessary and timed so as to minimize negative impacts to existing efforts

**References:** N/A

**Contact:** KD Auclair - LANL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** DL-6 Alternate Disposal Options for Crystalline Silicotitanate Ion Exchange Media (Mission Enablers)

**Gap or Opportunity Addressed:** Alternative disposition paths besides vitrification and disposal as HLW should be evaluated for spent crystalline silicotitanate (CST) ion exchange media for cost reduction opportunities

**Technology Idea or Concept:** Evaluate and implement alternative disposal options to vitrification for disposal of CST. Disposal options should include on-site and off-site disposal options considering the material is likely to be greater than Class C or TRU.

**Existing Funded Program:** a. NNLEMS CST Characterization Study report is presently being drafted. b. Grand Challenges and WRPS TEDS

| *WRPS Programs* | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| *Funded* | *Unfunded* | *2018_6_Disposal Path Determination for CST after use in LAW.docx;* | 2018_6_Disposal%20 Path%20Determinatic |
| *PTW-38 (Radioactive Waste Test Platform)* | | *2014_04_Simplified Disposition of Direct Feed Low Activity Waste Effluent.pdf;* | 2014_04_Simplified Disposition of Direct F |
| | | *2014_10_Proposal CST Cs removal & immobilization* | 2014_10_Proposal%2 0CST%20Cs%20remo |

**Connectivity to other Gap, Opportunity, or Concept:** B33.

**Proposed Technology – Technical Maturity/Process Simplicity:** 1. Concept – basic science required

**Complexity:** Describe the a) Number of Unit Operations affected: 3 - column operations, staging of material, and transport to disposal site b) Required system integration to implement the technology: Medium

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** Scoring approach: <5 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Low (<$10M)

**Deployment Costs (required funding):** $20M

**Additional investment over life cycle of Hanford mission:** $180M

**DL-6**

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Medium (5-10 years)

**ROM net Cost Savings over the life cycle***:* Estimate cost savings from a) Annual costs ($12 – 17M) b) Peak cost – ($12 – 17M) c) Total potential savings ($750 – 1,000M)

**Schedule Acceleration of the Hanford Mission***:* Estimated number of years saved (2 - 3)

**Net impact on Safety/Environment:** Minor Positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:**

95%

**Regulatory Permitting/Licensing changes required:** Major: Offsite: NEPA, non-HLW determination under DOE M 435-1, 5 years; Onsite: NEPA, non-HLW determination under DOE M 435-1, PA, permit mod, 10 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** Could potentially positively impact HLW glass waste loading. Could potentially make offsite shipment & disposal earlier & easier. Need PL-3 to implement

**Potential Applicability to Other Sites:** SRS

**Does the technology help buy down a Mission Risk?** NA

**Identify the category of the potential concept:** 3) Transformational – change in the baseline and has a mid-range costs

**Technology Insertion Time Frame:** After CST evaluation and assessment against disposal criteria.

**References:**

- 2018 Office of River Protection Grand Challenge Competition: Disposal Path Determination for Crystalline Silicotanate after use in LAW Processing
- 2016 ORP Grand Challenge Proposal AT-Tank Cesium Removal, Grand Challenge Proposal: Tank Waste Cesium Removal and Immobilization with Crystalline Silicotitanate (11-13-14)

**Contact:** Sharon Robinson – ORNL, Dan McCabe - SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PL-3 Optimize Cs loading of CST (Mission Enablers)

**Gap or Opportunity Addressed:** Currently, each cannister of CST costs roughly $1M to produce, and there are additional costs associated with disposition of these canisters. There are currently a number of constraints that limit the usage of the CST, primarily associated with meeting the performance requirements for cesium removal and limiting the curie loading associated with heat and gas generation in the canister during disposal. It is also possible that by further limiting the cesium loading that alternative disposition pathways for the spent CST could become available.

**Technology Idea or Concept:** The current operating scheme for the CST columns has not been optimized to achieve the maximum possible loading. The first set of columns in TSCR were taken off-line because of cesium removal performance well before the curie limit was reached. This situation will likely be exacerbated in future feeds that will have even lower curie loadings. Alternative operating schemes (relying on available process parameters) would be explored to evaluate whether higher column utility could be achieved. Key process parameters include the process throughput, temperature and feed sodium molarity as well as other matrix effects such as potassium and carbonate. In addition, this activity would evaluate whether alternative disposition paths could be made available if lower loading were achieved.

**Existing Funded Program:** No. There are no specific activities that are currently funded looking to optimize the cesium loading. That said, some of the exiting WRPS funded activities provide foundational information that could be built on to flesh out this concept. SRS is also generating data on CST performance that could be used to supplement this data.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | *2015_29_Swellable glass tailored for cesium and strontium sequestration for Hanford tank waste* | 2015_29_Swellable glass tailored for cesiu |
| *MTW-93* | | *2014_40_Separation and Vitrification of Cesium and Strontium in a Pretreatment Process* | 2014_40_Separation and Vitrification of Ce |
| | | *2014_31_Tank Waste Cesium Removal and Immobilization* | 2014_31_Tank Waste Cesium Removal and |

| | | | |
|---|---|---|---|
| | | *2015_27_Cesium Removal and Interim Storage in support of DFLAW* | 2015_27_Cesium Removal and Interim : |
| | | *2018_22_ Identification of Alt Non-Elutable IEX Media* | 2018_22_ Identification of Alt N( |

**Connectivity to other Gap, Opportunity, or Concept:** This is connected to PL-10 in that PL-10 is also focused on opening up alternative disposition pathways for the spent CST. DL-6 is also related as that is focused on evaluating the potential disposal pathways for the spent CST.

**Proposed Technology – Technical Maturity/Process Simplicity:** Depending upon which approach is taken, this ranges from 2 (lab demonstration for developing alternative disposition pathways) to 4 (full-scale demonstration for optimization of the CST usage).

Developing an alternative disposition pathway would require some concept development in order to evaluate what potential disposition pathways are viable and then to establish operating conditions that can meet those disposition pathways. Alternatively, optimization of the current CST usage profile could be integrated into existing TSCR operations with minimal disruption.

**Complexity:** Ranges from low to high. If the objective is to improve CST performance such that the cesium removal performance is not the limiting factor, then this is a relatively low complexity – i.e., just change the flowrate and you will get better CST usage. However, if the goal is to utilize the CST up to its maximum capacity, this would require DSA changes which would be high complexity. Similarly, if the goal is to open up alternative disposition pathways, this would involve the following unit operations: ion exchange, canister loading, transport and disposal.

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** Again, this is dependent upon which approach is deployed. Direct optimization could be readily achieved in < 5 years. However, developing alternative disposition paths by limiting loading would require 5-10 years to implement.

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Regardless of the approach taken, the estimated costs are low (<$10M) as this is a fairly mature technology.

**Deployment Costs (required funding):** The costs for this are relatively low, as the deployment costs would be associated with DSA changes – if required to achieve the maximum target CST loading. Alternative disposition pathways would require DL-6 investments.

**Additional investment over life cycle of Hanford mission:** None – this assumes that the alternative disposition costs are covered under DL-6.

**PL-3**

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years), for direct optimization. Medium (5-10 years), for alternative disposition pathways.

**ROM net Cost Savings over the life cycle***:* The current plan for treating AP-107 will utilize over $10M in CST columns. This rate of usage is expected to increase as the system operation becomes more stable. It is reasonable to expect that optimization could reduce the CST usage by 30%, resulting in at least $3M a year in savings. This would add up to $150M in total potential savings assuming 50 years of operation.

**Schedule Acceleration of the Hanford Mission***:* N/A. This activity is focused primarily on reducing costs associated with operations and is not expected to yield significant improvement in schedule performance. However, reducing the number of columns deployed will reduce the outage time to replace columns and will have a net positive effective on TSCR TOE, but it is not possible to assess the extent of that impact on overall Hanford Mission. If alternate disposal paths are pursued there could be some reduction in overall mission schedule due to the elimination of the need for vitrifying the CST.

**Net impact on Safety/Environment:** This activity is not expected to have any significant impact on safety or environment.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 90%

**Regulatory Permitting/Licensing changes required:** None

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:** The portion of this that looks to limit Cs loading to allow alternative disposition pathways is directly associated with DL-6, which looks to implement direct disposal options for spent CST.

**Potential Applicability to Other Sites:** TCCR at SRS would benefit directly from this activity.

**Does the technology help buy down a Mission Risk?** D2: Cs Removal

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet. Incremental cost reduction associated with CST usage. 3) Transformational – change in the baseline and has a mid-range cost. Transformational associated with supporting alternative disposition pathways for CST.

**Technology Insertion Time Frame:** Optimization can be implemented relatively quickly (<5 years). It should be noted to get the full benefit out of alternative disposition pathways, that scope would need to be addressed relatively quickly, as CST canisters are being loaded now, so that if this evaluation is delayed, there may be a sufficient number of canisters already produced so as to limit the benefit of opening up an alternative pathway.

**References:** N/A

**Contact:** Reid Peterson – PNNL, Kathryn Taylor-Pashow - SRNL

# NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** PS-9 Improved Offgas Treatment/ Abatement for Key Air Toxics (Mission Enablers)

**Gap or Opportunity Addressed:** Toxic air emissions from tank waste in both storage and processing operations (e.g., ammonia) can exceed permitted emissions limits and result in restrictions on operating conditions, such as reduced flowrates for exhausters, or reduced operating times for other process facilities (e.g., months/yr, or hours/day allowable operations). Abatement methods for key air toxics, or other methods to reduce emissions are needed to accelerate treatment mission.

**Technology Idea or Concept:** Waste treatment or offgas abatement methods to reduce impacts of key air toxics that are limiting waste processing operations.

**Existing Funded Program:**

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | *Comments* |
|---|---|---|---|
| ***Funded*** | ***Unfunded*** | *2017_32_Ammonia Getters for Liquid Secondary Waste Grout Formulations* | 2017_32_Ammonia Getters for Liquid Sec |
| *MW-02, Ammonia Vapor Mitigation* | *MTW-79, Autonomous Robotic Platform*<br><br>*PTW-49, Feasibility of Removing Nitrates from the LAW Feed* | *2017_24_GC Ammonia Remediation Supporting Hanford WTP Secondary Waste Processing* | 2017_24_GC%20ammonia%20remediatio |

**Connectivity to other Gap, Opportunity, or Concept:** Concept ID E8, WR&T-3b & 10a

**Proposed Technology – Technical Maturity/Process Simplicity:** 3. Pilot/prototype

**Complexity:**

a) Tank farm ventilation or process offgas vent system; abatement treatment operation (e.g., thermocatalytic oxidizer), stack monitoring/control system
b) Medium complexity

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M)

**Deployment Costs (required funding):**

a) $15M for pilot scale/demonstration
b) $25M for initial full-scale demonstration

**Additional investment over life cycle of Hanford mission:**

a) $150M for repeated deployment costs. Assume multiple system deployment on tanks or tank farm ventilation system, evaporators when retrieving wastes or operating campaigns. Assume 7 units maximum covering major farms, evaporators, and mobile for SST retrievals.
b) $100M in operating costs. Assume 50 yrs operation of 6-7 units with annual total operating cost of $2M/yr.
c) Other costs incurred above baseline technology assume thermocatalytic oxidizer without GAC polishing that would generate significant secondary wastes. May require additional costs if alternate abatement system selected.

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle***:*

a) Annual costs – cost avoidance
b) Peak cost – cost avoidance
c) Total potential savings – cost avoidance

**Schedule Acceleration of the Hanford Mission***:* Cost and schedule risk avoidance

**Net impact on Safety/Environment:** Major positive. Reduce air toxic emissions, reduce risk of occupational exposure and PPE requirements; avoid constraints on operating durations due to air permit compliance.

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment – 80%.

**Regulatory Permitting/Licensing changes required:** Class 2 or 3 RCRA permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - May have to do PS-9 to do PS-4 (possible permit condition for processing sludge in-tank)
b) Positive reinforcement - PS-9 makes PS-4; PS-2; PS-6; overall baseline WR&T better.
c) Mutually exclusive – N/A

**Potential Applicability to Other Sites:** N/A

**Does the technology help buy down a Mission Risk?** Risk of reduced TOE for retrievals, evaporators, and processing without air toxics abatement.

**PS-9**

**Identify the category of the potential concept:** 2) Incremental solution – fits in the existing baseline flowsheet or could be a change that is incremental to the existing flowsheet but could fit as addition to existing ventilation upgrades for the tank farms. 3) Transformational – change in the baseline and has a mid-range cost.

**Technology Insertion Time Frame:** 5-10 years, Driver for implementation may be significant increase in tank retrieval operations, or in-tank sludge processing with increased potential for air toxics emissions

**References:** N/A

**Contact:** Tom Brouns - PNNL

## NNLEMS Hanford Tank Waste Mission Acceleration Team

**Concept ID:** IF-14 Remote Automated Systems (Mission Enablers)

**Gap or Opportunity Addressed:** Robotic systems could improve efficiency of tank farm and waste processing/ immobilization operations and reduce exposure of workers to process hazards, such a tank vapors. These systems may allow operations during periods where exposure levels preclude hands-on work or reduce the time needed to complete tasks to lower exposure.

**Technology Idea or Concept:** Develop or adapt robotic systems to assist or replace hands-on work at Hanford. Robotic systems could be used to replace workers for selected tasks or could be used to assist workers for tasks that are not completely automated. Systems to be evaluated include autonomous systems that could perform rounds and other simple tasks to wearable devices that augment worker abilities.

The functionality of robotic systems is changing rapidly, and it is expected that a continued development of robotic systems would allow an increasing number of tasks to be performed without workers exposure.

**Existing Funded Program:** The existing Hanford TD program has funded tasks for robotics, EM-HQ is funding a multi-year DOE-EM Exoskeleton Testbed initiative headed by SNL and additional research is being performed by DOE-EM at a number of other national laboratories. In addition, the DOE-EM Inter-Agency Agreement (IAA) allows DOE to keep abreast of work in robotics in a number of other government agencies.

| ***WRPS Programs*** | | ***Grand Challenges Connection*** | ***Comments*** |
|---|---|---|---|
| *Funded* | *Unfunded* | | |
| *RTW-08 FUNDED* | *MTW-80<br>MTW-84<br>MTW-85<br>MTW-89<br>MTW-98<br>RTW-03<br>RTW-43<br>RTW-53<br>PTW-39<br>MW-10* | *2015-08, Use of Sonar and Ultrasound to Quantify Solids in Double-Shell Tanks* | |
| | | *2015-17, LAW Carbon Bed Carbon Filter Media Removal* | |
| | | *2015-18, Cockpit Operated Robotic Environment* | |

**IF-14**

| | | | |
|---|---|---|---|
| | | *2015-23, A new mobile and portable multiple-wavelength differential absorption LIDAR (DIAL) for real-time detection and reporting of gases and vapors from the tank farms at Hanford* | |
| | | *2015-30, Rapid Routine Real Time Mobile COPC Monitoring to Assure Worker Health & Safety at Hanford* | |
| | | *2015-37, Remote Wireless Video Monitoring for Reduce Worker Exposure* | |
| | | *2016-06, Implementing a Machinery Control & Monitoring System (MCMS) Offsite Test and Evaluation Facility (OTEF)* | |
| | | *2016-07, Traditional Secure Hybrid Tablets with Augmented Reality Capabilities* | |
| | | *2016-14, P-Scan Stack Phased Array System for Tank Inspection* | |
| | | *2016-17, A Steerable Needle for Inspecting the Hanford Tanks' Ventilation Ducts* | |
| | | *2016-30, Waste Tank Integrity Inspection via Air Flow Channels to Center Plenum* | |
| | | *2017-15, Demonstration of a Radiation Tolerant Multi-Use Manipulator System for Inspection and Repair of Double Shell Tanks* | |
| | | *2017-16, Remote System for Inspection and Maintenance of Hard to* | |

| | | | |
|---|---|---|---|
| | | *Reach (HTR) Pipe Work and Vessels in Nuclear Plant* | |
| | | *2017-18, 3-Dimensional Flash LIDAR to Map Waste Tanks* | |
| | | *2017-19, Wireless Remote Video Monitoring with Automated Visual Recognition* | |
| | | *2017-20, High-TRL Robotics for WTP PT Facility Black Cells Inspection & Repair* | |
| | | *2017-31, Hanford Mobile Robotic In-Tank Monitoring Platform* | |
| | | *2018-18, Development of an Industrial Steerable Needle to Support Tank Operations and Maintenance* | |

**Connectivity to other Gap, Opportunity, or Concept:** Concept ID J-38, While robotics could be used to aid processing throughout the waste treatment process, tank farm operations for waste retrieval and staging represent a focus area as operations can be limited by tank vapor exposure potential, high winds, high heat, radiological exposure hazards, or other environmental conditions that limit the ability for workers to perform tasks in the tank farms.

**Proposed Technology – Technical Maturity/Process Simplicity:** Concept/Demonstration

Robotic systems, including autonomous systems, have been adapted for use in numerous industries and commercial systems are available that could be adapted for use. In the DOE complex, remote operations in shielded cells and canyon facilities have been in use for decades, but these applications adapt the process to the available robotic tools rather than adapting the robotics to the process that is needed for wider use.

The ability of autonomous robotics to perform simple tasks such as performing visual and radiological inspections has a high technical maturity. As the complexity of the tank waste retrieval at some tanks (leakers) is greater than others, the technical maturity of COT's robotics solutions decreases as specialized adaptations become necessary. These adaptations require site specific development of the needed capabilities and testing to ensure functionality and safety requirements are met.

**Complexity:** a) Unit operation - All tank farm unit operations b) Medium integration required

**IF-14**

**Projected Timeline for Go/No-Go Technology Deployment Decision (technology-specific):** <5 years

**Estimated Costs to get to Go/No-Go Technology Deployment Decision:** Medium ($10M - $50M)

**Deployment Costs (required funding):** a) Pilot scale /demonstration - $25 M. b) Initial full-scale demonstration - $100M

The costs assume pilot scale demonstration and deployment of a robotic system capable of performing valving lineups and other simple processing tasks.

**Additional investment over life cycle of Hanford mission:**

a) Repeated deployment costs $2-5M/year
b) Operating costs N/A
c) Other costs incurred above baseline technology N/A

**Estimated Duration for Deployment/construction/commissioning (to first operation) post Go/No Go Decision:** Quick (<5 years)

**ROM net Cost Savings over the life cycle**:

a) Annual costs $60M
b) Peak cost $100M
c) Total potential savings $2.3 billion

The cost estimates assume a 5% overall savings in operating cost per year after deployment of robotic technology.

**Schedule Acceleration of the Hanford Mission**: Development of robotic systems to replace or augment workers mitigates the risk of Tank Farm work delays due to worker exposure concerns and could be applied to worker performed functions in the WTP as well.

**Net impact on Safety/Environment:** Minor Positive

**Project and Technical and Engineering Risks of Deploying the Proposed Technology:** Estimated probability of successful deployment - 100%

**Regulatory Permitting/Licensing changes required:** Assuming operation under final status RCRA permit, this requires class 2 permit mod, 2-3 years

**Synergies of the Proposed Technology with other proposals or the baseline flowsheet:**

a) Dependency with other - N/A
b) Positive reinforcement - Could be coupled with other robotic efforts
c) Mutually exclusive - N/A

**Potential Applicability to Other Sites:** Applicable across DOE complex

**IF-14**

**Does the technology help buy down a Mission Risk?** Development of robotic systems to replace or augment workers mitigates the risk of Tank Farm work delays due to worker exposure concerns and could be applied to worker performed functions in the WTP as well.

**Identify the category of the potential concept:** 2) incremental solution – some fit existing baseline/flowsheet but maybe not all. 1) risk mitigation-not schedule driven but protect the schedule

**Technology Insertion Time Frame:** 5-10 years

**References:** N/A

**Contact:** Paul Dixon - LANL

# Appendices

# Appendix A: Phase 1 Information

A cursory review of the following types of documents was performed to provide a foundation for the review:

- Studies performed to evaluate flowsheet options like DFLAW and DFHLW from the contractors and DOE
- Analyses of Alternatives for the overall Hanford Tank Waste mission and individual unit operations
- System Plan and life cycle planning and closure documents
- National Laboratory or directed institution studies performed on potential technology gaps and process improvements
- Tank waste roadmaps, science & technology roadmaps for EM and Hanford, and the integrated RPP mission gap and analyses documents

A bibliography of the documents reviewed, and the presentations provided by ORP and its contractors is provided below. Information from this review provided the initial ideas for the brainstorming efforts and allowed the core team members to have an understanding of past efforts and DOE's current priorities. The gaps, opportunities, ideas, and comments captured from the cursory review of the background documents are provided in Table A - 1.

**Bibliography of Reference Documents**

Documents

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"Initial Direct LAW Potential Gaps, Open Issues, Uncertainties and Improvements," PNNL- Peterson & SRNL-Wilmarth, *PNNL-SA-96639/ SRNL-L3100-2013-00060*, 04/2013

"ORP SFM Draft Documentation," MITRE

"ORP Systems Flow Model Use Case Scenarios," MITRE, 03/2016

"Preconceptual Engineering Study for Direct Feed High-Level Waste," WRPS-Esparza, *RPP-RPT-53225*, 09/2012

"Preliminary Assessment of the Hanford Tank Waste Feed Acceptance and Product Qualification Programs," PNNL-Peterson & SRNL-Herman, *PNNL-22116 / SRNL-STI-2012-00776*, 03/2013

"Preliminary Assessment of the Low-Temperature Waste Form Technology Coupled with Technetium Removal," PNNL-Brown & SRNL-Wilmarth, *PNNL-22103, Rev. 1 / SRNL-STI-2013-00002*, 05/0214

"Report of Analysis of Approaches to Supplemental Treatment of Low-Activity Waste at the Hanford Nuclear Reservation," EM Lab Network, *SRNL-RP-2018-00687*, 10/2019

"River Protection Project System Plan - Retrieve and Treat Hanford's Tank Waste and Close the Tank Farms to Protect the Columbia River," *WRPS/AEM, ORP-11242 Rev. 8,* 10/2017

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"CH-TRUM Waste Packaging Unit Dewatering System Technical Symposium," CH2M Hill- Tedeschi & DMJM Tech-Wiemers, *RPP-22232-VA Rev.0,* 07/2004

"Hanford Contact-Handled Transuranic Tank Waste Project: Project Background and Results of 2014 Qualitative Alternatives Analysis for SEE Group," WRPS-Tedeschi, 01/2018

"Hanford Tank Waste to WIPP - Maximizing the Value of our National Repository Asset," WRPS - Tedeschi & Wheeler*, WRPS-55779 -FP Rev. A,* 11/2013

"Procurement Specification for CH-TRU Mixed Waste Packaging Unit and Support Equipment," CH2M Hill- Leonard, *RPP-15048 Rev. 1*, 06/2003

"Supplemental Technology Contact Handled TRUM Packaging," Req #96249, 06/2003

"Technology and Innovation Roadmap," RPP-PLAN-43988_-_Rev_05.pdf

An Evaluation of Alternate Tank Waste Disposition Pathways.pdf

"Request for an Expression of Interest - Treat Hanford Contact-Handled Transuranic Tank Waste," WRPS-55519, 07/2013

"Basic Research Needs for Environmental Management, Report of the Office of Science Workshop on Environmental Management", DOE Office of Science, PNNL-25166, February 2016.

<u>Presentations</u>

"Hanford Low-Activity Waste Flowsheet", WRPS-Wagnon, 5/3/2021

"HLW Analysis of Alternatives," WRPS – Schubick, Sams, and Reaksecker, 5/3/21

"System Plan 9 Baseline Case," WRPS - Schubick, Sams, and Reaksecker, 5/3/21

"Hanford Site Enterprise Risk Management," ORP, 6/16/2021

"Multiple Disposition Pathway Flowsheet," WRPS-Britton, 6/16/2021

"Technology and Innovation Roadmap, Reducing Risk Through Technology Development," WRPS-Reid, 6/16/21

<u>Grand Challenges</u>

"2013_2 Supplemental Treatment Process Option," WRPS - Chris Burrows

"2013_3 Waste Treatment as Source," ORP - Isabelle Wheeler

"2014_4 Simplified Disposition of Direct Feed Low Activity Waste Effluent," WRPS - Paul Cavanah

"2014_10 Tank Waste Cesium Removal and Immobilization with Crystalline Silicotitanate," SRNL -Dan McCabe

"2014_11 Double Shell Tank Waste Space Gain," SRNL - Dan McCabe

"2014_13 Develop Basis to Support Future Risk-Informed Retrieval, Cleanup and Closure Decision Making," WRPS - Susan Eberlein

"2014_14 Subsurface Grouting Environmental Protection System," Energy Solutions - Bowan

"2014_16 Acquire Additional DST Space Through RMF Demonstration of Washing for Hanford Sludge Simulant," SRNL - David Herman

"2014_17 Salt Cake Waterless Retrieval System for Moving Slurry Across Site," SRNL - David Herman

"2014_19 TC Chemistry in Tanks and Impact on Waste Transfer and Supplemental Treatment," LANL

"2014_21 Cross-flow filtration (CFF) and Caustic-Side Solvent Extraction (CSSX)," Other

"2014_22 Geochemical Testing and Model Development – Residual Tank Waste," PNNL

"2014_25 Continuous Sludge Leaching in WTP Pretreatment Facility," PNNL

"2014_26 HLW Direct Vitrification," PNNL

"2014_28 Metal Organic Frameworks for Selective Removal of TcO4- from Low-Level Nuclear Waste," PNNL

"2014_29 Risk-Based Tank Retrieval and Closure of Hanford Waste Tanks," PNNL

"2014_31 Tank Waste Cesium Removal and Immobilization," PNNL

"2014_33 Nepheline Circumvention," PNNL

"2014_36 Maturation of Technetium Separation Technology," PNNL

"2014_37 Proposed IN-SITU Permeable Reactive Barrier to Mitigate Hanford Single- and Double-Shell Underground Tank Leaks," SNL-Mark Rigali, WRPS - Karthik Subramanian

"2014_39 Increased LAW Vitrification Facility Capacity," ORP - Albert Kruger

"2014_40 Separation and Vitrification of Cesium and Strontium in a Pretreatment Process," SNL - Mark J. Rigali

"2014_41 In-Line Solids Classification," PNNL

"2014_44 LAWPS + EMF + Offsite Sr Removal," WRPS

"2015_1 Alternative Engineering Strategy for WTP," ANR - Hannah Gallaghe

"2015_8 Use of Sonar and Ultrasound to Quantify Solids in Double-Shell Tanks," PNNL - Judith Bamberger

"2015_11 Using a High Pressure, Low Flow Rate Scarifier to Fragment Solids Coupled with Pneumatic Conveyance to Retrieve the Solids and Cutting Fluid Slurry with Reduced Fluid Use and Reduced Solids Dissolution in Leak prone SSTs," PNNL – Judith Bamberger and Carl Enderlin

"2015_12 HLW Direct Vitrification," PNNL - John Vienna

"2015_15 Tank Waste Radionuclide Removal and Immobilization Options Evaluation," SRNL - Daniel J. McCabe

"2015_16 In-Situ Radiological Characterization of HLW Tank Residues," SRNL - David DiPrete

"2015_20 Phased Deployment of NitroJet Technology with Columbia Energy's MARS for Hanford HLW Tank Hard Heel Removal," FIU - Leo Lagos

"2015_21 Methods to Acquire Additional DST Space," ORP - Jeremy Johnson

"2015_27 Cesium Removal and Interim Storage in support of Direct Feed to LAW," SRNL, Kurion

"2015_28 MARS-V Alternative and Dry Method for Waste Gathering," SRNL - Marc Rood

"2015_29 Swellable glass tailored for cesium and strontium sequestration for Hanford tank waste," LANL - Hakim Boukhalfa

"2015_35 Eliminate Regulated Organics from LAWPS/WTP Waste acceptance Criteria," WRPS - Renee Spires

"2015_39, Criticality Preventing Additive, INL - David Pernhard

"2016_11 In-line Mesofluidic Bump Arrays to Remove Large Particles from Noncompliant Waste Streams," PNNL - Leonard Pease

"2016_12 Reducing Liquid Introduction to SST Retrieval by Scarification," PNNL - Judith Bamberger

"2016_18 Techno-economic Assessment of Nitrate Destruction Options for Hanford Tank Waste," PNNL - Tom Brouns

"2016_23 Application of Commercial Mining Technology for Waste Retrieval of TRU for Disposal at WIPP," SRNL - David Herman

"2016_24 Mercury Abatement Technology, SRNL - M. E. Stone

"2016_26 AT-Tank Cesium Removal," Kurion - Matt McCormick

"2016-30, Waste Tank Integrity Inspection via Air Flow Channels to Center Plenum," SRNL

"2016_31 AT-Tank IX Column and Transportable Vitrification System for Hanford West Area Treatment," SRNL - David Herman

"2016_34 Optimization of Sodium Concentration in DFLAW Feed," ORP - Sahid C. Smith

"2017_2 Risk Informed Retrieval and Closure Strategy," WRPS - Marcel Bergeron

"2017_7 Development of a reductive separations process for Tc from the LAW Off-Gas Condensate via ZVI (Zero Valent Iron)," FIU - Yelena Katsenovich

"2017_11 Flowsheet Development to Support Dry Retrievals for Hanford Transuranic (TRU) Tanks," SRNL - David Herman

"2017_22 At-tank technetium and iodine removal and disposition," SRNL - Marissa Reigel

"2017_24 Ammonia Remediation Supporting Hanford WTP Secondary Waste Processing," SRNL -Charles Nash

"2017_32 Ammonia Getters for Liquid Secondary Waste Grout Formulations," PNNL - Tatiana Levitskia

"2017_33 Borehole Miner (BHM) Extendible-Nozzle System for Cleaning Tank Walls, In-Tank Hardware, and Floor Integrated with Optical Sensing to Identify Areas to Clean," PNNL - MJ Minette

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"2018_1 Hanford Waste Chemistry Book Project," WRPS - Jacob Reynolds

"2018_3 Treatment and Disposal of WTP Solid Secondary Waste," SRNL - Alex Cozzi

"2018_5 Waste Incidental to Reprocessing: West Area Opportunities for Low-Activity Feed (WIR-WOLF)," SRNL - Mike Stone

"2018_6 Disposal Path Determination for Crystalline Silicotitanate after use in LAW Processing," SRNL - Daniel McCabe

"2018_8 DST Leak Repair Method," SRNL - Daniel McCabe

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"2018_19 Accelerating Single-Shell Tank Retrieval and Closure by Combining In-Tank Characterization, Monitoring, and Enhanced Chemical Stabilization," PNNL - Carolyn Pearce

"2018_20 Cementitious Immobilization of Treated LAW and Ancillary Benefits to Risk Reduction in Cross-Site Transfer," PNNL - Matthew Asmussen

"2018_22 Identification of Alternative Non-Elutable Ion Exchange Media for the DFLAW Mission," PNNL - Philip Schonewill

"2018_24 In-Tank Particle Removal using Mesofluidic Bump Arrays (No out-of-tank filtration required)," PNNL - Leonard Pease

"2018_25 Chemically bonded phosphate ceramics for encapsulation of secondary solid waste," WRPS - David Swanberg

"2018_26 Petrographic Laboratory to Support Cast Stone Development Incorporating Cesium-Loaded Crystalline Silico-Titanate (CST) from Tank Side Cesium Removal (TSCR) and other Secondary Waste Streams," WRPS - Gary Cooke

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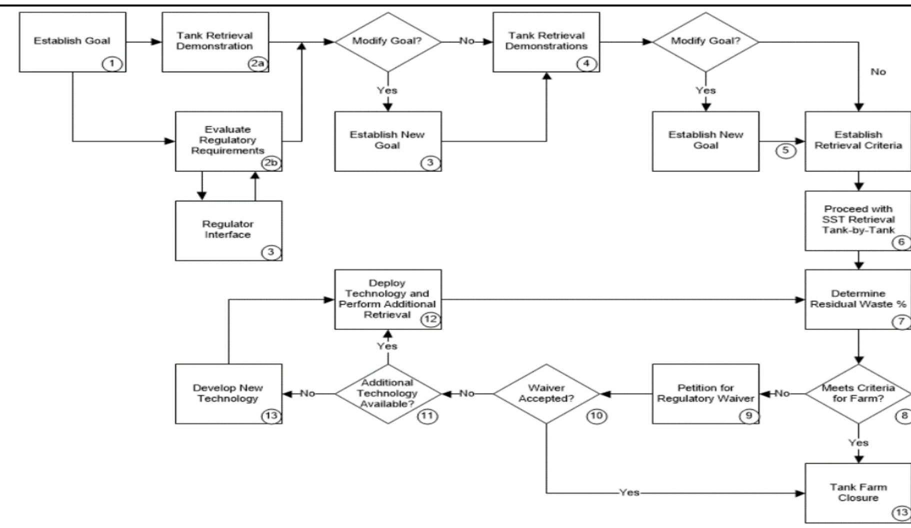
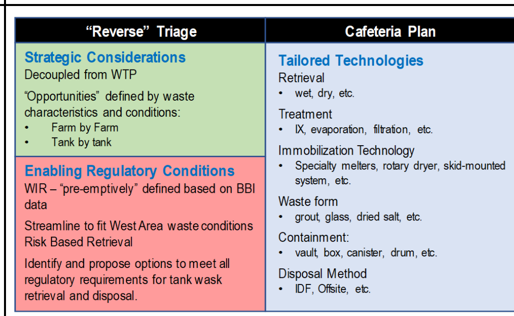
| Document Number/Title | Citation Location (page, section) | Concept, Idea and Comments | Treatment Pillar | | | | Anticipated Focus Area | | | | | | Enabling Technologies | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HLW Treat & Disp | LAW Treat & Disp | TRU Waste Disp | Solid & Secondary Waste Disp | Tank Waste Retrieval | Pre-treat/ Feed Prep | Immob Form & Processing | Waste Disposal | Reg Comp | FS Cost & Schedule Analysis | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| Analysis of Alternatives Addendum Waste Treatment and Immobilization Plant High-Level Waste Treatment (ALTERNATIVE 18) BPA Number: DE-NA0002895 Order Number: FNA000043 | 3.2.15 | Retrieval of SW Quadrant SSTs.<br>The SW Quadrant SSTs (S, SX, and U Tank Farms) will be retrieved immediately after completion of the SE Quadrant SSTs. The retrieval sequence will be prioritized based on highest inventory of Tc-99 and I-129 per retrieved solids volume. Since the S, SX, and U tank Farms are located near the SY Tank Farm, HIHTLs are planned to be used to transfer the retrieved bulk slurry to SY-102 (or SY-103). The solids and liquids will be separated by settling and decant operations in the receiving DST. | | | | | X | | | | | | | | | | |
| Analysis of Alternatives Addendum Waste Treatment and Immobilization Plant High-Level Waste Treatment (ALTERNATIVE 18) BPA Number: DE-NA0002895 Order Number: FNA000043 | 3.3.1 | RETRIEVAL OF NE QUADRANT SSTS<br>The NE Quadrant SSTs include the SSTs in the B, BX, and BY Tank Farms (referred to as "B complex"). These tank farms are located too far away from the SY Tank Farm to make HIHTLs practicable for transferring the retrieved waste using above-ground HIHTLs. The East Area WRF will provide new waste storage tanks and below grade pipe-in-pipe waste transfer lines to connect between the B complex and the WRF and between the WRF and the appropriate DST tank farm in the SE Quadrant.<br>Retrieval of the SSTs in the B complex starts in 2050, which is coincident with the start of operations in the higher capacity LAW treatment and HLW pretreatment facilities. As discussed in Rev 2 of the Model Results Report1, retrieval of the B complex SSTs will continue until 2071, which is 5 years before completion of tank waste treatment for Alternative 18. | | | | | X | | | | | | | | | | |
| Analysis of Alternatives Addendum Waste Treatment and Immobilization Plant High-Level Waste Treatment (ALTERNATIVE 18) BPA Number: DE-NA0002895 Order Number: FNA000043 | 3.3.21 | RETRIEVAL OF NW QUADRANT SSTS<br>The NW Quadrant SSTs include the SSTs in the T, TX, and TY Tank Farms (referred to as "T complex"). These tank farms are located too far away from the SY Tank Farm to make HIHTLs practicable for transferring the waste received. The West Area WRF will provide new waste storage tanks and pipe-in-pipe waste transfer lines to connect between the T complex and the WRF and between the WRF and SY Tank Farm.<br>As was the case for Phases 1 and 1B, the retrievals will be sequenced by tank farms and by individual SSTs within the tank farms to prioritize retrieval of the highest risk tanks first. Retrieval of the SSTs in T complex will start in 2055, which is coincident with completion of the SST retrievals in the SW Quadrant. Retrieval of the T complex SSTs will continue until 2068, which is seven years prior to mission completion for Phase 2. | | | | | X | | | | | | | | | | |
| Technology and Innovation Roadmap (2021) | RTW-39 | A volume-based retrieval standard has been used as defined in the<br>Tri-Party Agreement and Consent Decree. Single-shell tanks {SSTs} vary significantly in their risk characteristics. Retrieving tanks that do not pose a significant risk increases mission cost and increases worker exposure.<br>The objective of the work is to develop an analysis capability that would provide the technical basis for DOE to apply a risk-informed strategy for future tank retrievals and closures. | X | X | X | | X | | | | X | | X | | | X | |
| Grand Challenge 2014 (RISK-BASED TANK RETRIEVAL AND CLOSURE OF HANFORD WASTE TANKS) | LANL/PNNL | Milestone M-45-00 of the Tri-Party Agreement (TPA) specifies that closure of Hanford's 149 single-shell tanks (SSTs) will occur after retrieval of as much tank waste as technically possible. The retrieval goals are based on volume and do not take into consideration the risk posed by the residual waste in the SSTs. A 2010 Consent Decree with the state of Washington imposes additional requirements including deployment of up to three retrieval technologies to the "limits of technology" in an effort to reach the residual volume goal. Because of the recalcitrance of tank waste solids, a typical SST retrieval campaign requires deployment of up to three successive waste retrieval technologies at costs reaching $20 million per tank.<br><br>The proposed approach requires collecting and analyzing actual interim tank waste samples after successive tank retrieval campaigns to determine radionuclide release rates, and development of realistic waste tank degradation and an environmental release and transport model to evaluate dose and risk. | X | X | X | | X | | | | X | | X | | | X | |

| Document Number/Title | Citation Location (page, section) | Concept, Idea and Comments | Treatment Pillar | | | | Anticipated Focus Area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HLW Treat & Disp | LAW Treat & Disp | TRU Waste Disp | Solid & Secondary Waste Disp | Tank Waste Retrieval | Pre-treat/ Feed Prep | Immob Form & Processing | Waste Disposal | Reg Comp | FS Cost & Schedule Analysis | Enabling Technologies | | | | |
| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| Technology and Innovation Roadmap (2021) | RTW-52 | Hazardous and radioactive tank waste has migrated to the groundwater from surface spills and tank leaks, due to years of waste: storage, transfer and retrieval. There is a potential for future spills, tank leaks and active migration of past and future leaks. **Barrier technology** would provide a boundary between the waste source and ground water. The barrier would immobilize contamination at the surface, in the tanks or beneath the tanks, preventing waste from reaching the ground water. For leaker-tanks, this technology would allow the use of conventional and new retrieval methods. | X | X | X | | X | | | | X | | X | | | X | |
| Technology and Innovation Roadmap (2021) | RTW-56 | Getters: An alternative Hanford tank closure option would be to use **effective in-tank chemical stabilization of risk- driving contaminants** that supports the use of technically defensible tank retrieval endpoints and demonstrates significant reduction of risk to human health and the environment. | | X | | | X | | | | X | | X | | | X | |
| Technology and Innovation Roadmap (2021) | Tank Retrieval Flow Sheet |  | | | | | X | | | | | | | | | | |
| SST Drainable Liquid (RPP-RPT-60305 rev1) | | | X | X | X | | X | | | | | | | | | | |
| SST Retrieval (RPP-Plan-40145 rev7) | |  Fig. 1. Comparison of Predicted and Actual Waste Retrieval Rates from Tank C-103 | | | | | X | | | | X | | | | | | |
| Grand Challenge 2016: (Application of Commercial Mining Technology for Waste Retrieval of TRU for Disposal at WIPP) | | | | | X | | X | | | | X | | | | | | |
| Application of Commercial Mining Technology for Waste Retrieval of TRU for Disposal at WIPP (RPP-20658, Revision 3) | | | | | X | | X | | | | X | | | | | | |

| Document Number/Title | Citation Location (page, section) | Concept, Idea and Comments | Treatment Pillar | | | | Anticipated Focus Area | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HLW Treat & Disp | LAW Treat & Disp | TRU Waste Disp | Solid & Secondary Waste Disp | Tank Waste Retrieval | Pre-treat/ Feed Prep | Immob Form & Processing | Waste Disposal | Reg Comp | FS Cost & Schedule Analysis | Enabling Technologies | | | | |
| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| Technology and Innovation Roadmap (2021): Single-Shell Tank Waste Retrieval Criteria Procedure | Appendix H | | | | X | | X | | | | X | | | | | | |
| Grand Challenge 2017: Flowsheet Development to Support Dry Retrievals for Hanford Transuranic (TRU) Tanks. | | 3 wash technology requirement will remove 99% slurry, but leaves some "hard heal". What is RAD risk to leave very hard to retrieve waste?? | | | | | X | | | | X | | | | | | |
| Grand Challenge 2016: West Area Retrieval, Treatment, and Immobilization (WARTI) | | West Area Retrieval, Treatment and Immobilization (WARTI)<br>Incorporates evaporation, filtration, cesium removal, and immobilization into the WRFs<br>Specific technologies selected would be dependent on the tank waste to be treated by each WARTI facility<br>Baseline technologies<br>Caustic Adjustment / Dissolution – Continuous Stirred Tank Reactor **(Assumes nonleaker tanks and low water retrievals)**<br>Evaporation – Wiped film evaporator<br>Filtration – Rotary Microfilters<br>Cesium Removal – CST resin<br>LAW immobilization process– Grout<br>HLW immobilization process - Vitrification | X | X | X | | X | | | | X | | | | | | |
| Grand Challenge 2018: Waste Incidental to Reprocessing – West Area Options for Low Activity Feed (WIR-WOLF) | |  | X | X | X | | X | | | | X | | | | | | |
| Grand Challenge 20?? : Tank Integrity (PNNL: Proposal) | | | | | | | X | | | | X | | X | | | | |
| Basis for Exception to the Hanford Federal Facility Agreement and Consent Order Waste Retrieval Criteria for Single-Shell Tank 241-C-106 (RPP-20658 Revision 3) | | In response to HFFACO, Appendix H, Attachment 2, Criterion 3, an analysis of available additional alternative waste retrieval technologies was completed and is summarized in Section 2.2. This analysis compares four alternatives for deployment of additional available retrieval technologies (i.e., two modified sluicing alternatives under alternative configurations, the mobile retrieval system, and modified sluicing followed by use of the vacuum retrievalsystem). The alternatives evaluation includes documentation of the cost and schedule for each alternative as well as comparative analysis of the relative performance against waste retrieval functions and six criteria [i.e., cost, schedule, risk to workers, risk to human health and the environment (i.e., impacts to groundwater quality), ease of implementation, and impact on the River Protection Project mission]. The analysis shows there is sufficient uncertainty about whether the deployment of available alternative technologies would reduce the waste volume remaining in single-shell tank 241-C-106 to the HFFACO retrieval criteria and that no further consideration of deployment is warranted. | X | X | X | | X | | | | X | | X | | | X | |

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| | | | HLW Treat & Disp | LAW Treat & Disp | TRU Waste Disp | Solid & Secondary Waste Disp | Tank Waste Retrieval | Pre-treat/ Feed Prep | Immob Form & Processing | Waste Disposal | Reg Comp | FS Cost & Schedule Analysis | Enabling Technologies | | | | |
| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| [GC] 2017 At-Tank Tc and Iodine Removal … | throughout | Tank-side iodine and technetium removal | | x | | | x | x | | | | | | | | | |
| [GC] 2018 19. Accelerating SST Retrieval … | throughout | In situ stabilization of tank residuals using zerovalent iron and silver nitrate | x | | x | | x | | x | x | | | | | | | |
| [GC] AT-Tank IX Column and Transportable Vitrification … | throughout | Tank-side cesium removal with CST followed by mobile vitrification of CST | x | x | | | x | x | x | | | | | | | | |
| [GC] Tank Waste Radionuclide Removal and Immobilization Options Evaluation | throughout | Alternative disposition paths for Cs, LAW immobilization, and disposal | | x | | | x | x | x | x | | | | | | | |
| Evaluation of Alternative Strontium and Transuranic Separation Processes. RPP-RPT-48340, Rev. 0 | throughout | For the few tanks with high dissolved organically-complexed 90Sr, precipitate the 90Sr by adding KMnO4 and non-radioac+C34tive Sr. | | x | | | x | x | | | | | | | | | |
| [GC] Application of Commercial Mining Technology for Waste Retrieval of TRU for Disposal at WIPP | throughout | Use commercial mining/packaging technologies to remove/send waste from the TRU-containing tanks to WIPP | x | | x | | x | | x | x | x | | | | | | |
| [GC] Cementitious Immobilization of Treated LAW and Ancillary Benefits to Risk Reduction in Cross-Site Transfer [and references] | Current State of Development | Lowering in situ redox in grout stabilizes many radionuclides; adding sulfide getters decreases Tc release; other additives **discussed in references**. | x | x | x | | x | | x | | | | | | | | |
| RPP-PLAN-58003, Rev 02 One System River Protection Project Integrated Flowsheet Maturation Plan | pg. 5-6 | Need better Al solubility model to aid Al extraction | | x | | | x | x | | | | | | | | x | |
| NAP The Hanford Tanks: Environmental Impacts and Policy Choices (1996) | Exec. Summary | Need (1) in-tank waste stabilization methods that are intermediate between in situ vitrification and filling of the tanks with gravel, (2) subsurface barriers that could contain leakage from tanks, and (3) selective partial removal of wastes from tanks, with subsequent stabilization of residues, using the same range of treatment technologies as in the alternatives involving complete removal of wastes. | x | | | x | | | x | | x | | | | | | |

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| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| NAP The Hanford Tanks: Environmental Impacts and Policy Choices (1996) | Exec. Summary | Need research on subsurface containment barriers [vertical and horizontal], other materials and processes for stabilizing wastes left in the tanks, and a range of waste forms for the low-activity materials separated from the wastes removed from the tanks | x | | x | x | | | x | x | | | | | | | |
| NAP The Hanford Tanks: Environmental Impacts and Policy Choices (1996) | Exec. Summary | Must not consider tanks in isolation. Long-term leaching of what is left behind important too. | x | | x | | | | x | | x | | | | | | |
| NAP The Hanford Tanks: Environmental Impacts and Policy Choices (1996) | pg. 53 | Use bentonite to retard radionuclide movement from the interstices of stabilized [partially emptied] tanks? | | x | | | | | x | | | | | | | | |
| NAP The Hanford Tanks: Environmental Impacts and Policy Choices (1996) | Exec. Summary | What to do with the Cs/Sr capsules [~ 1/3 of the radioactivity at Hanford]? | x | | | | | | | x | | | | | | | |
| NDAA 3134 Supplemental Low Activity Waste FFRDC Team Study Overview [2018] | G. Guthrie pres. | I and Tc retardation in cast stone important question for IDF disposal | | x | | x | | | x | x | | | | | | | |
| Hanford Tank Waste to WIPP - Maximizing the Value of our National Repository Asset (WRPs-55779-FP, Rev A)/Hanford Contact-Handled Transuranic Tank Waste Project | General | Waste from original Bismuth-Phosphate 2nd decon cycle and Pu concentration processes where segregated in 200 West and 200 East tank farms. Never co-mengled with HLW. Options for disposition as CH-TRU (1.4M gallons) at WIPP (and to lesser extent WCS) have been investigated since 2003. Mostly hung up with regulatory issues: RCRA, NEPA, WIPP Part B that restricts DOE tank waste from going to WIPP, ESI, etc. CH-TRU disposition at WIPP rather than as HLW estimated to save 900 gal LAW glass canisters and 900 gal HLW glass canisters and $1.7B for CH-TRU waste (similar savings excepted for same volume of RH-TRU). | | | x | | x | | x | x | x | x | | | | | |
| Hanford Contact-Handled Transuranic Tank Waste Project | Slide 48 | Original concept used water sluicing and vacuum drying. Tested full-scale dryer system as part of DBVS project in FY07 with S-109 simulant (RPP-RPT-32739). Options analysis indicates reducing volume beyond that achieved by vacuum drying is of limited value. Retrieval/treatment systems resulting in larger volumes to WIPP increase costs significantly | | | x | | x | | x | x | | x | | | | | |
| Hanford Tank Waste to WIPP - Maximizing the Value of our National Repository Asset (WRPs-55779-FP, Rev A | Page 11 | Standard sluicing and vacuum retrieval systems will be non-capital asset. New retrieval technologies likely to make capital asset with DOE Order 413.3B applying. Treatment/packaging will likely be capital asset with technology readiness demonstrations required. | | | x | | | | | | | x | | | | | |
| SRNL-RP-2018 Hanford SLAW | Page 10/11/31 | Alternatives to vitrification for SLAW considered are grouting and steam reforming for disposal on-site and off-site at WCS. Grouting is the cheapest & quickest to implement. Might require organics pretreatment for on & off-site disposal and Iodine mitigation for on-site disposal. | | x | | | | x | x | x | x | x | | | | | |

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| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| SRNL-RP-2018 Hanford SLAW | Page 11/31 | Investigation of high performing grouts could reduce the need for iodine & technetium pretreatment for on-site disposal for SLAW | | x | | | | x | x | x | x | x | | | | | |
| SRNL-RP-2018 Hanford SLAW | Page 11/31 | Treatment of organics restricted from land disposal should be investigated for grouting for on and off-site disposal for SLAW. | | x | | | | x | x | x | x | x | | | | | |
| SRNL-RP-2018 Hanford SLAW | Page 31 | A hybrid variant strategy was identified for future investigation is to treat only LDR-organic-compliant SLAW feed by grouting and non-compliant SLAW feed by vitrification | | x | | | | x | x | x | x | x | | | | | |
| SRNL-RP-2018 Hanford SLAW | Page 9/11/14 | Study found that disposal of secondary waste generated may be viable for off-site disposal and should be explored. Vitrification produces the secondary waste with the largest volume and highest curie content, which is evaluated as the dominant contributor to onsite disposal releases when vitrification is the primary wasteform. Treatment of liquid secondary waste from vitrification will be required | | x | | x | | | x | x | x | x | | | | | |
| Notes from 6/14 & 16 Telecons. Some may be inaccurate? | | Now using System Plan 9. Major change from System Plan 8 is TSCR will be used for 5 years | | x | | | | x | | | | | | | | | |
| Notes from 6/14 & 16 Telecons. Some may be inaccurate? | | Wanting to use risk based tank and farm closure - partial closure based on characterization at PA results (Iodine) but Ecology has some concerns. RCRA/CERCLA closure requirements for tanks vs soil | | | | | | | | | x | | | | | | |
| Notes from 6/14 & 16 Telecons. Some may be inaccurate? | | ETF limited by evaporator and will drive schedule. 30 years old and must last until 2060 | x | | | | | x | | | | | | | | | |
| Notes from 6/14& 16 Telecons. Some may be inaccurate? | | Mission duration driven by WTP pretreatment. LAWPS & WTP evaporating water in under capacity vitrifiers | x | | | | | x | | | | | | | | | |
| Notes from 6/14& 16 Telecons. Some may be inaccurate? | | Britton TD suggestions: filtration for cesium removal | | x | | | | x | | | | | | | | | |
| Notes from 6/14& 16 Telecons. Some may be inaccurate? | | Britton TD suggestions: Retrieving/transferring 20 wt% solid feed | x | x | | | x | | | | | | | | | | |
| Notes from 6/14& 16 Telecons. Some may be inaccurate? | | Britton TD suggestions: reduce characterization time from 120 day turnaround. | x | x | | | | | | | | | x | | | | |
| WTP HLW AoA Addendum Rev A - Alternative 18 | General | All HLW vitrified. Uses TSCR and off-site grouting with WCS disposal. Uses vit and grouting of LAW for IDF disposal. Phased implementation flowsheets on pages 16, 20, 26 of 105 | x | x | | | x | x | x | x | x | x | | | | | |

| | | | Treatment Pillar | | | | Anticipated Focus Area | | | | | | | | | | |
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| | | | | | | | | | | | | | Enabling Technologies | | | | |
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| WTP HLW AoA Addendum Rev A - Alternative 18 | 7 & 13 of 105 | Assumes grouted LAW can meet IDF disposal criteria without organic, Tc, I or nitrate treatment and permits can be obtained in a timely fashion. 2 HLW melters are installed and operate until end of mission | | x | | | | x | x | x | x | | | | | | |
| WTP HLW AoA Addendum Rev A - Alternative 18 | Page 10 of 105 | Comparison table of AoA options results for unconstrainted funding. Alternative 18 scored second highest of 8 alternatives. LCC $97B compared Alt 1 (near baseline) of $151B but with a HLW completion date of 2075 (9 years less than Alt 1 but 10 more years than most alternatives) for unconstrained budget scenario. | | | | | | | | | | x | | | | | |
| WTP HLW AoA Addendum Rev A - Alternative 18 | Page 71 of 105 | Alt 18 is not viable under the constrained budget scenario | | | | | | | | | | x | | | | | |
| WTP HLW AoA Final Report RevD Alts 1-17 | Page 69 or 270 | Only alternative that is feasible in constrained budget scenario is Alt 17. | x | x | | | x | x | x | x | x | x | | | | | |
| WTP HLW AoA Final Report RevD Alts 1-17 | Page 69 or 270 | In unconstrained case Alt 14 is best: low TPC, low relative risk, low LCC, and completes HLW treatment in same time frame as next best alternatives. | x | x | | | x | x | x | x | x | x | | | | | |
| WTP HLW AoA Final Report RevD Alts 1-17 | pg 75 of 270 | Except for Alt 17, alternatives provide similar processing functions but accomplished in different facilities (See Table 62 on pg 76 of 270). | x | x | | | x | x | x | x | x | x | | | | | |
| WTP HLW AoA Final Report RevD Alts 1-17 | pg 101 of 270 | Alt 14 description & flowsheet - HLW Pretreatment with Filtration and Effluent Management in New HFPEM Facility | x | x | | | x | x | x | x | x | x | | | | | |
| WTP HLW AoA Final Report RevD Alts 1-17 | pg 116 of 270 | Alt 17 description & flowsheet - DFHLW from DSTs without Effluent Management | x | x | | | x | x | x | x | x | x | | | | | |
| WTP HLW AoA Final Report RevD Alts 1-17 | pg 155 of 270 | Discusses modifications required at ETF to address Iodine, Tc, etc. | | x | | x | | | | x | x | | | | | | |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 5, Sect. 3.2 | Scenario (Alternative) 1 = Baseline Case in SP8. Volume of HLW feed is the same as baseline RPP SP. HLW Facility has to be sized for full feed vector vs. suggestion not to address all waste in one facility now. Start small.<br><br>Too expensive, but believe important to carry baseline forward for reference. | x | | | | | x | x | | | x | | | | | |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 6-7, Table 11 | Scenarios 2, 3, 4, and 8 = new HFPF or HFEM for feed prep and effluent management. 8 is to treat west wastes in west area. Consider dropping as major flowsheets - too high CAPEX and some limited value add (4). Should we consider a screening criteria for major pillar alternatives, different potentially than AOA, that includes CAPEX or annual budget threshold? Possibly 2X current annual budget. that are properly focused on "time for longer term. | x | | | | | x | x | | | x | | | | | |

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| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 6, Table 11 | Scenario 5 - Repurposed PT<br>Consider carrying forward - intuitively makes sense to consider retrofit rather than build new, but costs are on par with other options to screen out. | x | | | | | x | x | | | x | | | | | |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 6, Table 11 | Scenario 6 - Alternatives to Vit Screened out due to only vit screening criteria in AOA. But possibly limit to later phase after HLW has started and after waste determination using DOE M 435.1-1. | x | x | x | | | | x | x | | x | | | | | |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 6, Table 11 | Scenario 7 - Immobilize HLW in-situ<br>Suggest carrying as option. Risks associated with compliant RCRA waste disposal and closure may make it regulatorily untenable. Consider altern. screening criteria that allows for "out of the box options" with lower TRL consistent with our mission. | | x | x | | | | x | x | | x | | | | | |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 7, Table 11 | Scenario 10, 11 = transferring HLW to facilities significantly distant from tank farms.<br>These options were screened out for low maturity. I don't think we should use low maturity, but also don't think transporting liquid HLW the distances envisioned here make safety or cost sense. In addition, SRS DWPF would be at/over design life, and both WTP and DWPF were previously screened out in AoA for INL calcine due to transport acceptability issues), and retrofitting FMEF would seem equally difficult to doing so as PT. | x | | | | | | x | ? | | x | | | | | |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 7, Table 11 | Scenarios 12, 14 = repurpose PT for HLW vit, or new HFPEM facility for pretreat.<br>Don't believe either of these options aids in reducing costs/accelerating as major need for capital investment in major retrofit or new facilities. 12 screened out for not technically viable anyway. The alt. 14 HFPEM is used in Alt. 18 for phase 1. | x | | | | | x | x | | | x | | | | | |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 7, Table 11 | Scenarios 13 = HLW bulk vit<br>A DFHLW option in west area where HLW sludge is fed to a smaller west area in container vit system may have benefits. 13 screened out for low maturity. Don't think maturity is appropriate for this study. Lots of historic work with pros/cons of in-can melting. May be worth considering, especially if benefits to INL calcine also. But only for Hanford if could substantially reduce major capex facility in west area (unlikely). | x | | | | | | x | | | x | | | | | |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 7, Table 11 | Scenarios 15-16 - DFHLW with new HEMF<br>TPC not substantially different than baseline ($35 vs. $38), LCC $125M less than Scenario #1) | x | | | | | x | x | | | x | | | | | |
| 2021-04-16 - WTP HLW AoA Final Report RevD | Pg. 7, Table 11 | Scenarios 17 - DFHLW (single melter) without effluent management (washing in DST), No SLAW<br>Without SLAW and no effluent. Management, LCC balloons to $5 trillion. TPC substantially lower ($9B than all prior scenarios). | x | x | | | | x | x | | | x | | | | | |
| 2021-04-16 - WTP HLW AoA Addendum Rev A | | Scenario 18 - 2 HLW melters, $2.5B annual funding constraint. LAW grout to IDF - Phase 1, 1B, 2<br>Higher TPC ($20B) than Scen. 17, but lower than all others. Lowest LCC ($199B). This scenario should be a key one for study, but add some alternatives/options that may require more tech. maturation but further reduce TPC and LCC. Assume Phase 2 used DOE M 435.1-1 to determine disposition location for some farms (e.g., B, T) that could further reduce cost/timeline if implementable. | x | x | | | | x | x | x | | x | | | | | |

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| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| RPP-PLAN-43988 Technology and Innovation Roadmap Rev 6_ 13May21_MASTER | | R&D Roadmap associated with near term RPP priorities around tank integrity, DFLAW, secondary waste, retrieval, and in line monitoring as key areas of emphasis.<br>Good basis for near term gaps/issues/opportunities. Should be basic part of our roadmap since TOC and ORP have already accepted these as needed TD. Note that our focus area structure doesn't explicitly capture "manage tank waste", including integrity issues. May want to make that clearer. | | x | | x | x | x | x | x | | | | | | | |
| RPP-PLAN-43988 Technology and Innovation Roadmap Rev 6_ 13May21_MASTER | Sect. 6.0, Tables 6-1 through 6-5, page 6-1 | Future technology needs - not currently being pursued, but do address several items not in the near term DFLAW priorities… such as HLW, TRU, etc.<br>Warrants review/ranking to see where these fit in terms of potential ranking/impact. Carry those forward we believe are hitting critical pinchpoints. | x | x | x | x | x | x | x | x | | | | | | | |
| Kaylin Burnett overview | | Need to consider risk based closure for the tank farms | | | | | x | | | | x | | | | | | |
| System Plan 9 Baseline Case Presentation | General | May have limitation on adding water to the tanks for retrieval | x | x | x | | x | | | | | x | | | | | |
| System Plan 9 Baseline Case Presentation | Slide 10 | Gives breakdown on liquid outputs and inputs to the tank farm - volumes | x | x | | x | x | x | | | | x | | | | | |
| System Plan 9 Baseline Case Presentation | Slide 23 | 242-A evaporator runs (6/year) limit production. Why is EMF shut down in some scenarios? | x | x | | x | | x | | | | x | | | | | |
| HLW Analysis of Alternatives Presentation | Slide 9 | Al dissolution modeling - assumed no leaching of boehmite and limited gibbsite at lower temperatures. Washing was to meet phosphate and sodium targets | x | x | | | | x | x | | | | | | | | |
| HLW Analysis of Alternatives Presentation | Slide 15 | HFPEM uses 2-85K gallon tanks with decants going through cross flow filters | x | x | | | | x | | | | | | | | | |
| HLW Analysis of Alternatives Presentation | | SST retrievals drive mission in option 18 | | x | | | x | | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Exec Summary | Processing alternatives used proven and established technologies - assumption<br>Charact./Corrosion/ Erosion/Modeling & Simulation/Process Intensification | x | | | | x | x | x | | x | x | x | | x | x | x |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Exec Summary | No scenarios for HLW processing at tank or modular | | | | | | | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 3.2 | IHLW must meet WASRD and WAPS -assumption | x | | | | | | x | x | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 3.2 | Volume of HLW is the same as in the baseline -assumption | x | | | | | | x | x | | | | | | | |

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| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 5, Alt 4 | Al leaching temperatures constrained to 60C to reduce H2 generation rate, risk of stress corrosion cracking, and thermal stresses on the vessels and the equipment. Part of Alternative 4. | x | | | | | x | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 5, Alt 8 | In can melting and transportable vit eliminated because not demonstrated on rad waste. Not the case for TVS | x | | | | | | x | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 5, Alt 9 | Eliminated because it assumed completing PT was cost prohibitive | x | | | | | x | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 5, alt 14 | Assumption is addition of cross flow filtration will allow decanting to occur more rapidly (i.e., reduce settle time) | x | | | | | x | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 5, Alt 16 | New HEMF facility for HLW treatment, uses settle/decant with a target of 15 wt% solids | x | | | | | x | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 5, Alt 17 | HFV transfers slurry to HLW in a continuous loop, why? | x | | | | | x | x | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 5, Alt 17 | No additional evaporation capacity added so limits production/tank farm space | x | x | | x | | x | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 8.2 | All scenarios assume start of HLW in FY2034 | x | | | | | | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 8.3 | Modeling assumed 40% TOE Process Intensification | x | | | | | | x | | | x | | | | | x |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 9.1.1, pg 25 | Risk of 242-A evaporator failure given its required operations in several scenarios, long service-life, and low demand currently. | x | x | | x | | x | | | | x | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 9.1.1, pg 25 | Risk of DST leak or other failure. Potential increase in risk due to change in operational mode of the tanks (mixing, washing, etc.) | x | x | | | x | x | | | x | x | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HLW Treat & Disp | LAW Treat & Disp | TRU Waste Disp | Solid & Secondary Waste Disp | Tank Waste Retrieval | Pre-treat/ Feed Prep | Immob Form & Processing | Waste Disposal | Reg Comp | FS Cost & Schedule Analysis | Enabling Technologies | | | | |
| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 9.1.2, pg 34 | Risk of delays in upgrades to ETF as well as ETF not being able to operate at needed throughput | | x | | x | | x | | x | | x | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | Sect 9.3, pg 43 | Costs can be affected by TOE for LAW/HLW processing and change to tank retrieval rates and TF operational efficiencies. | X | x | | | x | x | x | | | x | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, sect 1 pg 55 | During BOM phase, LAW pretreatment and treatment processing rates are assumed to increase to keep pace with HLW processing. LAWST is assumed to provide the additional LAW treatment capability. | | x | | | | x | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Table 62 pg 57 | Comparison of Processing Functions by Facility | | | | | | | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 2.1, pg 61 | Specific requirements for DST integrity assessments are identified in State of WA Ecology letter dated 2/12/20. Corrosion/ Erosion | x | x | | | x | x | | | | | | | x | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 2.3, pg 62 | Canisters are decontaminated with nitric acid/cerium wash | x | | | | | | x | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 2.5, pg 64 | Assumption that HLW canisters are shipped beginning in CY2034. Canister storage holds 4032 IHLW canisters. | x | | | | | | | x | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 2.8, pg 65 | Currently no disposal pathway is identified for the spent IX columns | x | | | | | | | x | x | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 2.13, pg 68 | Annual volume of process condensate generated during DFLAW phase is relatively constant 6.6Mgal | | | | x | | | | | | x | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 2.14, pg 69, 95 | New TFPT throughput is 10 gpm - 50 gpm depending on the scenario | | x | | | | x | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 3 pg 70-71, 73 | HLW Feed Prep and Effluent Management (HFPEM) facility - HLW slurry transferred to HFPEM for sampling, characterizing, and pretreating in HLW Feed Prep Vessels (HFPVs). Pretreated HLW is staged in HLW Feed Vessel (HFV) in a HLW Feed Prep Vault. Seven HFPVs of 300kgal and one HFV of 120 kgal for 7.4 MTG/day. Haz Cat 2 facility which includes an Effluent Collection Vessel for HLW effluents and transfer lines. Settling/decanting starts in the HFPV. Caustic leaching and solids washing also performed. Not clear how the impact of the pretreatment steps is considered on the waste qual sample. (Assumption is 112 days for prep & 120 days for analyzing the samples) | X | | | | | X | | | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HLW Treat & Disp | LAW Treat & Disp | TRU Waste Disp | Solid & Secondary Waste Disp | Tank Waste Retrieval | Pre-treat/ Feed Prep | Immob Form & Processing | Waste Disposal | Reg Comp | FS Cost & Schedule Analysis | Enabling Technologies | | | | |
| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 3.2 pg 71 | Al dissolution assumes 55C with 14 day reaction and settling time in HFPEM. Scenarios look at different volumes | x | | | | | x | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 3.2 pg 71 | Washing is assumed to ~1M Na | x | | | | | x | x | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 3.2 pg 71, 88 | Nominally concentrating post washing 15 wt%. Alternative 15 concentrated to 10 wt% because of assumptions on critical velocity and limitations on transfer line design pressure ratings | x | | | | | x | x | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 3.4 pg 74 | Two 72kgal evaporator feed vessels are required to keep evaporator running at design capacity for 6 days | x | | | x | | | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App A, Sect 5.2 pg 83 | Alternative 14 assumes supernate is recirculated through a Cross Flow Filter with concentration up to 15 wt% solids | x | | | | | x | | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App D, Sect 2.5 pg 152 | Alternative 13 uses bulk vit for CH TRU | | | x | | | | x | | | | | | | | |
| WTP HLW Treatment Analysis of Alternatives, Rev. D | App D, Sect 3.3 pg 155 | Alternative 8 evaluates West Area treatment system; dismissed at tank vit because not demonstrated on real waste. | x | | | | | | x | | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | ES-2 | Viable path for retrieving and processing the NE, NW, and SW quadrant tank waste w/out creating HLW or greater than Class C waste. Concentrating target and blending helped minimize the volume of HLW/ Greater than Class C. | x | x | x | | x | x | x | x | x | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | ES-2 | Drying TRU solids helps reduce volume of TRU grout (10-25%) | | | x | | | x | x | | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 3.1, pg 3-1 | Retrieval fluid volumes are assumed to be 3x saltcake volume reported in BBI. | | x | | | x | | | | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 3.3.1, pg 3-2 | Assume that retrieved supernatant and saltcake liqueur will be filtered using tank side system | | x | | | x | x | | | | | | | | | |

| Document Number/Title | Citation Location (page, section) | Concept, Idea and Comments | Treatment Pillar | | | | Anticipated Focus Area | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HLW Treat & Disp | LAW Treat & Disp | TRU Waste Disp | Solid & Secondary Waste Disp | Tank Waste Retrieval | Pre-treat/ Feed Prep | Immob Form & Processing | Waste Disposal | Reg Comp | FS Cost & Schedule Analysis | Enabling Technologies | | | | |
| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 4.1, pg 4-1 | Assume that sludge solids cannot be pumped higher than 20% | | x | | | | x | | | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 5.1, pg 5-1 | Assume that solids density is the same pre and post application of wash factors | x | x | | | | x | | | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 5.3, pg 5-2 | Assume average 137Cs capacity of TSCR CST column is 32,000 Ci | | x | | | | x | | | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 5.7, pg 5-4 | Assume IDF concentration limit for 99Tc is 0.91 Ci/m3 | | | | x | | | | x | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 5.8, pg 5-4 | Assume acceptable grout waste forms can be made w/20 wt% sludge or salt solids. Grout mass ratio is 0.60 kg liquid waste/kg grout dry mix (1.67 kg dry mix/kg liquid waste). | | x | | | | | x | | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 6.5.2, pg 6-6 | HLW only created from Tank SX-115 sludge slurry (<4,000 gal of waste) | x | | | | | | x | | x | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 7.2, pg 7-1 | Recommend drying TRU solids instead of grouting to minimize waste volume to WIPP. If grouting, maximize waste loading by concentrating sludge solids. | | | x | | | x | x | | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 7-3, pg 7-2 | Do not create tri-sodium phosphate dodecahydrate solids - line pluggage concern Process Intensification | | x | | | x | | | | | | | | | | x |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 7-3, pg 7-2 | Do not create NaNO3 or NaNO2 salts, which can cause problems with PA | | x | | x | | | x | x | | | | | | | |
| RPP-RPT-62534, An Evaluation of Alternate Tank Waste Disposition Pathways | Sect 8.0, pg 8-1 | Recommendation to evaluate sludge solids settling to get a better idea of rate. Use a mobile evaporator for quadrant tank farm options | x | x | | | x | x | | | | | | | | | |
| Why Grout Failed at Hanford | Page 2, Myth #2 | Grout failed or barely met leachability indices while glass performed better than 3 times the requirement. | | x | | | | | x | | x | | | | | | |

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| | | | HLW Treat & Disp | LAW Treat & Disp | TRU Waste Disp | Solid & Secondary Waste Disp | Tank Waste Retrieval | Pre-treat/ Feed Prep | Immob Form & Processing | Waste Disposal | Reg Comp | FS Cost & Schedule Analysis | Enabling Technologies | | | | |
| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| Why Grout Failed at Hanford | Page 3, Myth #4 | Extensive characterization and testing is required for each waste type to determine a grout formula. Also state requiring multiple pretreatment options for grout. Both of these apply for glass as well Charact. | | x | | | | | x | | x | | | x | | | |
| Why Grout Failed at Hanford | Page 3, Myth #5 | Grout at SRS and West Valley is Class A vs Class C at Hanford. This causes concerns with radiolytical heat generation and heat of hydration. | | x | | | | | x | | | | | | | | |
| Why Grout Failed at Hanford | Page 5, Jan 1990 | Petition to NRB to declare all tank waste HLW unless, "the largest technically achievable amount of activity from each tank has been isolated for vitrification prior to permanent disposal" and grout "meets temperature requirements for long term stability for LLW forms" and "that any other pretreatment processes have undergone appropriate evaluation by the NRC prior to implementation". | x | x | | | | | x | | x | | | | | | |
| Why Grout Failed at Hanford | Page 7, July 1991 | Glass process is subject to fewer problems than competing processes. Little to no new development is required to adapt existing technology to LLW disposal. | | x | | | | | x | | | | | | | | |
| Why Grout Failed at Hanford | Page 7, Oct 1991 | Technology programs to develop alternative LLW forms, which could reduce costs or improve waste form performance, will continue to be evaluated. | | x | | | | | x | | | | | | | | |
| Why Grout Failed at Hanford | Page 9, Nov 1991 | Organics also need to be removed or destroyed because they "can inhibit proper grout formulation" | | x | | | | | x | | | | | | | | |
| Why Grout Failed at Hanford | Page 11, Jun 1992 | Tests were unsuccessful at controlling the heat of hydration. One method to overcome was to dilute the waste by a factor of 100. | | x | | | | | x | | | | | | | | |
| Why Grout Failed at Hanford | Page 12, Jun 1992 | Proposed 270 or more grout vaults which requires NEPA coverage since EIS only envisioned 44. | | x | | | | | | x | | | | | | | |
| System Plan 9 Baseline Case | Slide 3 | at 200 East DST tanks looks like supernate and slurry are separated into two different waste streams with Slurry sent to "Tank Waste Characterization and staging" then transferred to the WPT Pretreatment Facility to be recombined with the Supernate waste stream, is this correct? | X | X | | | | | | | | | X | | | X | X |
| System Plan 9 Baseline Case | Slide 3 | Send treated Supernate from TSCR directly to the WTP LAW Vit facility, with all excess volume sent to LAW Supplemental treatment for Grouting. Bypass WTP Pretreatment facility | | X | | | | | | | | | X | | | X | X |
| System Plan 9 Baseline Case | Slide 4 | SST Retrievals: Why two month delay between retrievals? Could this be accelerated with new technology | | | | | X | | | | | | | | | | |
| System Plan 9 Baseline Case | Slide 4 | 242 A Evaporator: Why a Maximum of 6 campaigns per year with 90 day sampling time per campaign? Could they employ a Wiped Film Evaporator? | X | X | | | | X | | | | | | | | X | X |

| Document Number/Title | Citation Location (page, section) | Concept, Idea and Comments | Treatment Pillar | | | | Anticipated Focus Area | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | HLW Treat & Disp | LAW Treat & Disp | TRU Waste Disp | Solid & Secondary Waste Disp | Tank Waste Retrieval | Pre-treat/ Feed Prep | Immob Form & Processing | Waste Disposal | Reg Comp | FS Cost & Schedule Analysis | Enabling Technologies | | | | |
| | | | | | | | | | | | | | Charac. | Robot. | Corr./ Erosion | Model. & Sim. | Process Intens. |
| System Plan 9 Baseline Case | Slide 11 & 12 | 242 A Evaporator: Seems like this is the Bottleneck in the operations? What about ideas to reduce water consumption? Can ultrasonication be employed to reduce water requirements? Follow this with utilization of line tracing and other chemicals to inhibits precipitation? https://www.hielscher.com/ultrasonic-preparation-of-brines.htm | X | X | | | X | X | | | | | X | X | | X | X |
| System Plan 9 Baseline Case | Slide 16 | Alternative Approaches to remove Tc from waste streams as a secondary setup after the Cs removal at TSCR. See https://www.researchgate.net/publication/236427251_Simple_Method_for_Technetium_Removal_from_Aqueous_Solutions. Send waste to LAW Supplemental Treatment for Grouting | X | X | | X | | X | X | | | | X | | | | |
| HLW Analysis of Alternatives & A of A Report D | Slide 3 & page 71 | The entire solids/liquid separation, caustic leaching, washing, and concentration cycle time is estimated to be approximately 112 days on average. The timeframe for analyzing the HFPV samples and to evaluate the results is assumed to take 120 days. **What is the bottleneck to prevent shorter than 120 days?** | X | | | | | X | | | | | X | | | X? | |
| HLW Analysis of Alternatives | Slide 5 | ***Common Assumptions*** *:* The Integrated WTP operates at 40% TOE; WTP contract requires 70% TOE; Mission Integration Analysis survey of similar facilities found 40% TOE is the norm (RPP RPT 61717). Is there a specific root cause intensified? What is this value at SRS if there is a comparable one? How much does this value impact overall Cost estimations? | | | | | | | | | | X | | | | X | |

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## Appendix B: Phase 2 Information

As discussed in the main body of the deliverable, the expanded team met August 30 – September 1, 2021, to brainstorm technology concepts and to identify gaps and opportunities in the Hanford Tank Waste mission. To help facilitate the brainstorming with such a large group, three sub-teams were formed with a cross-section of technical areas of expertise and from the different laboratories, academia, and industry. The generated ideas were captured by Hanford mission functional area and are contained in Table B - 1 through Table B - 10. If the idea required a potential regulatory or programmatic basis change, this was identified during the review.

Figure B - 1 highlights the number of raw concepts and ideas by Functional area, based on the results from the full NNLEMS team brainstorming.

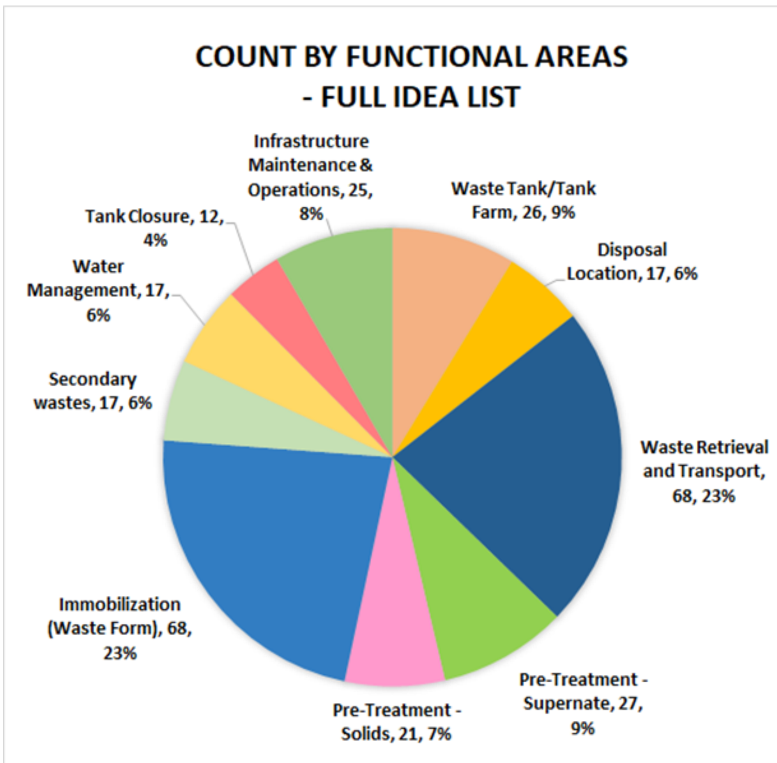


**Figure B - 1: Count and Percent of the 298 Identified Gaps and Ideas by Functional Area for the Full Ideation Database**

Table B - 11 provides a summarized list of Functional areas and the count of each of the Unit or Process Operations flagged for each of the raw ideation list rows. The cells in color highlight the most referenced unit or process operations for each of the Functional areas.

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| | | | Unit or Process Operations | | | | | | | | | | | | | | Enabling Technologies (Categories) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item # | Step | Function | 1 | 2 | 3 | 4 | 5 | Specific Unit or Process Operation Consideration to be Addressed (1-5) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 1 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A3, A4, A5 | Lack of discrete data and rheological properties for the tanks (SST in particular) | | Waste Retrieval (C4 items - PRD) | B29, C35, F30, D41, D54, I36, I25 | Efficient cost effective sampling & characterization, using Raman Spectroscopy. Also Flow through analysis using LIBS<br><br>Use simple at tank techniques when high accuracy not needed / Go-No Go measurements. Example: Density measurements, simple rheological property measurements | For LAW Supernate: Raman tested; LIBS is Feasible for Slurry. For HLW Slurry, current Raman techniques will not work. ATR-FT IR will work / TIR-Raman could work | | | X | X | | | | |
| 2 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Measurement of Rheology in tank, without sending to the Lab | | Waste Retrieval (C4 items - PRD) | F30 | Sabot Cup from Oil Industry. And Other example from Food or Cement (Slump test) | Demonstrated on one of the tanks to measure shear stress. An also simple turbidity tests of flashlight on stick to determine the interface | | | X | X | | | | |
| 4 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | After tank retrieval, the residual content needs to be characterized for content & Rads | | Waste Retrieval (C5 items - PRD) Tank Closure | C15,I36, I25, I28 | A skid of test methods | In line characterization skids | | | X | X | | | | |
| 5 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Reason for 120 day or analytes sample testing and results time (Likely a Lab optimized number) | | Waste Retrieval (C5 items - PRD)/ Regulatory | D40<br>K-14 | Refinement of the Analytical testing to those require from Regulatory need, and what is Operational standpoint | Known issue. If we can test more quickly can cut down tank sizes | X | X | X | X | | | | |
| 6 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | From System standpoint, develop DQO and what is really needed | | Pretreatment - Solids TB | D40 | Compare to SRS Strategy and prior lessoned learned. If we eliminate the WTP, could adjust process for more certain feed to original Storage tank (Direct Feed processing) | Modeling based on Tank Characterization | x | | X | | | | | |
| 8 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A3, A4, A5 | Use DOE M 435.1-1 once characterization and disposal location determined. | 1, 2, 3, 4 | | D54 | Characterization (sample and send) Need analytical techniques to easily and rapidly analyze | Need to develop automated sampling and rapid testing program. Do necessary Lab validation testing. | x | | | x | | | | |
| 11 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | NDA Techniques that can be automated (refer to Surplus Pu Disposition initiative in this arena) | | Waste Retrieval (C5 items - PRD) Tank Closure | D45 | Automation of manual NDA techniques | Preform at scale laboratory validation testing. | | | | x | | | | |

| Item # | Step | Function | Unit or Process Operations | | | | | Specific Unit or Process Operation Consideration to be Addressed (1-5) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Enabling Technologies (Categories) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 32 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Need physical/ rheological information from individual tanks to guide treatment | 2 | Waste Retrieval C5 items-PRD); Pre-Treatment - Solids, Immobi-lization | | Start with brute force bulk measurements, but need a magic bullet e.g. in situ? In-line? measurements correlated with a model to be more predictive [best done with post-mixed samples] | In situ or on-line measurement; as well as an estimation method for limited data tanks | | | | x | | | x | |
| 37 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A3, A4 | Must achieve maximum use of on-line monitoring, particularly during retrieval and treatment | | Waste Retrieval (C5 items-PRD) - Move to Retrieval? | B29, C35, F30, D41 | Interfacing existing technologies | Simple, inexpensive, flexible, and accurate on-line monitoring methods | | | x | x | | | | |
| 16 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A3, A4, A5 | Characterization to inform treatment path | 6, 20, 33 | | B58, D45 | Targeted characterization for constituents of concern (prioritize based on waste to be treated) | Perform Laboratory validation testing. | x | | | x | | | | |
| 18 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A3, A4, A5 | Identify any waste to be disposed offsite now with minimal treatment | | Disposal/ Immobi-lization | D54 | Start demonstrating treatment (B&T tanks?) | Permitting and infrastructure | x | | | | | | | |
| 33 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A3, A4, A5 | Must clarify waste characteristics before treating | | Immobi-lization?? Waste Retrieval (C5-PRD) | B58 | Confirming waste classify and how to deploy rad charact. | In situ/on-line measurement for quicker turnaround | x | | | x | | | | |
| 13 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4, A5 | Better characterization of data and understanding of uncertainty | 15 | | B58, C35 | Uncertainty improvements | Retrieval, inventory, full range of uncertainty | x | x | | x | | | x | |
| 15 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Better modeling and predictive capabilities for chemical and physical properties | 13 | | B58, C35 | Characterization data collection-sampling program | Additional characterization needed to inform | | | | x | | | x | |
| 17 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A1, A4 | Targeting batch composition to enable treatment | | Waste Retrieval (C5 items - PRD) | B58, C35 | Create characterization plan within a tank farm that enables potential blending of tanks to allow treatment | Tank space and improved characterization (real time analyses, in-situ or on-line) | x | | | x | | | | |
| 19 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Uncertainty of the iodine inventory | 13 | | | Evaluate uncertainty in Iodine content based on BBI and TWINS data | Determine if additional tank testing needed to reduce iodine concentration uncertainty. | | | | x | | | | |

| | | | Unit or Process Operations | | | | | | | | | | | | | | Enabling Technologies (Categories) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item # | Step | Function | 1 | 2 | 3 | 4 | 5 | Specific Unit or Process Operation Consideration to be Addressed (1-5) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 34 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A3, A4 | How to anticipate/ respond to waste heterogeneities that would prevent modular processing. How to mix upfront, or sample more representatively | | Waste Retrieval (C5 items - PRD) Tank Closure | C36 | How to predict complex in-tank interactions between waste matrix, organics, RCRA metals, etc.? | Methods for predicting and rapidly characterizing tank properties | | | x | x | | | x | |
| 3 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A3, A4, A5 | Flow or qualification loop to measure a suite of test methods | | Waste Retrieval (C4 items - PRD) | C28, A1 | A skid of test methods | In line characterization skids | | | X | X | | | | |
| 24 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A1, A3. A4. A5 | non-tco4- inventory estimate | | Moved from G-55 | | | | | | | | | | | |
| 56 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Near real-time non-tco4- measurement | | Moved from G-56 | | | | | | | x | | | | |
| 57 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | improve 129I inventory estimation; | | Waste Tank Farm | A-19, D-19, D-27, D-41, D-54 | | | | | | x | | | | |
| 58 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | near real-time 129I measurement | | | D-19, D-27, D-41, D-54 | Faster measurement of WTP-LAW caustic scrubber effluents to allow diversion of scrub solution to EMF evaporator if needed | On-Line or faster laboratory measurement of iodine in dilute NaOH solution (pH12) | | | | x | | | x | |
| 59 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Monitor feed streams to determine how to operate separations/ treatment - sample/ characterize prior to treatment decision | | Pretreatment | D4 | On-line monitoring | | | | x | x | | | | x |
| 60 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Real time characterization data to understand waste characteristics for compliance | | Pretreatment | D4 | Sample/send for feed to understand Tc & I concentration | Scale testing of inline or remote characterization systems | | | X | x | | | | X |
| 61 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Difficult to quickly determine I levels | | Pretreatment | D-4<br>G-54 | New Test method with required Acc/Precision | New measurement systems | | | | X | | | | |
| 62 | A | Waste Tank/Tank Farm | Process History | Previous Sampling | Waste classification | Characterization | Updated waste classification | A4 | Organic treatment/ destruction | | Pretreatment | D4 | Obtain additional information/ characterization on actual organic content | Laboratory validation testing | | | | x | | | X | |

| Item # | Step | Function | Unit or Process Operations 1 | 2 | 3 | 4 | 5 | Specific Unit or Process Operation Consideration to be Addressed (1-5) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Enabling Technologies (Categories): Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B1, 2, 3, 4, 5, | Concern around HLW Canister or Container being consistent with off-site acceptance criteria | | Immobi-lization | | Site Specific Waste Storage/ Transport Containers | Develop non-site specific storage/transport containers | x | | | | | | | |
| 21 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B1, 2, 3, 4, 5 | Overall performance criteria is highly conservative | B21, B32, B44, B60 | Immobi-lization Tank Closure | | Regulatory | Evaluate and reduce conservatism in performance models - targeted to specific areas where the models indicate issues. | x | x | | | | | x | |
| 29 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B2 | Is necessary characterization or strategy available for WIPP/TRU disposal | | Waste Tank Farm | D41, F30, A1 | Characterization or ratio strategy for TRU waste certification for disposal | Develop characterization methods to meet off-site disposal certification requirements | x | | | x | | | | |
| 30 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B3 | Requirement for retrievability for wastes added to IDF | B30, B31, B62 | | | Enhance the barrier for IDF to ensure integrity | Long term performance of barriers | x | | | | | | | |
| 31 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B3 | Requirement for retrievability for wastes added to IDF | B30, B31, B62 | | | Use "getter" in the liners or cap to help with any migration, grout or liquified aggregate barrier (Defense in Depth) | Barrier that goes after the constituent of concern | x | | | | | | | |
| 33 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B4, B5 | CST disposition path besides vitrification for cost reduction | | Secondary Wastes | G49 | Continue NNLEMS study to full disposition | Need alternative options besides vitrification of CST | x | | | | | | | |
| 34 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B3, B5 | Some of the alternative scenarios fill the IDF capacity | | Moved from Secondary Wastes | G-8 | Develop new IDF filling model with updated inventory basis | Develop Model of different filling options for IDF | | | | | | | x | |
| 39 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B1, B4 | Iodine from HLW off gas media disposition | 40 | Pretreat-ment/ Immobi-lization | D17, D31, D32, D36, D37, D38, D56, F22, F30, F41 | Capture media packaging and offsite disposal options | Offsite regulatory hurdles | x | | | | | | | |
| 40 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B1, B3, B5 | Iodine from HLW off gas media disposition | 39 | Pretreat-ment/ Immobi-lization | D17, D31, D32, D36, D37, D38, D56, F22, F30, F41 | Capture media packaging and onsite disposal options | Onsite regulatory hurdles; Getters research | x | | | | | | | |
| 41 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B5 | Addressing constituents of concern (I, Tc, NH4 and N03) | | Pretreat-ment/ Immobi-lization | D33, D34, D23, D57, F25 | Capture media packaging and onsite disposal options | Onsite regulatory hurdles; Getters research | x | | | | | | | |
| 44 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B3, B5 | PA assumptions need to be evaluated for excess (bounding/ compounding) conservatism | B21, B32, B44, B60 | | | modeling/ regulatory issues | More realistic PA Models (HPC?) | x | x | | | | | x | |

| | | | Unit or Process Operations | | | | | | | | | | | | | | Enabling Technologies (Categories) | | | | | |
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| Item # | Step | Function | 1 | 2 | 3 | 4 | 5 | Specific Unit or Process Operation Consideration to be Addressed (1-5) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 57 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B5 | Knowing parameters that impact IDF LLW performance. | 44 | Moved from Tank Closure, item #13 | | What are important factors that impact performance in a low-level waste disposal facility. One of the things the Low-Level Waste Disposal Federal Review Group (LFRG) requires in review of PAs are sensitivity and uncertainty analyses. I know the PA has been reviewed by LFRG and I would think there is a sensitivity analysis that has been performed and reviewed that indicates what variables drive performance. | PA Sensitivity Studies | x | | | | | | | |
| 58 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B2, B3, B4, B5 | Data is needed at each waste management/handling step for waste disposal certification | | | | Develop data collection systems to generate/track data for waste disposal steps throughout waste handling/processing flowsheet | Integrated data collection systems for process controls and waste disposal certification | x | | | | | | x | |
| 59 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B2, B3, B4, B5 | Lack of data to support enhanced performance assessments for alternative waste forms | B52, B59 | | | Better data to reduce uncertainty and conservatism in transport models and performance assessments to increase waste loading at disposal sites | R&D to generate data on alternative waste forms to feed enhanced performance assessments and transport models | x | | | | | | x | |
| 60 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B3, B4, B5 | Lack of enhanced performance and transport models | B21, B32, B44, B60 | | | Better transport and performance assessment models for alternative waste forms to increase waste loading at disposal sites | High performance computing applied to performance assessments for alternative waste forms | x | x | | | | | x | |
| 61 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B2, B3, B4, B5 | Lack of understanding of long-term interaction between waste packages and disposal environment | | | | Improve ability to credit waste containers in long term performance models to increase waste loading at disposal sites | Experimental data and models for waste package/disposal environment interactions | x | | | | | | x | |
| 62 | B | Disposal Location | HLW Federal Repository | WIPP | IDF | Off site (LLW) | Other on site | B3, B4, B5 | Lack of credited barriers at disposal sites | B30, B31, B62 | | | Provide credited barriers to allow increased waste loading at disposal sites | Long term performance of barriers | x | | | | | | | |

| Item # | Step | Function | Unit or Process Operations 1 | 2 | 3 | 4 | 5 | 6 | 7 | Specific Unit or Process Operation Consideration to be Addressed (1-7) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/ Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Enabling Technologies (Categories) Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
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| 33 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1, C2 | Waste retrieval and infrastructure cost reductions | 30 | | | Superstructure improvements | Do a process engineering evaluation to identify improvement areas | | | X | | | | X | X |
| 55 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C2 | Leak detection | | Infrastructure Maintenance and Op | | Robotic inspection | | | | | | X | X | | |
| 56 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C2 | Leak repair | 57 | Infrastructure Maintenance and Op | | Robotic repair | | X | | | | X | X | | |
| 57 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C2 | Tank refurbishment [against e.g. systemic corrosion] | 56 | Infrastructure Maintenance and Op | | Repair technology evaluation. | | X | | | | X | X | | |
| 60 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C2, C4 | Leak repair while retrieving | 56, 57 | Infrastructure Maintenance and Op | | | | | | | | X | X | | |
| 63 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C2 | "Same day" emergency barrier emplacement for tank stabilization? | | | | | | X | | | | | | | |
| 11 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3 | How to mobilize solids for dry retrieval in tank | 12 | | | Fluidize solids with something other than water (i.e. CO2) | New technology studies with CO2 or other inert gases | | | X | X | | | X | X |
| 12 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3 | Break up hard pan without water | 11 | | | Frozen CO2 pellets | New technology studies with solid CO2 or other inert gases | | | X | | X | | | X |
| 15 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3 | C-111 retrieval hardpan characterization | | | | Methods for characterization without sampling NDA | Testing of new NDA technologies in tank environments | | | X | X | X | | | |
| 16 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3, C4 | Basic Bulk Retrieval End effectors for solid and hardpan mobilization retrieval and transportation for both wet and dry applications | | | | End effectors for solid and hard pan removal | New testing of end effectors | | | X | | X | | | X |
| 20 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1, C3 | Dry retrieval technologies for mining out dry solids: | 8 | | | scrapper (bull dozers) chippers and vacuum | testing of commercial remote limited water mining technologies. | | x | | X | X | | | X |
| 23 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1, C3 | Dry solids retrieval | | | | Using end effectors or remote technologies | DOE National lab experiences and commercial vendor literature review required. Testing on representative simulant, deployment, recovery. Multiple tools maybe required. Receiving facility needs to be able to process the recovered material. | | | X | | | | X | X |

| Item # | Step | Function | Unit or Process Operations | | | | | | | Specific Unit or Process Operation Consideration to be Addressed (1-7) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/ Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Enabling Technologies (Categories) | | | | | |
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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 26 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1, C3 | Heel Removal | | | | Using end effectors or remote technologies | Review prior designs and canvas commercial. Testing on representative simulant, deployment, recovery. | | | | X | | | X | |
| 27 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3, C6 | Transport devices for at tank processing | | | | Transport via pneumatic/mechanical (dry or wetted) or fluid | Will the solids (or slurry) be transferred to a process near the tanks or transferred to another farm? Mitigate plugging and minimize liquid flush. | | | X | X | | | | X |
| 59 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3, C4 | Low/no liquid retrieval from leaking tanks | 16, 20, 23 | | | | | | | | | X | | | |
| 62 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3 | Non-chemical hardpan retrieval | 12 | | | | | | | | | X | | | |
| 64 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3 | Rapid emergency salt well emplacement, waste retrieval | | | | Pulse jet mixers, can also be used for at-tank processing. | | | | | X | | | | X |
| 8 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Effective slurry retrieval | 20 | | | Using small mixer settlers to achieve sludge processing | ? | | | | X | | | | X |
| 18 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Staging of sludge and solids | | | | Mixer pump technologies, water volume management | Testing of commercial mixer pump technologies. | | | | | | X | X | X |
| 19 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Mobilization and Mixing technologies of sludges within DST's | 18 | | | Mixer pump technologies, water volume management | Mixer pump technologies, water volume management | | | | | | X | X | X |
| 21 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1, C4 | Bulk retrieval | 18, 19 | | | Fully developed, sluicing, mixer pumps | Minimization of liquid addition. Use experience gained at other DOE facilities. | | | | | | | X | X |
| 22 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1, C4 | Bulk retrieval | 18, 19 | | | Pulse jet mixers, can also be used for at-tank processing. | Application to 1 M gallon unknown, number of access hole, operating conditions, and how the PJM can operate. | | | | | | | X | X |
| 24 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Bulk retrieval | 7 | | | Using a different sluicing fluid for mobilization and solids suspension. Objective is to entrain more solids (e.g. ORNL expert) | Determination of sluicing fluid and its downstream impact. | | | | X | | | | X |
| 2 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Application of Virtual reality as test bed | | | | Ability to practice waste removal virtually for greater productivity in Operations | | | | X | | X | | X | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 3 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Process Feedback to address operational challenges. Getting to a point of where we can condition the material input stream to enable Automated Process Control | | | | Process Automation & Feedback | How to address variable feed | | | X | X | | | X | X |
| 13 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Retrieval removal technology effectiveness (how much to retrieve and technology used) | 14 | Regulatory | K-16 | Predict effectiveness of retrieval technology (modeling, sensor or visual) | New PA Models that are more realistic | x | | X | X | | | X | |
| 14 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Risk based retrieval | 13 | Tank Closure, Regulatory | K-16 | Modeling risk | New PA Models that are more realistic | x | | | | | | X | |
| 28 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1, C3, C4 | Sampling | | Waste Tank Farm | | Inset or recirculation | Required to make engineering decisions. | | | X | X | | | | X |
| 30 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1, C3, C4 | Waste retrieval and infrastructure cost reductions | | | | Close proximity retrieving? Reduce shielding and support infrastructure | Cost benefit analysis of alternative retrieval mythologies. | | | X | | | | X | X |
| 31 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1 | Waste retrieval and infrastructure cost reductions | 16, 20, 23 | | | Remote retrievals to take humans out of the exposure | Evaluation of robotic/remote waste retrieval. | | | X | | X | | X | X |
| 35 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Delay in characterization information to inform the process and treatment | | Waste tank farm | | Chemical processing characterization on-line as waste is being retrieved | Develop real-time monitoring and characterization technologies for inline use | | | X | X | | | | X |
| 36 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Stratification within tank that has to be considered in understanding characterization info | | | | Develop new models or sampling capabilities to reduce uncertainty. | Develop new statistical methods to evaluate waste stratification when sampling is unrealistic or develop new ways to get representative samples from stratified waste tanks | | | | X | | | X | |
| 40 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Retrieval equipment disposition (secondary and solid waste) | 29 | Disposal / Secondary Wastes | | Size reduction capabilities for disposal. Repurposing of existing underutilized facilities for doing that work | Technology study to evaluate existing size reduction technologies | X | | X | | | | | |
| 41 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C1, C6 | Modularization for easier disposal | 30 | Disposal / Secondary Wastes | | Macro encapsulation in grout (B25 box) | Develop new engineering designs of modular components | | | X | | X | | | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 45 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Decontamination of retrieval equipment to reduce secondary waste volumes | | Disposal / Secondary Wastes | | Electrochemical decontamination | Demonstrate of scaling and portability | | | X | | X | X | | X |
| 65 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Monitored natural attenuation of un-emptied, low risk tanks | 14 | Disposal? | | Do 'mini-PA's for unemptied, low risk tanks, develop long-term monitoring protocol | | X | | | X | | | X | |
| 66 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 | Grout in place, cut and haul low risk tanks | | Disposal? Tank Closure | I-26? | In-situ grout mixing with waste, followed by cutting up and removing for disposal in a permitted facility | | X | | | | X | | | |
| 67 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C5 (retrieval sequencing) | Risk-based sequencing of tank treatment | 14 | Waste Tank Farm | | | | | | | X | | | X | |
| 1 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4, C6 | Additives to prevent Phosphate Precipitation | 6 | | | Additives for inhibitors (polyelectrolytes) | Stability at high concentration. Does not cause other downstream process issues | | | | | | | | X |
| 4 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4, C6 | Large particles in slurry in the stream that causes plug in line. Address the recycling of overheads back into the feed stream | 29 | Immobilization pvb-no | | High shear mixers and other concepts | Technology is present | | | X | X | | | X | X |
| 5 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4, C6 | Challenges creating initial high solids slurry of HLW that will flow and then not settle out and plug lines during transport | | | | Can ultrasonication be employed to reduce water requirements? Follow this with utilization of line tracing and other chemicals to inhibit materials settling and further slurry precipitation | Has this been tried already? https://www.hielscher.com/ultrasonic-preparation-of-brines.htm | | | X | X | | | X | X |
| 6 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Phosphate Removal to mitigate precipitation issue at high Molarity | 1 | Pretreatment | | Ability to remove PO4 from salt solution to reduce risk of precipitation. | Ion Exchange, RO, Membranes, Selective Precipitation??? | | | | X | | | | X |
| 7 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Slurry Rheology variation and stability during transport | 5 | | | Employ Rheology Modifiers to help stabilize the slurry for shipment | Rheology Modifiers need to work at high Ionic Strength Conditions (Check what is used for Bleach like products) Applicable industries: Check oil and gas industries | | | | X Testing needed | | | X | X |
| 25 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Bulk retrieval | 4, 7 | Infrastructure Maintenance and Op | J-5 | Critical velocity (the minimum required to maintain solids not settle in transfer lines. | In-line instrumentation, previously tested. | | | | X | | | X | |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 29 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3, C4, C5 | Size reduction (max size to be determined) | 4 | | | In-line or at point of mobilization | Abrasive/corrosion resistant materials for extended life. Easily installed/removed, insitu, cleanable, can process at the sludge rate of recovery. | | | | X | | X | | X |
| 32 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Waste retrieval and infrastructure cost reductions | | | | Remote hose in hose | Evaluation of waste retrieval technology | | | | | | | | X |
| 34 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Waste transfer within engineering standards | 25 | | | Waste transport modeling using in-line flowmeters or ultrasonics or ERT | Create better models of waste transfer solutions to evaluate potential rheology issues | | | X | X | | | X | |
| 37 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Cross site transfer without using the cross site transfer line | | Regulatory | K-17 | Obtain NRC certification for a package for shipment/transfer | Evaluate transport options for LLW rail/tanker etc. | x | x | | X | | | | X |
| 38 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Transport cross site or offsite to processing facilities | 39 | Regulatory | K-17 | Truck/Rail evaluations LR56 for the B&T HLW | Evaluate transport options for LLW rail/tanker etc. | x | x | | X | | | | X |
| 58 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Long distance, high solids [>10%] transport. | 5 | | | | | | | | | | | | |
| 68 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Flexible, stop and start transport | | | | Slurry pumps, augers, vacuum systems | Engineering upgrades and planning | | | | X | | | X | |
| 61 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | Staging | C7 | Use intact SST's as emergency volume backup? | | | | | Secondary Containment/leak prevention/ monitoring | X | | | X | | X | | |
| 69 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | Staging | C7 | Build new tanks to provide more volume? | | Regulatory | K-15 | Program management drivers on tank capacity needs | | | | | | | | | |
| 70 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | Staging | C7 | Easily deployed [mobile?] temporary volume capacity for specific sites in emergencies | | | | Evaluate use of tanker trucks with secondary containment staging area. | Secondary Containment/leak prevention/ monitoring | X | X | | | | | | |
| 72 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Transfer line plugging, evaporator line plugging | C1,3,5,6,7,29,34, C58,68 | Moved from J-17 | | Mechanical plug prevention and remediation | | | | | | X | | | |
| 73 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Addressing cross site transfer line longevity and plugging | C1,3,5,6,7,29,34, C37, 58,68 | Moved from J-6 | | Maintenance program and design component as well? | Material of construction | | | | | X | X | | |
| 74 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6, C4 | Predicting salts precipitation Thermodynamics and Kinetics of precipitation | C1,3,5,6,7,29,34, C37, 58,68 | Moved from J-7 | | Modeling systems? | Precipitation kinetics | | | | | | | X | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 29 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Water reuse | | Moved from H-29 | | Use recycle, condensate or wash water to help mobilize tank wastes | Evaluate water reuse options to see which offers the best performance and cost savings. | | | | | | | x | x |
| 75 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C6 | Operation of recirculation feed pump to WTP | | | | Pump | Can pump operate continuously without impacting slurry line operability? How often does it need to be flushed? | | | | | | | | |
| 76 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4, C5 | Heat removal | | | | Means to remove heat after processing | Heat exchanger internal or on recirculation line | | | | | | | | |
| 77 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Number and size of mixer pump | | | | Mixer pump | mixer pump operations on vessel integrity. Provide fully mixed condition. | | | | | | | | |
| 78 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Heat removal from mixer pump operations | | | | recirculation line | Cost effect cooling technologies evaluation for pumps | | | | | | | | |
| 79 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | Staging | C7 | Alternate storage for feed staging after pretreatment - limited tank space, avoid recontamination from residuals in DST | | | | poly tanks within containment; baker tanks; simple feed holding tanks vs. DSTs | | | | | | | | | |
| 80 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3 | Removing salt cake/TRU using minimal water with pneumatic transport | | | | End effectors that can break the salt surface using minimal water | Testing of remote equipment on appropriate simulants for breaking up salt cake and transport | | | | | | | | |
| 81 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3 | Removal of dry salts/TRU using remote mining/ surface removal equipment | | | | Remote mining equipment, end effectors | Testing of remote equipment on appropriate simulants for breaking up salt cake and transport | | | | | | | | |
| 82 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Traditional dilute/transfer using warm water to increase dissolution rates/concentration | | | | Concepts used at other DOE sites | Application to Hanford tanks, use of warm water for dissolution. | | | | | | | | |
| 83 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C3 | Packing/removal/ characterization of drum or container with the vessel | | | | Packaging and integration with item #1 | Remote technology | | | | | | | | X |
| 84 | C | Waste Retrieval and Transport | Tank Access | Tank Integrity | Dry Retrieval | Wet Retrieval | Other | Transport | | C4 | Mixer and transfer pumps to mobilize and transfer TRU waste to processing facility. | | | | Concepts used at other DOE sites | Technology transfer and onsite testing scale testing at Hanford. | | | | | | | | |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 49 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D1, D8 | Reduced TOE for Filtration (dead-end) in current TSCR due to need for frequent backflushing | 21, 49, 74 | | | Cross-flow filtration without high pressure penalties of original LAWPS design; or other in-riser or skid-based system | | | | | | | | | |
| 21 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D1, D8 | Improvement to filtration process operations | 21, 49 | | | New filtration technology | Approaches like SpinTek Technology. | | | | X | | | | X |
| 22 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D1, D8 | Improved Separation of Known existing technology | | Pre-treatment of Solids (Manage newly added polymers) | | Polymers to flocculate the suspended fines | understanding of commercial polymer stability and performance in high brine systems | | | | X | | | | X |
| 61 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D2 | What is maximum capacity of CST columns? Limited by current calculations | 65,61 | | | Current limit is 32,000 Ci but CST capacity is higher | Modelling or data to support loading behavior? Additional shielding? | x | x | | | | | | X |
| 20 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D2, D3 | Adsorb on RF Column, then elute off, enabling recycling, adsorb back to low cost IEX media. Also consider clinoptilolite? | 1,20,59 | | | Reuse RF | Demonstrate unit operation and Process would work. Trade off of the Sr removal | | | | X | | | | x |
| 59 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D2, D3 | Alternate Cs and Sr removal technologies for CST, cost and availability needs | 1,20,59 | | | Possible use of a lower performing CST | Create low-performing CST by changing CST stoichiometry [e.g. remove Nb] | | | | | | | | x |
| 50 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D2, D8 | Increase sodium molarity for PT to avoid excess water addition. Avoid precipitation of problem constituents (PO4, others). | | | | temperature increase? phosphate removal to avoid precipitation at higher Na molarity | | | | | | | | | X |
| 1 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D2, D3 | HLW Removal and/or LAW Immobilization of Cs and Sr from HLW | 1,20,59 | Immobilization | | Immobilization of Cs and Sr via mineralization and surface sorption in synthetic aggregate rock mixtures containing clay and iron oxides | Lithified Compact Rock Aggregate Mixtures | | | | | | | | X |
| 65 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D2, D3 | Limited by heat load and Hydrogen production in the spent CST Column. (Reduce the number of waste columns) | 65,61 | Pretreatment - supernate | | Max of 140K curies each column curies. Based on feed curie loading | Current limit for SB for column stability | | x | | | | | | |
| 28 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D4 | Organic treatment/ destruction | 28,66,51,24 | | | Evaporation of waste to volatilize organics | Laboratory validation testing | | | | | | | | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 66 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D4 | LDR organics | 28,66,51,24 | Pretreatment | | Evaporation destruction | Perform Laboratory validation testing. | x | | | | | | | X |
| 51 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D4, D7 | Organics destruction method | 28,66,51,24 | | | expected, low temp. oxidation, and evaporation | | | | | | | | | X |
| 24 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D4,7 | Pretreatment - LDR organics: Need to evaluate removal by evaporation and/or oxidization at scale and with radioactive samples<br>LDR Organics - evaluate improved methods for organic destruction to replace or improve low-temp oxidation<br>Also need to look at enhanced grouts to deal with organics | 28,66,51,24 | Immobilization | Enhanced grouts part of F2: Grout and item 29 on this tab. | Addressing LDR Organic Destruction for EPA | Other Destruction approaches | | | x | | | | | x |
| 53 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D5 | Nitrates and nitrites | | Immobilization | | biological destruction, NAC, other? | breakthroughs in low-temp nitrate destruction | | | | | | | | X |
| 15 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | Reduce TRU volume by Pu & other Ac Removal before Cs treatment with CST, which should make CST easier to dispose | | immobilization, Disposal Location | | MST strike of the supernate | Technology might be ready | | | | | | | | x |
| 17 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | I-129 removal methods would need to be identified, tested, and developed almost from scratch. Very little prior work in this area | 17,18,31,56 | immobilization | | Beside Ion Exchange Resin methods, what other separation means are available for I? | New Separation Technology | | | | | | | | X |
| 18 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | Determine models for I speciation to improve sequestration strategies | 17,18,31,56 | immobilization | G-59 | High I selectivity so as not to be swamped by other species | New Resin or New Separation process | | | | | | | x | X |
| 31 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | Iodine performance | 17,18,31,56 | | | Technology for removing iodine in aqueous caustic stream | Laboratory validation testing | | | | | | | | X |
| 33 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | Tc performance | 33,57 | | G-50 | Technology for removing Tc in aqueous caustic stream | Laboratory validation testing | | | | | | | | X |
| 34 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | Tc performance | | Immobilization | F2: Grout F-41 | getters for non-pertechnetate retention in low temperature waste forms | Laboratory validation testing | | | | | | | | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 56 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | Iodine removal to support on-site disposal; or avoid secondary waste impacts | 17,18,31,56 | Secondary Wastes/ Immobilization | | Scale up | New iodine retention mechanisms. | | | | | | | | x |
| 57 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | technetium (non-pertechnetate) removal | 33,57 | | | | New non-pertechnetate retention mechanisms for high pH solutions. | | | | | | | | x |
| 71 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | Non-tco4- separation | 57, 72 | Moved from G-51 | | | | | | | | | | | X |
| 73 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D4 | better demonstration of LDR organic destruction techniques | 28,66,51,24 | Moved from G-60 | | | | | | | | | | | X |
| 74 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D1 | Optimization of filtration systems | 21, 49 | Moved from H-34 | E-44 | reduce loading on filters to increase longevity. | i.e. Ultra sonic filtration | | | X | | | | | X |
| 75 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | Better iodine separation techniques for removal of iodine from WTP Effluents | 17,18,31,56, 47, 57 | Defined as iodine removal from effluents | | | | | | | | | | | |
| 76 | D | Pre-Treatment - Supernate | Solid-Liquid Sep | Cs removal | Sr removal | LDR organics treatment | Nitrite/Nitrate treatment | Other Rads removal | Other RCRA/LDR removal or treatment | Water Management | D6 | Cheap, easy tritium removal !!! | | Tritium removal is only needed from effluents | | Question whether H3 removal needed to recycle water for reuse. Principally a waste management issue. | low cost H3 removal | | | | | | | | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | | | | | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 11 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E1 | Size reduction equipment | 11,12,13,30 | | | recirculation line | Abrasive/corrosion resistant materials for extended life. Easily installed/removed, cleanable, can process at the sludge rate of recovery. | | | | X | | X | | |
| 12 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E1 | Size reduction (SR) equipment | 11,12,13,30 | | | In-situ | Abrasive/corrosion resistant materials for extended life. Effectiveness at single point in a large process vessel. | | | | | | | | |
| 13 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E1 | Size reduction (SR) equipment | 11,12,13,30 | Waste Retrieval & Transport | | In-situ mixer pumps | Abrasive/corrosion resistant materials for extended life. Impact of ability to control particle size due to continuous size reduction. Such pumps exist? | | | | | | | | |
| 30 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E1 | size reduction for large particles, or otherwise eliminate size limits | 11,12,13,30 | Waste retrieval and transport | | | mixing and transport to vitrification process | | | | | | | | |
| 16 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E1, E6, E7 | Conditioning feed for non-Newtonian characteristics. | | Waste Retrieval & Transport | | Dependent on waste composition, not a targeted wt.%, but rheology | Size reduction impact, measure in-situ or recirculation line. | | | | | | | | |
| 1 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E2 | Reduced cost for pretreatment | 1,29,19 | | | Al leaching at high temperature in Hastelloy tank | (probably in a tank side skid) | | x | | | | x | | X |
| 36 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E2, E6 | Modeling of Al dissolution behavior subject to several assumptions on boehmite & gibbsite solubility with regard to temperature | 36,32 | Waste Retrieval & Transport | | Update models based on actual testing and SRS data. | More up to date models from Office of Science and other work could improve performance predictions | | x | | | | x | x | |
| 32 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E2, E6 | How to model and predict chemical and physical behavior in highly concentration, highly alkaline multicomponent waste solutions | 36,32 | Waste Retrieval & Transport | | Expand Pitzer models | explore use of Spara or Geochemical Work bench | | | | | | | x | |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | | | | | | | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 19 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E2, E7 | Batch or continuous (which uses less water and is it worth the effort) | 1,29,19,44 | Pretreatment-supernate/ Waste Retrieval & Transport | | Decanting or filtration | Different type of filtration equipment. At tank. | | | | | | | | |
| 29 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E2, E7 | Improving filtration and concentration of sludges (throughput) for HLW or TRU | 1,29,19,44 | Pretreatment-supernate D1 | | filtration, settle-decant | in- or at-tank modular processing to reduce CAPEX for washing and filtration/settling | Use of DSTs for processing | | | | | | | X |
| 25 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E2, E7 | Utilized SRS approach for wash and leach process steps to improve operation flexibility | 25, 28, 20 | | | Duration of washing, water level used, and target a Na Molarity end point | Revise process model to target a Na Endpoint, versus a repeat of full wash operations | | | | | | | | |
| 7 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E5 | LDR organics treatment | 7,9,33 | Other pretreatment-D4 | | Permanganate, oxidizers | Lab testing and validation of technologies | | | | | | | | |
| 9 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E5 | Removal of Organics for pretreatment of grout | 7,9,33 | Immobilizatio n | D-24,28,51,66 | Removal of LDR Organics | Supercritical Fluid TOC Extraction | | | | | | | | |
| 33 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E5 | LDR organics issue in TRU sludge if processed as LAW | 7,9,33 | Waste Tank Farm | | | | | | | | | | | |
| 34 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E6 | Cesium removal from solids or low-water tank saltcake | | Pre-treatment - supernate/ Waste Retrieval | Possible C4 | Selective dissolution/low water retrieval in stages. | | | | | | | | | x |
| 44 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E6 | Optimization of filtration systems | 1,29,19,44 | Moved from H-34 | | reduce loading on filters to increase longevity. | i.e. Ultra sonic filtration | | | X | | | | | X |
| 8 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E6 | Ammonia release and other actors that limit the operating permit to 6 months/yr. | | Water Management - Evaporators? | | TD to minimize ammonia release and other permit problem actors | Lab testing and validation of technologies | x | x | | | | | | |
| 15 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E7 | Evaporation of water to increase solids content | | Water Management - Evaporators? | | Mixer pumps/ evaporation/ventil ation, wiped film evaporator | Develop better evaporation technologies or improve existing technologies. | | | | | | | | |

| | | | Unit or Process Operations | | | | | | | | | | | | | | | Enabling Technologies (Categories) | | | | | | |
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| Item # | Step | Function | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Specific Unit or Process Operation Consideration to be Addressed (1-7) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/ Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 45 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E7 | During the washing phase of sludge, is it beneficial to perform feed and bleed operations (continuous) or batch processing to remove salts from the supernate to further reduce water utilization. | 1,29,19,44 | Moved from H-41 | | Cross flow filtration or spinet (or another way to continuously remove the liquid) would be required. | Develop better process for sludge washing and salt removal | | | | | | | | |
| 43 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E7, E4 | Reduces overall volume of wastes | | Moved from H-31 | | Clean salt to separate sodium nitrate (Dan Herting) - fractional crystallization | Develop cost effective NaNO3 removal technologies | | | | | | | | X |
| 46 | E | Pre-Treatment - Solids | Size Reduction | Al Leaching/ Partitioning | Cr Leaching/ Partitioning | Anion removal | LDR organics treatment | Other | Water Management | E7 | Reduces overall volume of wastes | | Moved from H-31 | E-43 (duplicate) | Clean salt to separate sodium nitrate (Dan Herting) - fractional crystallization | Develop cost effective NaNO3 removal technologies | | | | | | | | X |

| Item # | Step | Function | Unit or Process Operations | | | | | | Specific Unit or Process Operation Consideration to be Addressed (1-6) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Enabling Technologies (Categories) | | | | | | |
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| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 15 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2, F5 | Reevaluate how we reassess performance with the "Good as Glass". Example of use of DI water for the PA, versus real world water | | Disposal Location | | Needs to be relevant to the actual environment being employed at disposal facility | Performance test to demonstrate alternative waste form in IDF environment | x | | | X | | | X | |
| 16 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Perception around Grout Waste form | 25, 40, 41, 42, 43, 45, 46, 55, 57, 91 | | | Immobilization - A continuously funded program coordinated across the NLs is needed to develop improvements in grouting processes and performance. The focus should be in leach rates of species that are in the pore water, performance testing, etc. (Reinvigorating CBP http://cementbarriers.org ) | Build fundamentals to understand overall Grout performance window and high to drive greater performance features | x | | | | | | X | |
| 17 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Improved Retention of Semi-volatile species | 25, 40, 41, 42, 43, 45, 46, 55, 57, 91 | Secondary Waste | | New Glass Formulations for LAW to reduce I release | R&D to improve glass formulations E.g. VSL Ferrous oxalate additive may improve Iodine capture in Glass | | | | | | | X | |
| 21 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F5 | Ensure the Grout container for SSW will be large enough to hold the HEPA filters for example | | Secondary Wastes/ Disposal | | Grout Container sizing based on Needs | Engineering assessment to determine optimal container(s) size. | | | | | | | X | |
| 22 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2, F4, F5 | Address/quantify Iodide Speciation and capture at different Unit Operations | 27 | | | Fix It Now Team Effort and outcome to drive next steps | Potential improvements include:<br>- Increase retention in melter<br>- Recycle caustic scrubber<br>- Remove I from caustic scrub solution | | | | x | | | x | |
| 24 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4, F6 | Decon of canisters - sounds like it may be of benefit compared to some of the "manual" discussion I heard in one of the briefings but may only apply to LAW | 72 | | | Laser or Electrochemical Decontamination | Evaluation of technologies or LAW container decontamination | | | x | | X | | | |
| 25 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste | Water Management | F1, F2, F5 | LLW and TRU waste disposition | 29 | | | Grout or Lithified solid aggregate mixtures w/ getters | Testing to evaluate new grouts/getters | | | | | | | | |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 27 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2, F5 | Provide options for immobilizing specific constituents of concern | 22,25 | | | Low temperature waste form options | testing to evaluate new grouts/getters | | | | | | | | |
| 28 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | overall system performance for the offgas system - concerns with integrated performance | 35, 51 | | | issues in offgas system handling Tc/I and Hg | Integrated testing of offgas system at scale system | | | | | | | x | x |
| 29 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Strategies or technologies to improve LAW preparation or reduce time to prepare | 25,26 | Pretreatment - supernate | | Review industry standards and make sure Hanford grout formulation is optimized. | Integrated testing of feed system at scale system | | | X | | | | | x |
| 30 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F1, F2, F3, F4, F5 | Real time characterization data to understand waste characteristics for compliance. Mainly would apply to grout options | | Could be applied after TSCR...similar items already in Tank Farm and Retrieval tabs | A-1, A-2 | Sample/send for feed to understand Tc & I concentration | Develop technologies to rapidly sample and evaluate in line samples | | | x | x | | | | |
| 31 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F1 | Upon supernatant treatment in removing radionuclides, dry out supernatant using de-saltation technology and place dried salts into waste containers and dispose. | | Disposal Location/ Pretreatment-Supernate | | Desalination technology is mature. No water utilization, minimum waste volume. | Need to determine a process flowsheet and identify disposal paths. | | | X | | | | | X |
| 32 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F1 | Overall handling of the drying/packaging of TRU remotely. Any experience in the drying/handling. | 44 | Disposal Location/ Pretreatment-Supernate | | Remote technology, drying and processing of such solids. | Identify and test proposed strategies for improving CH-TRU process | | | X | | X | | | |
| 33 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Robust grout formulation. Mixing systems are mature as well as the waste containers. | 41, 46 | | | Grout formulation | Evaluation and testing proposed grout processes with simulants from lab-scale testing to full scale. | | | X | | X | | | X |
| 35 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4, F5 | Off gas waste stream components (HEPAs, Charcoal bed or Ag mordenite beds, etc.) | 28, 51 | Secondary waste | | Evaluation of newer technologies for off gas components: Improved capture technologies for off gas components | Evaluate performance of newer technologies for off gas components. If necessary, component development and testing will be initiated. | | | X | X | | | | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 36 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Better melter and bubbler replacement concepts | 17, 55, 58 | Infrastructure & Maintenance | J-10, G-48 | Corrosion of bubbler materials | New bubbler material development and testing | | | x | | x | x | | |
| 38 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Avoid cost of HLW Vit completion | | | | In-can melting, modular deployment at tank. Low inventory requirement to avoid large CAPEX facility | Evaluate performance and scalability of alternatives to current HLW process | X | | X | X | X | | X | X |
| 39 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F3, F4, F5 (other HLW form) | More efficient, but less durable waste forms for HLW | | | | Optimize waste form efficiency | Evaluate performance, durability tradeoffs and scalability of alternatives including steam reforming, other mineral waste forms, low-durability glasses, low calcium cements. | x | | | | | | X | x |
| 40 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | How to treat current CH-TRU as LAW? | 25,29 | Disposal Location | | Handling as TRU is more expensive given WIPP requirements for container sizing and handling. Much lower cost to dispose as LAW | Confirm performance of grout and evaluate disposal alternatives. | x | | | | | | X | X |
| 41 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Advanced grout formulations that readily meet performance targets for Tc, I, nitrate/nitrite | 33, 46 | | | getters, improved grout retention, formulation | Development and testing of advanced grouts and getter combinations. | | | | | | | | x |
| 42 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Long-term performance not credible with short-term and small-scale tests at representative scale | 25,29,43 | | | Scale-up methods for predicting long-term grout performance | Develop and utilize new short-time experimental methods that can be projected over very long time spans | x | | | X | | | x | x |
| 43 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | $CO_2$ footprints - impacts from cements | 25 | | | Leach testing, scale up | Lime-free cements with similar performance | | | | | | | x | |
| 44 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F1 | TRU sludge dewatering/drying | 32 | | | sludge dewatering | Assess dewatering options considering with consideration of scale-up, cost and safety | | | | | | | | x |
| 45 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Anion transport in/from grouts | 25 | | | Plug natural analogues into Hanford PA to demonstrate long-term performance | Identify more/better natural analogs for cement waste forms. Note that the absence of better analogues may necessitate an experimental work. | | | | | | | x | |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 46 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Robust grout formulations to minimize need for tailoring to an analysis. | 33, 41 | | | Individual grout components that perform multiple, overlapping functions | Define specific functional needs and develop components that need these needs. | | | | | | | x | x |
| 48 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Are there specifications such as canister size or durability limiting production/ throughput? | | | | Assumption is that IHLW must meet WASRD and WAPS | Assess canister properties in light of WASRD and WAPS | x | | | | | | | |
| 49 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Nitrate to NOX compounds gas generation for vit. Mitigation of worker health risk | | Immobilization | | Risk transfer | Evaluate measures to reduce the amount of NOx generation during Melter operation and/or exposure potential for on-site workers | | | X | | X | | X | X |
| 50 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4, F6 | Water Management - Adjust glass former particle size to avoid water additions for low waste loading batches or add water only as needed based on in situ analysis of yield stress | | Waste tank farm | | Rheological property controls | Identify impact of GFC particle size on melter feed rheology - Online rheometer | | | | X | | | X | X |
| 51 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F1, F3, F4, F5 | Improved methods for Hg removal – eliminate carbon beds | 28, 35 | | | Replace carbon bed with newer technology | No - Existing commercial products available - Evaluation of these products for application to HLW/ LAW processes is needed | X | | | | | | | X |
| 52 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F1, F3, F4, F5 | Reusable HEPA filters – clean and reuse – add effluents back to CRV – eliminate Tc in IDF from HEPAs | 28, 35 | | | Replace disposable HEPA with a reusable, cleanable version | No - Existing commercial products available - Evaluation of these products for application to HLW/ LAW processes is needed | X | | X | | | | | X |
| 53 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F1, F2 | Improved closure and sealing methods for containerized grout/dried solids | | | | Developed automated solutions for container closure | No - Existing commercial products available - Evaluation of these products for application to HLW/ LAW processes is needed | | | X | | X | | | |
| 54 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Develop smaller melter if HLW mission is reduced to allow earlier start | 56,59 | | | Small scale melter technologies | No - Existing commercial products available - Evaluation of these products for application to HLW/LAW processes is needed | | | | | | | | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 55 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Iodine in grout | 30, 33, 41, 46 | Immobilization | | Advanced grouts for iodine uptake. | Evaluate and/or develop grout compatible I getters and assess by Laboratory validation testing. | | | | x | | | x | x |
| 56 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | improve plug and play of melter replacement | 36, 58 | Also on Infrastructure Maint & Op Tab | | Melter design | Improve melter design to facilitate plug and play. | | | X | | X | | | |
| 57 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Inconsistent raw materials for grout production | | | | Evaluate alternative sources of fly ash to ensure consistent reductant source | Replace fly ash with natural Pozzolans | | | | | | | | X |
| 58 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Demonstrating that HLW vitrification alternatives still meet LDR or [even better] de-listing requirements | 38,56 | | Combine B52, B59, B61 Moved from Disposal, B-52 | Data integration and access | Build leach test library for LDR organics and metals, etc. in grouts | x | | | x | | | x | |
| 59 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Melter life is 5 years. Can this be extended? Corrosion driven lifetime. K-3 is the refractory materials we think. Cr into the glass is an outcome | F-36 , F-55 | Moved from J-12 | J-23, 36,55 | New materials design and selection for refractory | Study refractory option and rate of erosion/ corrosion | | | | | | X | X | |
| 60 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Carbon Bed life due to Hg contamination saturation and damage from NOx. Sulfur drop in Carbon beds noted in testing. | F-35, F51 | Moved from J-14 | | Overall Speciation and Distribution of COCs. | Evaluate fundamentals of reaction/ adsorption | | | | | | X | | |
| 61 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Have certain number of bubbler spares on hand and stock materials to make spares | F-36, | Moved from J-11 | G-48 | Bubbler durability and performance. | Review Materials and processes for bubbler construction. | | | | | | X | | |
| 63 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4, F6 | Optimization of flushing in melter off gas system (i.e. Deluge of WESP) | 8, 64, 65 | Moved from H-33 | | Volume of water in process needs to be reduced. | Develop new technology to replace deluge rinsing in WESP | | | X | | X | | | X |
| 64 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F6, F4 | Reduce Generation of Secondary Waste. Example Caustic Scrubber has water Spray (4 GPM) operating | 63. 65 | Moved from H-11 | G15 | Review process needs for Water Spray | General Review of Water Generation | | | X | | | | X | |
| 65 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F5 | Reduce/eliminate organic byproducts from vitrification (e.g., acetonitrile) | 62,63 | Moved from G-45 | | Sucrose reduction in vitrification | Identify and validate alternative reductant(s) with non-hazardous degradation products | | | | | | | | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 66 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Far more accurate iodine partitioning through ETF flowsheet | | Duplicated concept from G-59 | G-59 | Improve I measurement capability through the ETF. | Improved sampling and measurement of I. Real time sensors could be considered. | | | | X | | | x | |
| 67 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | non-sucrosic reductant[s]. Increase nitrate destruction, avoid production of acetonitrile/other hazardous organics not destroyed in off-gas system. | 64, 65, 71 | Moved from G-63 | | Improved reductants for vitrification | Identify and validate alternative reductant(s) with non-hazardous degradation products | | | | X | | | X | X |
| 68 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | ammonia alternative for NOx reduction in off-gas. Reduce short-term hazard with NH3 use for SCR. | 69 | Moved from G-65 | | NOx Management | Evaluate alternatives to ammonia usage. | X | | | X | | | X | X |
| 69 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | achieve nitrate destruction prior to/in melter (to eliminate NH3/NOX abatement) and eliminate nitrate release from grouted waste. | 67 | Moved from G-66 | D-53 | denitrification alternatives | Evaluate biodenitrification systems and their integration into the process flow sheets. | | | | X | | | X | X |
| 70 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F3 | come back to fibs down the road | | Moved from G-67 | | Vit alternatives | office of science task to reevaluate FBSR for immobilization of HLW | X | | | | | | X | X |
| 71 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | improve melter design to reduce 2ndary waste issues | 67 | Moved from G-68 | | Melter design and engineering | Improved melter design to minimize secondary waste streams. | | | | | | | X | X |
| 72 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | | 25,29 | Moved from G-69 | | Grout performance | DOE EFRC and/or center for fundamental to applied research on grouts. | X | | | X | | X | X | X |
| 73 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Decontamination of HLW canisters: Are there alternatives to decontaminating with nitric acid/cerium wash to minimize water | 24 | Moved from G-71 | | Improve HLW canister decontamination | research & develop alternative decon processes w/minimal secondary wastes | x | x | | X | x | | | |
| 74 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Nitrate to NOX compounds in grout. IDF release issues | 25,29 | Moved from B-37 | | Risk transfer | Mitigate onsite regulatory hurdles for nitrite/nitrate release in IDF | x | | | X | | | X | X |

| Item # | Step | Function | Unit or Process Operations 1 | 2 | 3 | 4 | 5 | 6 | Specific Unit or Process Operation Consideration to be Addressed (1-6) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Enabling Technologies (Categories): Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
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| 75 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4, F5 | New LDR organics from sugar fortified melter! | 71, 67 | Moved from B-38 | E5, E7, D24, D66 | There are sufficient treatment options in offgas-ETF-LERF system | Confirmatory lab testing of ability of the LAW offgas and ETF systems to deal with organics from LAW vit | x | | | X | | | X | X |
| 76 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 , F5 | Flammable gas generation from NH4 in grout (struvite?) | | Moved from B-42 Applies to grouting brine waste from ETF | D33, D34, D23, D57, F25 | Low pH geopolymer needs more testing (NH4, Tc and I) | Onsite regulatory hurdles; Getters research | | | | X | | | X | X |
| 77 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Reduce sludge washing requirements for sludge to vitrification. Leave aluminum, chrome, sulfur, sodium, nitrate | 25, 28, 20 | Immobilization | F4 | Higher Na HLW glasses | Adjust glass formulations and HLW vit off gas treatment to handle higher LAW-like feeds: Less of an issue if less sludge to HLW | | x | | | | | X | X |
| 78 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Glass former chemicals (GFCs) | 25, 28, 20 | Immobilization - F4 | F4 | Can other GFCs be used to reduce or mitigate the needs of leaching/washing? | determination of other GFCs and glass formulation efforts | | | | | | | X | X |
| 79 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | SSW - Bubblers. Inconel 690 w/MA-758 shin guard?. Failure at melt line or nozzle. | 36 | Immobi-lization/ Infrastructure | J-10 | Improve bubbler life time | Increase corrosion resistance of bubbler materials. | | | | | | x | | |
| 80 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Remove/better incorporate ammonia in grout for ETF brine solution | 25,29 | Applies to ETF brine. Left here | | Ammonia management. | Research ammonia removal and/or retention in grout. | | | | | | | | |
| 81 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Demonstrate performance of a grout waste form to retain organic of concern | | Regulatory | K-20 | Is there justification for changing CFR for LDR organic BDAT? | Laboratory validation testing and regulatory discussions | x | | | | | | X | X |
| 82 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Addressing Nitrates/Nitrites in supernate that will be grouted. Highly soluble and could be leached from Grout | 23, 30 | | | Lessen Leaching of pour water from Grout | New Grout Formulations/Systems Approach | | | | | | | X | X |
| 83 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Nitrite/nitrate performance with low temperature waste form | 23, 30 | | | Nitrate mgt. | New Grout Formulations/Systems Approach | | | | | | | X | X |
| 84 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Iodine performance | 41 | | | Iodine mgt. | Laboratory validation testing of better I getters. | | | | | | | X | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | Criticality or DSA Concerns (N/A or specifics) | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 85 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Tc performance | 41 | | | Technetium Management | Laboratory validation testing of getters for non-pertechnetate retention in low temperature waste forms. | | | | | | | X | X |
| 86 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Iodine or Tc performance in melter | 17 | | | Management of I and Tc volatility. | Laboratory validation testing of redox adjustment to control volatility of radioactive species. | | | | | | | X | X |
| 87 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Iodine performance in melter off gas | 88.89 | | | Iodine mgt. | Laboratory validation testing of alternative media for capturing iodine in the off gas system. | | | | | | | X | X |
| 88 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | Iodine performance in melter offgas system of melter | 89 | | | Iodine mgt. | Laboratory validation testing of pH adjustments in offgas scrubber system to capture iodine species | | | | | | | X | X |
| 89 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F4 | iodine performance in the system | 88 | Secondary Wastes | G-53 | Iodine mgt. | improve modeling to understand partitioning of iodine through the system | | | | | | | X | |
| 90 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Non-pertechnetate ineffectively immobilized in grout | 85, 25,29,74 | | | Technetium Management | Laboratory validation testing improve modeling to understand partitioning of iodine through the system | | | | | | | X | X |
| 91 | F | Immobilization (Waste Form) | Dried product | Grout | Steam Reformed product | Glass | Other (secondary waste form) | Water Management | F2 | Can we treat current CH-TRU as LAW? Handling as TRU is more expensive given WIPP requirements for container sizing and handling. Much lower cost to dispose as LAW | 17 | | | Alternative waste form and disposal pathway. | Evaluate CH-TRU immobilization in grout and its potential disposal pathways. | x | | | | | | X | X |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 4 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | Characterization | G1 | Secondary LLW waste stream | | Applies to handling of solid secondary waste, not waste feed - mess | | Grouting or lithified aggregate mixture +/- getters | New grouting compositions or lithification technology | X | | | | | | | |
| 40 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G3 | Assessment of TRU condensate from drying, compatibility with ETF | 41 | Immobilization | | characterize and/or prediction compositions of stream from source information | Data needed to assess technology need, flowsheet required. | | | | | | | x | |
| 16 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G3 | Addressing High Ammonia Waste stream | 64 | immobilization-F5 | | Sequestration or destruction of Ammonia | Develop system that can meet Waste Perf Criteria | | | | | | | | X |
| 35 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | Characterization | G5 | Measurement of Tc and I on HEPA. | 36 | Immobilization | | Sampling and Measurement of Rad level per HEPA to stay below 17 Curies which is in the PA | new Measurement method? | | | | X | | | | |
| 36 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | Characterization | G5 | Measurement of Tc and I on HEPA. Amounts modelled by Process Engineering | 35 | Immobilization | | Very low value of Curie release is presumed based on PA - How to measure expected amounts of Tc | | | | | X | | | x | |
| 41 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G3 | Assessment of TRU condensate from drying, compatibility with ETF | 40 | Immobilization | | characterize and/or prediction compositions of stream from source information | | | | | | | | | |
| 42 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G2, G3 | Avoid sending all wastewater to LERF/ETF - send offsite | | Water management | | Divert certain effluent streams to offsite treat/dispose. | | X | | | | | | | |
| 43 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G4 | Wastewater reuse for retrievals, process water, line flushing, etc. | | Waste Retrieval/H5: Reuse of Water | H-24 | Could it be used in off gas scrubbers? Challenge to handle contaminated. | Tritium issue with stream, organics, NH3 large volume 6m gal/yr plus evap o/h's. Most water use in WTP off gas scrubber systems. | | | | | | | | |
| 44 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G3, G5 | UV Oxidation efficiency at ETF - (Ability to destroy acetonitrile) | | | | | ETF adding steam stripper in addition to UV Ox. | | | | | | | | |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 46 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G1, G3 | SSW - HEPA (Tc). Alternative to finding better grout matrix for macroencapsulation. | | Pretreatment/ Immobilization, Disposal Location | | Washing to concentrate Tc in low volume liquid stream. Grout formulation to better immobilize | | | | | | | | | x |
| 47 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G1, G3 | SSW - GAC. Not clear if still an issue, without significant Iodine | 47 (pretreatment) with 57 | Pretreatment/ Immobilization? | | Pretreatment to avoid iodine on GAC, or better immobilization? | | | | | | | | | |
| 49 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G1, G2 | TSCR - Columns disposition | | Disposal location - could be carried in one place | B-33 | Alternatives to vitrification. Ability to delist and ways to disposition it | | x | | | | | | | x |
| 50 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G3 | Develop Tc-only separation for SBS condensate | | Should apply to SBS condensate, not waste feed - mess | | | | | | | | | | | |
| 59 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G5 | Far more accurate iodine partitioning through ETF flowsheet | | Updated this task for ETF. Will add task in immobilization section for WTP-LAW | D-18 | steady state measurements | | | | | | | | x | |
| 72 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G5 | Characterization and certification of Failed equipment, PPE and contaminated equipment (secondary waste items) | 8, 35 | Moved from A-22 | | RWMB or WIR process improvements (regulatory) What analysis or certification needed for disposition? | Need to work regulatory issues | x | | | x | | | | |
| 73 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G5 | Improve disposition of analytical samples | 8 | Moved from A-23 | D45 | RWMB or WIR process improvements (regulatory) or NDA inline analytical processes | Need to work regulatory issues | x | | | x | | | | |
| 74 | G | Secondary wastes | Immobilization process | Disposal Location | Treatment needed | Waste Minimization | Other | | G1 | Tc stream stabilization/immobilization | | Moved from G-52. Should move back to G-52 | D6: 57, 71 | G-4 | | | | | | | | | |

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| | | | 1 | 2 | 3 | 4 | 5 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 12 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H1, H2, H3, H4 | Take Advantage of Current Evaporation Technology | | | | Wiped Film & Others | Other know technologies? | | | x | | | | | x |
| 13 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H1, H2, H4 | SPG limit for Current Evaporator | | | | Operational and Regulatory Assessment | ? | x | x | | X | | | | |
| 14 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H1 | Improvement in permitting guidelines to enable efficient use of Evaporator | | Regulatory/ Pretreatment - supernate | K-18/ D-64 | Regulatory Review | ? | x | x | | X | | | | |
| 15 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H1 | Address boil down study 90 day Qualification period | | | | Regulatory Review - Is this the performance or time required for regulatory? | ? | x | x | | X | | | | |
| 20 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H5 | Assessment of water needs , can recycled waste flushes be used multiple times | | Waste Retrieval (C5 tie - PRD) | | Apply improved strategy via refined operation methods & definition requirements | | | | | | | | X | |
| 21 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H1, H2, H3, H4, H5 | For new piping, design the system for effective pigging approaches | | Waste Transfer (Tied to C6, C4, and C3 - PRD) | | CO2 or Water/ICE Pig | | | | | | | | | |
| 22 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H4 | Enhanced Evaporation Flexibility with Model Evaporator in SW TF | | | | Could there be coupled with several unit operators (TSCR?) | | | | | | | | X | |
| 23 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H1, H2, H3, H4 | Understanding how much water can be removed before precipitation of inorganics | | | | Enhanced models, Characterization or feeds, as well as simulant work | | | | | x | | x | | x |
| 24 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H5 | Improved water utilization | | Pretreatment - supernate/ Waste Retrieval (C4 and C3 ties - PRD) | | Employ countercurrent water wash strategy, which should reduce needs for the baseline evaporation level of current approach | | | | | | | | X | |
| 27 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H1,3,4 | Excessive water utilization | 24? | | | Known and mature | Scale testing | | | X | | | | | |
| 30 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H1 | Single point of failure in 242-A | | | | Evaluate evaporator failure modes | Develop mitigation strategies for component failures | | x | X | | | | | |
| 36 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H5 | Water use optimization | 11, 38 | Waste Retrieval (C4 and C3 tie - PRD) | | Start w/manufacturer's recommendations. Need to optimize from there. All major facilities and unit operations. | Scrubbers, retrieval, WESP, quenchers. | | | | | | | x | x |

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| | | | 1 | 2 | 3 | 4 | 5 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 38 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H5 | Wastewater reuse for retrievals, process water, line flushing, etc. Tritium issue with stream, organics, NH3 large volume 6m gal/yr plus evap o/h's. Most water use in WTP off gas scrubber systems. | 36,11 | Waste Retrieval (C4 and C3 tie - PRD) | | Could wastewater reuse be applied to offgas scrubbers? Challenge to handle contaminated fluids. | | | | | | | | | x |
| 40 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | | H2 | Some scenarios assume EMF shuts down | | | | Continue to use EMF throughout the life of Hanford mission | Develop technical basis and evaluate concepts for full utilization | | | | | | | X | |
| 44 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H5 | Grey water reuse | | Moved from J-18 | | Purple pipes, separate piping system | | | | | | | | | |
| 45 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H3 | Use of evaporators in PT (or in storage) | | Moved from J-19 | | Repurpose to support additional evaporators across mission | | | | | | | | | x |
| 46 | H | Water Management | 242-A evaporator | EMF | PT Evaporators | Other evaporation technology | Re-use of water | H4 | ETF Evaporator capacity is the constraint to ETF Processing | | Moved from J-16 | | Significant work ongoing to update ETF. Impact on overall WTP and LAW productivity | What are the notable challenges | | | | | | X | | X |

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| | | | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 7 | I | Tank Closure | Tank cleaning | Tank cleaning post retrieval | | Waste Tank Tank Farm - Retrieval | C3, C4, C5 | Laser Tank Cleaning (may already have been looked at but lots of vendors out there) | Evaluation of existing technologies | x | x | | | | | | |
| 8 | I | Tank Closure | Other (monitoring or barriers) | Engineered Grout Tank Barrier | Item 9 | | | Engineered Grout Barrier w/ additives | R&D Engineered compositions | x | | | | | | | |
| 9 | I | Tank Closure | Other (monitoring or barriers) | Engineered Aggregate Rock Tank Barrier | Item 8 | | | Engineered Lithified Rock Aggregate barrier w/ additives | R&D Engineered compositions | x | | | | | | | |
| 10 | I | Tank Closure | Current 3 methods or 99% removal/ Tank Cleaning | Time studies should also be performed to determine how effective the technology is in removing the waste and achieving the targeted end dates. | N/A | Waste Tank Farm - Retrieval | C3, C4, C5 | Process Engineering Evaluation | Engineering process modeling | x | | | | | | x | |
| 25 | I | Tank Closure | Current 3 methods or 99% removal/ Risk Based | Improved Technology for determining the residual remaining in the tank. 3D Mapper and Laser to determine surface area for Volume remaining quantification | Item 36 | Waste Tank Farm/ Waste Retrieval | A-4/C-15 | Risk based assessment could reduce the need for Op Consideration 1. Tc is the major risk driver | Defining meaningful requirements to the assessment | x | | | X | | | | |
| 26 | I | Tank Closure | Grout tank for closure | How to best demonstrate how the residual waste heel is incorporated into the grout | Item 27 | Immobilization | | Small scall trial of macroencapsulation of tank residuals in grout to determine viability of concept | Mixing & small scale modeling studies | x | | | X | | | X | |
| 27 | I | Tank Closure | Grout tank for closure | Grout Formulation improvement to enhance retention of the residuals in heel of tank | Item 26 | Immobilization | F2 | Grout recipe modification to cause chemical stabilization of residuals e.g. through leaching of getter agents from the grout into the residuals | New capture additives for species of interest | x | | | X | | | | X |
| 28 | I | Tank Closure | Risk based | Improved In-situ characterization | Item 25, 36 | Waste Tank / Waste Retrieval | A4, A1 | Similar to earlier to Characterization on a skid | Breakthrough technology for at tank characterization | | | | X | | | | |

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| | | | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 36 | I | Tank Closure | Risk based | Real-time tank heel analysis to confirm inert residuals, and stop further retrieval (rad content, phase characterization) | Item 25, 28 | Waste Retrieval | A3 | 'Magic wand' rapid measure of leachability | Characterization method that also assesses leachability to support heel retrieval decisions and performance assessment [tomb][that rapidly demos sufficient leachability to halt further retrieval-pub] | x | | | x | | | | |
| 29 | I | Tank Closure | Closure paperwork/modeling (PA, etc.) | Improved model of Groundwater movement | | | | Use existing models and data to understand movement of contaminants from earlier releases | Update modelling based on newest information to reduce conservatism | x | | | x | | | x | |
| 37 | I | Tank Closure | Current 3 methods or 99% removal/ Risk Based | Significant effort is expended to deploy 3 technologies for tank closure without assessment of the risk assessment of the contaminants remaining | | Waste Retrieval/ Regulatory | C3, C4, C5, K-16 | Single-technology retrieval - bulk to move onto higher risk tanks vs. 3-technology/99% removal. Tradeoff of remob costs. | Regulatory agreement and characterization technology and rapid assessment method to identify residual risk | x | | | | | | | x |
| 38 | I | Tank Closure | Risk Based/ Closure Paperwork/modeling (PA, etc.) | Prioritize risk reduction activities. Defer closure costs till after higher risk reduction efforts with waste removal. | | Waste Retrieval | | No new technology; focus on closure sequencing and highest risk | Planning with Regulators and Modeling of Sequence | x | | | | | | x | |

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| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 1 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J5, J6 | Transport: Critical velocity | | Copy topic goes to Waste Retrieval & Transport (C6) but fits into other areas also | C-25 | Technical basis (pulse echo measurement or other technologies) | New technology testing | | x | | | | | | |
| 2 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J5, J6 | Transport: Flushing velocity | 1 | Copy topic goes to Waste Retrieval & Transport (C6) but fits into other areas also | C-25 | Technical basis (Bingham fluids velocity dependent (demonstrate at 10ft/sec. Use 6ft/sec in baseline, SRNL uses 4ft/Sec) | New modeling of fluid dynamics in transfer lines. | | x | | | | | x | |
| 8 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J1, J2, J6 | Tank patching technology to prolong life | 9 | Tank Farm (PRD) | | What is the state of the art? | New approaches | | | | | X | X | | |
| 5 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J3, J5 | Erosion (& possible Corrosion) degradation for 242A Evaporator transfer lines back to tank farm. | | Water management - evaporators | H-30 | for 242A, new lines being installed. Is this a concern for other areas | Material of construction | | | | | | x | | |
| 15 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J4 | ETF is 30 years old and has known maintenance issues (filter replacement & plugging of H2O2 decomposer) | | Secondary Waste | | Impact of chemical on equipment life | Understanding Materials of Construction life | | | | | | X | | |
| 3 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J5 | Life extension of the Hose and Hose transfer lines | | Ties into Waste Retrieval & transport (C4 grouping) | | What is the optimal material and system design? | explore new materials for longevity studies | | | | | | X | | |
| 10 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J6 | Melter Bubblers will be replaced after 6 months. (18 in each LAW Melter, and maybe 6 in HLW?). Idling does Not accelerate bubbler life, but still contributes to corrosion | 11 | Immobilization [pub-no]/ Secondary Wastes | F-36, G-48 | Potential Life extension to 10 months? | Understanding Materials of Construction life | | | | | | X | X | |
| 9 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J1, J2 | Addressing tank leaks | | Ties into Waste Retrieval & transport (C4 grouping) | | Unique barrier systems to handle variable leaky scenarios | External known technology | | | | | | X | | |
| 4 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J1, J3, J5, J6 | SCUBA Apparatus disposal. Are these items one time use? | | Secondary wastes | | Greater equipment longevity & reusability | Develop alternative technology | | | x | x | x | | | |
| 13 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J4, J6 | HEPA filter waste generations | | Secondary wastes/ Immobilization | F-35 | Recycling Filter Use and cleanable HEPA | Understanding Materials of Construction life | | | | | | X | | |
| 21 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other structures | | J1, J2, J7 | Superstructure/ gantry/for enhanced tank farm operations | 20 | (Not TD) | | | | | | X | | | | | |

| Item # | Step | Function | Unit or Process Operations | | | | | | | | Specific Unit or Process Operation Consideration to be Addressed (1-8) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/ Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Enabling Technologies (Categories) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | | | | | | | | | | Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
| 16 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | | | J4 | ETF Evaporator capacity is the constraint to ETF Processing | | Move to Water management? CCH | | Significant work ongoing to update ETF. Impact on overall WTP and LAW productivity | What are the notable challenges | | | | | | X | | X |
| 20 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other structures | | J7 | Temporary vs. permanent tank farm infrastructure (electrical, transfer piping, ventilation systems, leak detection, vapor monitoring and mitigation) | 21 | | | Develop methods for tank side retrieval and treatment that don't require permanent infrastructure. | | | | X | | X | | | |
| 22 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other structures | | J7 | Windbreaks/ barriers/pavilions that could reduce wind/dust/ issues. Does this help or hurt - vapors, crane use, riser height | | Move to Waste retrieval & transport (c1 grouping - PRD) (not moved - not TD) | | | | | | X | | X | | | |
| 24 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other structures | | J7 | Cost of expensive capital projects. | | | | There are a number of facilities at Hanford that have completed their missions, e.g., canyons, that have not been fully D&D'd, Some of these might have full confinement ventilation systems, fire protection systems and other hazard controls that may provide some savings versus a "green field" new facility (Hanford has done this with T-Plant storing K-Basin | Regulatory studies for facility reuse | x | x | | | | | X | |
| 25 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J8 | Does statutory capacity at WIPP exist | | | | Evaluate available inventory at WIPP to determine whether Hanford TRU disposition is achievable | Modeling of capacity and decision on expansion | x | | | | | | X | |
| 26 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J8 | Is adequate RH TRU shipping/ receipt capability available at WIPP? | | | | Model or system to coordinate shipments to WIPP to meet site specific closure dates. | Modeling of capacity and decision on expansion or enhancement to receipt capability | | | | | | | x | |
| 27 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J7 | Need for permitted storage on site awaiting WIPP availability - is adequate storage available? | | | | Ensure planning includes sufficient storage for TRU packages waiting to ship | Evaluate needed capacity for stabilized TRU storage | x | | | | | | | |

| Item # | Step | Function | Unit or Process Operations 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Specific Unit or Process Operation Consideration to be Addressed (1-8) | Specific Gap to be addressed (What is the Root Problem)? | Connectivity to Other Gap Item (list Item #) for this Sheet | Connectivity to Other Function (Name), on other tabs | Connectivity to Other Gap Item (list Item #), on other tabs | Technology/ Science Concept? | Scientific and/or Engineering Breakthrough Needs | Regulatory Component Consideration | Criticality or DSA Concerns (N/A or specifics) | Enabling Technologies (Categories): Process Automation | Charact. (including On Line Monitoring or Controls) | Robotics | Corrosion / Erosion | Modeling & Simulation | Process Intensification |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 28 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J7 | Addressing the need for onsite interim storage, that provides flexibility for Hanford processing, while not exceeding Wash State Permit or concerns | | | | Validate existing storage capacity vs potential needs and the permit allowance | Infrastructure | x | | | | | | X | |
| 29 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J8 | NRC TRU shipping package not approved | | | | Certify TRU package for disposal | Develop Shipping/ Transport containers | x | x | | | | | | |
| 30 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J4 | Reduction of overall operating costs for life cycle | | Moved from G-7 | | Automation of LERF/ETF | Study LERF/ETF functions that can be automated | | | x | | | | x | |
| 36 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J7 | Robust enclosures to prevent e.g. wind shutdowns | | Moved from A-36 | | None [facilities] | None | | | | | x | | | x |
| 38 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J6, J7 | How to make more agile [less costly] temporary above-ground activities. Also, substitute remote work for hands-on | | Moved from A-37 | | None [facilities] | None | | | | | x | | | x |
| 39 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J2 | Is feed staging or preparation allowed? | | Infrastructure Maintenance & Ops/ Waste retrieval & transport | | Re-use existing DSTs for preparing waste to mitigate need for new tankage; use monitoring or remediation techniques for any leaks | Establish testing program that will assure tank reuse is safe. Work with regulators to assure them tanks can be reused safely if the following protocols are followed. | | | | | | | | |
| 40 | J | Infrastructure Maintenance & Operations | Tank Integrity Program | Tank Life Extension | 242-A evaporator | LERF/ETF | Transfer Lines | WTP | Other Hanford structures | DOE Facilities | J3, J5 | Evaporator 242A maintenance and rebuild waste | | Pretreatment/ Water management | J3: 242-A evaporator | investigate issues? | evaluate technologies to reduce maintenance and replacement of evaporator components | | | | | | | | |

**Table B - 11: Summary of Functional Areas, Unit or Process Operations and Idea Count**

| Options/ Unit Operations/ Count of Function | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Function | Unit or Process Operation Consideration | Unit or Process Operation Consideration | Unit or Process Operation Consideration | Unit or Process Operation Consideration | Unit or Process Operation Consideration | Unit or Process Operation Consideration | Unit or Process Operation Consideration | Unit or Process Operation Consideration |
| Waste Tank/Tank Farm | Process History (2) | Previous Sampling | Waste classification (9) | Characterization (26) | Updated waste classification (8) | | | |
| Disposal Location | HLW Federal Repository (4) | WIPP (6) | IDF (12) | Off site (LLW) (9) | Other on site (13) | | | |
| Waste Retrieval and Transport | Tank Access (13) | Tank Integrity (8) | Dry Retrieval (18) | Wet Retrieval (30) | Other (22) | Transport (13) | Staging (4) | |
| Pre-Treatment - Supernate | Solid-Liquid Sep (4) | Cs removal (6) | Sr removal (4) | LDR organics treatment (5) | Nitrite/Nitrate treatment (1) | Other Rads Removal (10) | Other RCRA/LDR removal or treatment (2) | Water Management (5) |
| Pre-Treatment - Solids | Size Reduction (5) | Al Leaching/ Partitioning (6) | Cr Leaching/ Partitioning | Anion removal (1) | LDR organics treatment (3) | Other (6) | Water Management (8) | |
| Immobilization (Waste Form) | Dried product (8) | Grout (28) | Steam Reformed product (4) | Glass (36) | Other [secondary waste form] (11) | Water Management (4) | | |
| Secondary Wastes | Immobilization process (6) | Disposal Location (2) | Treatment needed (8) | Waste Minimization (1) | Other (6) | Characterization | | |
| Water Management | 242-A evaporator (7) | EMF (4) | PT Evaporators (4) | Other evaporation technology (7) | Re-use of water (6) | | | |
| Tank Closure | Current 3 methods or 99% removal (3) | Risk based (5) | Grout Tank for Closure (2) | Other (Monitoring or Barriers) (4) | Tank cleaning (4) | Closure paperwork/ modeling [PA, etc.] (2) | | |
| Infrastructure Maintenance & Operations | Tank Integrity Program (4) | Tank Life Extension (4) | 242-A evaporator (3) | LERF/ETF (4) | Transfer Lines (7) | WTP (6) | Other Hanford structures (8) | DOE Facilities (3) |
| Regulatory | DOE Order (6) | Federal Law or Regulation (6) | State Requirement or Permit (19) | EPA (12) | Federal Repository (3) | Current NEPA determinations & Records of Decisions (9) | Transportation (1) | |

Cross Walked Concepts / Gaps / Opportunities to Funded Programs

During Phase 2, the expanded SME team brainstormed and identified a broad range of current or potential gaps and opportunities associated with Functional areas and specific unit operational areas. To understand how the ideas collected mapped to current (funded or unfunded) programs underway at Hanford, an assessment was completed to cross walk the concepts collected to the WRPS Technology and Innovation Roadmap (RPP-PLAN-43988, Rev. 5). In the WRPS Roadmap, these programs are either funded or unfunded Technology Element Description Summary (TEDS) concepts. Additionally, the team reviewed a select list of the historical Grand Challenges provided by ORP, 185 total from 2013 to 2018, to determine how the concepts connected with challenges and potential gaps identified by this program's technical team. Of the Grand Challenges, there were 66 selected to be reviewed in detail versus the raw concepts generated from this NNLEMS team effort. Furthermore, an assessment of the functional focused areas was completed for the different stages of the current program to gain a broader understanding of the landscape for the future technology development program.

The goals of this initial set of reviews were as follows:

1. Cross-reference the brainstormed ideas from the NNLEMS team with WRPS TEDS funded & unfunded concepts.
2. Cross-reference the brainstormed ideas from the NNLEMS team with select ORP Grand Challenges that were preidentified by the project team.
3. Screen the compiled data from the full list of brainstormed ideas and gaps for other data trends to assess the raw ideas collected with the subunit operations and enabling technology focused areas.

The Enabling Technology subteam reviewed the WRPS Technology & Innovation Roadmap (RPP-Plan-43988-Rev 5) to identify related technology development programs and how they currently mapped to this team's list of concepts. Table B - 12 contains the summary information.

**Table B - 12: Table of Summary Metrics Pertaining to WRPS Technology & Innovation Roadmap Areas of Focus**

| Area | Funded | Unfunded | Total | % Funded |
|---|---|---|---|---|
| Manage Tank Waste (MTW) | 9 | 35 | 44 | 20.5% |
| Retrieve Tank Waste (RTW) | 4 | 28 | 32 | 12.5% |
| Process Tank Waste (PTW) | 5 | 12 | 17 | 29.4% |
| Manage Waste (MW) | 1 | 4 | 5 | 20% |
| Dispose Tank Waste (DTW) | 5 | 5 | 10 | 50% |
| **Total** | **24** | **84** | **108** | **22.2%** |

As evident in Table B - 12, most concepts in the WRPS Technology and Innovation Roadmap are unfunded. This R&D Roadmap effort collected 324 unique concepts (*vide infra*) as part of the ideation process, of which 26 ideas were categorized as Regulatory. The non-Regulatory ideas were individually cross correlated by the Enabling Technologies subteam to the specific WRPS TEDS concepts. A concept with some technical and functional area connected to a specific WRPS TEDS program was noted as such, whether it was funded or unfunded.

As shown in Table B - 13, from a review of the Hanford Acceleration concepts, the team cross-referenced 18 of the 24 Funded programs noted in RPP-PLAN-43988, Rev. 5, indicating these **Funded** TEDS concepts had some connection to the gaps and concept identified by this team. (It should be noted that the connection would not necessarily mean the technical solution being proposed was the same for the TEDS connected concepts and those from this effort. In many cases, the TEDS technical approaches are focused on established technology, and not the exploration of new technology development concepts.)

**Table B - 13: Summary of Cross-Referencing for Hanford Acceleration Team & Funded WRPS TEDS Programs**

| Funded Programs | Count | Percent |
|---|---|---|
| Cross Referenced TEDS cross identified and **Included** in Hanford Acceleration Team Idea List | 18 | 75.0% |
| Cross Referenced TEDS not identified and **Not Included** in Hanford Acceleration Team Idea List | 6 | 25.0% |
| **Total** | **24** | |

An examination of the detailed data shows that specific TEDS **Funded** programs are connected with multiple unique concepts generated from this roadmap effort. This detailed frequency of TEDS connection is located in Table B - 14. The table contains a count of the number of times a specific TED Funded concept was referenced in the raw ideation list from this team's effort.

Similarly, as shown in Table B - 15, the team cross-referenced 59 of the 84 **Unfunded** programs noted in RPP-PLAN-43988, Rev. 5, indicating these **Unfunded** TEDS concepts had some connection to the gaps and concepts identified by this team. Table B - 16 summarizes the specific TEDS Unfunded program cross-referenced by the team and how many times it was cited in the raw idea list. The number of TEDS programs that are linked to this Phase 2 ideation list was similar for the Funded and Unfunded programs, being 75% and 70%, respectively.

**Table B - 14: WRPS TED Funded Programs Citing Count for Roadmap Ideas**

| TED # | TEDS Funded Title | Count of Times Cited in Ideation List |
|---|---|---|
| PTW-23 | Methods for Mitigating DFLAW Flowsheet Gaps (M) | 12 |
| PTW-54 | Real-Time Process Control for DFLAW (H) | 11 |
| DTW-02 | Low Temperature Waste Form Process (M) | 10 |
| DTW-07 | Solidification & Stabilization of Solid Secondary Waste (H) | 10 |
| MW-02 | Ammonia Vapor Mitigation (H) | 5 |
| MTW-73 | Tertiary Leak Detection & Foundation Robotic Inspection (H) | 4 |
| RTW-08 | Dry Sludge Retrieval System (H) | 4 |
| MTW-83 | Secondary Liner Bottom Damage Mitigation Technologies (H) | 3 |
| MTW-92 | Tank Repair (H) | 3 |
| PTW-55 | Chemical Process Modeling Software to Support DFLAW Operations (H) | 3 |
| DTW-08 | IDF Long-Term Lysimeter Data Study (H) | 3 |
| MTW-87 | Real-Time Localized Corrosion Monitoring Probe (H) | 2 |
| RTW-01 | Retrieval and Closure Solid Waste Sampling Tools (H) | 2 |
| MTW-77 | Large-Volume Supernatant Sampler & Transportation System (M) | 1 |
| RTW-02 | Residual Volume Measuring System (RVMS) (H) | 1 |
| RTW-12 | Development of New Riser Installation System (M) | 1 |
| PTW-38 | Radioactive Waste Test Platform (H) | 1 |
| DTW-10 | Test Bed Initiative Phase 2 (H) | 1 |

*Parentheticals denote priority High (H), Medium (M), or Low (L) as from the WRPS report.*

**Table B - 15: Summary of Cross-Referencing for Hanford Acceleration Team & Unfunded WRPS TEDS Programs**

| Unfunded Program | Count | Percent |
|---|---|---|
| Cross Referenced **Included** in Hanford Accel Team Idea List | 59 | 70.2% |
| Cross Referenced **Not Included** in Hanford Accel Team Idea List | 25 | 29.8% |
| **Total** | **84** | |

**Table B - 16: WRPS TED Unfunded Programs Citing Count for Roadmap Ideas**

| TED # | TEDS Unfunded Title | Count of Times Cited in Ideation List |
|---|---|---|
| MW-15 | At-Tank Technetium and Iodine Removal & Disposition (H) | 13 |
| MTW-76 | Online Monitoring using Raman Spectroscopy (H) | 12 |
| PTW-49 | Feasibility of Removing Nitrates from the LAW Feed (H) | 10 |
| DTW-12 | Evaluation of Natural Analogues to Support Tailored Grout (M) | 10 |
| MTW-37 | Tank Waste Characterization & Identification (H) | 9 |
| MTW-24 | Vapor Monitoring, Characterizing & Remediation (H) | 8 |
| RTW-21 | Improve ESP – A Thermodynamic Modeling Program (L) | 8 |
| RTW-55 | Hanford Waste End Effector (Deployment Options) (H) | 8 |
| RTW-07 | Post Waste Retrieval Updates to WMA C PA Maintenance (M) | 8 |
| RTW-15 | Evaluate Back-Up Options for HLW Delivery from Tank Farms (L) | 7 |
| RTW-39 | Risk-Informed Tank Retrieval Modeling Optimization (H) | 7 |
| RTW-19 | TRU/SR-90 Precipitation in Double-Shell Tanks (L) | 7 |
| MTW-91 | Tank-Side Waste Evaporation (L) | 6 |
| RTW-29 | Improved Solubility Modeling of Phosphate (M) | 6 |
| RTW-44 | Use of Sonar & Ultrasound to Quantify Solids in DSTs (M) | 6 |
| PTW-45 | Operations Productivity & Analysis Tools (M) | 6 |
| PTW-46 | Advance CH-TRU Tank Waste Treatment Technologies (M) | 6 |
| RTW-28 | Solubility Modeling of Oxalate, Fluoride & Other Simple Mixtures (M) | 5 |
| RTW-56 | Technology to Support Risk-Based Retrieval & Closure (H) | 5 |
| DTW-13 | Long-Term Durability of Cementitious Waste Forms | 5 |
| MW-10 | Remotely Operated or Automated ETF Internal Tank Cleaning Device (M) | 4 |
| RTW-25 | Highly Flowable Grout (H) | 4 |
| MTW-59 | High Silica (Zeolite)-Containing PPE (L) | 4 |
| RTW-23 | Waste Transfer Pipe Unplugging (L) | 4 |
| RTW-27 | Improved Solubility Modeling of Aluminum (M) | 4 |
| RTW-34 | Extended Reach Sluicing System Modifications (M) | 4 |
| RTW-52 | Barrier Technology Research (M) | 4 |
| MTW-57 | Predicting Behavior of Mercury in EMF (H) | 3 |
| RTW-16 | Develop Integrated HLW Feed Qualification Plan (L) | 3 |
| MTW-84 | Pipeline Forensic Inspection Technology (H) | 3 |
| MTW-86 | Protective Measures for Waste Transfer System Lines (L) | 3 |
| DTW-14 | Complex-Wide Database for Cementitious Waste Form Properties | 3 |
| RTW-03 | Remote Tank Farm Above Ground Inspections (M) | 2 |
| MW-12 | Upgrade Solid Waste Information & Tracking System (M) | 2 |
| MTW-10 | Phased Array UT Testing Implementation for DST Walls (M) | 2 |

| TED # | TEDS Unfunded Title | Count of Times Cited in Ideation List |
|---|---|---|
| MTW-13 | Improve Liquid Observation Well Data Acquisition (H) | 2 |
| MTW-71 | Improve Best-Basis Inventory with TWINS Database (M) | 2 |
| RTW-10 | Development Testing of High-Radiation Hose Materials (L) | 2 |
| RTW-17 | Access Deep Sludge Pump Reliability for DST Mixer & Transfer Pumps (L) | 2 |
| RTW-18 | Improved Heat Removal for AW & AN Tanks TSR Heat Limits (L) | 2 |
| PTW-24 | Advanced Dynamic Simulation Modeling Platform (H) | 2 |
| PTW-53 | DFLAW Process Operational Troubleshooting (H) | 2 |
| PTW-40 | High-Level Waste Phased Approach (H) | 1 |
| MTW-20 | Upgraded Still & Video System for Tank Inspection (H) | 1 |
| RTW-53 | Three-Dimensional Flash LIDAR (H) | 1 |
| MTW-36 | Slurry Property Investigation (M) | 1 |
| MTW-40 | Improve Sampling Methods of Head Space (L) | 1 |
| MTW-41 | Analytical Method Development for Chemicals of Concern (H) | 1 |
| MTW-78 | In-Tank Volumetric Nondestructive Examination (M) | 1 |
| MTW-79 | Autonomous Robotic Platform (M) | 1 |
| MTW-80 | Automated Visual Recognition Wireless Remote Video Monitoring (M) | 1 |
| MTW-85 | Remote Profilometry Use for Surface Examination (H) | 1 |
| MTW-89 | Remote Concrete Surface Cleaning Apparatus (L) | 1 |
| MTW-90 | Water/Waste Volume Measurement for 242-A C-A-1 Vessel (H) | 1 |
| MTW-98 | Long Reach Robotic Tool for Tank Farm Pits (H) | 1 |
| RTW-31 | In-Tank Sampling Technologies for Plutonium Particles (L) | 1 |
| RTW-43 | Computer Simulator to Measure Retrieval Operator Skills (M) | 1 |
| PTW-39 | Virtual Workbench for Waste Processing (M) | 1 |
| DTW-11 | Integrated Disposal Facility Risk Budget Tool Monitoring (H) | 1 |

*Parentheticals denote priority High (H), Medium (M), or Low (L) as from the WRPS report.*

A full accounting of the technical ideas generated by the NNLEMS team, as listed by Functional areas, is shown in Table B - 17. There were 298 concepts. Of these listed, 132 separate ideas did not have a clear connection to Funded or Unfunded TEDS concepts, based on a first pass cross examination.

**Table B - 17. Summary of the Hanford Acceleration Team Idea Metrics by Functional Area Cross Walked to the Funded or Unfunded WRPS TEDS Programs.**

| Functional Area | Count of Ideas by Function - Full List | Count of Idea by Function with No TEDS Connection | Percent of unique Ideas with No TEDS Connection |
|---|---|---|---|
| Waste Tank/Tank Farm | 26 | 8 | 30.8% |
| Disposal Location | 17 | 5 | 29.4% |
| Waste Retrieval and Transport | 68 | 24 | 35.3% |
| Pre-Treatment - Supernate | 27 | 14 | 51.8% |
| Pre-Treatment - Solids | 21 | 10 | 47.6% |
| Immobilization (Waste Form) | 68 | 35 | 51.5% |
| Secondary Wastes | 17 | 8 | 47.1% |
| Water Management | 17 | 4 | 23.5% |
| Tank Closure | 12 | 11 | 91.7% |
| Infrastructure Maintenance & Operations | 25 | 14 | 56.0% |
| **Total** | **298** | **133** | **44.6%** |

A full list of the Grand Challenge titles and some select information was provided to the team for all proposals collected from the 2013 to 2018 ORP sponsored Grand Challenge meetings. Over the 6-years that the Grand Challenges were held, a broad range of participants including national laboratories, universities, ORP, stakeholders, and industry provided proposals. Given the proprietary nature of the proposals, the Core technical team down selected from the full list of 185 Grand Challenge concepts provided to obtain detailed information for 66 concepts. The Grand Challenge proposals (as listed in Appendix A) were reviewed in detail versus the 298 technology concepts. From this cross walk, only eight Grand Challenges were not immediately connected to ideas generated from this initiative.

## Appendix C: Concept Expansion and Initial Team Screening

The team identified the appropriate technology development (concepts) for each of the functional areas and unit operations during the first expanded team brainstorming meetings. The team also developed the key gaps and/or the opportunity that the concept addressed. Over 100 concepts were identified for evaluation. Table C - 1 provides a summary list of this condensed list of gaps/opportunities and associated technologies with a newly generated Concept ID number and designation as to the type of technology concept.

The evaluation process was done in two phases. The first was the *screening phase* of the 100+ concepts into a smaller sub-set and the sub-sets were further evaluated in second *detailed evaluation phase* of the evaluation. The specifics of this evaluation are discussed in Appendix D. During the screening phase, the team used a set of screening criteria as shown below.

Screening Criteria -- Incremental and Transformational

1. Probability of Achieving Capability
   a. High (>66%); Mod (33-66%); Low (<33%) disqualifying
2. Probability that the capability leads to intended benefit (cost, schedule, budget)
   a. High (>66%); Mod (33-66%); Low (<33%) disqualifying
3. Regulatory Change Needed to Realize the Benefit:
   a. None, Minor, Major
4. Development and Implementation Cost if TD is Successful
   a. Incremental: High (>$200M); Mod ($50-$200M); Low (<$50M)
   b. Transformational: High (>$500M); Mod ($200-500M); Low (<$200M
5. Time to Begin Realizing the Benefit
   a. <5, 10, 20+ years
6. Short term costs to obtain capability
7. Cost/schedule benefit (best case)
   a. Schedule acceleration (low – 0 to 3 years; mod – 4-9 years; high- >10 years)
   b. Cost reduction High (>$25B); Mod ($250M-$25B); Low (<$250M)
   c. Reduction in peak annual costs for mission (Affordability) [None, Minor, Major]
8. Net Reduction of Environmental/safety risks
   a. None, Minor, Major

| Concept ID | Concept | Gap/Opportunity Addressed | Links to Brainstorm Sheet | Concept Type |
|---|---|---|---|---|
| WT-1 | In Situ Characterization: Chemical Composition for tank contents and heels<br>- Raman, LIBS, and other techniques to analyze tank and tank heel contents to include anions and metal data. | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required to obtain characterization data as well as the number of samples taken would expedite tank farm processes. | A1, A4, A33, A37, A8, A59, A60 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| WT-2 | In Situ Characterization: Physical Properties for tank contents and heels<br>- Rheological properties, solid property measurements, pH, and density | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required to obtain characterization data as well as the number of samples taken would expedite tank farm processes. | A1, A2, A4, A37, A32, A59 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| WT-3 | In Situ Characterization: Radiological Properties for tank contents and heels<br>- Alpha, beta, gamma counters, spatial mapping of dose for heels | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required to obtain characterization data as well as the number of samples taken would expedite tank farm processes. | A4, A37, A8, A33, A58, A59, A60 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| WT-4 | In Situ Characterization: Organic content for tank contents and heels | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required to obtain characterization data as well as the number of samples taken would expedite tank farm processes. | A59, A62 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| WT-5 | Laboratory Characterization<br>- Improved laboratory techniques for LDR organic analysis<br>- improved Turn-Around-Time (I-129, Non-pertechnetate, etc.) | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required and the detection limits for sample analysis would improve tank farm processes and provide the additional data needed for LDR treatment of waste if needed. | A4, A5, A8, A24, A56, A33, A58, A61, A62 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| WT-6 | Automated Tank Integrity non-destructive evaluation (NDE) Techniques | The physical arrangement of the waste tanks makes non-destructive evaluation (e.g. ultrasonic wall thickness measurements) difficult. An automated process to perform these measurements would provide additional assurances and information for the tank integrity programs. The information would also provide information on current state of the tank for any retrieval or waste preparation process. | A11 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| WT-7 | Update characterization needs depending on disposal path<br>- Eliminate analytes not needed, ensure data is available for needed analytes | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the number of samples needed or the analytical measurements required for each sample would reduce the time and cost for characterization of waste during processing. | A16, A6 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| WT-8 | Develop system tools to allow tank data and uncertainty to be understood<br>- Address uncertainty in current waste data<br>- I-129 and Non-pertechnetate estimates<br>- Impact of varying retrieval and blending<br>- Data needed for waste classification<br>- Prediction of complex interactions between waste during blending<br>- Improved blend plans<br>- Inhomogeneity during retrieval<br>- Identify wastes that can be retrieved with minimal treatment (e.g. CH-TRU) | The Hanford Tank Waste mission is currently planned and modelled based on information in the Hanford Best Basis Inventory (BBI) and using TOPSim models. The uncertainty in the BBI and especially in the estimates of selected species is a challenge to assess and apply to the mission level models. Evaluation of this uncertainty as well as improvements to the system modeling tools would improve the mission level estimates and flowsheets for treatment of the tank waste. | A13, A34, A19, A34, A15, A17, A24, A18, A57, A62 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |

| Concept ID | Concept | Gap/Opportunity Addressed | Links to Brainstorm Sheet | Concept Type |
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| WT-9 | Better sampling methods<br> - Flow-through loops , tank mixing, etc. | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. Improving the sampling methods would reduce the time and dose required for retrieval and processing the tank waste. | A34, A3 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WT-10 | Evaluate methods for LDR organic destruction<br> - Laboratory studies with Hanford tank waste matrix | LDR treatment is needed for flowsheets that do not destroy the organics during immobilization (i.e. low temperature processes such as grout). Evaluation of potential treatment methods (evaporation to remove volatile organics, low-temperature oxidation, and other methods) on simulants as well as actual tank waste is needed to confirm these processes will perform as expected. | A-62 | 3) transformational –change in the baseline and mid range costs |
| IF-1 | Improve modeling or measurements for understanding critical velocity needs for pipe transfers and flushes as well as better methods to determine and/or confirm required flush volumes. | Settling of solids during transfers of slurries must be avoided to prevent buildup of materials that could plug transfer lines or lead to high dose or corrosion rates. The velocity needed to prevent solids settling is estimated based on process history, but would be different for each sludge transfer. In addition, flushing to clean out process slurries from the process lines after a transfer are also based on past processing history with the volume and velocity specified in standard operating protocols. Better understanding of these parameters could prevent processing delays from plugged transfer lines and/or reduce the flush volume requirements. | J-1, J-2 | 1) risk mitigation-not schedule driven but protect the schedule |
| IF-2 | Develop improved methods to detect and repair leaks in Hanford tank farm tanks<br>- NDA and robotic systems for tank inspection<br>- Patching systems to repair leaks | The physical arrangement of the waste tanks and transfer lines makes non-destructive analysis (e.g. ultrasonic wall thickness measurements) difficult. An automated process to perform these measurements would provide additional assurances and information for the tank integrity programs.<br><br>Methods to inspect and repair the tanks and/or transfer lines would allow greater confidence in utilization of existing resources for HLW preparation processes as well as the potential to avoid building new facilities if existing facilities can be utilized. | J-8, J-9 | 1) risk mitigation-not schedule driven but protect the schedule |
| IF-3 | Life extension for process systems and components - Low temperature processes<br>- Better predictive tools for determining life expectancy<br>- Improved understanding of process chemistry on corrosion rates | Improving the understanding of erosion/corrosion of systems to better understand service life as well as improvements in materials to extend the life of process equipment (e.g. rotors on a grout mixer) would lead to reduced downtime and improved operating efficiency. | J-5, J-15, J-3 | 1) risk mitigation-not schedule driven but protect the schedule |
| IF-4 | Life extension for process systems and components - High temperature processes<br>- Better predictive tools for determining life expectancy<br>- Improved understanding of process chemistry on corrosion rates | Improving the understanding of erosion/corrosion of systems to better understand service life as well as improvements in materials to extend the life of process equipment (e.g. melters and bubblers) would lead to reduced downtime and improved operating efficiency. | J-10 | 1) risk mitigation-not schedule driven but protect the schedule |
| IF-5 | Improved PPE with increased ability to re-use components | Improvements in the use of PPE would lead to decreased operating costs. | J-4 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| IF-6 | Reusable HEPA filters | The ability to clean and reuse HEPA filters would reduce secondary waste generated from tank waste treatment. | J-13 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| IF-7 | Develop methods to improve evaporative capacity at ETF for brine. | ETF treatment capacity improvements are needed to process effluents from vitrification processes. | J-16 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |

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| IF-8 | Evaluate re-use of existing Hanford buildings:<br>There are a number of facilities at Hanford that have completed their missions, e.g., canyons, that have not been fully D&D'd. Some of these might have full confinement ventilation systems, fire protection systems and other hazard controls that may provide some savings versus a "green field" new facility (Hanford has done this with T-Plant storing K-Basin | A large portion of the cost for processing facilities for tank waste treatment are the reinforced structures to contain the process as well as the ancillary equipment (vent and fire systems, etc.) Use of existing structures could reduce costs for these facilities, but these savings could be eliminated based on the need for modification of a contaminated facility or increased transfer line length if facility is not close to existing facilities. | J-24 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IF-9 | Evaluate WIPP capacity to receive RH-TRU and needed Hanford systems to ship the material as well as the need for temporary storage at Hanford. | Assuming RH-TRU and other Hanford tank waste can be shipped to WIPP, it is not clear whether WIPP will have the needed design capacity. System modeling is needed to ensure capacity is available and whether on-site storage capability will be needed. | J-25, J-26, J-27 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IF-10 | Address the need for on-site storage of waste for all off-site shipping options. | Determine the size and type of storage needed to allow efficient operation and shipping of waste. | J-28 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IF-11 | Determine/ develop shipping packages needed to ship CH-TRU or LAW (liquid or immobilized waste) offsite. | Selection of a package early in the design process to allow the system design to incorporate and/or allow a new package to be developed if needed. | J-29 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IF-12 | Evaluation of process intensification of LERF-ETF process to include automation. | ETF treatment capacity improvements are needed to process effluents from vitrification processes. | J-30 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IF-13 | Develop robust but easy to setup systems to prevent weather shutdowns (e.g. high wind conditions) | Outdoor processing activities are dependent upon weather conditions. Development of tools to allow operation during bad weather would improve efficiency of tank farm operations. | J-22. J-36 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IF-14 | Improve techniques for operational support for tank farm operations<br>- Remote or automated systems to replace hands-on work | Remote or automated systems would improve efficiency of tank farm operations and reduce potential for worker exposure. In addition, these systems may allow operations in periods of weather that workers could not be used. | J-38 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IF-15 | Improved systems for mobilization, sampling, retrieval and transfer of tank wastes. | Over-arching task to improve each step in the processes required to transfer waste from the storage tank to the treatment facility...these items should be in the tasks for retrieval, etc. | J-20, J-21 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IF-16 | Utilize existing DSTs for waste feed staging, washing, and leaching for HLW.<br>- Establish testing program that will assure tank reuse is safe.<br>- Work with regulators to assure them tanks can be reused safely if the protocols are followed. | Utilizing existing DSTs would reduce the capitol cost and schedule for HLW vitrification options with the Pretreatment Facility. | J-39 | 3) transformational –change in the baseline and mid range costs |
| IF-17 | Improved methods for operation and maintenance of the 242-A evaporator<br>- Evaluate technologies to reduce maintenance and replacement of evaporator components | The 242-A evaporator is the only water removal/volume reduction capability in the tank farms. Waste retrieval and transfer operations can add significant amounts of water that needs to be removed prior to qualification, particularly for direct-feed processes. Ensuring the 242-A remains available and improving operations would allow the current mission and could lead to improvements in direct-feed missions. | J-40 | 1) risk mitigation-not schedule driven but protect the schedule |
| TC-1 | Evaluate existing technologies (e.g. Laser Tank Cleaning may be option) for tank cleaning. Use process engineering assessments to determine the time that may be required for residuals removal with the selected technologies. | Alternative methods for tank cleaning are needed to improve efficiency and minimize water addition. | I-7, I-10 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |

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| TC-2 | Technology to be developed would allow for 1) characterization of residuals in place, 2) characterization method that also assesses leachability to support heel retrieval decisions and performance assessment, 3) method that provides 3D mapping of residuals in the tank so total volume of material is known | Real-time tank heel analysis to confirm inert residuals, and stop further retrieval (rad content, phase characterization) based on risk remaining for closure. This option would allow some material to be left behind if it can be shown to be inert or minimal risk. | I-36, I-28, I-25 | 4) long-range programs - 10 to 15 years with potential big payoff if accomplished |
| TC-3 | Work with Regulators/Stakeholders to prioritize sequencing and timing of tank closures to address highest risk | Current tank closure sequencing doesn't include the risk of the residuals to the environment. | I-38, I-37 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| TC-4 | Use improved characterization methods and performance assessments to identify the residual risk of the materials remaining to determine tank cleaning end point. | Current tank closure end-state is based on achieving specific volume removal and number of methods used, if unable to achieve volume, versus the actual risk remaining. | I-25, I-37 | 3) transformational - change in the baseline and mid range costs |
| TC-5 | Use existing models and data to understand movement of contaminants from earlier releases. Update models based on this information and inform definition for tank closure. | Tank cleaning end-state may be based on out-dated assumptions on contaminant transport behavior which may drive the removal of more material than necessary from a risk stand point. | I-29 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| TC-6 | Perform testing to demonstrate macroencapsulation of tank residuals in grout using tailored formulations for contaminant of concern chemical stabilization. | Grouting of the residuals to allow for tank closure is expected to be a requirement. Tailored formulation of the grout for the contaminants of concern may allow for some residuals to remain while simultaneously reducing their migration risk. | I-26, I-27 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| TC-7 | Develop barriers (e.g., cementitious or lithified rock aggregate systems) with additives targeting contaminants of concern for the outside of tanks and demonstrate deployment strategies. | Utilize barriers on the outside of the tank to mitigate the impact of any migration of residual contaminants that would allow reduction in volume of contents removed. | I-8, I-9 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| DL-1 | Provide credited barriers to allow increased waste inventory at disposal sites | Lack of credited barriers at disposal sites because of lack of long term performance data on barriers results in low waste loadings at disposal sites and requirements for retrievability for waste at IDF (or to a saltstone disposal unit type system) | B30, B31, B62 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| DL-2 | Provide data for enhanced performance assessments of disposal sites and to credit waste containers in long term performance models | Better data is needed to reduce uncertainty and conservatism in crediting waste containers, transport models, and performance assessments to increase waste loading at disposal sites | B59, B61 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| DL-3 | Evaluate assumptions for performance assessments for excessive conservatism and develop better transport and performance assessment models for multiple waste forms to increase waste loadings at disposal sites | Better transport and performance assessment models are needed to reduce the conservatism in performance models. High performance computing may need to be applied to performance assessments, particularly for alternative waste forms | B21, B34, B44, B57, B60 | 3) transformational –change in the baseline and mid range costs |
| DL-4 | Develop integrated data collection technology to allow characterization data to be collected at each waste management/handling step for waste disposal certification | Integrated data collection systems are needed for process control and waste disposal certification for both on-site and off-site disposal options. | B29, B58 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| DL-5 | Develop capture media packaging to allow disposal of I, Tc, $NH_4$ and $NO_3$ for on-site and off-site disposal options | If the species of concern can not be removed from the waste by upstream processing, methods need to be developed to allow disposal of the materials at waste disposal sites | B39, B40, B41 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |

| Concept ID | Concept | Gap/Opportunity Addressed | Links to Brainstorm Sheet | Concept Type |
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| DL-6 | Evaluate direct disposal options versus vitrification for disposal of CST for on-site and off-site disposal options | Alternative disposition paths besides vitrification and disposal as non-HLW should be evaluated for cost reduction opportunities | B33 | 3) transformational –change in the baseline and mid range costs |
| DL-7 | Develop non-site-specific storage/transport containers | There is a need to make sure waste is put in a container that can be accepted at the final disposal site if the disposal site location changes after the material is processed and put into interim storage on the Hanford site. | B1 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IM-1 (a & b) | Improvements in a) LAW Glass Waste Form or b) HLW Glass Waste Form | Alternative glass formulations and additives to improve volatile retention (principally Tc and I) followed by durability testing and modeling to assess the long term performance of glasses in disposal environments.<br>- Improve loading of LAW in glass to 25% Na2O<br>- Improve loading of HLW in glass to > 50%<br>- Improve Tc and I retention in glass sufficiently to make recycle adequate | F15, F17, F22, F49, F65, F67, F75, F77, F78, F86 | 2) incremental –some fit existing baseline/flowsheet but maybe not all (HLW improvements) |
| IM-2 (a, b, & c) | Improvements on HLW Facility and Melter Technology | Explore alternative designs to improve melter performance (throughout) and lifetime. Improve the understanding of erosion/corrosion to extend the life of process equipment (e.g., melters and bubblers) to reduce downtime and improve operating efficiency.<br>a) Double bubbler lifetime (HLW and LAW)<br>b) Increase LAW facility to equivalent melter throughput to 40 tG/d<br>c) Increase HLW facility to equivalent melter throughput to 8 tG/d. | F38, F50, F54, F56, F59, F71 | 2) incremental –some fit existing baseline/flowsheet but maybe not all (HLW improvements) |
| IM-3 | Technetium and Iodine Management (Excluding Glass Waste Forms, combined with IM-5) | There is a need for improved characterization technologies as well as evaluations of alternative capture methods and wasteforms for the management of technetium and iodine. | F28, F30, F53, F41, F76, F85, F90 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| IM-4 | NOX Management | Improved methods/technologies to reduce NOX generation and worker exposure.<br>- HLW to handle direct feed without significant washing<br>- LAW to minimize PICS impact by changing sugar<br>- LAW + HLW NH3 safety risk | F35, F68, F69, F83 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IM-5 | Mercury Management | Improved capture methods for mercury including carbon bed alternatives and management strategies.<br>- Implement Hg management approach that decreases contaminated secondary waste by >50% | F35, F51, F60 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| IM-6 | Supernatant Treatment Process(es) | Upon supernatant treatment in removing radionuclides, dry out supernatant using de-saltation technology and place dried salts into waste containers and dispose.<br>- Treat supernate and saltcake to generate form for off-site disposal | F31 | 3) transformational-change in the baseline and mid-range costs. |
| IM-7 | Container Decontamination | Evaluation and selection of technologies for LAW/LLW/HLW container decontamination.<br>- Non manual LAW decon<br>- Reduce water by 90% relative to HLW Ce-nitrate process | F24, F73 | 2) incremental - some fit existing baseline/ flowsheet but maybe not all |
| IM-8 | Waste Container Design | Ensure that containers are properly selected and/or designed to hold the expected waste components/waste streams. | F21, F48, F53 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IM-9 | Remote handled TRU | Evaluate/Develop/Select technologies for remote handled TRU.<br>- Demonstrate/implement technology for RH-TRU treatment for shipment to WIPP | F32 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |

| Concept ID | Concept | Gap/Opportunity Addressed | Links to Brainstorm Sheet | Concept Type |
|---|---|---|---|---|
| IM-10 | High Efficiency Waste forms | Develop and assess more efficient (increased capacity, reduced cost etc.) waste forms for HLW. Examine cost, efficiency and durability trade offs (life cycle analysis or LCA) of these materials.<br>- Assume this means running waste through HLW vit, but, without meeting WASRD/WAPS | F39 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| 1M-11 | Process Water Usage | Evaluate and implement strategies for more efficient water use. (What is the target for water use reduction?) | F63, F64 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| IM-12 | Waste Dewatering | Assess and implement dewatering options with consideration of scale-up, cost and safety.<br>- Necessary to treat tank waste other than HLW | F44 | 3) transformational –change in the baseline and mid range costs |
| IM-13 | Grout Development, Performance and Durability | There is a need to develop improved containerized grout formulations as well as to validate their durability and long term performance)<br>- Needed to implement Grout SLAW<br>- Assume on-site disposal | F16, F25, F27, F29, F33, F40, F42, F43, F45, F46, F57, F58, F72, F74, F80, F81 | 3) transformational –change in the baseline and mid range costs |
| IM-14 | Treat TRU as LAW/LLW | Immobilize TRU in grout and its potential disposal pathways as LAW/LLW. | F25, F40, F91 | 3) transformational –change in the baseline and mid range costs |
| IM-15 | FBSR | Scientific investigation to reevaluate FBSR for immobilization of HLW | F70 | 3) transformational –change in the baseline and mid range costs |
| WR&T-1 | Infrastructure Cost Evaluation through development of a System Model | Waste retrieval and infrastructure cost reductions (Superstructure improvements, reduced shielding and support infrastructure). Do a cost benefit/engineering analysis of retrieval technologies. | C30, C33 | 1) risk mitigation-not schedule driven but protect the schedule<br>2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-2a | Leak Detection and monitoring. | Evaluate leak detection and monitoring both before and during retrieval to mitigate potential release to the environment. | C55, C56, C57, C60, C63 | 1) risk mitigation-not schedule driven but protect the schedule |
| WR&T-2b | Leak Repair (Quick win). Assess remote robotic repair and in situ barrier technologies. | Evaluate life extension and leak repair technologies for deployment both before and during retrieval to mitigate potential release to the environment. | C55, C56, C57, C60, C63 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-3 | Dry Waste Retrieval Technologies | Evaluate dry or minimal liquid retrieval technologies for known leaker tanks to mitigate potential release to the environment.. National lab experiences and commercial vendor literature review required for existing technologies. | C11, C20, C23, C31, C59, C64, C80, C81 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-4 | Hard Heel Removal Technologies | Evaluate minimal water hard heel removal technologies | C12, C15, C16, C26, C62, H21 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |

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| WR&T-5 | Liquid Waste Retrieval Technologies | Evaluate type of liquid and liquid reuse for wet retrieval technologies for HLW, LLW and TRU tank waste to minimize introduction of new chemicals/ liquid to the tank farm. National lab experiences and commercial vendor literature review required. Technology transfer evaluation from other sites. | C24, C29, C75, C78, C82, C84 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-6 | Liquid Waste Mixing Technologies | Expensive systems are not capable of homogeneously mixing. Evaluate pumps (PJM's and small in tank mixer pumps) for mixing, cooling and staging on wastes in tank. | C8 C18, C19, C21, C22, C76, C77 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-7a | Process Automation and Feedback | Develop process feedback systems to address operational challenges and effectiveness. Use VR/XR to optimize productivity. Create better predictive capabilities to evaluate the effectiveness of retrieval technologies (modeling, sensor or visual) | C2, C3, C30 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-7b | Process Automation and Feedback | Develop process feedback systems to address operational challenges and effectiveness. Use AI and edge computing to optimize productivity and give feedback. Create better predictive capabilities to evaluate the effectiveness of retrieval technologies (modeling, sensor or visual) | C2, C3, C30 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-8 | Risk Based Retrieval | Evaluate though PA models, chemistry models or other engineering practices the maximization of risk based retrieval of tank waste | C13, C14, C28, C65, C66, C67, C36 | 3) transformational –change in the baseline and mid range costs |
| WR&T-9 | Equipment Decontamination and Disposal | Evaluate new waste retrieval and infrastructure equipment decontamination and disposal options (could be used address concerns with Tc/I disposition in IDF and open release of cleaned equipment) | C40, C41, C45 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-10a | Realtime Monitoring (Dry) | Develop new Realtime monitoring capabilities for dry/bulk process feeds to reduce sampling time and minimize waste | C35 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-10b | Realtime Monitoring (Liquid/Fluid) | Develop new Realtime monitoring capabilities for liquid process feeds to reduce sampling time and minimize waste | C35 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-11 | Controlling Phosphate Precipitation | Test additives that might be inhibitors (polyelectrolytes) of phosphate precipitation as well as investigate methods to removal or separate out phosphate so it's not a plugging issue | C1, C6, C74 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-12 | Dealing With High Solid Slurries | Transfer of solids could lead to solids deposition. Develop or improve existing methods for dealing with high solid slurries (new high shear mixers, use of ultrasonics, develop new inline monitoring and/or size reduction capabilities) | C4, C7, C25, C29, C34 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WR&T-13 | Cross Site Waste Transfer | Evaluate existing and new cross site transfer technologies (hose in hose, rail, tanker truck, new models and technologies to prevent mechanical plugging and minimize costs of refurbishing transfer line) | C5, C32, C37, C38, C58, C68, C72, C73 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |

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| WR&T-14 | Tank Storage and Stage Capacity is minimal due to volume of waste and inability to reuse | Evaluate needed tank storage through a cost benefit analysis of building new tanks, creating a modular/mobile tank system or evaluate reuse of SST's for staging. | C61, C69, C70, C79 | 3) transformational –change in the baseline and mid range costs |
| WR&T/WM-System Model | Integrated System and Cost model for process evaluation and benefit. | In order to evaluate cost, schedule and risk management improvements a new system model for tank farm and WTP operations model needs to be developed. | | 3) transformational –change in the baseline and mid range costs |
| WM-1 and WM-4 | Reuse of Facility and Systems (Evaporators/TSCR) | Integrated technical and regulatory risk of evaporator reuse | H40, H45 | 1) risk mitigation-not schedule driven but protect the schedule |
| WM-2 | Evaluation of New and Known Technology | Cost schedule and risk management improvement in use of evaporators | H12, H13, H14 and H15 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WM-3/SW-6 | Water (LIQUID) Reuse in Tank Farm Systems | Apply improved strategy via refined operation methods & definition requirements for water (LIQUID) utilization | H20, H24, H27, H36, H38, H44, G43 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| WM-5 | Enhanced Models, Characterization or Feeds, as well as Simulant Work | Alternative Analysis of Enhanced Evaporator Operations to allow additional processing time per year to mitigate large volumes of water to be generated during tank waste treatment operations | H22, H23, H30, H46 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| PL-1 | Improved supernate filtration methods that could be deployed in modular/skid-based system (e.g., TSCR) and without high pressure penalties or increased operational maintenance. Examples include CUF, Rotary, or ultrasonic methods | Supernate filtration is required to meet WIR requirements for removal of entrained solids that may contain insoluble radionuclide complexes, and to protect downstream pretreatment processing such as ion exchange which would be negatively impacted by solids fouling or plugging. Dead-end filtration is currently used in the TSCR and TCCR system, and requires frequent backflushing to maintain effective operations, reducing the overall TOE. Improved filtration methods with greater TOE are needed that can be deployed in skid-based systems. | D21, D49, D74 | 1) risk mitigation-not schedule driven but protect the schedule |
| PL-2 | Improving or optimizing existing filtration or processes through filtration additives | Supernate filtration is required to meet WIR requirements for removal of entrained solids that may contain insoluble radionuclide complexes, and to protect downstream pretreatment processing such as ion exchange which would be negatively impacted by solids fouling or plugging. Dead-end filtration is currently used in the TSCR and TCCR system, and requires frequent backflushing to maintain effective operations, reducing the overall TOE. Improvements to existing filtration processes that increase TOE are needed. | D22 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| PL-3 | Optimize Cs loading of CST | Non-elutable CST columns have been selected for Cs removal at Hanford for TSCR, and is expected to be used in proposed TFPT facilities. Optimizing loading of Cs columns is needed to reduce costs while balancing demands of loading limitations due to heat load, shielding, and hydrogen generation in spent CST columns. | D61, D65 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| PL-4 | Alternative IX process for Cs removal (e.g., RF, clinoptilite, low-performing CST) | Non-elutable CST columns have been selected for Cs removal at Hanford for TSCR. The cost of single use CST material, shielded columns, baseline disposition path (vitrification of CST resin with HLW) and single supplier are primary disadvantages of CST use. Cost effective use of alternative elutable IX resins or lower-cost non-elutable CST alternative may reduce the overall mission costs and risks. | D1, D20, D59 | 3) transformational –change in the baseline and mid range costs |

| Concept ID | Concept | Gap/Opportunity Addressed | Links to Brainstorm Sheet | Concept Type |
|---|---|---|---|---|
| PL-5 | RCRA Organics Removal from Tank Supernate<br>- oxidation/destruction<br>- volatilization/evaporation<br>- extraction (e.g., solvent/supercritical) | Tank waste supernate containing RCRA organics may need to be treated for the organics to meet RCRA LDR standards for non-vitrification or other thermal options for LAW immobilization. Evaporation may be effective for many LDR organics, but needs to be verified for the range of CoCs expected in Hanford tanks, and may require supplemental treatment methods to assure LDR compliance. | D24, D28, D51, D66, D73, A62 | 3) transformational –change in the baseline and mid range costs |
| PL-6 | Iodine separation technologies effective for alkaline tank waste and secondary liquid waste streams from thermal treatment offgases | Iodine, despite low total inventory in tank waste, is the primary risk driver to groundwater due to its high volatility within the vitrification process and substantial transfer to secondary waste streams, and high mobility in the subsurface. There are limited current technologies for iodine separation from either high ionic strength alkaline tank waste or liquid secondary waste streams from vitrification offgas systems. Effective iodine IX resins or sorbents that can enable separation from primary and secondary liquid waste streams are needed. | D17, D18, D31, D56, D75 | 1) risk mitigation-not schedule driven but protect the schedule |
| PL-7 | Technetium - non-pertechnetate - separation technologies effective for alkaline tank waste and secondary liquid waste streams from thermal treatment offgases | Several effective Tc ion exchange materials are available for Tc (pertechnetate) removal from alkaline tank waste, including the Superlig 644 resin originally planned for use in WTP. However, no resins or other practical separations technologies have been developed for non-pertechnetate that is known to exist in Hanford tank waste, especially the complexant waste tanks. | D33, D57, D71 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| PL-8 | Sodium nitrate separation or low-temperature destruction<br>- fractional crystallization<br>- clean salt<br>- denitrification (biological, NAC) | Sodium nitrate represents a significant fraction of the waste requiring treatment. Nitrates/NOX abatement represents a significant cost and risk for thermal waste treatment such as vitrification, and a potential long-term groundwater risk for most low-temperature treatment processes such as waste grouting. Methods for safe destruction of nitrates or separation of sodium nitrate from tank wastes | D53 | 3) transformational –change in the baseline and mid range costs |
| PL-9 | Identify methods to increase and maintain higher sodium molarity during transfers and treatment to avoid multiple dilutions and/or evaporation adjustments | Supernate processing involves adjustment of sodium molarity through water addition/dilution and evaporation/concentration as it progresses from retrieval through filtration, ion exchange, and final feed to vitrification. These adjustments are made to reduce potential precipitation of problematic chemical species, improve ion exchange, etc. If sodium molarity could be increased but maintained at levels or with handling to avoid unwanted precipitation or processing effectiveness, the needs for water addition and/or re-concentration could be avoided and water usage reduced. | D50 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| PL-10 | Methods for pretreating supernate prior to Cs removal with CSTs to remove Pu and actinides | Pu and other actinides in tank waste supernate will be removed to some degree during pretreatment using CSTs, potentially increasing the potential that loaded CSTs column are classified as TRU waste, and complicating ultimate disposition of CST canisters. Methods for actinide pretreatment, such as a monosodium titanate strike may be helpful in reducing potential for actinide loading on the CST. | D15 | 3) transformational –change in the baseline and mid range costs |
| PL-11 | Assess opportunity to reuse treated effluent water as process water to reduce overall water use. Methods for tritium removal from liquid effluent streams may be a need if increases in tritium levels through a recycle flywheel impacted final discharge. | Treated liquid effluents currently discharge to SALDS after processing through LERF and ETF. Recycle and reuse of treated effluents as makeup water, in lieu of clean process water could reduce overall water addition and better water management. Uncertainty in whether trace contaminants permitted for SALDS discharge would be potentially problematic if recycled back through tank waste processing. Tritium, for example, could increase in concentration through reuse. An assessment is needed to determine benefits and potential issues with treated effluent recycle. | E15 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |

| Concept ID | Concept | Gap/Opportunity Addressed | Links to Brainstorm Sheet | Concept Type |
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| PS-1 | Improved Methods and Equipment for Solids Size Reduction or Control | Specific need/gap is not specified. May include need to assure adequate suspension/ mixing in downstream process vessels. but issues could be made worse by size reduction. Also possible connection to monitoring and control for transfer velocity to avoided settling/line plugging. | E11, E12, E13, E30 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| PS-2 | At-Tank Treatment Capabilities for Sludge Pretreatment<br>- elevated temperature washing, countercurrent washing, filtration, improved filter performance with high solids, | Sludge washing, settling, and concentration is needed to remove problematic species such as Al, PO4, SO4, nitrate, halides that can significantly impact HLW vitrification, transferring these constituent to the LAW stream for immobilization. Baseline in PT may be cost prohibitive, and in-DST processing may have difficulty meeting washing or throughput requirements. | E1, E19, E29, E44, E45 | 3) transformational –change in the baseline and mid range costs |
| PS-3 | Improved understanding of aluminum chemistry to support sludge retrieval, transport, and washing<br>- fundamental chemistry data<br>- improved models | Aluminum is a key constituent of HLW sludges, and is manifested in different chemical forms with varying solubility and processing difficulty. Improved chemical understanding and predictive models are needed to better optimize sludge retrieval, transport, and washing. | E32, E36 | 4) long-range programs –10 to 15 years with potential big payoff if accomplished |
| PS-4 | In-Tank Treatment Optimization for Sludge Pretreatment<br>- washing fluid composition, time, temperature, selected endpoints<br>- mixer type, operating regime<br>- settling time, aids | In tank sludge processing is the primary option for sludge preparation without completion/operation of the PT facility. In-DST processing may have difficulty meeting washing or throughput requirements due to sludge properties. | E25 (reference to E20, E28 - but no longer in E workbook) | 3) transformational –change in the baseline and mid range costs |
| PS-5 | RCRA Organics Removal from Tank Solids<br>- oxidation/destruction<br>- volatilization/evaporation<br>- extraction (e.g., solvent/supercritical) | Tank waste sludges containing RCRA organics may need to be treated for the organics to meet RCRA LDR standards if non-vitrification options for immobilization could be applied (e.g., TRU sludges). | E7, E9, E33 | 3) transformational –change in the baseline and mid range costs |
| PS-6 | Evaporation and/or drying technologies to increase solids concentration and manage water from waste processing | Solids and supernate concentration is needed in both sludge and supernate processing, respectively. Filtration and evaporation are regularly used in tank waste processing. Improved evaporation methods | E15 | 3) transformational –change in the baseline and mid range costs |
| PS-8 | Cesium removal from saltcake or sludges to enable processing without significant water addition, e.g.,<br>- selective dissolution (saltcake)<br>- sludge washing (limited wash) | Cesium removal from saltcake wastes is needed to meet WIR requirements for treatment; however, standard Cs separations require water dissolution and retrieval. Cs removal methods that could be effective with dry-retrieved wastes or low-water based retrieval methods would reduce water demand, need for subsequent evaporation, and potentially enable direct grouting or drying of solids or slurries into LLW forms. | E34 | 3) transformational –change in the baseline and mid range costs |
| PS-9 | Waste treatment or offgas abatement methods to reduce impacts of key air toxics that are limiting waste processing operations | Toxic air emissions from tank waste in both storage and processing operations (e.g., ammonia) can exceed permitted emissions limits and result in restrictions on operating conditions, such as reduced flowrates for exhausters, or reduced operating times for other process facilities (e.g., months/yr, or hours/day allowable operations). Abatement methods for key air toxics, or other methods to reduce emissions are needed to accelerate treatment mission | E8 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| PS-10 | Conditioning sludge feeds to reduce impacts of non-Newtonian characteristics. May include<br>- improved monitoring<br>- adjustments or additives to control waste composition or concentrations<br>- establishing and maintaining waste transfer mixing and pumping velocities | Many of the tank waste sludge slurries exhibit non-Newtonian characteristics, making their mobilization, retrieval, and transfer more complex, demanding specific system design, monitoring, and control to assure the materials are effectively mobilized and transferred. Methods to better predict, measure, and modify rheology to manage non-Newtonian characteristics are needed. | E16 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |

| **Concept ID** | **Concept** | **Gap/Opportunity Addressed** | **Links to Brainstorm Sheet** | **Concept Type** |
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| SW-1 | New grouting compositions or lithified aggregate mixtures with getters may present a viable option. | The Secondary LLW represents a potentially large volume to be dispositioned and will contain constituents of concern for long-term disposal. A cementitious waste form is the baseline technology but retention of some species is a concern by regulators and may represent a significant volume for disposal. | G4 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| SW-2 | Use characterize and/or prediction of compositions of stream from source information and assess technology need, flowsheet requirements. | A potential treatment for TRU tanks is drying the material. The condensate will likely need to be treated with ETF. Based on recent lessons learned, the condensate could result in a new or elevated hazard to the ETF. | G40, G41 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| SW-3 | Evaluate technologies for sequestration or destruction of ammonia; or evaluate process for alternatives that do not generate the ammonia | High ammonia waste stream represents a potential worker hazard during immobilization process. | G16 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| SW-4 | Sampling and Measurement of Rad level per HEPA to stay below 17 Curies which is in the PA | Accurate measurement of Tc and I on the HEPA filters will help with meeting IDF waste acceptance criteria and potentially allow for higher volume of disposition with known quantities. | G35, G36 | 1) risk mitigation-not schedule driven but protect the schedule |
| SW-5 | Divert certain effluent streams to offsite treat/dispose. | Minimize the volume of wastewater to LERF/ETF to decrease risk of achieving higher operating capacity (ELIMINATES FLYWHEEL) | G42 | 3) transformational –change in the baseline and mid range costs |
| SW-7 | ETF adding steam stripper in addition to UV Ox. | UV Oxidation efficiency at ETF is questionable - (Ability to destroy acetonitrile) | G44 | 1) risk mitigation-not schedule driven but protect the schedule |
| SW-8 | 1. Washing of the HEPAs could be performed to concentrate Tc in low volume liquid stream. 2. Grout formulation to better immobilize and then send offsite | An alternative to finding better grout matrix for macroencapsulation of SSW - HEPA (Tc) may be needed to reduce risk. | G46 | 1) risk mitigation-not schedule driven but protect the schedule |
| SW-9 | Perform pretreatment to remove the iodine or provide a more robust grout formulation for the GAC media. | Grouting of the spent GAC may be problematic because of the iodine captured on the media | G47 | 1) risk mitigation-not schedule driven but protect the schedule |
| SW-10 | Develop Tc separation techniques for SBS condensate | SBS condensate is predicted to have a high concentration of Tc. In the baseline this Tc would have to be recycled or would eventually be dispositioned as secondary waste increasing the concentration of Tc in the secondary waste. | G50 | 2) incremental –some fit existing baseline/flowsheet but maybe not all |
| SW-11 | Improved methods for characterization and certification of Failed equipment, PPE and contaminated equipment (secondary waste items) would help with IDF WAC compliance and accurate disposal quantities. | The required analyses for secondary waste disposition are not clearly identified. Process assessments/evaluations could identify the required analytes. | G72 | 1) risk mitigation-not schedule driven but protect the schedule |
| SW-12 | Hold regulatory discussions to determine disposition path for samples that are generated incidental to processing. | Analytical samples will be generated in large volumes and will need a clear disposition path. For SRS, tank waste samples must be returned to the tank farm. A clear path for disposition besides the tank farm would help minimize overall waste to be immobilized. | G73 | 1) risk mitigation-not schedule driven but protect the schedule |

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The screening followed the process identified by the core NNLEMS team. The concepts were identified as transformational or incremental improvements. The lists were assessed separately using different criteria and scoring approach.

Definitions:

- Incremental – Project implementable in near-medium term within existing Hanford program
- Transformational – Project either not implementable within Hanford program or long-term to realize

The SME teams assessed each concept against the evaluation criteria emphasizing the potential for major benefits (cost, schedule, or risk), cost-effectiveness, probability of success. These were analyzed using the total technology development costs, success of the technology, return on investment based on the cost savings versus overall investment (for development and field installation), schedule savings and rank ordered within the concept focus areas to identify the smaller sub-set. The data for this screening are provided in Table C - 2. After a few additional combinations of similar concepts across functional areas, the sub-set of this screening was a down-selected list consisting of the top 35 ideas (shaded in green or yellow) with an additional 7 items (shaded in gray) that should continue to be pursued as part of the baseline technology development program. The concepts not considered for further evaluation were kept in the overall concepts/ideas listing for documentation and future considerations.

To summarize, at the start of Phase 2, ~300 ideas consisting of technologies, gaps, and opportunities were generated by the expanded team. These ideas were condensed into ~100 broader concepts to resolve the gaps and opportunities. Figure C - 1 provides the categorization of these concepts by the R&D type (i.e., risk mitigation, incremental, transformational, or long-range program). After screening, 35 concepts were selected for further evaluation. This process and the cross walk to the mission functional category are provided in Table C - 3.

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| Concept ID | Concept | Gap/Opportunity Addressed | Category | Links to Brainstorm Sheet | Item 1- Probability of Achieving Capability [High >66%, Mod (33-66%), Low (<33%)] | Item 2 - Probability capability leads to intended benefit [High >66%, Mod (33-66%), Low (<33%)] | Item 3 - Regulatory Change Needed to Realize the Benefit [None, Minor, Major] | Item 4a (incremental) - Development and Implementation Cost [High (>$200M), Mod ($50-200M), Low (<$50M)] | Item 4b (Transformational) - Development and Implementation Cost [High (>$500M), Mod ($200-500M), Low (<$200M)] | Item 5 - Time to implement (yrs) | Item 6 - Short term costs to obtain capability | Item 7a - Schedule Acceleration [Low - 0 to 3 yrs, Mod - 4 to 9 yrs, High > 10 yrs | Item 7b - Cost Reduction [High (>$25B), Mod ($250M-25B), Low (<$250M)] | Item 7c - Reduction in peak annual costs [None, Minor, Major] | Item 8 - Net Reduction of Environmental / Safety Risks [None, Minor, Major] | Synergies with other proposals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WT-1 | In Situ Characterization: Chemical Composition for tank contents and heels - Raman, LIBS, and other techniques to analyze tank and tank heel contents to include anions and metal data. | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required to obtain characterization data as well as the number of samples taken would expedite tank farm processes. | Waste Tanks / Tank Farms | A1, A4, A33, A37, A8, A59, A60 | Moderate | Moderate | None | Moderate | NA | 5 | 10M (flat over 5 years) | Low to Moderate | Low | No impact | Minor | TC-2, DL-4, WR&T-10 |
| WT-2 | In Situ Characterization: Physical Properties for tank contents and heels - Rheological properties, solid property measurements, pH, and density | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required to obtain characterization data as well as the number of samples taken would expedite tank farm processes. | Waste Tanks / Tank Farms | A1, A2, A4, A37, A32, A59 | Moderate | Moderate | None | Low | NA | 5 | 5M | Low | Low | No impact | Minor | TC-2, DL-4, PS-10, WR&T-10, WR&T-12, PS-10 |
| WT-3 | In Situ Characterization: Radiological Properties for tank contents and heels - Alpha, beta, gamma counters, spatial mapping of dose for heels | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required to obtain characterization data as well as the number of samples taken would expedite tank farm processes. | Waste Tanks / Tank Farms | A4, A37, A8, A33, A58, A59, A60 | Moderate | Moderate | None | Low | NA | 5 | 5M | Low to Moderate | Low | No impact | Minor | TC-2, DL-4, WR&T-10 |
| WT-4 | In Situ Characterization: Organic content for tank contents and heels | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required to obtain characterization data as well as the number of samples taken would expedite tank farm processes. | Waste Tanks / Tank Farms | A59, A62 | Moderate | Moderate | None | Low | NA | 5 | 3M | Low to Moderate | Low | No impact | Minor | TC-2, DL-4, WR&T-10 |
| WT-5 | Laboratory Characterization - Improved laboratory techniques for LDR organic analysis - improved Turn-Around-Time (I-129, Non-pertechnetate, etc.) | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the time required and the detection limits for sample analysis would improve tank farm processes and provide the additional data needed for LDR treatment of waste if needed. | Waste Tanks / Tank Farms | A4, A5, A8, A24, A56, A33, A58, A61, A62 | High | High | None | Low | NA | 3 | 10M | Low | Low | No impact | Minor | TC-2, DL-4, WR&T-10 |
| WT-6 | Automated Tank Integrity non-destructive evaluation (NDE) Techniques | The physical arrangement of the waste tanks makes non-destructive evaluation (e.g. ultrasonic wall thickness measurements) difficult. An automated process to perform these measurements would provide additional assurances and information for the tank integrity programs. The information would also provide information on current state of the tank for any retrieval or waste preparation process. | Waste Tanks / Tank Farms | A11 | High | High | None | Low | NA | <5 | 15M | Low | Low | Minor | Major | IF-2, IF-16, WR&T-2 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WT-7 | Update characterization needs depending on disposal path<br>- Eliminate analytes not needed, ensure data is available for needed analytes | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. These samples are analyzed using laboratory techniques that require extensive preparation work and can take long periods of time. Reducing the number of samples needed or the analytical measurements required for each sample would reduce the time and cost for characterization of waste during processing. | Waste Tanks / Tank Farms | A16, A6 | High | High | Minor | Low | NA | 2 | <1M | Low | Low | None | Minor | DL-4, Tie to DOE M 435.1-1 |
| WT-8 | Develop system tools to allow tank data and uncertainty to be understood<br>- Address uncertainty in current waste data<br>- I-129 and Non-pertechnetate estimates<br>- Impact of varying retrieval and blending<br>- Data needed for waste classification<br>- Prediction of complex interactions between waste during blending<br>- Improved blend plans<br>- Inhomogeneity during retrieval<br>- Identify wastes that can be retrieved with minimal treatment (e.g. CH-TRU) | The Hanford Tank Waste mission is currently planned and modelled based on information in the Hanford Best Basis Inventory (BBI) and using TOPSim models. The uncertainty in the BBI and especially in the estimates of selected species is a challenge to assess and apply to the mission level models. Evaluation of this uncertainty as well as improvements to the system modeling tools would improve the mission level estimates and flowsheets for treatment of the tank waste. | Waste Tanks / Tank Farms | A13, A34, A19, A34, A15, A17, A24, A18, A57, A62 | High | High | None | Low | NA | 5 | 5M | Low | Low | None | Minor | TC-5, PS-3, WM-5 |
| WT-9 | Better sampling methods<br>- Flow-through loops , tank mixing, etc. | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. Improving the sampling methods would reduce the time and dose required for retrieval and processing the tank waste. | Waste Tanks / Tank Farms | A34, A3 | High | High | Minor | Moderate | NA | 10 | 10M | Moderate | Moderate | Major | Minor | |
| WT-10 | Evaluate methods for LDR organic destruction<br>- Laboratory studies with Hanford tank waste matrix | LDR treatment is needed for flowsheets that do not destroy the organics during immobilization (i.e. low temperature processes such as grout). Evaluation of potential treatment methods (evaporation to remove volatile organics, low-temperature oxidation, and other methods) on simulants as well as actual tank waste is needed to confirm these processes will perform as expected. | Pretreatment - Liquid | A-62 | Delete task and score in PL section | Delete task and score in PL section | Delete task and score in PL section | Delete task and score in PL section | Delete task and score in PL section | Delete task and score in PL section | Delete task and score in PL section | Delete task and score in PL section | Delete task and score in PL section | Delete task and score in PL section | Delete task and score in PL section | PL-5 |
| IF-1 | Improve modeling or measurements for understanding critical velocity needs for pipe transfers and flushes as well as better methods to determine and/or confirm required flush volumes. | Settling of solids during transfers of slurries must be avoided to prevent buildup of materials that could plug transfer lines or lead to high dose or corrosion rates. The velocity needed to prevent solids settling is estimated based on process history, but would be different for each sludge transfer. In addition, flushing to clean out process slurries from the process lines after a transfer are also based on past processing history with the volume and velocity specified in standard operating protocols. Better understanding of these parameters could prevent processing delays from plugged transfer lines and/or reduce the flush volume requirements. | Infrastructure | J-1, J-2 | Moderate | Moderate | None | Low | NA | <2 | <0.5M | Low | Low | Low | Minor | WR&T-12 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IF-2 | Develop improved methods to detect and repair leaks in Hanford tank farm tanks<br>- NDA and robotic systems for tank inspection<br>- Patching systems to repair leaks | The physical arrangement of the waste tanks and transfer lines makes non-destructive analysis (e.g. ultrasonic wall thickness measurements) difficult. An automated process to perform these measurements would provide additional assurances and information for the tank integrity programs.<br><br>Methods to inspect and repair the tanks and/or transfer lines would allow greater confidence in utilization of existing resources for HLW preparation processes as well as the potential to avoid building new facilities if existing facilities can be utilized. | Infrastructure | J-8, J-9 | High | High | Minor | Moderate | Low | 5 | 20 M | 5/tank | Moderate | Yes | Minor | WT-6, IF-16, WR&T-2 |
| IF-3 | Life extension for process systems and components - Low temperature processes<br>- Better predictive tools for determining life expectancy<br>- Improved understanding of process chemistry on corrosion rates | Improving the understanding of erosion/corrosion of systems to better understand service life as well as improvements in materials to extend the life of process equipment (e.g. rotors on a grout mixer) would lead to reduced downtime and improved operating efficiency. | Infrastructure | J-5, J-15, J-3 | High | Moderate | None | Low | Low | 2 | 5M | Low | Low | Minor | Minor | |
| IF-4 | Life extension for process systems and components - High temperature processes<br>- Better predictive tools for determining life expectancy<br>- Improved understanding of process chemistry on corrosion rates | Improving the understanding of erosion/corrosion of systems to better understand service life as well as improvements in materials to extend the life of process equipment (e.g. melters and bubblers) would lead to reduced downtime and improved operating efficiency. | Infrastructure | J-10 | High | Moderate | None | Low | NA | 2 | <1M | Moderate | Moderate | Minor | Minor | IM-2, IM-3 |
| IF-5 | Improved PPE with increased ability to re-use components | Improvements in the use of PPE would lead to decreased operating costs. | Infrastructure | J-4 | Moderate | High | None | Low | NA | 2 | <1M | Low | Low | Minor | Minor | |
| IF-6 | Reusable HEPA filters | The ability to clean and reuse HEPA filters would reduce secondary waste generated from tank waste treatment. | Infrastructure | J-13 | Moderate | High | None | Low | NA | 5 | <1M | Low | Low | Minor | Minor | |
| IF-7 | Develop methods to improve evaporative capacity at ETF for brine. | ETF treatment capacity improvements are needed to process effluents from vitrification processes. | Infrastructure | J-16 | Moderate | High | Minor | Low | NA | 5 | 2M | Low | Moderate | Minor | None | IF-12 |
| IF-8 | Evaluate re-use of existing Hanford buildings:<br>There are a number of facilities at Hanford that have completed their missions, e.g., canyons, that have not been fully D&D'd, Some of these might have full confinement ventilation systems, fire protection systems and other hazard controls that may provide some savings versus a "green field" new facility (Hanford has done this with T-Plant storing K-Basin | A large portion of the cost for processing facilities for tank waste treatment are the reinforced structures to contain the process as well as the ancillary equipment (vent and fire systems, etc.) Use of existing structures could reduce costs for these facilities, but these savings could be eliminated based on the need for modification of a contaminated facility or increased transfer line length if facility is not close to existing facilities. | Infrastructure | J-24 | Moderate | High | Major | High | High | 10 | 50M | Moderate | Moderate | Major | None | IF-16 |
| IF-9 | Evaluate WIPP capacity to receive RH-TRU and needed Hanford systems to ship the material as well as the need for temporary storage at Hanford. | Assuming RH-TRU and other Hanford tank waste can be shipped to WIPP, it is not clear whether WIPP will have the needed design capacity. System modeling is needed to ensure capacity is available and whether on-site storage capability will be needed. | Infrastructure | J-25, J-26, J-27 | High | High | Major | Low | Moderate | 2 | <0.5M | Low to Moderate | Moderate | Minor | None | |
| IF-10 | Address the need for on-site storage of waste for all off-site shipping options. | Determine the size and type of storage needed to allow efficient operation and shipping of waste. | Infrastructure | J-28 | High | High | None | Low | NA | 2 | <0.5M | Low | Low | None | None | |
| IF-11 | Determine/ develop shipping packages needed to ship CH-TRU or LAW (liquid or immobilized waste) offsite. | Selection of a package early in the design process to allow the system design to incorporate and/or allow a new package to be developed if needed. | Infrastructure | J-29 | High | High | None | Low | NA | 2 | <0.5M | Low | Low | None | None | |
| IF-12 | Evaluation of process intensification of LERF-ETF process to include automation. | ETF treatment capacity improvements are needed to process effluents from vitrification processes. | Infrastructure | J-30 | Moderate | Moderate | Minor | Moderate | NA | 10 | 25M | Low | Moderate | Minor | None | IF-7 |

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| IF-13 | Develop robust but easy to setup systems to prevent weather shutdowns (e.g. high wind conditions) | Outdoor processing activities are dependent upon weather conditions. Development of tools to allow operation during bad weather would improve efficiency of tank farm operations. | Infrastructure | J-22. J-36 | High | High | None | Low | NA | 2 | 1M | Low | Low | Minor | Minor | Waste retrieval, staging and transfers |
| IF-14 | Improve techniques for operational support for tank farm operations<br>- Remote or automated systems to replace hands-on work | Remote or automated systems would improve efficiency of tank farm operations and reduce potential for worker exposure. In addition, these systems may allow operations in periods of weather that workers could not be used. | Infrastructure | J-38 | High | High | None | Low | NA | 5 | 2M | Low | Moderate | Minor | Major | Waste retrieval, staging and transfers |
| IF-16 | Utilize existing DSTs for waste feed staging, washing, and leaching for HLW.<br>- Establish testing program that will assure tank reuse is safe.<br>- Work with regulators to assure them tanks can be reused safely if the protocols are followed. | Utilizing existing DSTs would reduce the capitol cost and schedule for HLW vitrification options that do not use the PT Facility. | Infrastructure | J-39 | Delete task and score in WR&T section | Delete task and score in WR&T section | Delete task and score in WR&T section | Delete task and score in WR&T section | Delete task and score in WR&T section | Delete task and score in WR&T section | Delete task and score in WR&T section | Delete task and score in WR&T section | Delete task and score in WR&T section | Delete task and score in WR&T section | Delete task and score in WR&T section | IF-2, IF-8, IF-16, WRT-1, WRT-2, WRT-14 Waste retrieval, staging and transfers |
| IF-17 | Improved methods for operation and maintenance of the 242-A evaporator<br>- Evaluate technologies to reduce maintenance and replacement of evaporator components | The 242-A evaporator is the only water removal/ volume reduction capability in the tank farms. Waste retrieval and transfer operations can add significant amounts of water that needs to be removed prior to qualification, particularly for direct-feed processes. Ensuring the 242-A remains available and improving operations would allow the current mission and could lead to improvements in direct-feed missions. | Infrastructure | J-40 | High | High | None | Moderate | NA | 10 | 100M | Low | Low | Minor | Minor | WR&T 11, Water management |
| TC-1 | Evaluate existing technologies (e.g. Laser Tank Cleaning may be option) for tank cleaning. Use process engineering assessments to determine the time that may be required for residuals removal with the selected technologies. | Alternative methods for tank cleaning are needed to improve efficiency and minimize water addition. | Tank Closure | I-7, I-10 | High | High | Minor | Moderate | N/A | <5 | 5M | Low | Moderate |  | Minor | WT-2, WR&T-12, WR&T-13, TC-2 |
| TC-2 | Technology to be developed would allow for 1) characterization of residuals in place, 2) characterization method that also assesses leachability to support heel retrieval decisions and performance assessment, 3) method that provides 3D mapping of residuals in the tank so total volume of material is known | Real-time tank heel analysis to confirm inert residuals, and stop further retrieval (rad content, phase characterization) based on risk remaining for closure. This option would allow some material to be left behind if it can be shown to be inert or minimal risk. | Tank Closure | I-36, I-28, I-25 | Moderate | High | Major | N/A | Low | 10 | 20M | Low - Moderate | Low | Minor | Minor | WT-1, WT-2, WT-3, WT-4, WR&T-4, TC-1, TC-4 |
| TC-3 | Work with Regulators/Stakeholders to prioritize sequencing and timing of tank closures to address highest risk | Current tank closure sequencing doesn't include the risk of the waste contents to the environment or tank conditions. | Tank Closure | I-38, I-37 | High | Moderate | None | Low | N/A | <5 | 2M | Low | Low |  | Minor - Major | WR&T-7, WR&T-8, WR&T-12, and WR&T-13<br>K-16 |
| TC-4 | Use improved characterization methods and performance assessments to identify the residual risk of the materials remaining to determine tank cleaning end point. | Current tank closure end-state is based on achieving specific volume removal and number of methods used, if unable to achieve volume, versus the actual risk remaining. | Tank Closure | I-25, I-37 | Moderate | High | Minor | N/A | Low | 10 | 20M | Moderate | Moderate | Minor | Minor | WT-1, WT-2, WT-3, WT-4, WR&T-4, WR&T-8, TC-2 |
| TC-5 | Use existing models and data to understand movement of contaminants from earlier releases. Update models based on this information and inform definition for tank closure. | Tank cleaning end-state may be based on outdated assumptions on contaminant transport behavior which may drive the removal of more material than necessary from a risk stand point. | Tank Closure | I-29 | Moderate | Moderate | Major | Low | N/A | 10 | 10M | Low | Moderate |  | Minor | WT-8 |

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| TC-6 | Perform testing to demonstrate macroencapsulation of tank residuals in grout using tailored formulations for contaminant of concern chemical stabilization. | Grouting of the residuals to allow for tank closure is expected to be a requirement. Tailored formulation of the grout for the contaminants of concern may allow for some residuals to remain while simultaneously reducing their migration risk. | Tank Closure | I-26, I-27 | Moderate | Moderate | Major | Moderate | N/A | 10 | 10M | Moderate | Moderate | | Minor | Immobilization |
| TC-7 | Develop barriers (e.g., cementitious or lithified rock aggregate systems) with additives targeting contaminants of concern for the outside of tanks and demonstrate deployment strategies. | Utilize barriers on the outside of the tank to mitigate the impact of any migration of residual contaminants that would allow reduction in volume of contents removed. | Tank Closure | I-8, I-9 | Moderate | Moderate | Minor - Major | Moderate | N/A | 10 | 20M | Moderate | Moderate | | Major | Immobilization - targeted grouts for COCs |
| DL-1 | Provide credited barriers to allow increased waste inventory at disposal sites | Lack of credited barriers at disposal sites because of lack of long term performance data on barriers results in low waste loadings at disposal sites and requirements for retrievability for waste at IDF (or to a saltstone disposal unit type system) | Disposal Location | B30, B31, B62 | Moderate | High | Minor | Low | NA | 20+ | 10M | Low | Moderate | None | None | Enable SLAW grout or minimize needs for Tc/I removal and accelerate tank retrievals |
| DL-2 | Provide data for enhanced performance assessments of disposal sites and to credit waste containers in long term performance models | Better data is needed to reduce uncertainty and conservatism in crediting waste containers, transport models, and performance assessments to increase waste loading at disposal sites | Disposal Location | B59, B61 | High | Mod | Minor | Low to Mod | NA | 10 | 30M | Low | Low | None | None | |
| DL-3 | Evaluate assumptions for performance assessments for excessive conservatism and develop better transport and performance assessment models for multiple waste forms to increase waste loadings at disposal sites | Better transport and performance assessment models are needed to reduce the conservatism in performance models. High performance computing may need to be applied to performance assessments, particularly for alternative waste forms | Disposal Location | B21, B34, B44, B57, B60 | High | Mod | Minor | Low | NA | <5 | 10M | Low | Moderate | None | None | |
| DL-4 | Develop integrated data collection technology to allow characterization data to be collected at each waste management/ handling step for waste disposal certification | Integrated data collection systems are needed for process control and waste disposal certification for both on-site and off-site disposal options. Assumed that data needed would mostly be taken from the batch solidification feed tank. Make sure the data required for disposal site is taken. | Disposal Location | B29, B58 | High | High | None | Low | NA | <5 | 5M | Low | Low | None | None | WT-1, WT-2, WT-3, WT-4, WT-5, WT-7 |
| DL-5 | Develop capture media packaging to allow disposal of I, Tc, NH4 and NO3 for on-site and off-site disposal options | If the species of concern cannot be removed from the waste by upstream processing, methods need to be developed to allow disposal of the materials at waste disposal sites | Disposal Location | B39, B40, B41 | Low | Low/Moderate | None | Mod to High | NA | 10+ | 40M | Low | Low | None | None | Enable SLAW grout or minimize needs for Tc/I removal and accelerate tank retrievals, IM-4, IM-5, IM-6, PL-7, PL-8, PS-9 |
| DL-6 | Evaluate direct disposal options versus vitrification for disposal of CST for on-site and off-site disposal options | Alternative disposition paths besides vitrification and disposal as non-HLW should be evaluated for cost reduction opportunities | Disposal Location | B33 | High | Moderate/High | Major | High | Low | 10 | 20M | Low | Moderate | None | Minor | IM-11, PL-10, PL-3, PL-4, |
| DL-7 | Develop non-site-specific storage/transport containers | There is a need to make sure waste is put in a container that can be accepted at the final disposal site if the disposal site location changes after the material is processed and put into interim storage on the Hanford site. | Disposal Location | B1 | High | Low | Minor | High | NA | 10 | 50M | Low | Low | None | Minor | IM-10 |
| IM-1 | Improvements in Glass Waste Form | Alternative glass formulations and additives to improve volatile retention (principally Tc and I) followed by durability testing and modeling to assess the long term performance of glasses in disposal environments.<br>- Improve loading of LAW in glass to 25% Na2O<br>- Improve loading of HLW in glass to > 50%<br>- Improve Tc and I retention in glass sufficiently to make recycle adequate | Immobilization (Waste Form) | F15, F17, F22, F49, F65, F67, F75, F77, F78, F86 | High | High | None | Low to Mod (depending on incremental change) | N/A | N/A | $10M | HLW - High<br>LAW - N/A | High | Major<br>HLW - replace PT with multi-TSCR + HEMF + HLW feed prep<br>LAW - potential to replace SLAW with 6-pack of DST's brought online as needed | Minor technical benefit, Major stakeholder benefit by reducing Tc and I in secondary wastes | Synergy with IM-2 |

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| IM-2 | Improvements on Melter/Bubbler Technology | Explore alternative designs to improve melter performance and lifetime. Explore alternative designs to improve bubbler performance and lifetime.<br>- Double bubbler lifetime<br>- Increase LAW melter throughput to 40 tG/d<br>- Increase HLW melter throughput to 8 tG/d | Immobilization (Waste Form) | F38, F50, F54, F56, F59, F71 | High (plant throughput increase to 40 t/d)<br>High (double bubbler life) | High (for bubblers)<br>Mod for high throughput | None | Mod | N/A | N/A | $50M, but, can select the year and only bubbler life should be done until more TSCR capacity comes on line | HLW - High<br>LAW - N/A | High | Major, (can reduce cost of SLAW to 6-pack of DST and also HPTF drastically)<br>Major (increase bubbler life can accelerate HLW) | Minor to major, if higher LAW throughput and SLAW becomes DST storage, None otherwise | Synergy with IM-1 |
| IM-3 | Technetium and Iodine Management (Excluding Glass Waste Forms, combined with IM-5) | There is a need for improved characterization technologies as well as evaluations of alternative capture methods and waste forms for the management of technetium and iodine. | Immobilization (Waste Form) | F28, F30, F53, F41, F76, F85, F90 | High (capability can be achieved if cost is favorable) | Mod | Minor (potential for dispose of Tc and I offsite) | Mod to High (new process required to implement removal and immobilization) | N/A | N/A | Not necessarily near-term, can implement later. If near-term build then $100M | This depends on what fraction of the tank waste would change from HLW to LLW if Tc and I removed. | Mod-High (reduce capacity of SLAW, but, costs to implement new process), (if reduce HLW amount, high) | Unknown | Minor to major (Includes activities to reduce Tc and I in IDF) | Synergy with IM-1 and IM-2 |
| IM-4 | NOX Management | Improved methods/technologies to reduce NOX generation and worker exposure.<br>- HLW to handle direct feed without significant washing<br>- LAW to minimize PICS impact by changing sugar<br>- LAW + HLW NH3 safety risk | Immobilization (Waste Form) | F35, F68, F69, F83 | Mod (explain) | High | None | Mod | N/A | N/A | 13.36901522 | Potentially high for HLW (compared to operating at a SCR rate with DFHLW, but, other solution such as over washing could also serve) | High (eliminate need to over wash and manage liquid, e.g., build evaporator) | Unknown | Minor (worker safety, PICS management) | IM-2 |
| IM-5 | Mercury Management | Improved capture methods for mercury including carbon bed alternatives and management strategies.<br>- Implement Hg management approach that decreases contaminated secondary waste by >50% | Immobilization (Waste Form) | F35, F51, F60 | Low-Mod | Low (Hg has a habit of migrating to many locations in system) | None | Mod | N/A | N/A | Unknown | None | Low-Mod | None-Minor | Minor (reduced Hg contaminated secondary wastes for disposal) | |
| IM-6 | Supernatant Treatment Process(es) | Upon supernatant treatment in removing radionuclides, dry out supernatant using de-saltation technology and place dried salts into waste containers and dispose.<br>- Treat supernatant and saltcake to generate form for off-site disposal | Immobilization (Waste Form) | F31 | High (technologies demonstrated at large scale) | Mod - High | Major (if attempting to go to reclassify, None if WIR) | N/A | Mod - High | 10+ | $5M near-term, $100M at point of implementation | High | Mod - High (replaces SLAW, if SLAW is grout mod if SLAW is vit high) | Major (if replaces SVIT)<br>Minor (if replaces SGROUT) | None | |
| IM-7 | Container Decontamination | Evaluation and selection of technologies for LAW/LLW/HLW container decontamination.<br>- Non manual LAW decon<br>- Reduce water by 90% relative to HLW Ce-nitrate process | Immobilization (Waste Form) | F24, F73 | High (there are a number of decon technologies that can be used) | Low | None | Low | N/A | N/A | Unknown | None | Low | None | Minor (LAW)<br>None (HLW) | |
| IM-8 | Waste Container Design | Ensure that containers are properly selected and/or designed to hold the expected waste components/waste streams. | Immobilization (Waste Form) | F21, F48, F53 | High | High | None (may need to be transported in which case transport license is needed) | Low | N/A | N/A | Unknown | None | None | None | None | |
| IM-9 | Remote handled TRU | Evaluate/Develop/Select technologies for remote handled TRU.<br>- Demonstrate/implement technology for RH-TRU treatment for shipment to WIPP | Immobilization (Waste Form) | F32 | High | High (assume more than current RHTRU tanks)<br>Mod (may turn out to be cheaper to operate HLW vit for additional year than build this) | Major (need to change land withdrawal act for WIPP to send RH-TRU) | Unknown (One previous study concluded that HLW vit was cost competitive to Drying and sending to WIPP). | N/A | N/A | Unknown | Mod (assuming HLW drives mission life & RH-TRU tanks separately treated)<br>High (assuming HLW drives mission & more characteristically TRU tanks treated separately) | Unknow, depending on comparative cost to treat and ship TRU to WIPP vs HLW vit | None (will increase peak annual cost by installing new capability to manage RHTRU) | None | IM-14, IM-12 |

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| IM-10 | High Efficiency Waste forms | Develop and assess more efficient (increased capacity, reduced cost etc.) waste forms for HLW. Examine cost, efficiency and durability tradeoffs (life cycle analysis or LCA) of these materials.<br>- Assume this means running waste through HLW vit, but, without meeting WASRD/WAPS | Immobilization (Waste Form) | F39 | High | Mod | No change in regulation, but, change in repository WAC | Low (assuming use of HLW glass melters)<br>High (if different process is in focus) | N/A | N/A | $5M (only R&D money and WAC negotiations) | High (assuming HLW drives mission life) | High (assuming HLW drives mission life) | None (shorter mission life but, no new facilities) | Minor (HLW does not influence CSNF designed repository performance) | |
| 1M-11 | Process Water Usage | Evaluate and implement strategies for more efficient water use. (What is the target for water use reduction?) | Immobilization (Waste Form) | F63, F64 | High (HLW)<br>Mod (LAW) | High | None | Low | N/A | N/A | Very little or none | Low (models don't project water limitations now) | Low | Minor (Likely reduce cost of HEMF, EMF, ETF, and 242A already built) | None | IM-2 |
| IM-12 | Waste Dewatering | Assess and implement dewatering options with consideration of scale-up, cost and safety.<br>- Necessary to treat tank waste as non-HLW | Immobilization (Waste Form) | F44 | High | High | Not by itself, but, waste determination requires approval | Mod to High (costs for Littleford day rotary drier was generated, but, other options need to be considered). | N/A for current TRU inventory, Mod for waste determination | N/A | $100M | Low (current TRU tanks)<br>High (waste determination for broader range of TRU) | None (Current for CH-TRU tanks)<br>High (broader range) | No change (current CHTRU)<br>High (if SLAW or expensive HLW treatment capability are avoided) | Minor (there are inherent risks in HLW treatment that may be significantly lower for "drying") | IM-9 |
| IM-13 | Grout Development, Performance and Durability | There is a need to develop improved containerized grout formulations as well as to validate their durability and long term performance)<br>- Needed to implement Grout SLAW<br>- Assume on-site disposal | Immobilization (Waste Form) | F16, F25, F27, F29, F33, F40, F42, F43, F45, F46, F57, F58, F72, F74, F80, F81 | High | Mod | None For SLAW (Not regulation *perse*, permit for non-glass SLAW would be needed)<br>Major For Reclassification | N/A transformational (assuming SLAW and reclassification) | Low-Mod | 10+ (to convince state to permit) | $25M (e.g., TBI) | High | High | Major (if replaces SLAW) | None to negative but will meet requirements | |
| IM-14 | Treat TRU as LAW/LLW | Immobilize TRU in grout and its potential disposal pathways as LAW/LLW. | Immobilization (Waste Form) | F25, F40, F91 | either low or high depending on final characteristics after treatment | either low or high depending on final characteristics after treatment | Minor-Major | N/A (transformational) | Low (would be offset by planned WIPP preparation process) | 10+ | Unknown | Low | Unknown (differential cost for shipment to and disposal in WIPP vs other facility) | Minor | None to negative but will meet requirements | IM-9 |
| IM-15 | FBSR | Scientific investigation to reevaluate FBSR for immobilization of HLW | Immobilization (Waste Form) | F70 | Mod | Low | None For SLAW (Not regulation *perse*, permit for non-glass SLAW would be needed)<br>Major For Reclassification | N/A | High | 10+ | $75M (full scale pilot operation) | Unknown | High (proponents estimate significant lower staff requirements compared to vitrification) | Unknown | Unknown | |
| WR&T-1 (Hanford-1 (TEDS KD Auclair)) | Infrastructure Cost Evaluation through development of a System Model | Waste retrieval and infrastructure cost reductions (Superstructure improvements, reduced shielding and support infrastructure). Do a cost benefit/engineering analysis of retrieval technologies. | C30, C33 | C30, C33 | moderate to high - dependent upon any new tech identified and potential impacts | high | None | Low ($10M-$15M Full Benefit )<br>Basian Model<br>Non-Basian Model<br>Goldsim<br>Digital Twin (integrated OR, design, flow sheet, chemistry and risk analysis)<br><br>Low ($5M-$7M Imcremetal Benefit) | N/A | <5 | $4M-$6M | Low | Moderate Full Benefit ($30B based on 25% cost savings lifetime) allows uninterrupted retrieval & transport operations that provide feed to a plant 24/7<br><br>Incremental Benefit (Retrieval timing & required infrastructure optimization to reduce mission life (i.e. melters needed)<br><br>Assumption Cost savings are $500M/ yr annualized over 60 years. | N/A | Minor-Major | |

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| WR&T-2a | Leak Detection and monitoring. | Evaluate leak detection and monitoring both before and during retrieval to mitigate potential release to the environment. | C55, C56, C57, C60, C63 | C55, C56, C57, C60, C63 | High | High | None | Low | N/A | <5 | $5M-$10M | Low | Low | N/A | Major | WT-6, IF-2 |
| WR&T-2b | Leak Repair (Quick win). Assess remote robotic repair and in situ barrier technologies. | Evaluate life extension and leak repair technologies for deployment both before and during retrieval to mitigate potential release to the environment. | C55, C56, C57, C60, C63 | C55, C56, C57, C60, C63 | High | High | Minor to major (implementation of what you intend to do) | $25M-$30M (Development, initial field implementation and qualification of a leak mitigation for a single shell tank) | $50M-$100M (Development, initial field implementation, life extension and qualification of a high value double shell tank) | 5 to <10 years | $5M - $15M | Moderate | $500M-$1B (High value double shell tanks/life extension mitigating building of new tank/loss of process tank e.g. SY-104/AP-106)<br><br>$250M for double shell tank to mitigate a storage tank e.g. AY-102 | Major ($1M/day lost production) | Major | WT-6, IF-2 |
| WR&T-3 | Dry Waste Retrieval Technologies | Evaluate dry or minimal liquid retrieval technologies for known leaker tanks to mitigate potential release to the environment.. National lab experiences and commercial vendor literature review required for existing technologies. | Waste retrieval and Transport | C11, C20, C23, C31, C59, C64, C80, C81 | Moderate to High | Moderate to High | None | $15M-$25M Testing and qualifying existing commercial equipment | N/A | 5 to <10 years | $5M to $15M | High | Moderate: Reduction of schedule will be in reduced daily operational costs for wet retrieval costs. Additional costs are realized in less water in system reduced chemical costs associated with final waste form | N/A | Major | |
| WR&T-4 | Hard Heel Removal Technologies | Evaluate minimal water hard heel removal technologies | Waste retrieval and Transport | C12, C15, C16, C26, C62, H21 | Moderate to High | Moderate to High | None | Low | N/A | 5 to <10 years | $5M to $15M | Low to Moderate | Moderate | N/A | Major | TC-4 |
| WR&T-5 | Liquid Waste Retrieval Technologies | Evaluate type of liquid and liquid reuse for wet retrieval technologies for HLW, LLW and TRU tank waste to minimize introduction of new chemicals/ liquid to the tank farm. National lab experiences and commercial vendor literature review required. Technology transfer evaluation from other sites. | Waste retrieval and Transport | C24, C29, C75, C78, C82, C84 | High | Moderate to High | Minor | Low (18%-40% energy reduction per EPRI study of large cooling towers vs mechanical evaporators) | N/A | <5 years | $5M to $15M | Low to Moderate | Moderate | N/A | Minor | PL-11 |
| WR&T-6 | Liquid Waste Mixing Technologies | Expensive systems are not capable of homogeneously mixing. Evaluate pumps (PJM's and small in tank mixer pumps) for mixing, cooling and staging on wastes in tank. | Waste retrieval and Transport | C8 C18, C19, C21, C22, C76, C77 | Moderate to High | Moderate to High | Minor | Moderate | N/A | 5-10 years | $25M-$100M | Moderate | Low to Moderate | N/A | Minor | |
| WR&T-7a | Process Automation and Feedback | Develop process feedback systems to address operational challenges and effectiveness. Use VR/XR to optimize productivity. Create better predictive capabilities to evaluate the effectiveness of retrieval technologies (modeling, sensor or visual) | Waste retrieval and Transport | C2, C3, C30 | High | High (avoidance of safety, ALARA and human performance issues) | None | With the development of a successful model<br><br>$75M-$100M (Physical plant items e.g. integrated control, RAMAN, Digital Twin, and Radionuclide speciation) | N/A | <5 | $1M to $10M (based on technology and extent of implementation ) | Low | Low (could be moderate if you have issues) | N/A | Moderate to Major | |

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| WR&T-7b | Process Automation and Feedback | Develop process feedback systems to address operational challenges and effectiveness. Use AI and edge computing to optimize productivity and give feedback. Create better predictive capabilities to evaluate the effectiveness of retrieval technologies (modeling, sensor or visual) | Waste retrieval and Transport | C2, C3, C30 | High | Moderate | None | With the development of a successful model, $75M-$100M (Physical plant items e.g. integrated control, RAMAN, Digital Twin, and Radionuclide speciation)<br><br>For incremental, additional cost 7a & 7b can be done in parallel | High | 5yr to 10yr | $10M to $25M | High | Moderate<br>Full Benefit (Assuming WR&T/WM model implementation. $2B cost savings lifetime)<br><br>Incremental Benefit (Process optimization, sampling requirements and associated process time). An enhancement forward feed process and melter utilization and reduce canister count.<br><br>Assumption Cost savings are $50M/yr annualized over 40 years. | Moderate to Major | Major | Ties to other programs such as FE, NE, ARPA-E |
| WR&T-8 | Risk Based Retrieval | Evaluate though PA models, chemistry models or other engineering practices the maximization of risk based retrieval of tank waste | Waste retrieval and Transport | C13, C14, C28, C65, C66, C67, C36 | High | High | Major | N/A | N/A assuming model exist. Cost to build the model is included in WR&T 1 or WR&T/WM systems model.<br><br>$3M-$5M per year | <5 yrs (regulatory hurdles could greatly expand) | $3M-$5M | High | $15M/tank up to $2.3B for all tanks in current dollars (based on 50% saving per tank emptied) | Major | Moderate to Major | TC-3, TC-4; tie to Tank Closure |
| WR&T-9 | Equipment Decontamination and Disposal | Evaluate new waste retrieval and infrastructure equipment decontamination and disposal options (could be used address concerns with Tc/I disposition in IDF and open release of cleaned equipment) | Waste retrieval and Transport | C40, C41, C45 | High | Moderate to High | None | Moderate to Low | N/A | <5 | $5M to $10M (based on leveraging existing programs across government) | Low to Moderate | Low to Moderate | N/A | Moderate to Major | |
| WR&T-10a | Realtime Monitoring (Dry) | Develop new Realtime monitoring capabilities for dry/bulk process feeds to reduce sampling time and minimize waste | Waste retrieval and Transport | C35 | High | High | None | $15M-$50M Testing and qualifying existing commercial equipment | N/A | <5 | $1M to $10M (based on technology and extent of implementation) | Low to Moderate | Moderate $250M-$500M Overall integrated risk reduction and cost avoidance for uninterrupted retrieval and transport operations that provide input feed to a plant 24/7 | N/A | Minor | WT-1, WT-2, WT-3, WT-4, WT-5 |
| WR&T-10b | Realtime Monitoring (Liquid/Fluid) | Develop new Realtime monitoring capabilities for liquid process feeds to reduce sampling time and minimize waste | Waste retrieval and Transport | C35 | High | High | None | $15M-$50M Testing and qualifying existing commercial equipment | N/A | <5 | $1M to $10M (based on technology and extent of implementation) | Low to Moderate | Moderate $250M-$500M Overall integrated risk reduction and cost avoidance for uninterrupted retrieval and transport operations | N/A | | WT-1, WT-2, WT-3, WT-4, WT-5 |
| WR&T-11 | Controlling Phosphate Precipitation | Test additives that might be inhibitors (polyelectrolytes) of phosphate precipitation as well as investigate methods to removal or separate out phosphate so it's not a plugging issue | Waste retrieval and Transport | C1, C6, C74 | Moderate to High | Moderate to High | None | Low to Moderate | N/A | 5yr to 10Yr | $1M to $20M (based on scale) | Low to Moderate | Low to Moderate (adjust molarity 8M to 2M and not in baseline) | N/A | Minor | IF-17, PS-2, PL-9 |

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| WR&T-12 | Dealing With High Solid Slurries | Transfer of solids could lead to solids deposition. Develop or improve existing methods for dealing with high solid slurries (new high shear mixers, use of ultrasonics, develop new inline monitoring and/or size reduction capabilities) | Waste retrieval and Transport | C4, C7, C25, C29, C34 | High | High | None | Low to Moderate | N/A | <5 yrs | $10M to $50M (Leverage SRNL Capabilities) | Low to Moderate | Low to Moderate | N/A | None | WT-2, IF-1, TC-3, PS-2 |
| WR&T-13 | Cross Site Waste Transfer | Evaluate existing and new cross site transfer technologies (hose in hose, rail, tanker truck, new models and technologies to prevent mechanical plugging and minimize costs of refurbishing transfer line) | Waste retrieval and Transport | C5, C32, C37, C38, C58, C68, C72, C73 | Moderate to High | Low to Moderate | None | Low ($10M-$15M Full Benefit ) Basian Model Non-Basian Model Goldsim Digital Twin (integrated OR, design, flow sheet, chemistry and risk analysis)<br><br>Low ($5M-$7M Imcremetal Benefit) | N/A | 5yr to 10yr | >$100M (Modeling, permits and physical system) | Low to Moderate | Low to Moderate | N/A | Potentially Negative if Not Solved! | |
| WR&T-14 | Tank Storage and Stage Capacity is minimal due to volume of waste and inability to reuse | Evaluate needed tank storage through a cost benefit analysis of building new tanks, creating a modular/mobile tank system or evaluate reuse of SST's for staging. | Waste retrieval and Transport | C61, C69, C70, C79 | High | High | Major | Low ($10M-$15M Full Benefit ) Basian Model Non-Basian Model Goldsim Digital Twin (integrated OR, design, flow sheet, chemistry and risk analysis)<br><br>Low ($5M-$7M Imcremetal Benefit) | N/A | <5 yr | $5M to $10M | Moderate to High | Moderate | N/A | Major | |
| WR&T/WM-System Model | Integrated System and Cost model for process evaluation and benefit. | In order to evaluate cost, schedule and risk management improvements a new system model for tank farm and WTP operations model needs to be developed. | Waste Retrieval and Transport/ Water Management System Model | | High | High | None | Low ($10M-$15M Full Benefit ) Basian Model Non-Basian Model Goldsim Digital Twin (integrated OR, design, flow sheet, chemistry and risk analysis)<br><br>Low ($5M-$7M Imcremetal Benefit) | N/A | <5yr -7yr | $7M to $12M | Moderate to High | Moderate Full Benefit ($30B based on 25% cost savings lifetime) Allows uninterrupted retrieval & transport operations that provide feed to a plant 24/7<br><br>Incremental Benefit (Retrieval timing & required infrastructure optimization to reduce mission life (i.e. melters needed)<br><br>Assumption Cost savings are $500M/ yr annualized over 60 years. | N/A | Major | |
| WM-1 and WM-4 | Reuse of Facility and Systems (Evaporators/TSCR) | Integrated technical and regulatory risk of evaporator reuse | Water Management | H40, H45 | High | Moderate to High | Minor (Systems need to repermitted for intended use or moderate if there is a change e.g. process chemistry Tc/I removal). Evaporators will need additional modeling for impact assessment. | Moderate | N/A | <5 yr to 10 yr | <$5M | Moderate | Low to Moderate | N/A | Minor | |

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| WM-2 | Evaluation of New and Known Technology | Cost schedule and risk management improvement in use of evaporators | Water Management | H12, H13, H14 and H15 | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model |
| WM-3/ SW-6 | Water (LIQUID) Reuse in Tank Farm Systems | Apply improved strategy via refined operation methods & definition requirements for water (LIQUID) utilization | Water Management | H20, H24, H27, H36, H38, H44, G43 | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | IM-13, PL-11 Integrate with advanced modeling and analysis described in WR&T/ WM-System Model |
| WM-5 | Enhanced Models, Characterization or Feeds, as well as Simulant Work | Alternative Analysis of Enhananced Evaporator Operations to allow additional processing time per year to mitigate large volumes of water to be generated during tank waste treatment operations | Water Management | H22, H23, H30, H46 | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | WT-8; Integrate with advanced modeling and analysis described in WR&T/ WM-System Model |
| SW-5 | Divert certain effluent streams to offsite treat/dispose. | Minimize the volume of wastewater to LERF/ETF to decrease risk of achieving higher operating capacity (ELIMINATES FLYWHEEL) | G42 | G42 | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/WM-System Model | Integrate with advanced modeling and analysis described in WR&T/ WM-System Model to identify quantity & disposition of secondary waste (water and contaminates of concern) to achieve process improvements |
| PL-1 | Improved supernatant filtration methods that could be deployed in modular/skid-based system (e.g., TSCR) and without high pressure penalties or increased operational maintenance. Examples include CUF, Rotary, or ultrasonic methods | Supernate filtration is required to meet WIR requirements for removal of entrained solids that may contain insoluble radionuclide complexes, and to protect downstream pretreatment processing such as ion exchange which would be negatively impacted by solids fouling or plugging. Dead-end filtration is currently used in the TSCR and TCCR system, and requires frequent backflushing to maintain effective operations, reducing the overall TOE. Improved filtration methods with greater TOE are needed that can be deployed in skid-based systems. | Pretreatment - Supernate | E21, E49, E74 | High | High | None | Low | N/A | <5 | $10M | Low | Low-Moderate | Minor | None | |
| PL-2 | Improving or optimizing existing filtration or processes through filtration additives | Supernate filtration is required to meet WIR requirements for removal of entrained solids that may contain insoluble radionuclide complexes, and to protect downstream pretreatment processing such as ion exchange which would be negatively impacted by solids fouling or plugging. Dead-end filtration is currently used in the TSCR and TCCR system, and requires frequent backflushing to maintain effective operations, reducing the overall TOE. Improvements to existing filtration processes that increase TOE are needed. | Pretreatment - Supernate | E22 | Moderate | Low | None | Low | N/A | <5 | $5M | Low | Low-Moderate | Minor | None | |

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| PL-3 | Optimize Cs loading of CST | Non-elutable CST columns have been selected for Cs removal at Hanford for TSCR, and is expected to be used in proposed TFPT facilities. Optimizing loading of Cs columns is needed to reduce costs while balancing demands of loading limitations due to heat load, shielding, and hydrogen generation in spent CST columns. | Pretreatment - Supernate | E61, E65 | High | Moderate | Minor | Low-Moderate | Low | <5 | <$5M | Low | Low | Minor | Minor | Disposal of loaded CSTs |
| PL-4 | Alternative IX process for Cs removal (e.g., RF, clinoptilite, low-performing CST) | Non-elutable CST columns have been selected for Cs removal at Hanford for TSCR. The cost of single use CST material, shielded columns, baseline disposition path (vitrification of CST resin with HLW) and single supplier are primary disadvantages of CST use. Cost effective use of alternative elutable IX resins or lower-cost non-elutable CST alternative may reduce the overall mission costs and risks. | Pretreatment - Supernate | E1, E20, E59 | Moderate-High | Moderate | Minor | Moderate | N/A | 10 | $15M | Low | Low | Minor | Minor | |
| PL-5 | RCRA Organics Removal from Tank Supernate<br>- oxidation/destruction<br>- volatilization/evaporation<br>- extraction (e.g., solvent/supercritical) | Tank waste supernatant containing RCRA organics may need to be treated for the organics to meet RCRA LDR standards for non-vitrification or other thermal options for LAW immobilization. Evaporation may be effective for many LDR organics, but needs to be verified for the range of CoCs expected in Hanford tanks, and may require supplemental treatment methods to assure LDR compliance. | Pretreatment - Supernate | E24, E28, E51, E66, E73, A62 | Moderate | Moderate | Major | Moderate-High | Low - Moderate | 10 | $10M | Low-Moderate | Moderate | Major | Minor | WT-10, PS-5 |
| PL-6 | Iodine separation technologies effective for alkaline tank waste and secondary liquid waste streams from thermal treatment offgases | Iodine, despite low total inventory in tank waste, is the primary risk driver to groundwater due to its high volatility within the vitrification process and substantial transfer to secondary waste streams, and high mobility in the subsurface. There are limited current technologies for iodine separation from either high ionic strength alkaline tank waste or liquid secondary waste streams from vitrification offgas systems. Effective iodine IX resins or sorbents that can enable separation from primary and secondary liquid waste streams are needed. | Pretreatment - Supernate | E17, E18, E31, E56, E75 | Moderate | Moderate | None | Moderate | Moderate | 10 | $20M | Low | Low-Moderate | None | Major | IM-5 |
| PL-7 | Technetium - non-pertechnetate - separation technologies effective for alkaline tank waste and secondary liquid waste streams from thermal treatment offgases | Several effective Tc ion exchange materials are available for Tc (pertechnetate) removal from alkaline tank waste, including the Superlig 644 resin originally planned for use in WTP. However, no resins or other practical separations technologies have been developed for non-pertechnetate that is known to exist in Hanford tank waste, especially the complexant waste tanks. | Pretreatment - Supernate | E33, E57, E71 | Moderate | Moderate | None | Low-Moderate | N/A | 10 | $15M | Low | Low-Moderate | None | Minor | IM-4 |
| PL-8 | Sodium nitrate separation or low-temperature destruction<br>- fractional crystallization<br>- clean salt<br>- denitrification (biological, NAC) | Sodium nitrate represents a significant fraction of the waste requiring treatment. Nitrates/NOX abatement represents a significant cost and risk for thermal waste treatment such as vitrification, and a potential long-term groundwater risk for most low-temperature treatment processes such as waste grouting. Methods for safe destruction of nitrates or separation of sodium nitrate from tank wastes | Pretreatment - Solids | E43, (E46 duplicate), D53 | Moderate-High | Moderate-High | None | High | Moderate | 10 to 20 | $25M | Low | Moderate | None | Minor | |

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| PL-9 | Identify methods to increase and maintain higher sodium molarity during transfers and treatment to avoid multiple dilutions and/or evaporation adjustments | Supernate processing involves adjustment of sodium molarity through water addition/dilution and evaporation/concentration as it progresses from retrieval through filtration, ion exchange, and final feed to vitrification. These adjustments are made to reduce potential precipitation of problematic chemical species, improve ion exchange, etc. If sodium molarity could be increased but maintained at levels or with handling to avoid unwanted precipitation or processing effectiveness, the needs for water addition and/or re-concentration could be avoided and water usage reduced. | Pretreatment - Supernate | E50 | Moderate | Moderate-High | None | Low | N/A | <5 | $15M | Low | Moderate | Minor | None | |
| PL-10 | Methods for pretreating supernatant prior to Cs removal with CSTs to remove Pu and actinides | Pu and other actinides in tank waste supernatant will be removed to some degree during pretreatment using CSTs, potentially increasing the potential that loaded CSTs column are classified as TRU waste, and complicating ultimate disposition of CST canisters. Methods for actinide pretreatment, such as a monosodium titanate strike may be helpful in reducing potential for actinide loading on the CST. | Pretreatment - Supernate | E15 | High | Moderate | Major/Minor | Low-Moderate | N/A | 5 to 10 | $10M | Low | Low | Minor | Minor | Disposal of loaded CSTs |
| PL-11 | Assess opportunity to reuse treated effluent water as process water to reduce overall water use. Methods for tritium removal from liquid effluent streams may be a need if increases in tritium levels through a recycle flywheel impacted final discharge. | Treated liquid effluents currently discharge to SALDS after processing through LERF and ETF. Recycle and reuse of treated effluents as makeup water, in lieu of clean process water could reduce overall water addition and better water management. Uncertainty in whether trace contaminants permitted for SALDS discharge would be potentially problematic if recycled back through tank waste processing. Tritium, for example, could increase in concentration through reuse. An assessment is needed to determine benefits and potential issues with treated effluent recycle. | Pretreatment - Supernate | E15 | Moderate | Moderate-High | None | Low-Moderate | N/A | 5 to 10 | $20M | Low | Low | None | Minor | WR&T-5, WM-3 |
| PS-1 | Improved Methods and Equipment for Solids Size Reduction or Control | May include need to assure adequate suspension/ mixing in downstream process vessels. but issues could be made worse by size reduction. Also possible connection to monitoring and control for transfer velocity to avoid settling/line plugging. | Pretreatment - Solids | E11, E12, E13, E30 | Moderate | Low-Moderate | None | Moderate | N/A | 10 | $10M | Low | Low-Moderate | None | None | WR&T-12 |
| PS-2 | At-Tank Treatment Capabilities for Sludge Pretreatment<br>- elevated temperature washing, countercurrent washing, filtration, improved filter performance with high solids, | Sludge washing, settling, and concentration is needed to remove problematic species such as Al, PO4, SO4, nitrate, halides that can significantly impact HLW vitrification, transferring these constituent to the LAW stream for immobilization. Baseline in PT may be cost prohibitive, and in-DST processing may have difficulty meeting washing or throughput requirements. | Pretreatment - Solids | E1, E19, E29, E44, E45 | High | High | None | Moderate | Moderate | 10 | $15M | Moderate-High | Moderate | Major | None | |
| PS-3 | Improved understanding of aluminum chemistry to support sludge retrieval, transport, and washing<br>- fundamental chemistry data<br>- improved models | Aluminum is a key constituent of HLW sludges, and is manifested in different chemical forms with varying solubility and processing difficulty. Improved chemical understanding and predictive models are needed to better optimize sludge retrieval, transport, and washing. | Pretreatment - Solids | E32, E36 | High | Moderate | None | Low | Low | 10 | $15M | Low-Moderate | Moderate | Minor | None | WT-8 |

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| PS-4 | In-Tank Treatment Optimization for Sludge Pretreatment<br>- washing fluid composition, time, temperature, selected endpoints<br>- mixer type, operating regime<br>- settling time, aids | In tank sludge processing is the primary option for sludge preparation without completion/ operation of the PT facility. In-DST processing may have difficulty meeting washing or throughput requirements due to sludge properties. | Pretreatment - Solids | E25 (reference to E20, E28 - but no longer in E workbook) | Moderate-High | Moderate | Minor | Moderate | Moderate | 5 to 10 | $10M | Low-Moderate | Low-Moderate | Major | None | |
| PS-5 | RCRA Organics Removal from Tank Solids<br>- oxidation/destruction<br>- volatilization/evaporation<br>- extraction (e.g., solvent/supercritical) | Tank waste sludges containing RCRA organics may need to be treated for the organics to meet RCRA LDR standards if non-vitrification options for immobilization could be applied. | Pretreatment - Solids | E7, E9, E33 | Low-Moderate | Moderate | Major | Moderate-High | Moderate-High | 10 | $15M | Low | Moderate | Minor | Major | PL-5 |
| PS-6 | Evaporation and/or drying technologies to increase solids concentration and manage water from waste processing | Solids and supernatant concentration is needed in both sludge and supernatant processing, respectively. Filtration and evaporation are regularly used in tank waste processing. Improved evaporation methods (water management in general) | Pretreatment - Solids | E15 | High | High | None | Moderate | N/A | <5 | $10M | Low | Low-Moderate | None | None | Water management |
| PS-8 | Cesium removal from saltcake or sludges to enable processing without significant water addition, e.g.,<br>- selective dissolution (saltcake)<br>- sludge washing (limited wash) | Cesium removal from saltcake wastes is needed to meet WIR requirements for treatment; however, standard Cs separations require water dissolution and retrieval. Cs removal methods that could be effective with dry-retrieved wastes or low-water based retrieval methods would reduce water demand, need for subsequent evaporation, and potentially enable direct grouting or drying of solids or slurries into LLW forms. | Pretreatment - Solids | E34 | Low-Moderate | Low-Moderate | Major | Moderate-High | Moderate-High | 10 | $10M | Moderate | Low-Moderate | Minor | None | Water management |
| PS-9 | Waste treatment or offgas abatement methods to reduce impacts of key air toxics that are limiting waste processing operations | Toxic air emissions from tank waste in both storage and processing operations (e.g., ammonia) can exceed permitted emissions limits and result in restrictions on operating conditions, such as reduced flowrates for exhausters, or reduced operating times for other process facilities (e.g., months/yr, or hours/day allowable operations). Abatement methods for key air toxics, or other methods to reduce emissions are needed to accelerate treatment mission | Pretreatment - Solids | E8 | Moderate-High | Moderate-High | Minor | Moderate | N/A | 5 to 10 | $20M | Moderate | Moderate | None | Major | Dry Retrieval |
| PS-10 | Conditioning sludge feeds to reduce impacts of non-Newtonian characteristics. May include<br>- improved monitoring<br>- adjustments or additives to control waste composition or concentrations<br>- establishing and maintaining waste transfer mixing and pumping velocities | Many of the tank waste sludge slurries exhibit non-Newtonian characteristics, making their mobilization, retrieval, and transfer more complex, demanding specific system design, monitoring, and control to assure the materials are effectively mobilized and transferred. Methods to better predict, measure, and modify rheology to manage non-Newtonian characteristics are needed. | Pretreatment - Solids | E16 | Moderate | Low-Moderate | None | Low-Moderate | N/A | 10 | $10M | Low | Low-Moderate | None | Minor | WT-2 |
| SW-1 | New grouting compositions or lithified aggregate mixtures with getters may present a viable option. | The Secondary LLW represents a potentially large volume to be dispositioned and will contain constituents of concern for long-term disposal. A cementitious waste form is the baseline technology but retention of some species is a concern by regulators and may represent a significant volume for disposal. | G4 | G4 | High | Moderate | Minor | Low | N/A | <5 | $25M | Moderate | Moderate | Minor | Minor | Immobilization |

| Concept ID | Concept | Gap/Opportunity Addressed | Category | Links to Brainstorm Sheet | Item 1- Probability of Achieving Capability [High >66%, Mod (33-66%), Low (<33%)] | Item 2 - Probability capability leads to intended benefit [High >66%, Mod (33-66%), Low (<33%)] | Item 3 - Regulatory Change Needed to Realize the Benefit [None, Minor, Major] | Item 4a (incremental) - Development and Implementation Cost [High (>$200M), Mod ($50-200M), Low (<$50M)] | Item 4b (Transformational) - Development and Implementation Cost [High (>$500M), Mod ($200-500M), Low (<$200M)] | Item 5 - Time to implement (yrs) | Item 6 - Short term costs to obtain capability | Item 7a - Schedule Acceleration [Low - 0 to 3 yrs, Mod - 4 to 9 yrs, High > 10 yrs | Item 7b - Cost Reduction [High (>$25B), Mod ($250M-25B), Low (<$250M)] | Item 7c - Reduction in peak annual costs [None, Minor, Major] | Item 8 - Net Reduction of Environmental / Safety Risks [None, Minor, Major] | Synergies with other proposals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SW-2 | Use characterize and/or prediction of compositions of stream from source information and assess technology need, flowsheet requirements. | A potential treatment for TRU tanks is drying the material. The condensate will likely need to be treated with ETF. Based on recent lessons learned, the condensate could result in a new or elevated hazard to the ETF. | G40, G41 | G40, G41 | | | | | | | | | | | | |
| SW-3 | Evaluate technologies for sequestration or destruction of ammonia; or evaluate process for alternatives that do not generate the ammonia | High ammonia waste stream represents a potential worker hazard during immobilization process. | G16 | G16 | High | Moderate | none | Low | n/a | <5 | $10M-20M | Low | Low | None | Minor | Immobilization |
| SW-4 | Sampling and Measurement of Rad level per HEPA to stay below 17 Curies which is in the PA | Accurate measurement of Tc and I on the HEPA filters will help with meeting IDF waste acceptance criteria and potentially allow for higher volume of disposition with known quantities. | G35, G36 | G35, G36 | High | Low | None | Low | N/A | 10 | $15M | Low | Low | None | Minor | |
| SW-7 | ETF adding steam stripper in addition to UV Ox. | UV Oxidation efficiency at ETF is questionable - (Ability to destroy acetonitrile) | G44 | G44 | High | High | None | Low-Moderate | N/A | <5 | $5M | Low | Low-Moderate | None | Minor | Pretreatment |
| SW-8 | 1. Washing of the HEPAs could be performed to concentrate Tc in low volume liquid stream. 2. Grout formulation to better immobilize and then send offsite | An alternative to finding better grout matrix for macroencapsulation of SSW - HEPA (Tc) may be needed to reduce risk. | G46 | G46 | Moderate | Moderate | None | Moderate | N/A | 10 | $5M | Low | Low | None | Minor | Immobilization |
| SW-9 | Perform pretreatment to remove the iodine or provide a more robust grout formulation for the GAC media. | Grouting of the spent GAC may be problematic because of the iodine captured on the media | G47 | G47 | Moderate | Moderate | None | Low-Moderate | N/A | 5 to 10 | $20M | Low | Low-Moderate | None | Minor | Pretreatment/ Immobilization |
| SW-10 | Develop Tc separation techniques for SBS condensate | SBS condensate is predicted to have a high concentration of Tc. In the baseline this Tc would have to be recycled or would eventually be dispositioned as secondary waste increasing the concentration of Tc in the secondary waste. | G50 | G50 | High | Moderate | None | Moderate | N/A | 5 to 10 | $5M | Low | Low-Moderate | None | Minor | Pretreatment |
| SW-11 | Improved methods for characterization and certification of Failed equipment, PPE and contaminated equipment (secondary waste items) would help with IDF WAC compliance and accurate disposal quantities. | The required analyses for secondary waste disposition are not clearly identified. Process assessments/evaluations could identify the required analytes. | G72 | G72 | High | Low | None | Low | N/A | <5 | $10M | Low | Low | None | Minor | |
| SW-12 | Regulatory discussions need to occur now for samples that are generated incidental to processing. | Analytical samples will be generated in large volumes and will need a clear disposition path. For SRS, tank waste samples must be returned to the tank farm. A clear path for disposition besides the tank farm would help minimize overall waste to be immobilized. | G73 | G73 | Mod | High | Minor | Low | N/A | <5 | <2M | Low | Low | None | Minor | |

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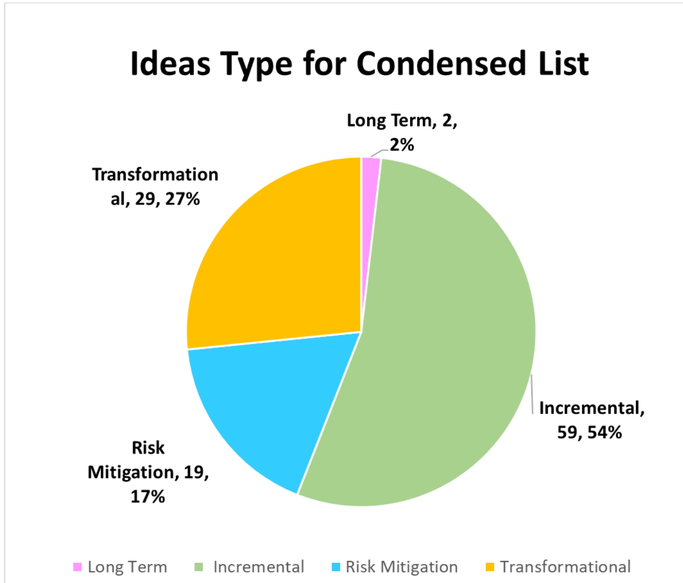


**Figure C - 1: Condensed Ideas by RD&D Type**

**Table C - 3: Summary Depiction of the Ideation and Screening Process with Cross Walk to the Functional Category**

| Functional Category | Count of Idea by Functional Category - Full List | Count of Idea by Functional Category - Condensed List | Final Count of Ideas by Functional Category – Prioritized List |
|---|---|---|---|
| Waste Tank/Tank Farm | 26 | 10 | 1 |
| Disposal Location | 17 | 7 | 3 |
| Waste Retrieval & Transport | 68 | 17 | 10 |
| Pretreatment - Supernate | 27 | 11 | 7 |
| Pretreatment - Solids | 21 | 9 | 5 |
| Immobilization (Waste Form) | 68 | 14 | 5 |
| Secondary wastes | 17 | 12 | 3 |
| Water Management | 17 | 5 | 0 |
| Tank Closure | 12 | 7 | 4 |
| Infrastructure Maintenance & Operations | 25 | 16 | 4 |
| **TOTAL (Not including Regulatory)** | 298 | 108 | 42 |

Note: For the "Condensed List" and the "Prioritized List" above, some of the ideas were a combination of two or more Functional Categories to yield the ultimate idea. These combined ideas are counted in the Functional Category for all the parent ideas in the above table. Thus, the "42" count from the table above is really more than the final number of actual combined ideas.

# Appendix D: Phase 3 Information

To perform the final evaluation to determine the most viable concepts for recommendation to be included in the R&D Roadmap, the teams populated the evaluation spreadsheet with the applicable information for each concept. As discussed in the main body of the deliverable, technical maturity, complexity, estimated costs, and projected savings and implementation schedule were considered for each idea. ORP provided data on potential operational and life cycle costs, and a budget of $2.5B was assumed for each year of operation. While it is recognized that operating budgets will change over the lifecycle of the project due to escalation and other changes (e.g., program decisions), this allowed all concepts to be compared on a common basis. The data for the evaluation is provided in Table D - 1.

The concepts and the inputted information were then analyzed, and rank ordered based on the return on investments over the program life cycle and the schedule savings. The rank ordering was performed as follows:

a. Rank Ordering for return on investment (ROI): Rank #1 - 11 – Green; Rank #13 - 20 – Yellow; Rank #21 - 38 - White
b. Rank Ordering for Schedule: Rank #1 - 13 – Green; Rank #14 - 22 – Yellow; Rank #23 - 38 – White

The rank ordering created a color coding individually for ROI and schedule savings. The ROI scores are based on a ratio of probably cost benefits to expected investment costs. Specifically, probably benefits are the product of expected life-cycle savings, multiplied by both the probability of achieving success of the technology and the probability of the capability leading to the intended benefit. The investment costs are estimates of both costs to obtain the capability and development and implementation costs. It was apparent that some concepts had green in both the ROI and schedule savings columns, but other combinations of rankings were also observed. As discussed in the body of the report, a tiered approach was developed to distinguish the research areas: Top Priority, High Priority, and Medium Priority.

The final results were then sorted by the concepts and the Grouping showing the prioritized concepts as recommendations from the NNLEMS team. See Table D - 2 for this prioritized list.

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| | | | | Evaluation Criteria | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concept ID | Concept | Gap/Opportunity Addressed | Links to Table B1 through B11 | Item 1: Proposed Technology Maturity. | Item 2a: Complexity - unit ops affected | Item 2b: Complexity - Required systems Integration | Item 3: Projected Timeline for go/no go decision | Item 4: Estimated costs for #3: Low (<$10M), Medium ($10M-$50M), High (> $50) | Item 5a: Deployment Costs Pilots/ demos (if any) | Item 5b: Deployment Costs Initial Full Scale | Item 6a: Additional Investment req'd over life cycle - Repeated Investment | Item 6b: Additional Investment req'd over life cycle - Operating Costs | Item 6c: Additional Investment req'd over life cycle - Other costs incurred | Item 7: Estimated Time for deployment or construction (Post #3) | Item 8a: ROM Net Cost Savings Annual cost | Item 8b: ROM Net Cost Savings Peak Cost | Item 8c: ROM Net Cost Savings Total Savings | Item 9: Schedule Acceleration of the Hanford Mission | Item 10: Net Impacts on safety/ environment | Item 11: Estimated probability of successful deployment | Item 12: Regulatory permitting/ licensing changes required | Item 13a: Synergies with other proposals: Dependency | Item 13b: Synergies with other proposals: Positive reinforcement | Item 13c: Synergies with other proposals: Mutually exclusive | Item 14: Technology applicable to other sites | Primary Concept Type Grouping | Secondary Concept Type Grouping | Technical Area |
| WT-9 | Better sampling methods for retrieval, staging and transport to WTP in DST system for waste feed qual - Flow-through loops, tank mixing, etc. | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. Improving the sampling methods would reduce the time and dose required for retrieval and processing the tank waste. | A34, A3 | Concept / Demonstration | Waste tank unit ops, pumping processes, tank superstructure | Medium | <5 years | Medium | 10-50M | 50-500M | 500K/year | 500K/year | N/A | Depends on tank configuration: 5-10 years for 4 pumps, <5 years for 2 pumps | 400-500 M avoidance per year during HLW preparation facility construction. Saving in operations cost for DST versus TF HLW prep facility are likely minimal | 400-500M avoidance per year during TF HLW preparation facility construction. Saving in operations cost for DST versus TF HLW prep facility are likely minimal | 1-4 billion | Decrease costs | none | 2 pumps, 20% 4 pumps, 90% Flow loop, 100% | Assuming operation under final status RCRA permit, this requires class 2 permit mod, 2-3 years | Have to do this to do in tank feed qual | Makes pretreatment, in tank and at tank qualification better | N/A | SRS | 2) incremental –some fit existing baseline/flowsheet but maybe not all | 3) transformational –change in the baseline and mid range costs | Waste Retrieval, Transport, & Closure |
| IF-2 & WR&T-2a and 2b | Develop improved methods to detect and repair leaks in Hanford tank farm DSTs - NDA and robotic systems for tank inspection and repair - Patching systems to repair leaks | The physical arrangement of the waste tanks and transfer lines makes non-destructive analysis (e.g. ultrasonic wall thickness measurements) difficult. An automated process to perform these measurements would provide additional assurances and information for the tank integrity programs.<br><br>Methods to inspect and repair the tanks and/or transfer lines would allow greater confidence in utilization of existing resources for HLW preparation processes as well as the potential to avoid building new facilities if existing facilities can be utilized. Technologies for deployment both before and during retrieval to mitigate potential release to the environment | J-8, J-9 | Demonstration | waste tanks | Medium | 5-10 years | Medium | 10-50M | 25 to 300M | 1-5M to repair a tank side 10-50M each time a repair is performed for tank bottom | N/A | Enhanced cleaning required for a tank bottom repair would generate secondary waste | External sides, <5 years Internal tank, 5-10 years | N/A | N/A | 250-500M per tank repaired of cost avoidance | Risk mitigator of 2-5 years | major positive | 75% | Assuming operation under final status RCRA permit, this requires class 2 permit mod, 2-3 years | N/A | Helps with WT-9, PS-2, 3, 4 and potentially WR&T | N/A | SRS | 1) risk mitigation-not schedule driven but protect the schedule | 3) transformational –change in the baseline and mid range costs | Waste Retrieval, Transport, & Closure |
| IF-7 & IF-12 | Evaluation of process intensification of LERF-ETF process to include automation. | ETF treatment capacity improvements are needed to process effluents from vitrification processes. | J-16 | concept | All of LERF/ETF - several | High | <5 years | Medium | 5-10M | 50 to 150M | 500K/year | n/a | N/A | 5-10 years | 25M | 25M | 500M | None | minor positive | 90% | Already operating under final status RCRA permit, this requires class 3 permit mod, 2-3 years | N/A | Makes SLAW vitrification less expensive (needed capacity upgrades) | N/A | Other rad effluent treatment facilities (SRS, others) | 2) incremental –some fit existing baseline/flowsheet but maybe not all | 1) risk mitigation-not schedule driven but protect the schedule | Secondary Waste Treatment |
| IF-14 | Improve techniques for operational support for tank farm & waste processing/immobi-lization operations - Remote or automated systems to replace hands-on work - Should transition to continuous technology updating system to reduce worker exposure | Remote or automated systems would improve efficiency of tank farm and waste processing/immobilization operations and reduce potential for worker exposure. In addition, these systems may allow operations in periods of weather that workers could not be used. | J-38 | Concept/Demonstration | All tank farm unit operations | Medium | <5 years | Medium | 50M | 250M | 2-5M/year | n/a | N/A | <5 years | 60M | 100M | 2.3 billion | Mitigating risk of environmental impacts in Tank Farm and potential worker exposure | minor positive | 100% | Assuming operation under final status RCRA permit, this requires class 2 permit mod, 2-3 years | N/A | Could be coupled with other robotic efforts | N/A | Applicable across DOE complex | 2) incremental –some fit existing baseline/flowsheet but maybe not all | 1) risk mitigation-not schedule driven but protect the schedule | Mission Enablers |
| TC-3 | Work with Regulators/Stakeholders to prioritize retrieval and sequencing and timing of tank closures to address highest risk | Current tank closure retrieval and closure sequencing doesn't include the risk of the residuals to the environment | I-38, I-37 | Full scale demo - elsewhere | Tank retrieval, sequencing (Integrated Waste Feed Delivery Plan) | Low - sequencing | <5 years | Low | $1M | N/A | negligible | N/A | N/A | 5-10 years | 45-90M | N/A | 7-12B | 3- 5 years | Minor/ Major Positive if sequence addresses potential leaker with rads | 95% | TPA negotiations followed by permit mods, 5 years | TC-3 tied to retrieval technology | TC-7 could make TC-3 better | N/A | SRS already uses this method | 2) incremental –some fit existing baseline/flowsheet but maybe not all | | Waste Retrieval, Transport, & Closure |
| TC-4 (TC-5,WR&T-8) | Use improved characterization methods to include in-situ techniques and performance assessments to identify the residual risk of the materials remaining to determine tank cleaning end point. Update PA models based on information available from earlier releases and contaminant transport behavior. | Current tank closure end-state is based on achieving specific volume removal and number of methods used, if unable to achieve volume, versus the actual risk remaining. Residuals may not contain constituents of concern from a hazard standpoint. Contaminant transport assumptions may also be inaccurate driving more material than necessary. | I-25, I-37, C13, C14, C28, C65, C66, C67, C36 | Charact - lab scale PA - Pilot/ prototype | Characterization/ sampling, tank retrieval, PA models (tank farms?) | Medium - PA ties | <5 years | 10M | Charact `$10M | PA 10M | Each tank-charact PA - each tank farm | Charact - cost differential over baseline? PA - maintenance costs same as baseline | N/A | >10 years | 20 - 160M | N/A | 10-15B | 4-6 years | Minor Positive | 70% | TPA negotiations followed by PA update and permit mods, 10 years | N/A | TC-7 makes TC-4 better; Could aid the overall tank retrieval time if you stop earlier but need to have capacity to treat the waste (glass or grout) | N/A | SRS for characterization | 3) transformational –change in the baseline and mid range costs | | Waste Retrieval, Transport, & Closure |
| DL-3 | Evaluate assumptions for performance assessments for excessive conservatism and develop better transport and performance assessment models for multiple waste forms to increase waste loadings at disposal sites | Better transport and performance assessment models are needed to reduce the conservatism in performance models. High performance computing may need to be applied to performance assessments, particularly for alternative waste forms | B21, B34, B44, B57, B60 | Pilot Prototype | PA assessment (includes Waste Form and the Disposal site) | Med | < 5 years | $10M | Negligible | 0 | NA - No increase over existing program | NA - No increase over existing program | NA - No increase over existing program | 5-10 years | 4-160M | | 0.250-10B | 5-10 years | Minor Positive | 40% | PA update and permit mods, 10 years | N/A | SW-1 & IM-13 would benefit from DL-3 | N/A | Hanford Specific | 3) transformational –change in the baseline and mid range costs (Aids grout) | | Waste Retrieval, Transport, & Closure |

| | | | | Evaluation Criteria | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Concept ID | Concept | Gap/Opportunity Addressed | Links to Table B1 through B11 | Item 1: Proposed Technology Maturity. | Item 2a: Complexity - unit ops affected | Item 2b: Complexity - Required systems Integration | Item 3: Projected Timeline for go/no go decision | Item 4: Estimated costs for #3: Low (<$10M), Medium ($10M-$50M), High (> $50) | Item 5a: Deployment Costs Pilots/ demos (if any) | Item 5b: Deployment Costs Initial Full Scale | Item 6a: Additional Investment req'd over life cycle - Repeated Investment | Item 6b: Additional Investment req'd over life cycle - Operating Costs | Item 6c: Additional Investment req'd over life cycle - Other costs incurred | Item 7: Estimated Time for deployment or construction (Post #3) | Item 8a: ROM Net Cost Savings Annual cost | Item 8b: ROM Net Cost Savings Peak Cost | Item 8c: ROM Net Cost Savings Total Savings | Item 9: Schedule Acceleration of the Hanford Mission | Item 10: Net Impacts on safety/ environment | Item 11: Estimated probability of successful deployment | Item 12: Regulatory permitting/ licensing changes required | Item 13a: Synergies with other proposals: Dependency | Item 13b: Synergies with other proposals: Positive reinforcement | Item 13c: Synergies with other proposals: Mutually exclusive | Item 14: Technology applicable to other sites | Primary Concept Type Grouping | Secondary Concept Type Grouping | Technical Area |
| TC-7, WR&T-2b, DL-1 | Develop barriers (e.g., cementitious or lithified rock aggregate systems) with additives targeting contaminants of concern for the outside of tanks or for disposal sites and demonstrate deployment strategies. | Utilize barriers on the outside of the tank or at disposal sites to mitigate the impact of any migration of residual contaminants that would allow reduction in volume of contents removed. | I-8, I-9 | Pilot to Full scale for similar applications | Barrier formulation, barrier injection technology, monitoring system, PA/system performance models | Low-barriers with monitoring Medium - if feedback system is involved | <5 years | Medium | Captured in 4 | Depend on where to demo - $40M | At each farm, assume 10 farms | Differential in monitoring - Potentially negligible since most tank farms had $65M in management costs for closure | N/A | >10 years | 12-152M | N/A | 9.5-14.5B | 4 - 6 years | Major positive (controlling migration of water into the tank and contents out of the tank) | 65% | PA update and permit mods, maybe NEPA analyses, 10 years | N/A | TC-7 makes TC-4 better; could also aid IDF disposal of grout waste forms; could accelerate tank retrievals if harder to retrieve/low hazard material can be left behind | N/A | SRS use in S&GW applications; potential tank applicability | 2) incremental –some fit existing baseline/flowsheet but maybe not all | 3) transformational technology based? | Waste Retrieval, Transport, & Closure |
| DL-6 | Implement direct disposal options versus vitrification for disposal of CST for on-site and off-site disposal options (likely greater than Class C or TRU) | Alternative disposition paths besides vitrification and disposal as non-HLW should be evaluated for cost reduction opportunities (ship and dispose easily) | B33 | Concept | 3 - column operations, staging of material, transport to disposal site | Medium | <5 years | Low | $20M | $20M | $180M | Included in 6a | Included in 6a | 5 to 10 | 12-17M | | $750M - $1B | 2-3 years | Minor Positive | 95% | Offsite: NEPA, WIR or waste determinatinon, 5 years. Onsite: NEPA, Waste Determination, PA, permit mod, 10 years | N/A | Potentially impact to HLW glass WL, offsite shipment & disposal earlier & potentially easier, | Need PL-3 to enable DL-6 | SRS | 3) transformational –change in the baseline and mid range costs (Aids grout) | | Mission Enablers |
| IM-1b | Improvements in HLW Glass Waste Form | Alternative glass formulations and additives to improve volatile retention (principally Tc and I) followed by durability testing and modeling to assess the long term performance of glasses in disposal environments to include improvement in waste loading by >10%?. | F15, F17, F22, F49, F65, F67, F75, F77, F78, F86 | Concept / Demonstration | washing, leaching, feed prep, melter, offgas | Medium | >10 years (assume HLW running) | Medium | $50M | 0 = Assumes no new silos | 1 million per year | trivial | trivial | <5 years | 0 - assumes melter operation is not appreciably changed except for WL | 0 - assumes melter operation is not appreciably changed except for WL | 15 billion | With baseline schedule - 5 to 10 years | none | 85% | PA update and permit mods, 5 years | Assuming baseline, N/A | PS-2, PS-3, PS-4, IM-2c | N/A | N/A | 2) incremental –some fit existing baseline/flowsheet but maybe not all | 1) risk mitigation-not schedule driven but protect the schedule<br><br>4) long-range programs –10 to 15 years with potential big payoff if accomplished. | Waste Immobilization & Disposal |
| IM-2c | Improvements on HLW Facility and Melter Technology | Improve HLW vit facility throughput<br>- Increase HLW facility to equivalent Melter Throughput to 8tG/d<br>-Improving the understanding of erosion/corrosion to extend the life of process equipment (e.g. melters and bubblers) to reduce downtime and improve operating efficiency. | F38, F50, F54, F56, F59, F71 J10? | Concept | washing, leaching, feed prep, melter, offgas, canister handling | Medium-High | < 5 years | Medium | $75M | TBD - likely at least 150M but will depend on extent of improvements | 2 million/year | trivial | trivial | 5-10 years | 50M | N/A - Costs could be higher during construction but save on mission length | 15 billion | With baseline schedule - 5 to 10 years | Major positive (waste out of tanks faster) | 60% | Class 3 RCRA permit mod, 2-3 years | Assuming baseline, N/A | PS-2, PS-3, PS-4, IM-1b | N/A | N/A | 2) incremental –some fit existing baseline/flowsheet but maybe not all | 1) risk mitigation-not schedule driven but protect the schedule | Waste Immobilization & Disposal |
| IM-4 | NOX Management (HLW system offgas design and washing endpoint) | Improved methods/technologies to reduce NOX generation and worker exposure.<br>- HLW to handle direct feed without significant washing<br>- LAW to minimize PICS impact by changing sugar<br>- LAW + HLW NH3 safety risk | F35, F68, F69, F83 | Lab Demonstration/ Pilot/ Prototype | washing, HLW vit, LAW vit, offgas, (possibly ETF)? | Medium | < 5 years | Medium ($10M-15M) | $25M | 50M | N/A | TBD depending concept | TBD depending concept | 5-10 years | 150M | N/A | 3 billion | 0-5 years | none | 50% | Class 2 or 3 RCRA permit mod, 2-3 years | Assuming baseline, N/A | PS-2, PS-3, PS-4, IM-2c | N/A | N/A | 2) incremental –some fit existing baseline/flowsheet but maybe not all | 1) risk mitigation-not schedule driven but protect the schedule | Waste Immobilization & Disposal |
| IM-12 | Waste Dewatering/Dried waste form (Dispose Tank Waste as LLW) | Assess and implement dewatering options with consideration of scale-up, cost and safety.<br>- Remove tank sludge, dry it and dispose as LLW or TRU<br>-Immobilize TRU in grout and its potential disposal pathways as LAW/LLW. | F44 | Lab Demonstration/ Pilot/ Prototype | Retrieval, drying, condensate capture & disposal, container, immobilize as necessary, shipping, disposal location | Medium | <5 years | Low | $10M for equipment readiness | 600M | 5M/year to account for varying waste types and qualification processes | TBD depending concept | trivial | 5-10 years | 2 billion | 2 billion | 25 billion | LLW, 0 years DOE M 435.1-1, 5-10 years | TBD depending on disposal site | 85% | Offsite: NEPA, DOE M 435.1-1, 5 years.<br>Onsite: NEPA, DOE M 435.1-1, PA, permit mod, 10 years | N/A | TRU dried and offsite can help IM-12: IM-12 reduces need for cross site transfers | N/A | Idaho calcine? | transformational –change in the baseline and mid range costs | long-range programs –10 to 15 years with potential big payoff if accomplished. | Waste Immobilization & Disposal |
| IM-13 | Cementitious Materials Development, Performance and Durability for LAW | There is a need to develop improved containerized grout formulations as well as to validate their durability and long term performance)<br>- Needed to implement Grout SLAW for onsite disposal<br>- Could be offsite or onsite disposal<br>- Cementitious waste form improvement not offsite disposal at selected sites | F16, F25, F27, F29, F33, F40, F42, F43, F45, F46, F57, F58, F72, F74, F80, F81 | Concept/ Demonstration | Separations, Formulation, Mixing, transport, containerization, disposal location | Low | Offsite, <5 years Onsite, <5 years | Medium | $50M | Transfer from NDAA NNLEMS SLAW study | 1 M/ year | trivial | trivial | Offsite, <5 years Onsite, 5-10 years | Transfer from NDAA NNLEMS SLAW study | Transfer from NDAA NNLEMS SLAW study | Transfer from NDAA NNLEMS SLAW study | 10-20 years | TBD depending on disposal site | 80% | Offsite: NEPA, DOE M 435.1-1, 5 years Onsite: NEPA, DOE M 435.1-1, PA, permit mod, 10 years | N/A | SW-1 | N/A | Most LLW processes could benefit from improved grout formulations | 3) transformational –change in the baseline and mid range costs | 4) long-range programs –10 to 15 years and possibly less with potential big payoff if accomplished. | Waste Immobilization & Disposal |
| SW-1 | New grouting compositions or lithified aggregate mixtures (for liquid and solid SW) with getters may present a viable option. | The Secondary LLW represents a potentially large volume to be dispositioned and will contain constituents of concern for long-term disposal. A cementitious waste form is the baseline technology but retention of some species is a concern by regulators and may represent a significant volume for disposal. | G4 | Lab Demonstration | Depends on disposal location - Separations/ size reduction, Formulation, Mixing, transport - container or disposal location | Medium | < 5 years | Low | 10 Million | 5 Million | 0 | 1 million/year for processing secondary waste | trivial above baseline for on site Disposal | <5 years | 0 | 0 | 0 | 0 | Minor Positive | 80% | PA update and permit mods, 5 years | N/A | IM-13 | N/A | N/A | 2) incremental –some fit existing baseline/flowsheet but maybe not all | | Secondary Waste Treatment |

| Concept ID | Concept | Gap/Opportunity Addressed | Links to Table B1 through B11 | Evaluation Criteria | | | | | | | | | | | | | | | | | | | | | | Primary Concept Type Grouping | Secondary Concept Type Grouping | Technical Area |
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| Hanford-1 | Infrastructure Cost Evaluation through development of a System Model (roll up as an overall system) - was WR&T-1 | Waste retrieval and infrastructure cost reductions (Superstructure improvements, reduced shielding and support infrastructure). Do a cost benefit/engineering analysis of retrieval technologies. | C30, C33 | Deployable COTS/GOTS for the platform. Site specific modeling will be required. | All (7 or 8 modules) | High (integrate software and processes) | < 5 years to initiate | Medium: $10M-$15M Full Benefit<br>Bayesian Model<br>Non-Bayesian Model<br>Goldsim<br>Digital Twin (integrated OR, design, flow sheet, chemistry and risk analysis)<br><br>Low: $5M-$7M Incremental Benefit | $5M-$7M | $10M-$15M | $1.5M-$3M | N/A but does take into account hotel load ($1.5M-$3M/yr) $15M-$30M life cycle to address configuration mgmt., bench marking, version control, out year modelling etc. | N/A | <5 years | Annual Cost savings are $500M/yr annualized over 60 years. | N/A | Full Benefit ($30B based on 25% cost savings lifetime) allows uninterrupted retrieval and transport operations that provide input feed to a plant 24/7.<br>Incremental Benefit (Retrieval timing and required infrastructure optimization to reduce mission life (i.e. melters needed) | Potentially 10 years if integration and optimization of the tank waste system can be obtained | Minor-Major | 90% to implement successfully; breadth of model may be a question or uncertain | None | N/A | All better with A | N/A | Platform is usable at all sites but must be made site specific with tailored modules. | With full implementation of concept:<br><br>3) Transformational –change in the baseline and mid range costs | With partial implementation of concept. Develop a model framework and add modules as necessary:<br><br>2) Incremental –some fit existing baseline/flowsheet but maybe not all | Mission Enablers |
| WR&T-3 | Dry Waste Retrieval Technologies | Evaluate dry or minimal liquid retrieval technologies for known leaker tanks to mitigate potential release to the environment. National lab experiences and commercial vendor literature review required for existing technologies. | C11, C20, C23, C31, C59, C64, C80, C81 | Demonstrable and deployable with potential engineering changes for hardware and mockup | Waste tanks, mobilization, transfer/retrieval | Low to Moderate | <5 yrs | Medium | $15M-$25M Testing and qualifying existing commercial equipment | $5M-$10M | $5M-$10M (assume new in tank equipment for each tank retrieval) | Expected savings in operating costs relative to current retrieval costs due to reduction in schedule by 60%. (no treatment costs included) | Similar to wet retrieval D&D costs ($1M-$2M) | <5yrs | Estimated at 40% of annual wet retrieval costs | N/A (minimal capital cost and cost savings are in operations) | Estimated at 40% life cycle savings over wet retrieval costs assuming similar annual savings | 10-15 years (accelerating retrievals not treatment) | Major | High (Based on implementation of current industry practices) | Class 3 RCRA permit mod, 2-3 years | N/A | Accelerates TRU or other direct disposal options | N/A | Yes | Incremental –some fit existing baseline/flowsheet retrieval problems but maybe not all | N/A | Waste Retrieval, Transport, & Closure |
| WR&T-7b | Process Automation and Feedback | Develop process feedback systems to address operational challenges and effectiveness. Use AI and edge computing to optimize productivity and give feedback. Create better predictive capabilities to evaluate the effectiveness of retrieval technologies (modeling, sensor or visual) | C2, C3, C30 | Range (COTS mature deployable. Enhancement to AI and machine learning requires RDT&E. Will be enhanced by development of Hanford 1 model) | Supports all retrieval and transfer unit operations | Low-High | < 5 years to initiate | $1M-$25M | incremental $1M-$10M based on technology and extent of implementation | Initial FULL SCALE $25M to $100M for integrated mission unit operations imple-mentation | Tied to Hanford 1 and emerging issues | Tied to Hanford 1 and emerging issues | N/A | 5y-10yrs full scale 1-5yrs for incremental | Dependent on where deployed, implementation level and level of integration | Dependent on where deployed, implementation level and level of integration | Dependent on where deployed, implementation level and level of integration | >10 Years | Major (Optimization of waste form through forward-feed processing and reduce mission schedule) | High (Based on implementation of current and emerging industry practices i.e. industry 4.0) | None unless permitted systems are changed | N/A | Ties to other programs such as FE, NE, ARPA-E if considering external programs. | N/A | YES | 2) Incremental –some fit existing baseline/flowsheet but maybe not all. | 1) Risk mitigation-not schedule driven but protect the schedule. | Waste Retrieval, Transport, & Closure |
| WR&T-9 | Equipment Decontamination and Disposal | Evaluate new waste retrieval and infrastructure equipment decontamination and disposal options (could be used address concerns with Tc/I disposition in IDF and open release of cleaned equipment) | C40, C41, C45 | Pilot/Prototype, Full-scale demo | Supports all retrieval, transfer, characterization and disposal unit operations | Low-Med | <5 years | Low ($1M-$10M) | $1M-$3M (complexity dependent) | $3M-$10M | $1M-$2M (Maintenance costs) | Part of existing annual operating costs | Part of existing annual operating costs | <5yrs | $5M-$15M | N/A | $200M-$600M | Unknown as it depends on how deployed and why | Positive/ Minor | Low to med | None unless PA changes result from better technetium and iodine levels | N/A | Positive Minor Allows more robust implementation of WR&T 10a/b & WR&T-3 and Hard heal removal | N/A | Yes | 2) Incremental –some fit existing baseline/flowsheet but maybe not all. | N/A | Mission Enablers |
| WR&T-10a | Realtime Monitoring (Dry) - applicable to TRU for offsite | Develop new Realtime monitoring capabilities for dry/bulk process feeds to reduce sampling time and minimize waste | C35 | Deployable COTS/GOTS for the platform. Supplies data for system level modeling. | Minimal impact on system when implemented | Low to Medium (real-time data) does not include full integration with Hanford1 model. | <5 years | Low for COTs/GOTs<br><br>Low to moderate for full integration with hanford1 | $1M-$2M (complexity dependent) | $1M-$10M (complexity dependent) | $<1M-$2M (complexity dependent) | Part of existing annual operating costs | Part of existing annual operating costs | <5years | $15M-$25M | N/A | $600M-$1B | 5 years to 10 years | Positive/ Minor | High (Based on implementation of current and emerging industry practices i.e. industry 4.0) | Class 2 or 3 RCRA permit mod, 2-3 years (assuming installation of equipment in tank system) | N/A | Positive/ Minor | N/A | Yes | As monitoring capabilities added<br><br>2) Incremental –some fit existing baseline/flowsheet but maybe not all | 4) Long-range benefit due to forward feed optimization and reduced sampling/turnaround time. | Waste Retrieval, Transport, & Closure |
| WR&T-10b | Realtime Monitoring (Liquid/Fluid) | Develop new Realtime monitoring capabilities for liquid process feeds to reduce sampling time and minimize waste | C35 | Deployable COTS/GOTS for the platform. Supplies data for system level modeling. | Minimal impact on system when implemented | Low to Medium (real-time data) does not include full integration with Hanford1 model. | <5 years | Low for COTs/GOTs<br><br>Low to moderate for full integration with hanford-1 | $1M-$2M (complexity dependent) | $1M-$10M (complexity dependent) | $<1M-$2M (complexity dependent) | Part of existing annual operating costs | Part of existing annual operating costs | <5years | $15M-$25M | N/A | $600M-$1B | 5 years to 10 years | Positive/ Minor<br><br>Would allow more robust implementation of WR&T 7b and Hanford 1 | High (Based on implementation of current and emerging industry practices i.e. industry 4.0) | Class 2 or 3 RCRA permit mod, 2-3 years (assuming installation of equipment in tank system) | N/A | Doing this makes WR&T 7b and Hanford 1 better | N/A | Yes | 2) Incremental –some fit existing baseline/flowsheet but maybe not all | 4) Long-range benefit due to forward feed optimization and reduced sampling/turnaround time. | Mission Enablers |
| WR&T-14 | Tank Storage and Stage Capacity is minimal due to volume of waste and inability to reuse | Evaluate needed tank storage through a cost benefit analysis of building new tanks, creating a modular/mobile tank system or evaluate reuse of SST's for staging. | C61, C69, C70, C79 | Deployable COTS/GOTS with site specific tailoring. | This is an offline activity for evaluation | Low: Does not include integration with Hanford-1, nor consideration of regulatory impacts to implement the model benefit | <5 years | Low | N/A | N/A | N/A | Very small annualized cost | N/A | < 5years | $350M-$500M | N/A | $3.5B-$6B | Model will highlight potential schedule acceleration with a risk informed approach | Positive/ Major | High - Model development and analysis | None if just a cost benefit analysis. If the cost benefit analysis shows a positive impact then a potential major regulatory change may be needed (e.g. for tank reuse). | N/A | Doing this makes WR&T 7b and Hanford 1 better | N/A | Yes | 3) transformational systems operations (Could lead to risk informed changes in the baseline and life-cycle costs when implemented.) | | Waste Retrieval, Transport, & Closure |

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| PL-1 | Improved supernate filtration methods that could be deployed in modular/skid-based system (e.g., TSCR) and without high pressure penalties or increased operational maintenance. Examples include CUF, Rotary, or ultrasonic methods | Supernate filtration is required to meet WIR requirements for removal of entrained solids that may contain insoluble radionuclide complexes, and to protect downstream pretreatment processing such as ion exchange which would be negatively impacted by solids fouling or plugging. Dead-end filtration is currently used in the TSCR & TCCR system, and requires frequent backflushing to maintain effective operations, reducing the overall TOE. Improved filtration methods with greater TOE are needed that can be deployed in skid-based systems. | E21, E49, E74 | Pilot/prototype, full-scale demo for similar problem | Pumping, filtration, solids return to tank farm, supernate feed to IX | Medium. Would replace or augment current dead-end filter. Additional TSCR skid or change to future TSCR units | <5 years | Low: <$5M | N/A | $10M | $20M | N/A | N/A | <5 years | Cost Avoidance - increased costs due to reduction in TOE of current TSCR dead end filtration due to higher solids loading than current feeds. | N/A - expect similar or slightly higher peak costs for upgraded TSCR units, but not significant | Cost Avoidance - increased costs due to reduction in TOE of current TSCR dead end filtration due to higher solids loading than current feeds. | N/A - avoids schedule delay due to lower TOE than design basis for TSCR systems. | None. | 95% | Class 2 or 3 RCRA permit mod, 2-3 years | N/A | N/A | N/A | SRS (if TCCR experiences filtration issues) | 1) Risk Mitigation | 2) Incremental | Waste Pretreatment |
| PL-2 | Improving or optimizing existing filtration or processes through filtration additives | Supernate filtration is required to meet WIR requirements for removal of entrained solids that may contain insoluble radionuclide complexes, and to protect downstream pretreatment processing such as ion exchange which would be negatively impacted by solids fouling or plugging. Dead-end filtration is currently used in the TSCR and TCCR system, and requires frequent backflushing to maintain effective operations, reducing the overall TOE. Improvements to existing filtration processes that increase TOE may be needed. | E22 | Lab Demonstration | filtration, ion exchange, transfer, vitrification | High (assure downstream impacts of additives fully evaluated) | <5 years | Low | $20M (real waste testing necessary at small scale; may need to test with range of tank waste feeds (simulant or real wastes) to assure compatibility as mission progresses) | $5M | N/A | $1-$5M (additives costs and compatibility verification as feeds change) | N/A | 5-10 years | Cost Avoidance - increased costs due to reduction in TOE of current TSCR dead end filtration due to higher solids loading than current feeds. | N/A - expect similar or slightly higher peak costs for upgraded TSCR units, but not significant | Cost Avoidance - increased costs due to reduction in TOE of current TSCR dead end filtration due to higher solids loading than current feeds. | N/A - avoids schedule delay due to lower TOE than design basis for TSCR systems. | None | 50% | Class 2 RCRA permit mod, 2-3 years | N/A | N/A | N/A | SRS (if TCCR experiences filtration issues) | 1) Risk Mitigation | 2) Incremental | Waste Pretreatment |
| PL-3 | Optimize Cs loading of CST | Non-elutable CST columns have been selected for Cs removal at Hanford for TSCR, and is expected to be used in proposed TFPT facilities. Optimizing loading of Cs columns is needed to reduce costs while balancing demands of loading limitations due to heat load, shielding, and hydrogen generation in spent CST columns. | E61, E65 | Lab Demonstration | ion exchange, canister loading, transport, disposal (includes DSA implications and alternate disposal options to HLW vit) | High (based on DSA & disposal alternatives) | 5-10 years | Low | <5M (principally DSA update if needed, no change in process equipment expected. | N/A (assume alternate disposition covered in DL-6) | N/A | N/A | N/A | 5-10 years | $3M | N/A | $150M | N/A - minor. Reduces downtime for CST changeout | None | 90% | None | A: PL-3<br>B: DL-6 Alt disposition option would require DL-6 investments | A: PL-3<br>B: DL-6 (Improves options for disposal) | N/A | SRS (if TCCR column loading or alt. disposal advantageous) | 2) - incremental - decrease CST use/reduce costs | 3) Transformational - alternate disposal pathway | Mission Enablers |
| PL-5 | RCRA Organics Removal from Tank Supernate<br>- oxidation/destruction<br>- volatilization/evaporation<br>- extraction (e.g., solvent/supercritical)<br>- capture evaporator concerns with ammonia abatement from IF-17 | Tank waste supernate containing RCRA organics may need to be treated for the organics to meet RCRA LDR standards for non-vitrification or other thermal options for LAW immobilization. Evaporation may be effective for many LDR organics, but needs to be verified for the range of CoCs expected in Hanford tanks, and may require supplemental treatment methods to assure LDR compliance. | E24, E28, E51, E66, E73, A62 | Lab Demonstration | evaporator, condensation, GAC filtration, condensate to ETF for treatment and/or GAC treatment for organics destruction, reuse or disposal of GAC, immobilization/ disposal of any secondary waste/ non-liquid residues | Medium | <5 years | Low | $5M (real waste testing necessary at small scale for select, representative tank wastes) | $25M | $25-50M (assuming up to 3 units associated with TSCR units in east/west areas | N/A | N/A | 5-10 years | Transfer from NDAA NNLEMS SLAW study | Transfer from NDAA NNLEMS SLAW study | Transfer from NDAA NNLEMS SLAW study | 10-20 years | minor positive | 75% | NEPA, Class 3 RCRA permit mod, 10 years | A: PL-5<br>B: IM-13 | N/A | N/A | N/A | 3) transformational –change in the baseline and mid range costs (enabling grouting of LAW and offsite disposal) | 4) Long-range programs (enabling onsite disposal of grouted LAW) | Waste Pretreatment |
| PL-8 | Sodium nitrate separation or low-temperature destruction<br>- fractional crystallization<br>- clean salt<br>- denitrification (biological, NAC) | Sodium nitrate represents a significant fraction of the waste requiring treatment. Nitrates/NOX abatement represents a significant cost and risk for thermal waste treatment such as vitrification, and a potential long-term groundwater risk for most low-temperature treatment processes such as waste grouting. Methods for safe destruction of nitrates or separation of sodium nitrate from tank wastes | E43, (E46 duplicate), D53 | Pilot/Prototype | filtration, chemical, electrochemical and/or membrane separation of sodium salts, treatment/ immobilization of sodium salt stream and disposal, transfer of low sodium/ nitrate stream with to LAW immobilization | High | 5-10 years | Low | $15M | $34.2M | $68.4M | $90M | N/A | 10-15 years | ? | N/A | $394M | N/A | Positive (if reduces LAW fraction being vitrified) | 70% | For vitrification, class 3 RCRA permit mod, 2-3 years For non-vitrification, NEPA, class 3 RCRA permit mod, 10 years | N/A | N/A | N/A | N/A | 3) Transformational | 4) Long-range programs (reduce LAW, recycle caustic for sludge processing, retrieval) | Waste Pretreatment |
| PL-10 | Methods for pretreating supernate prior to Cs removal with CSTs to remove Pu and actinides | Pu and other actinides in tank waste supernate will be removed to some degree during pretreatment using CSTs, potentially increasing the potential that loaded CSTs column are classified as TRU waste, and complicating ultimate disposition of CST canisters. Methods for actinide pretreatment, such as a monosodium titanate strike may be helpful in reducing potential for actinide loading on the CST. | E15 | Pilot/Prototype | Alpha strike tank or IX column, settling/separation (if strike tank) and storage of resin, transfer to HLW feed for vitrification | Medium | <5 years | Low | Hot cell demo <5M | $10-15M | $20M (assuming replicate system with each TSCR facility) | $10M | N/A | 5 years | N/A (cost avoidance) | N/A | N/A | N/A | Minor Positive (reduces TRU content potential in CST and LAW) | 95% | Class 3 RCRA permit mod, 2-3 years | N/A | A: PL-10<br>B: DL-6 (improves potential for alternate CST disposition) | N/A | SR (TCCR) if needed | 3) Transformational | 1) Risk Mitigation | Waste Pretreatment |

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| PS-2 | At-Tank Treatment Capabilities for Sludge Pretreatment<br>- elevated temperature washing, countercurrent washing, filtration, improved filter performance with high solids, | Sludge washing, settling, and concentration is needed to remove problematic species such as Al, PO4, SO4, nitrate, halides that can significantly impact HLW vitrification, transferring these constituent to the LAW stream for immobilization. Baseline in PT may be cost prohibitive, and in-DST processing may have difficulty meeting washing or throughput requirements. | E1, E19, E29, E44, E45 | Prototype | Washing, leaching, filtration, solids collection, Filter flush | Medium | <5 years | Low | $10M | $150M | N/A | N/A - Similar level as TSCR annual operating costs, slightly lower than expected annual PT costs/ See savings for ROM estimate and basis. | N/A | <5 years | $8M (annual). See comment for basis) | $6-$8B (annual peak) | $15B | 15-20 years | Major Positive | 90% | Class 2 or 3 RCRA permit mod, 2-3 years | PS-2 or PS-4 or PT needed for HLW Vitrification | PS-3 makes PS-2 better | N/A | SRS | 3) Transformational | 4) Long-range programs | Waste Pretreatment |
| PS-3 | Improved understanding of aluminum chemistry to support sludge retrieval, transport, and washing<br>- fundamental chemistry data<br>- improved models | Aluminum is a key constituent of HLW sludges, and is manifested in different chemical forms with varying solubility and processing difficulty. Improved chemical understanding and predictive models are needed to better optimize sludge retrieval, transport, and washing and to alter target amount removed/compound. | E32, E36 | Concept | TBD or N/A | TBD or N/A | <5 years | Low | Hot cell demo- $10M (endpoint) | | | | | <5 years | | | | TBD | Minor Positive | 100% something will be deployed | None | | PS-3 makes PT, PS-2 and PS-4 better | N/A | SRS | | | Waste Pretreatment |
| PS-4 | In-Tank Treatment Optimization for Sludge Pretreatment<br>- washing fluid composition, time, temperature, selected endpoints<br>- mixer type, operating regime<br>- settling time, aids | In tank sludge processing is the primary option for sludge preparation without completion/operation of the PT facility. In-DST processing may have difficulty meeting washing or throughput requirements due to sludge properties. | E25, E20, E28 | Full scale demo - elsewhere | Mixing, Washing, leaching-temp dependence, settling/filtration, Filter flush | High | <5 years | Low | $15M | $30M | $780M | $10M (assume modest increase over existing sludge retrieval program | N/A | <5 years | $47M (annual). | $6-$8B (annual peak) | $16.3B | 15-20 years | Major Positive/ Minor negative if DST leaks | 95% | Class 2 or 3 RCRA permit mod, 2-3 years | PS-4 or PS-2 or PT needed for HLW Vitrification | PS-3 makes PS-4 better; PS-2 may make PS-4 better (PS-2 handles problematic wastes) | N/A | SRS | 3) Transformational | 4) long-range programs | Waste Pretreatment |
| PS-6 | Evaporation and/or drying technologies to increase solids concentration and manage water from waste processing. Or alternative dewatering process to concentration sludges after transfer at more dilute levels. | Solids and supernate concentration is needed in both sludge and supernate processing, respectively. Filtration and evaporation are regularly used in tank waste processing. Improved evaporation methods, or alternate dewatering approaches that would concentrate sludges for subsequent processing without adding additional water evaporation penalty to HLW melters. | E15<br>IM12 | Pilot/Prototype | Sludge transport from feed tank or post sludge preparation vessel, evaporation or physical dewatering, water recycle to tank farms/evaporator/ or ETF, concentrated sludge mixing and transport to treatment unit | Medium | <5 years | Low | Hot cell demo ($5M) and cold/simulant pilot | $150M | N/A | N/A | N/A | <5 years | $8M (annual). See PS-2 comment - similar rationale as this is function originally within PT. | $6-$8B (annual peak) | $15B | 15-20 years | Minor positive (avoid solids settling / plugging in transfer lines due to transfers from TF at too high of solids concentration/bulk density. | 90% | Class 2 or 3 RCRA permit mod, 2-3 years | PS-6 needed for IM-2c (esp. for DFHLW) | PS-6 may make IM-12 better (IM-12 similar) | N/A | | 3) Transformational | 4) long-range programs | Waste Pretreatment |
| PS-9 | Waste treatment or offgas abatement methods to reduce impacts of key air toxics that are limiting waste processing operations | Toxic air emissions from tank waste in both storage and processing operations (e.g., ammonia) can exceed permitted emissions limits and result in restrictions on operating conditions, such as reduced flowrates for exhausters, or reduced operating times for other process facilities (e.g., months/yr, or hours/day allowable operations). Abatement methods for key air toxics, or other methods to reduce emissions are needed to accelerate treatment mission. | E8 | Pilot/Prototype | Tank farm ventilation or process offgas vent system; abatement treatment operation (e.g., thermocatalytic oxidizer), stack monitoring/control system | Medium | <5 years | Medium | $15M | $25M | $150M | $100M | N/A | <5 years | N/A - cost avoidance | N/A - cost avoidance | N/A - cost avoidance | N/A - cost and schedule risk avoidance | Major positive. Reduce air toxic emissions, occupational exposure risk, and PPE requirements. Avoid constraints on operating durations due to air permit compliance. | 80% | Class 2 or 3 RCRA permit mod, 2-3 years | May have to do PS-9 to do PS-4 (possible permit condition for processing sludge in-tank) | PS-9 makes PS-4; PS-2; PS-6; overall baseline WR&T better. | N/A | N/A | 2) Incremental (not part of current baseline, but could fit as addition to existing ventilation upgrades for tank farms. | 3) transformational | Mission Enablers |
| SW-9 | Remove the iodine post melter from offgas | Uncertainty in partitioning of Iodine in the melter and offgas system causing process and disposition risks. Grouting of the spent GAC may be problematic because of the iodine captured on the media which causes IDF risks (performance issues) and HazCat issues for LERF/ETF. | G47 | Concept | Separation/scrub from offgas or media in offgas to capture; immobilization; disposal | Medium: Melter and offgas system ties; potential new process incorporation | 5-10 years | Medium | 5 million | 5 Million | 0 | 5 million | 5 million | <5 years | NA - cost avoidance | NA - cost avoidance. A replacement media or guard bed for GAC may avoid cost of new unit operation or additional liquid waste stream | NA - cost avoidance | 0 years. Dependent on whether stream is recycled - not baseline currently . SWAG: More likely a schedule slip avoidance of 1-2 years. | minor positive | 80% | Class 2 or 3 RCRA permit mod, 2-3 years | N/A | This will reduce load on LERF-ETF, potentially | N/A - likely not to be on site disposal | None identified for DOE sites. Potential appli-cability to advanced reactors | 1) risk mitigation-not schedule driven but protect the schedule | 2) incremental –some fit existing baseline/flowsheet but maybe not all | Secondary Waste Treatment |

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| Concept ID | Concept | Gap/Opportunity Addressed | Links to Table B1 through B11 | Item 1: Proposed Technology Maturity. | Item 2a: Complexity - unit ops affected | Item 2b: Complexity - Required systems Integration | Item 3: Projected Timeline for go/no go decision | Item 4: Estimated costs for #3: Low (<$10M), Medium ($10M-$50M), High (> $50) | Item 5a: Deployment Costs Pilots/ demos (if any) | Item 5b: Deployment Costs Initial Full Scale | Item 6a: Additional Investment req'd over life cycle - Repeated Investment | Item 6b: Additional Investment req'd over life cycle - Operating Costs | Item 6c: Additional Investment req'd over life cycle - Other costs incurred | Item 7: Estimated Time for deployment or construction (Post #3) | Item 8a: ROM Net Cost Savings Annual cost | Item 8b: ROM Net Cost Savings Peak Cost | Item 8c: ROM Net Cost Savings Total Savings | Item 9: Schedule Acceleration of the Hanford Mission | Item 10: Net Impacts on safety/ environment | Item 11: Estimated probability of successful deployment | Item 12: Regulatory permitting/ licensing changes required | Item 13a: Synergies with other proposals: Dependency | Item 13b: Synergies with other proposals: Positive reinforcement | Item 13c: Synergies with other proposals: Mutually exclusive | Item 14: Technology applicable to other sites | Primary Concept Type Grouping | Secondary Concept Type Grouping | Technical Area |
| PL-6 | Iodine separation technologies effective for alkaline tank waste and secondary liquid waste streams from thermal treatment offgases | Iodine, despite low total inventory in tank waste, is the primary risk driver to groundwater due to its high volatility within the vitrification process and substantial transfer to secondary waste streams, and high mobility in the subsurface. There are limited current technologies for iodine separation from either high ionic strength alkaline tank waste or liquid secondary waste streams from vitrification offgas systems. Effective iodine IX resins or sorbents that can enable separation from primary and secondary liquid waste streams are needed. | E17, E18, E31, E56, E75 | Concept to Pilot/ prototype | Separation from supernate or liquid effluent; elute I-rich liquid stream from media and immobilize or immobilize loaded resin directly; disposal (likely offsite) | Medium: Integration of new process at WTP or within ETF for liquid effluent, or in concert with TSCR upstream of WTP vitrification. | 5-10 years | Medium | 5 million | $15-50M | 0 | $5M | $5M | <5 years | NA - cost avoidance. Mitigates risk of non-compliant liquid effluent that cannot be treated at ETF, or cannot be disposed at IDF without additional costly mitigations | NA - cost avoidance. | NA - cost avoidance | N/A - no schedule acceleration. Avoidance of cost and/or schedule slippage | Minor positive | 70% | Class 2 or 3 RCRA permit mod, 2-3 years | N/A | If we do PL-6, this will reduce load on LERF-ETF, potentially, avoiding Cat. 3 facility at ETF. | N/A - if w do removal of I, likely not to be on site disposal | N/A | 1) risk mitigation-not schedule driven but protect the schedule | 2) incremental –some fit existing baseline/flowsheet but maybe not all | Secondary Waste Treatment |
| SW-10 | Develop Tc separation techniques for SBS condensate allowing disposition of other constituents in offgas stream elsewhere and Tc to be incorporated in glass. | SBS condensate is predicted to have a high concentration of Tc (as well as Cl, S, and F.). In the baseline this Tc would be recycled but the Cl, F, and S could limit waste loading. Recycling the Tc without the Cl, F, and S would reduce potential negative impact on Melter operations and performance. The Cl, F, and S will be dispositioned as secondary waste | G50 | demonstration | Add unit Operations to remove Tc from Condensate prior to evaporations, and send evaporated bottoms off site. Recycle Tc back to LAW. | Sending different solids (Sn Completed) to LAW Melter, so feed integration. Should be straightforward to tie in liquid stream to ETF. Need to understand Rad levels | <5 years | <10 million | <10 million | 40 million | 0 | 5 million | 0 | 5-10 years | NA - cost avoidance, no likely impact on annual costs | NA - cost avoidance, no likely impact on annual costs | NA - cost avoidance. Could reduce impact of having higher than expected S, Cl, and F in recycle stream that could reduce waste loadings and increase SLAW waste generated. | N/A - no schedule acceleration. Would expect more supplemental LAW and increased costs. | Minor Positive | 75% | Class 2 or 3 RCRA permit mod, 2-3 years | N/A | N/A | N/A | N/A | 2) incremental –some fit existing baseline/flowsheet but maybe not all | | Secondary Waste Treatment |
| IF-1 | Improve modeling or measurements for understanding critical velocity needs for pipe transfers and flushes as well as better methods to determine and/or confirm required flush volumes. | Settling of solids during transfers of slurries must be avoided to prevent buildup of materials that could plug transfer lines or lead to high dose or corrosion rates. The velocity needed to prevent solids settling is estimated based on process history, but would be different for each sludge transfer. In addition, flushing to clean out process slurries from the process lines after a transfer are also based on past processing history with the volume and velocity specified in standard operating protocols. Better understanding of these parameters could prevent processing delays from plugged transfer lines and/or reduce the flush volume requirements. | J-1, J-2 | | | | | | | | | | | | | | | | | | | | | | | | | |
| IF-3 | Life extension for process systems and components - Low temperature processes - Better predictive tools for determining life expectancy - Improved understanding of process chemistry on corrosion rates | Improving the understanding of erosion/corrosion of systems to better understand service life as well as improvements in materials to extend the life of process equipment (e.g. rotors on a grout mixer) would lead to reduced downtime and improved operating efficiency. | J-5, J-15, J-3 | | Tank system | | | | | | | | | | | | | | | | | | | | | | | |
| IF-4 | Life extension for process systems and components - High temperature processes - Better predictive tools for determining life expectancy - Improved understanding of process chemistry on corrosion rates (combined with IM-2) | Improving the understanding of erosion/corrosion of systems to better understand service life as well as improvements in materials to extend the life of process equipment (e.g. melters and bubblers) would lead to reduced downtime and improved operating efficiency. | J-10 | | | | | | | | | | | | | | | | | | | | | | | | | |
| IF-9 | Evaluate WIPP capacity to receive RH-TRU and needed Hanford systems to ship the material as well as the need for temporary storage at Hanford. | Assuming RH-TRU and other Hanford tank waste can be shipped to WIPP, it is not clear whether WIPP will have the needed design capacity. System modeling is needed to ensure capacity is available and whether on-site storage capability will be needed. | J-25, J-26, J-27 | | | | | | | | | | | | | | | | | | | | | | | | | |
| WR&T-13 | Determine whether Cross Site Waste Transfer will be necessary in mission scenarios and then determine most cost effective solution. | Evaluate existing and new cross site transfer technologies (hose in hose, rail, tanker truck, new models and technologies to prevent mechanical plugging and minimize costs of refurbishing transfer line) | C5, C32, C37, C38, C58, C68, C72, C73 | | | | | | | | | | | | | | | | | | | | | | | | | |
| SW-3 | Evaluate process for alternatives that do not generate the ammonia | High ammonia waste stream represents a potential worker hazard during immobilization process. | G16 | | | | | | | | | | | | | | | | | | | | | | | | | |
| SW-7 | ETF adding steam stripper in addition to UV Ox. | UV Oxidation efficiency at ETF is questionable - (Ability to destroy acetonitrile) | G44 | | | | | | | | | | | | | | | | | | | | | | | | | |

| Concept ID with Screening Color | Concept | Gap/Opportunity Addressed | Primary Concept Type Grouping | Secondary Concept Type Grouping | Technical Area | Estimated Return on Investment | Rank Order ROI 1 - 11 - G 13-20 - Y 21-38 - White | Rank Order Schedule 1-13 - G 14-22 - Y 23-38 - W | Tier |
|---|---|---|---|---|---|---|---|---|---|
| WR&T-9 | Equipment Decontamination and Disposal | Evaluate new waste retrieval and infrastructure equipment decontamination and disposal options (could be used address concerns with Tc/I disposition in IDF and open release of cleaned equipment) | When deployed:<br><br>Incremental –some fit existing baseline/flowsheet but maybe not all. | N/A | Mission Enablers | 500 | 4 | 1 | A |
| WR&T-10a | Realtime Monitoring (Dry) - applicable to TRU for offsite | Develop new Realtime monitoring capabilities for dry/bulk process feeds to reduce sampling time and minimize waste | As add monitoring capabilities<br><br>Incremental –some fit existing baseline/flowsheet but maybe not all | Long-range benefit due to forward feed optimization and reduced sampling/turnaround time. | Waste Retrieval, Transfer, & Closure | 313 | 10 | 12 | A |
| WR&T-10b | Realtime Monitoring (Liquid/Fluid) | Develop new Realtime monitoring capabilities for liquid process feeds to reduce sampling time and minimize waste | As add monitoring capabilities<br><br>Incremental –some fit existing baseline/flowsheet but maybe not all | Long-range benefit due to forward feed optimization and reduced sampling/turnaround time. | Mission Enablers | 313 | 10 | 12 | A |
| DL-3 | Evaluate assumptions for performance assessments for excessive conservatism and develop better transport and performance assessment models for multiple waste forms to increase waste loadings at disposal sites | Better transport and performance assessment models are needed to reduce the conservatism in performance models. High performance computing may need to be applied to performance assessments, particularly for alternative waste forms | Transformational –change in the baseline and mid-range costs (Aids grout on site) | N/A | Waste Immobilization & Disposal | 500 | 4 | 12 | A |
| IM-1b | Improvements in HLW Glass Waste Form | Alternative glass formulations and additives to improve volatile retention (principally Tc and I) followed by durability testing and modeling to assess the long term performance of glasses in disposal environments to include improvement in waste loading by >10%?. | Incremental –some fit existing baseline/flowsheet but maybe not all | Risk mitigation-not schedule driven but protect the schedule<br><br>Long-range programs –10 to 15 years with potential big payoff if accomplished. | Waste Immobilization & Disposal | 500 | 4 | 1 | A |
| IM-4 | NOX Management (HLW system offgas design and washing endpoint) | Improved methods/technologies to reduce NOX generation and worker exposure.<br>- HLW to handle direct feed without significant washing<br>- LAW to minimize PICS impact by changing sugar<br>- LAW + HLW NH3 safety risk | Incremental –some fit existing baseline/flowsheet but maybe not all | Risk mitigation-not schedule driven but protect the schedule | Waste Immobilization & Disposal | 333 | 8 | 12 | A |
| IM-13 | Cementitious Materials Development, Performance and Durability for LAW | There is a need to develop improved containerized grout formulations as well as to validate their durability and long term performance)<br>- Needed to implement Grout SLAW as an option for onsite disposal<br>- Could be offsite or onsite disposal<br>- Cementitious waste form improvement not offsite disposal at selected sites | Transformational –change in the baseline and mid-range costs | Long-range programs –10 to 15 years and possibly less with potential big payoff if accomplished. | Waste Immobilization & Disposal | 500 | 4 | 1 | A |
| PS-2 | At-Tank Treatment Capabiltilites for Sludge Pretreatment<br>- elevated temperature washing, countercurrent washing, filtration, improved filter performance with high solids, | Sludge washing, settling, and concentration is needed to remove problematic species such as Al, PO4, SO4, nitrate, halides that can significantly impact HLW vitrification, transferring these constituent to the LAW stream for immobilization. Baseline in PT may be cost prohibitive, and in-DST processing may have difficulty meeting washing or throughput requirements. | Transformational –change in the baseline and mid range costs | Long-range programs –10 to 15 years and possibly less with potential big payoff if accomplished. | Waste Pretreatment | 156 | 19 | 1 | A |
| PS-3 | Improved understanding of aluminum chemistry to support sludge retrieval, transport, and washing<br>- fundamental chemistry data<br>- improved models | Aluminum is a key constituent of HLW sludges, and is manifested in different chemical forms with varying solubility and processing difficulty. Improved chemical understanding and predictive models are needed to better optimize sludge retrieval, transport, and washing and to alter target amount removed/compound. | Long-range programs –10 to 15 years and possibly less with potential big payoff if accomplished. | Incremental –some fit existing baseline/flowsheet but maybe not all | Waste Pretreatment | 500 | 4 | 20 | B |
| PS-4 | In-Tank Treatment Optimization for Sludge Pretreatment<br>- washing fluid composition, time, temperature, selected endpoints<br>- mixer type, operating regime<br>- settling time, aids | In tank sludge processing is the primary option for sludge preparation without completion/operation of the PT facility. In-DST processing may have difficulty meeting washing or throughput requirements due to sludge properties. | Transformational –change in the baseline and mid-range costs | Long-range programs –10 to 15 years and possibly less with potential big payoff if accomplished. | Waste Pretreatment | 556 | 3 | 1 | A |

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|---|---|---|---|---|---|---|---|---|---|
| WR&T-14 | Tank Storage and Stage Capacity is minimal due to volume of waste and inability to reuse | Evaluate needed tank storage through a cost benefit analysis of building new tanks, creating a modular/mobile tank system or evaluate reuse of SST's for staging. | This study will identify potential transformational systems operations (Could lead to risk informed changes in the baseline and life-cycle costs when implemented.)<br>e.g. reuse of tanks for temporary storage and staging , enables use of pourable modular treatment /temporary storage/transportation systems etc..... | N/A | Waste Retrieval, Transfer, & Closure | 1000 | 2 | 11 | A |
| PS-6 | Evaporation and/or drying technologies to increase solids concentration and manage water from waste processing. Or alternative dewatering process to concentration sludges after transfer at more dilute levels. | Solids and supernatant concentration is needed in both sludge and supernatant processing, respectively. Filtration and evaporation are regularly used in tank waste processing. Improved evaporation methods, or alternate dewatering approaches that would concentrate sludges for subsequent processing without adding additional water evaporation penalty to HLW melters. | Transformational –change in the baseline and mid-range costs | Long-range programs –10 to 15 years and possibly less with potential big payoff if accomplished. | Waste Retrieval, Transfer, & Closure | | 18 | 1 | B |
| Hanford-1 | Infrastructure Cost Evaluation through development of a System Model (roll up as an overall system) - was WR&T-1 | Waste retrieval and infrastructure cost reductions (Superstructure improvements, reduced shielding and support infrastructure). Do a cost benefit/engineering analysis of retrieval technologies. | With full implementation of concept:<br><br>Transformational –change in the baseline and mid-range costs | With partial implementation of concept. Develop a model framework and add modules as necessary:<br>Incremental –some fit existing baseline/flowsheet but maybe not all | Mission Enablers | 1250 | 1 | 21 | B |
| DL-6 | Implement direct disposal options versus vitrification for disposal of CST for on-site and off-site disposal options (likely greater than Class C or TRU) | Alternative disposition paths besides vitrification and disposal as non-HLW should be evaluated for cost reduction opportunities (ship and dispose easily) | Transformational –change in the baseline and mid-range costs (Aids grout) | N/A | Mission Enablers | 125 | 20 | 21 | B |
| IM-2c | Improvements on HLW Facility and Melter Technology | Improve HLW vit facility throughput<br>- Increase HLW facility to equivalent Melter Throughput to 8tG/d<br>-Improving the understanding of erosion/corrosion to extend the life of process equipment (e.g. melters and bubblers) to reduce downtime and improve operating efficiency. | Incremental –some fit existing baseline/flowsheet but maybe not all | Risk mitigation-not schedule driven but protect the schedule | Waste Immobilization & Disposal | 111 | 22 | 1 | B |
| PL-5 | RCRA Organics Removal from Tank Supernate<br>- oxidation/destruction<br>- volatilization/evaporation<br>- extraction (e.g., solvent/supercritical)<br>- capture evaporator concerns with ammonia abatement from IF-17 | Tank waste supernate containing RCRA organics may need to be treated for the organics to meet RCRA LDR standards for non-vitrification or other thermal options for LAW immobilization. Evaporation may be effective for many LDR organics, but needs to be verified for the range of CoCs expected in Hanford tanks, and may require supplemental treatment methods to assure LDR compliance. | Transformational –change in the baseline and mid-range costs (enabling grouting of LAW and offsite disposal) | Long-range programs (enabling onsite disposal of grouted LAW) | Waste Pretreatment | 7 | 32 | 1 | B |
| TC-3 | Work with Regulators/ Stakeholders to prioritize retrieval and sequencing and timing of tank closures to address highest risk | Current tank closure retreival and closure sequencing doesn't include the risk of the tank constiuents to the environment nor potential tank integrity. | Incremental –some fit existing baseline/flowsheet but maybe not all | N/A | Waste Retrieval, Transfer, & Closure | 200 | 16 | 21 | B |
| WR&T-3 | Dry Waste Retrieval Technologies | Evaluate dry or minimal liquid retrieval technologies for known leaker tanks to mitigate potential release to the environment.. National lab experiences and commercial vendor literature review required for existing technologies. | Incremental –some fit existing baseline/flowsheet retrieval problems but maybe not all-TRU<br>Transformational - LLW depending on volume | Risk mitigation for tank leaks | Waste Retrieval, Transfer, & Closure | 179 | 17 | 1 | B |
| IF-2 & WR&T-2a and 2b | Develop improved methods to detect and repair leaks in Hanford tank farm DSTs<br>- NDA and robotic systems for tank inspection and repair<br>- Patching systems to repair leaks | The physical arrangement of the waste tanks and transfer lines makes non-destructive analysis (e.g. ultrasonic wall thickness measurements) difficult. An automated process to perform these measurements would provide additional assurances and information for the tank integrity programs.<br><br>Methods to inspect and repair the tanks and/or transfer lines would allow greater confidence in utilization of existing resources for HLW preparation processes as well as the potential to avoid building new facilities if existing facilities can be utilized. Technologies for deployment both before and during retrieval to mitigate potential release to the environment | Risk mitigation-not schedule driven but protect the schedule | Transformational –change in the baseline and mid-range costs | Waste Retrieval, Transfer, & Closure | 83 | 24 | 12 | B |

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|---|---|---|---|---|---|---|---|---|---|
| WR&T-7b | Process Automation and Feedback | Develop process feedback systems to address operational challenges and effectiveness. Use AI and edge computing to optimize productivity and give feedback. Create better predictive capabilities to evaluate the effectiveness of retrieval technologies (modeling, sensor or visual) | As automation is added:<br><br>Incremental –some fit existing baseline/flowsheet but maybe not all. | As automation is added:<br><br>Risk mitigation-not schedule driven but protect the schedule. | Waste Retrieval, Transfer, & Closure | 76 | 25 | 1 | B |
| WT-9 | Better sampling methods for retrieval, staging and transport to WTP in DST system for waste feed qual<br>- Flow-through loops , tank mixing, etc. | Characterization of the tank contents and heels is performed using grab and core samples that are difficult to obtain. Improving the sampling methods would reduce the time and dose required for retrieval and processing the tank waste. | Incremental –some fit existing baseline/flowsheet but maybe not all | Transformational –change in the baseline and mid-range costs | Waste Retrieval, Transfer, & Closure | 45 | 28 | 12 | B |
| TC-7, WR&T-2b, DL-1 | Develop barriers (e.g., cementitious or lithified rock aggregate systems) with additives targeting contaminants of concern for the outside of tanks or for disposal sites and demonstrate deployment strategies. | Utilize barriers on the outside of the tank or at disposal sites to mitigate the impact of any migration of residual contaminants that would allow reduction in volume of contents removed. | Incremental –some fit existing baseline/flowsheet but maybe not all or | Transformational –change in the baseline and mid-range costs | Waste Retrieval, Transfer, & Closure | 3 | 34 | 12 | B |
| SW-1 | New grouting compositions or lithified aggregate mixtures (for liquid and solid SW) with getters may present a viable option. | The Secondary LLW represents a potentially large volume to be dispositioned and will contain constituents of concern for long-term disposal. A cementitious waste form is the baseline technology but retention of some species is a concern by regulators and may represent a significant volume for disposal. | Incremental –some fit existing baseline/flowsheet but maybe not all | N/A | Secondary Waste Treatment | 333 | 8 | 32 | B |
| IF-14 | Improve techniques for operational support for tank farm and waste processing/immobilization operations<br>- Remote or automated systems to replace hands-on work<br>- Should transition to continuous technology updating system to reduce worker exposure | Remote or automated systems would improve efficiency of tank farm and waste processing/ immobilization operations and reduce potential for worker exposure. In addition, these systems may allow operations in periods of weather that workers could not be used. | Incremental –some fit existing baseline/flowsheet but maybe not all | Risk mitigation-not schedule driven but protect the schedule | Mission Enablers | 1 | 35 | 21 | C |
| PS-9 | Waste treatment or offgas abatement methods to reduce impacts of key air toxics that are limiting waste processing operations | Toxic air emissions from tank waste in both storage and processing operations (e.g., ammonia) can exceed permitted emissions limits and result in restrictions on operating conditions, such as reduced flowrates for exhausters, or reduced operating times for other process facilities (e.g., months/yr, or hours/day allowable operations). Abatement methods for key air toxics, or other methods to reduce emissions are needed to accelerate treatment mission | Risk mitigation - protect the schedule<br><br>Incremental (not part of current baseline, but could fit as addition to existing ventilation upgrades for tank farms. | Transformational –change in the baseline and mid-range costs | Mission Enablers | 125 | 20 | 21 | C |
| IM-12 | Waste Dewatering/Dried waste form (Dispose Tank Waste as LLW) | Assess and implement dewatering options with consideration of scale-up, cost and safety.<br>- Remove tank sludge, dry it and dispose as LLW or TRU<br>-Immobilize TRU in grout and its potential disposal pathways as LAW/LLW. | Transformational –change in the baseline and mid range costs | Long-range programs –10 to 15 years with potential big payoff if accomplished. | Waste Immobilization & Disposal | 41 | 29 | 1 | C |
| PL-1 | Improved supernate filtration methods that could be deployed in modular/skid-based system (e.g., TSCR) and without high pressure penalties or increased operational maintenance. Examples include CUF, Rotary, or ultrasonic methods | Supernate filtration is required to meet WIR requirements for removal of entrained solids that may contain insoluble radionuclide complexes, and to protect downstream pretreatment processing such as ion exchange which would be negatively impacted by solids fouling or plugging. Dead-end filtration is currently used in the TSCR and TCCR system, and requires frequent backflushing to maintain effective operations, reducing the overall TOE. Improved filtration methods with greater TOE are needed that can be deployed in skid-based systems. | Risk mitigation-not schedule driven but protect the schedule | Incremental –some fit existing baseline/flowsheet but maybe not all | Waste Pretreatment | 250 | 12 | 21 | C |
| PL-2 | Improving or optimizing existing filtration or processes through filtration additives | Supernate filtration is required to meet WIR requirements for removal of entrained solids that may contain insoluble radionuclide complexes, and to protect downstream pretreatment processing such as ion exchange which would be negatively impacted by solids fouling or plugging. Dead-end filtration is currently used in the TSCR and TCCR system, and requires frequent backflushing to maintain effective operations, reducing the overall TOE. Improvements to existing filtration processes that increase TOE are needed. | Risk mitigation-not schedule driven but protect the schedule | Incremental –some fit existing baseline/flowsheet but maybe not all | Waste Pretreatment | 250 | 12 | 21 | C |

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|---|---|---|---|---|---|---|---|---|---|
| PL-3 | Optimize Cs loading of CST | Non-elutable CST columns have been selected for Cs removal at Hanford for TSCR, and is expected to be used in proposed TFPT facilities. Optimizing loading of Cs columns is needed to reduce costs while balancing demands of loading limitations due to heat load, shielding, and hydrogen generation in spent CST columns. | Incremental - decrease CST use/reduce costs | Transformational - alternate disposal pathway | Mission Enablers | 40 | 30 | 21 | C |
| PL-8 | Sodium nitrate separation or low-temperature destruction<br>- fractional crystallization<br>- clean salt<br>- denitrification (biological, NAC) | Sodium nitrate represents a significant fraction of the waste requiring treatment. Nitrates/NOX abatement represents a significant cost and risk for thermal waste treatment such as vitrification, and a potential long-term groundwater risk for most low-temperature treatment processes such as waste grouting. Methods for safe destruction of nitrates or separation of sodium nitrate from tank wastes | Transformational –change in the baseline and mid-range costs | Long-range programs (reduce LAW, recycle caustic for sludge processing, retrieval) | Waste Pretreatment | 100 | 23 | 21 | C |
| PL-10 | Methods for pretreating supernatant prior to Cs removal with CSTs to remove Pu and actinides | Pu and other actinides in tank waste supernatant will be removed to some degree during pretreatment using CSTs, potentially increasing the potential that loaded CSTs column are classified as TRU waste, and complicating ultimate disposition of CST canisters. Methods for actinide pretreatment, such as a monosodium titanate strike may be helpful in reducing potential for actinide loading on the CST. | Transformational –change in the baseline and mid-range costs | Risk mitigation-not schedule driven but protect the schedule | Waste Pretreatment | 3 | 33 | 21 | C |
| SW-10 | Develop Tc separation techniques for SBS condensate allowing disposition of other constituents in offgas stream elsewhere and Tc to be incorporated in glass. | SBS condensate is predicted to have a high concentration of Tc (as well as Cl, S, and F.). In the baseline this Tc would be recycled but the Cl, F, and S could limit waste loading. Recycling the Tc without the Cl, F, and S would reduce potential negative impact on Melter operations and performance. The Cl, F, and S will be dispositioned as secondary waste | Incremental –some fit existing baseline/flowsheet but maybe not all | N/A | Secondary Waste Treatment | 50 | 26 | 32 | C |
| SW-9 | Remove the iodine (score here) post melter in gas phase | Uncertainty in partitioning of Iodine in the melter and offgas system causing process and disposition risks. Grouting of the spent GAC may be problematic because of the iodine captured on the media which causes IDF risks (performance issues) and HazCat issues for LERF/ETF. | Risk mitigation-not schedule driven but protect the schedule | Incremental –some fit existing baseline/flowsheet but maybe not all | Secondary Waste Treatment | 250 | 12 | 32 | C |
| IF-7 & IF-12 | Evaluation of process intensification of LERF-ETF process to include automation. | ETF treatment capacity improvements are needed to process effluents from vitrification processes. | Incremental –some fit existing baseline/flowsheet but maybe not all | Risk mitigation-not schedule driven but protect the schedule | Secondary Waste Treatment | 47 | 27 | 21 | C |
| PL-6 | Iodine separation technologies effective for alkaline tank waste and secondary liquid waste streams from thermal treatment offgases (combine with SW-9 and check scoring) | Iodine, despite low total inventory in tank waste, is the primary risk driver to groundwater due to its high volatility within the vitrification process and substantial transfer to secondary waste streams, and high mobility in the subsurface. There are limited current technologies for iodine separation from either high ionic strength alkaline tank waste or liquid secondary waste streams from vitrification offgas systems. Effective iodine IX resins or sorbents that can enable separation from primary and secondary liquid waste streams are needed. | Risk mitigation-not schedule driven but protect the schedule | Incremental –some fit existing baseline/flowsheet but maybe not all | Secondary Waste Treatment | 250 | 12 | 32 | C |
| TC-4 (TC-5,WR&T-8) | Use improved characterization methods to include in-situ techniques and performance assessments to identify the residual risk of the materials remaining to determine tank cleanng end point. Update PA models based on information available from earlier releases and containant transport behavior. | Current tank closure end-state is based on achieving specific volume removal and number of methods used, if unable to achieve volume, versus the actual risk remaining. Residuals may not contain constituents of concern from a hazard standpoint. Contaminant transport assumptions may also be inaccurate driving more material than necessary. | Transformational –change in the baseline and mid range costs | N/A | Waste Retrieval, Transfer, & Closure | 10 | 31 | 12 | C |