Second Informational Webinar: DOE National Laboratory Program Announcement (LAB-23-EM001) Hanford Tank Waste R&D

Action	Date
Initial Announcement Issue Date:	June 7, 2023
Initial Informational Webinar Date:	June 9, 2023
Amendment 001 Issue Date:	August 10, 2023
Second Informational Webinar Date:	August 28, 2023, 11 am-2 pm Eastern Time (ET)
Submission Deadline for Amendment 001 Comments:	September 1, 2023, at 5 PM ET
Submission Deadline for Updated Letter of Intent:	September 15, 2023 at 5 PM ET
Submission Deadline for Proposals:	October 16, 2023 at 5 PM ET

Disclaimer: This presentation summarizes the contents of the Funding Announcement to DOE National Labs (Lab Call). Nothing in this webinar is intended to add to, take away from, or contradict any of the requirements of the Lab Call. If there are any inconsistencies between the Lab Call and this presentation or statements from DOE personnel, the Lab Call is the controlling document.

OFFICE OF ENVIRONMENTAL MANAGEMENT

Webinar Agenda

11 am – 11:15 am:	Ming Zhu (EM), Lab Call Amendment
11:15 am – 12:30 pm:	Paul Schroder (DOE Hanford), Karthik Subramanian (WRPS) and Albert Kruger (DOE Hanford), Hanford Site-funded TD Projects
12:30 – 1 pm:	Rod Rimando (EM), EM TD Office-funded TD Projects
1 – 1:30 pm:	Bob Ledoux (ARPA-E), ARPA-E Program Overview
1:30 – 2 pm:	Q&A

Amendment 001

On the Cover page, the due date for proposals has been extended, and additional schedule dates are provided for second Informational Webinar, comments on the Amendment 001, and updated Letter of Intent.

Revised Schedule	
Action	**Date**
Initial Announcement Issue Date:	**June 7, 2023**
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Amendment 001 (ctd)

Section I:

- Information is provided about the Website where information about the Lab Call is posted (p. 2).
- Additional information is provided about the focus of this Lab Call on long term R&D as well as current R&D efforts undertaken by the Hanford Site, EM headquarters and the Advanced Research Projects Agency–Energy (ARPA-E) (p. 2).
- Information about teaming requirements has been incorporated into Section III, under the new heading "D. LIMITATIONS ON SUBMISSIONS - TEAMING" (pp. 10 and 11).

Section IV:

- Under "APPENDIX 1: BIOGRAPHICAL SKETCH", the maximum number of pages for the biographical information (curriculum vitae) for each person is changed from 2 to 3 (p. 16).

Amendment 001 (ctd)

Section V:

- A clarification is made about the initial compliance review as opposed to the merit review. The review criteria have been slightly modified (pp. 19 and 20).
- Under "REVIEW AND SELECTION PROCESS", the sentence about the merit review schedule is removed (p. 20).
- Under "C. ANTICIPATED NOTICE OF SELECTION AND AWARD DATES", the anticipated schedule for proposal awards has been updated from the end of September 2023 in FY 2023 to December, 2023 in FY 2024 (p. 21).

Section VIII:

- Under "4. How to Prepare a List of Individuals Who Should Not Serve as Reviewers", the bullet of "Close associates of the senior/key person over the past 48 months" has been removed (p. 28).

Letter of Intent

- Each National Lab should submit one Letter of Intent (LOI) that includes a list of lead PIs for all participating institutions and up to 7 project/priority areas.
- DOE will use the LOIs to set up the peer review teams. No additional feedback will be provided by DOE unless there are questions about the LOI.
- In the event that a National Lab would like to request adjustments to their proposed lead PIs for any participating institution(s) and any project/priority area(s) after the submittal of the LOI, DOE will be willing to consider the request on a case-by-case basis.
- There is no specific format requirement for the LOI.

Proposals

- Proposals must be submitted to PAMS. DO NOT email proposals to EM-LabCall@em.doe.gov or the Program Manager.
- You can make changes to the submitted proposals before the deadline. The last submitted proposal will be considered final.
- Please review Amendment 001 for the PAMS submission information and ensure that you submit your final version and do not leave your submission in editing mode at the deadline.

Participation of Foreign Nationals

Participation of foreign nationals in this Lab Call is allowed as long as the National Lab complies with DOE P 485.1A, DOE O 486.1A and DOE O 142.3B Chg I, and any other applicable requirements. There are disclosure requirements, e.g., biosketch, and current and pending support, in the Lab Call.

Integration with Other EM Funded Projects

- The Hanford Site directs TD activities to address near term project deliverable needs
- EM Technology Development Office (TDO) funded initial tasks within 3 Quick Win projects for specific scope and a short period of time.
- EM TDO is also in the process of making 1-time awards of several R&D projects, in response to an Internal Call to certain national labs and universities.
- Proposals to this Lab Call are encouraged to build on the work done by the Hanford Site and EM TDO funded projects and the full body of knowledge available throughout the EM cleanup complex. Specifically, products/information generated from the currently funded projects will be made available for projects funded by this Lab Call.
- Proposals should not duplicate work already funded through another program. They can address new approaches to the same challenge or expand upon work already done, but they must involve original work that is distinct from work funded by another source.

References

Additional reference documents have been posted to the EM Website (https://www.energy.gov/em/hanford-tank-waste-national-laboratory-funding-announcement), including:

- WRPS Technology and Innovation Roadmap, RPP-PLAN-43988, Rev. 7. 10/12/2022
- SC Basic Research Needs for Environmental Management, Report of the Office of Science Workshop on Environmental Management, July 8-11, 2015. Feb. 2016

In addition, ARPA-E program information can be found on the ARPA-E Website:

- ONWARDS: https://arpa-e.energy.gov/technologies/programs/onwards
- CURIE: https://arpa-e.energy.gov/technologies/programs/curie

Questions?

Send email to:

EM-LabCall@em.doe.gov

Or contact:

Dr. Ming Zhu
EM Senior Advisor for Laboratory Policy
Ming.Zhu@em.doe.gov
(301) 903-9240

Backup

Amendment 001 (ctd)

- In Section I, information is provided about the Website where information about the Lab Call is posted (p. 2).

Information of this Lab Call, including the announcement, amendments, Informational Webinar presentations, comments and responses, and additional documents can be found on the EM Website at https://www.energy.gov/em/hanford-tank-waste-national-laboratory-funding-announcement.

Amendment 001 (ctd)

- In Section I, additional information is provided about the focus of this Lab Call on long term R&D as well as current R&D efforts undertaken by the Hanford Site, EM headquarters and the Advanced Research Projects Agency–Energy (ARPA-E) (p. 2).

> The Lab Call builds on the current R&D efforts undertaken by the Hanford Site to support near-term project deliverables, the EM Technology Development Office-funded tank waste R&D projects, and the ARPA-E-funded programs that may provide technologies and approaches relevant to the Hanford tank waste mission. Additional information about the ongoing EM headquarters and Site-funded Hanford tank waste R&D projects will be posted on the Website: https://www.energy.gov/em/hanford-tank-waste-national-laboratory-funding-announcement. Information about the relevant ARPA-E Optimizing Nuclear Waste and Advanced Reactor Disposal Systems (ONWARDS) and Converting UNF Radioisotopes Into Energy (CURIE) programs can be found at https://arpa-e.energy.gov/technologies/programs/onwards and https://arpa-e.energy.gov/technologies/programs/curie.

Amendment 001 (ctd)

- In Section I, information about teaming requirements has been incorporated into Section III, under the new heading "D. LIMITATIONS ON SUBMISSIONS - TEAMING" (pp. 10 and 11).

D. LIMITATIONS ON SUBMISSIONS – TEAMING

…

The proposed research and development should involve National Laboratory-led, multi-investigator, multidisciplinary research teams with comprehensive expertise to address these challenges. Collaborative applications, e.g., submissions of identical proposals by different institutions, will not be accepted under this National Laboratory Program Announcement. EM encourages the teams to include unique capabilities from other Federally Funded Research and Development Centers, academic institutions (including MSIs and Historically Black Colleges and Universities), and industry to supplement core competencies of the DOE National Lab complex.

…

Amendment 001 (ctd)

- In Section IV, under "APPENDIX 1: BIOGRAPHICAL SKETCH", the maximum number of pages for the biographical information (curriculum vitae) for each person is changed from 2 to 3 (p. 16).

APPENDIX 1: BIOGRAPHICAL SKETCH

Provide a biographical sketch for the PI and each senior/key person as an appendix to your technical narrative.

- Provide the biographical sketch information as an appendix to your project narrative.
- Do not attach a separate file.
- The biographical sketch appendix will not count in the project narrative page limitation.
- The biographical information (curriculum vitae) for each person must not exceed 3 pages when printed on letter-size (8.5 x 11 inch) paper with 1 inch margins (top, bottom, left, and right) with font not smaller than 11 point

Amendment 001 (ctd)

- In Section V, a clarification is made about the initial compliance review as opposed to the merit review (p. 19).

Initial Compliance Review Criteria

Prior to a comprehensive merit evaluation, DOE will perform an initial compliance review to determine that (1) the applicant is eligible for the award; (2) the information required by the Program Announcement has been submitted; (3) all mandatory requirements are satisfied; (4) the proposed project is responsive to the objectives of the Program Announcement, and (5) the proposed project is not duplicative of programmatic work. Proposals that fail to pass the initial review will not be forwarded for merit review and will be eliminated from further consideration.

Amendment 001 (ctd)

- In Section V, the review criteria have been slightly modified (pp. 19 and 20.

MISSION RELEVANCE (WEIGHTED 35%)

- Does the proposal demonstrate a clear understanding of the current state of the mission and ongoing tank waste research and development efforts needs that do not duplicate current efforts?

Scientific and/or Technical Merit of the Proposed Research (weighted 35%)

- Does the proposed work reasonably provide confidence in meeting its objectives in a way that others have not previously considered or exploited?

Amendment 001 (ctd)

- In Section V, the review criteria have been slightly modified (pp. 19 and 20).

APPROPRIATENESS OF THE PROPOSED METHOD OR APPROACH (WEIGHTED 20%)

- Is the proposal reasonably sufficient to achieve the proposed results?
- …
- Does the applicant clearly identify risk and an analysis of alternative strategies/solutions?

COMPETENCY OF APPLICANT'S PERSONNEL AND ADEQUACY OF PROPOSED RESOURCES (WEIGHTED 10%)

- …
- What is the rational for the team members and does it seem reasonable to cover the depth and breadth of the proposed approach and results?

Amendment 001 (ctd)

- In Section V, under "REVIEW AND SELECTION PROCESS", the sentence about the merit review schedule is removed (p. 20).

B. REVIEW AND SELECTION PROCESS

DOE EM anticipates a merit review panel of subject matter experts to evaluate proposals submitted to this Announcement.

Amendment 001 (ctd)

- In Section V, under "C. ANTICIPATED NOTICE OF SELECTION AND AWARD DATES", the anticipated schedule for proposal awards has been updated from the end of September 2023 in FY 2023 to December, 2023 in FY 2024 (p. 21).

C. ANTICIPATED NOTICE OF SELECTION AND AWARD DATES

It is anticipated that the award selection will be completed by December, 2023. It is expected that awards will be made in Fiscal Year 2024

Amendment 001 (ctd)

- In Section VIII, under "4. How to Prepare a List of Individuals Who Should Not Serve as Reviewers", the bullet of "Close associates of the senior/key person over the past 48 months" has been removed (p. 28).

4. How to Prepare a List of Individuals Who Should Not Serve as Reviewers

To assist in identifying individuals who should not serve as merit reviews, provide the following information for each and every senior/key person who is planned to be or is identified in Section A of the proposal budget for the applicant and any proposed subrecipients:

- Advisees (graduate students or postdocs) of the senior/key person
- Advisors of the senior/key person while a graduate student or a postdoc
- Co-authors of the senior/key person over the past 48 months
- Co-editors of the senior/key person over the past 48 months
- Co-investigators of the senior/key person over the past 48 months
- Collaborators of the senior/key person over the past 48 months

THE HANFORD SITE

WRPS Technology Development Program

8/28/2023

Agenda

- Technology and Innovation Roadmap
- Technology Program
- DOE-EM Integration
- DOE-EM Call for Proposals

Technology Roadmap

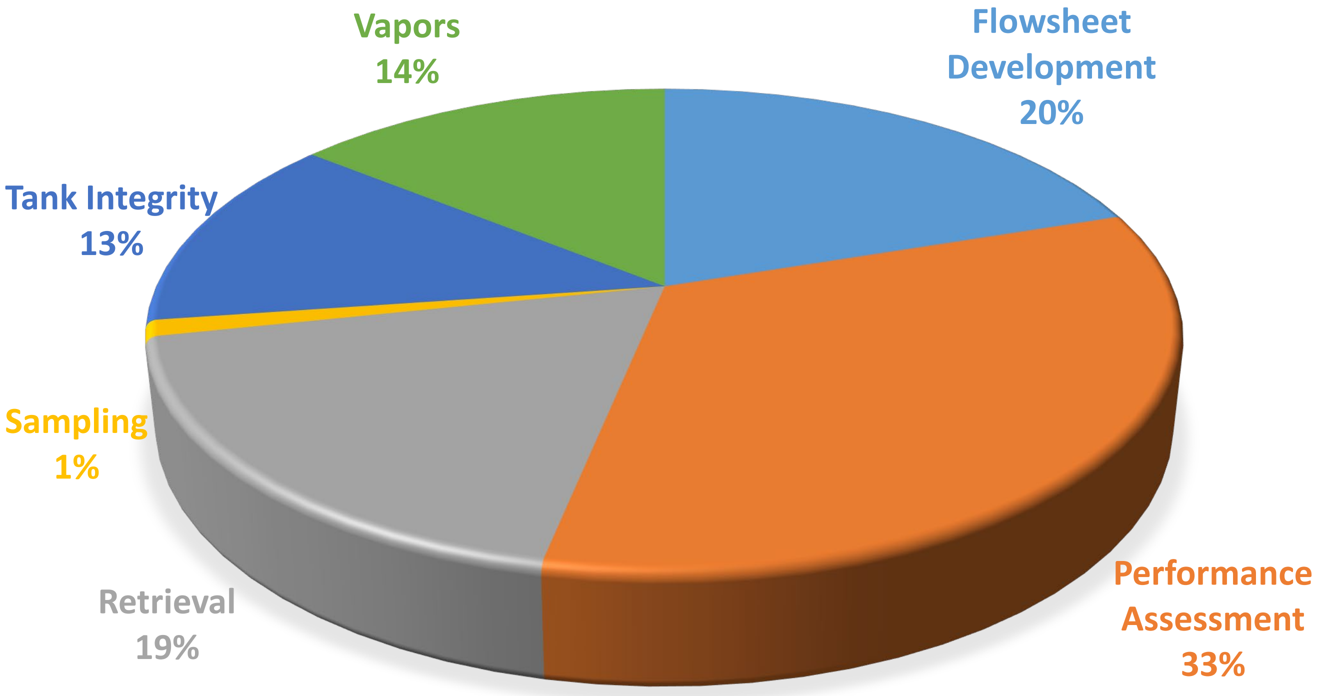
- Address identified Mission Risks
- Support whole Mission Technology needs
- Reduce risk and cost, enhancing efficiency
- Guide fiscal planning
  - Provide annual planning input
  - Capture available technology with supporting cost and schedule
- Assess Technologies
  - Highlight over 100 technologies
  - Catalog ideas for evaluation

Technology Maturation & Execution (TM&E) Charts

- The Roadmap includes two swimlane type charts that highlight priority work areas and the related technology development in a timeline of events divided into major mission programs divided into two areas:
- Direct Feed Low-Activity Waste (DFLAW) Operations Support
  - Immobilized Low-Activity Waste Glass
  - Tank-Side Cesium Removal (TSCR)
  - Cementitious Waste Forms
  - Supplemental Low-Activity Waste
- Mission Support
  - Alternate Retrieval Technology Identification and Development
  - Tank Integrity Technology Identification and Development
  - Sampling & Monitoring Technology Identification and Development
  - Worker Protection
  - High Level Waste (HLW) Pre-Treatment and Immobilization

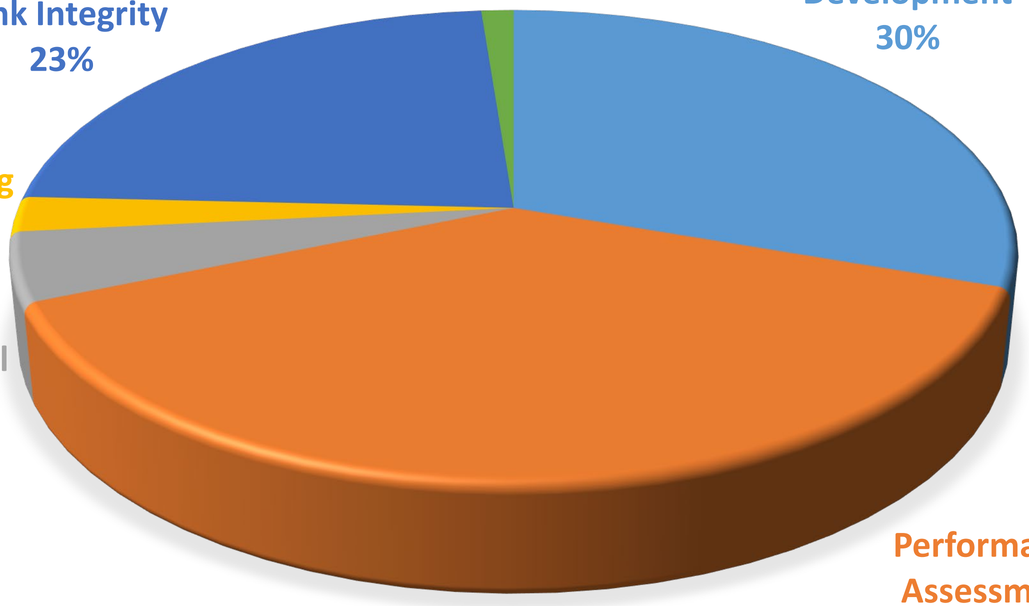
Past Technology Program

- Tank Integrity:
  - Residual Volume Measuring System
  - Tank Annulus Floor Cleaning
  - Visual Inspection of DST Primary Tank Bottoms
- Retrieval:
  - Mechanical Waste Gathering System
  - Alternate Retrieval Technology
  - Tank Dome Core Cutting System
  - Hanford Waste End Effector (HWEE)
- Vapors/Worker Protection:
  - Vapor Monitoring and Detection System (VMDS)
  - Health Process Plan
  - Fugitive Emissions
  - Portable Gamma Radiation Monitoring System
  - Continuous Effluent Monitor / Smart Sampler
  - Vapors Mobile Lab
  - Personal Ammonia Monitors
  - IH Data Analysis and Visualization (IDAV)
- Sampling:
  - Off Riser Sampling
  - Shielded Sampler and Hedgehog III
  - Isolok Sampler
- Performance Assessment:
  - Lysimeter
- Flowsheet Development:
  - Supplemental LAW Treatment Alternatives
  - Radioactive Waste Test Platform
  - Tank Side Cesium Removal



Recent Technology Program

- Performance Assessment:
  - Lysimeter and IDF PA Support
  - Secondary Waste form Development
  - Immobilized Low Activity Waste Glass testing for IDF
  - Secondary Liquid Waste Stream Technical Maturity
  - Secondary Solid Waste Form Technical Maturity (DFLAW)
- Flowsheet Development:
  - Supplemental LAW Treatment Alternatives
  - Radioactive Waste Test Platform
- Tank Integrity:
  - Machine Learning for corrosion identification
  - Tank Refurbishment (Cold Spray)
  - Volumetric Non-Destructive Examination
  - Improved lighting and camera system
- Retrieval:
  - Dry Waste Retrieval System
  - Small Riser Slurry Pump
  - Development of High Radiation Hose Materials
  - Extra Small Residual Volume Measuring System
- Vapors/Worker Protection:
  - NUCON / Thermal Oxidation System
  - Wearable Robotics
- Sampling:
  - Off Riser Sampling



Continuing Technology Program

- Performance Assessment:
  - Lysimeter and IDF PA Support
  - Secondary Waste form Development
  - Immobilized Low Activity Waste Glass testing for IDF
  - Secondary Waste Stream Technical Maturity (Solid and Liquid)
- Flowsheet Development:
  - Supplemental LAW Treatment Alternatives
  - Radioactive Waste Test Platform
- Tank Integrity:
  - Machine Learning for corrosion identification
  - Tank Refurbishment (Cold Spray)
  - Volumetric Non-Destructive Examination
  - Improved lighting and camera system
- Retrieval:
  - Dry Waste Retrieval System
  - Small Riser Slurry Pump
  - Development of High Radiation Hose Materials
  - Extra Small Residual Volume Measuring System
- Vapors/Worker Protection:
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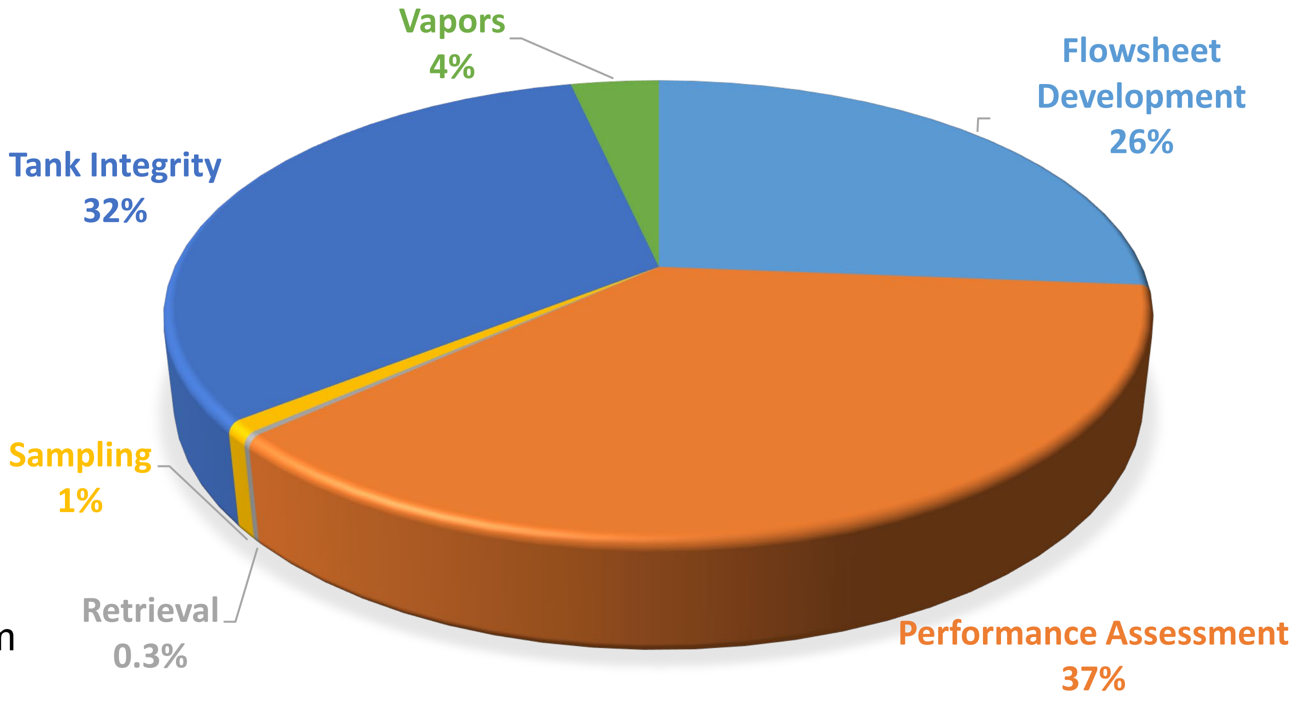
- Sampling:
  - Off Riser Sampling



DOE EM Integration

- The WRPS Technology & Innovation Roadmap is a comprehensive compendium of technology needs for the Hanford Tank Farm mission
  - Currently DFLAW Mission focused
  - Transitioning to new mission needs
- Direct DOE-EM funding has the potential to:
  - Accelerate Hanford Tank Farm Technology Development
  - Supplement alternatives for current and future identified Hanford Tank Farm needs
  - Expand application of existing technologies
  - Address holistic negotiation technology needs
  - High Risk – High Reward efforts

Transitioning Technology Needs For Example

- S, SX, & U Farms Retrievals
  - Enhanced Salt Dissolution to control solids in West Area pretreatment system
  - Continuous Sludge Leaching
  - Evaluation of Zeolite as an alternate ion exchange media
  - Waste Characterization
    - In-line Monitoring
- High Level Waste Feed Qualification
- Specialized Retrieval for Damaged Tanks, A-104 & A-105
  - Novel removal of air-lift circulators
  - Removing waste under the liner
- Waste Transfer System Protection
  - Corrosion Inhibitors for encasement

Questions

Hanford: Remediation of the Legacy Doing So in a Cost-Effective Manner Office of River Protection Enhanced Waste Glass Program

Presented by: Albert A. Kruger, Glass Scientist,
U.S. Department of Energy

August 28, 2023

Key Messages

- Enhanced Waste Glass (EWG) Program Goal
- Challenges and Approaches for Hanford Vitrification
- Advanced LAW & HLW glass formulations allow the additional flexibility to reconsider feed vectors to the WTP.
- Performance enhancements through improved glass formulations are essentially transparent to the engineered facility.

ORP EWG Program to Support Sustained Operations

- The overall goal and work performed is to expand the flexibility of the as-delivered WTP. By delivering the chemistry to expand the waste loading or enhance the tolerance for artificially conservative component limits (e.g., aluminum, chromium, halides, phosphates, sulphates, etc.) that date back to the mid-90s.
- Glass chemistry and melting efforts report back to the ability to allow far greater processing capacity that can be introduced to the WTP as sustained operations are initiated and operator/operations experience are realized.
- Understanding of the influence of glass former and waste components on the feeding and processing of our waste will allow for the inclusion of common practice machine learning controls of the as designed/delivered WTP. As an example, decisions on feeding rates would no longer be an exercise of “let’s spin the knob on the control panel”

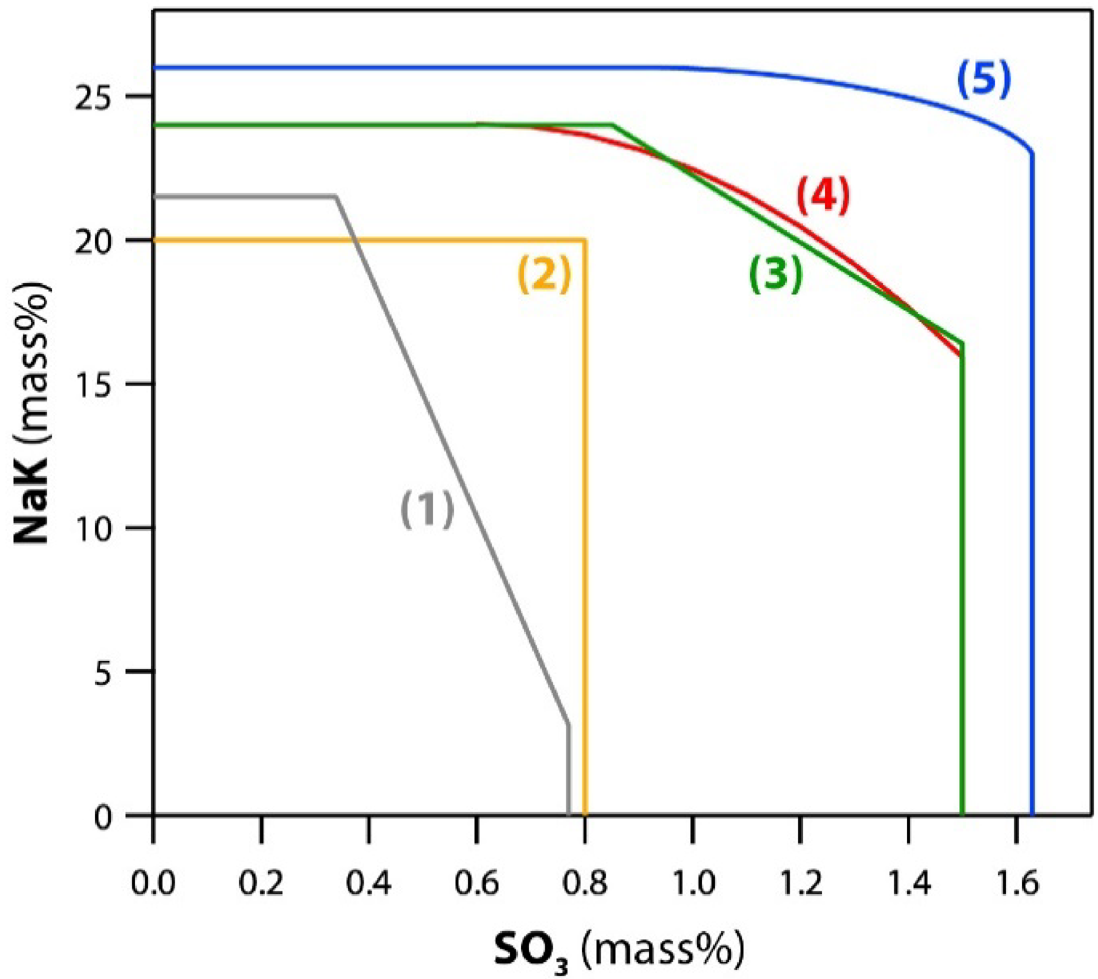
WTP Baseline Treatment Mission Projections

	BNI/WTP Baseline Models	2008 TUA[a] Baseline
HLW Canisters	18,400	14,838
LAW Containers	145,000	91,400
Total Canisters and Containers	163,000	106,238

[a] The "2008 models" were altered in anticipation of our work.

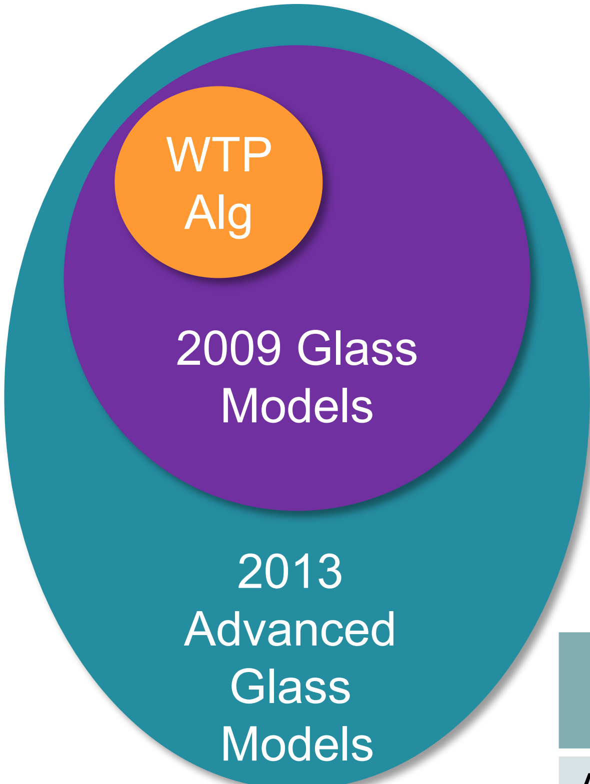
BNI = Bechtel National, Inc.
TUA = tank utilization assessment

Waste NaK (= Na_2O+ $0.66K_2O$) and SO_3 Loading (Mass%)



(1) ORP-56326, (2) ORP-68871, (3) PNNL-25835, (4) VSL-19R4460-1, and (5) PNNL-30932

Office of River Protection Enhanced Waste Glass Work



- Recent glass testing has covered significantly broader composition space and new methods have reduced conservatism
- Large increases in loadings of Al, Cr, Na, and S have been demonstrated at lab and melter scale

HLW Comp	WTP Baseline	HTWOS Models	Adv Models	Demonstrated
Al_2O_3	13	20	28	>30
Cr_2O_3	0.6	1.2	3	6
Na_2O	20	21.4	23	26
SO_3	0.44	0.6	1.6	1.9

Glass Formulation Options

- Interpolation between successful glass compositions
  - Successfully used for WTP baseline LAW glass formulation (validated)
  - Reduce risk of process upsets
  - Necessitates significant conservatism
- Numerical optimization using property models and constraints
  - Successfully used for WTP baseline HLW glass formulation (validated)
  - Reduces conservatism
  - Easily handles unanticipated waste feed compositions
  - Directly addresses process uncertainties

Formulating Glass

$$g_i = Ww_i + (1-W)a_i$$

$$P = \widehat{P}_T\,(g_1, g_2, \dots, gn)$$

For a given waste composition (w_i),
determine mineral addition (a_i),
to obtain glass composition (g_i),
with optimized properties (P),
and maximized waste loading (W)

The selection of properties to be optimized depends on melter technology and glass acceptability criteria

Summary of Component Concentration Effects on ILAW Glass Properties

Oxide	Al_2O_3	B_2O_3	CaO	Cr_2O_3	Fe_2O_3	K_2O	Li_2O	MgO	Na_2O	SiO_2	SnO_2	TiO_2	ZnO	ZrO_2	Other
Viscosity	↑	↓	↓	↔	↔	↓	↓	↓	↓	↑	↑	↓	↔	↑	–
EC	↔	↔	↔	↔	↔	↑	↑	↔	↑	↓	↔	↔	↔	↔	–
Crystal	↑	↓	↓	↑	↑	↓	↓	↔	↓	↓	↑	↑	↑	↑	NiO, MnO
PCT	↓	↓	↔	↔	↔	↑	↑	↑	↑	↓	↓	↓	↔	↓	–
VHT	↓	↓↔	↔	↔	↔	↑	↑	↔	↑	↓	↓	↓	↔	↓	–
Nepheline	↑	↓	↑	↔	↔	↑	↑	↔	↑	↓	↔	↔	↔	↔	–
Salt	↑	↓	↓	↑	↔	↓	↓	↔	↓	↑	↔	↔	↔	↔	SO_3, Cl, V_2O_5 –
TCLP	↓	↑	↔	↔	↔	↑	↑	↔	↑	↓	↓	↔	↑	↓	–
Corrosion	↓	↔	↔	↓	↓	↑	↑	↔	↑	↓	↓	↔	↓	↓	–

↑ = increase property; ↓ = decrease property; ↔ = small effect on property.
Multiple arrows are for nonlinear effects; the first is for lower concentrations and the second for higher concentrations.
TCLP = toxicity characteristic leaching procedure.
Corrosion denotes corrosion of glass contact materials (primarily Monofrax™ K-3 and Inconel™ 690).

PNNL Scope

- **Glass formulation algorithm** – enable the plant to implement enhancements in glass formulation (which expanded the glass composition envelope to reduce risk and allow for broader range of waste feeds).
- **Glass data in areas of high uncertainty** – reduce conservatism and increase precision in property prediction (allows for increased loading).
- **Expand glass composition boundaries** – increase process flexibility and allow for broader range of waste composition variations.
- **Cold cap and melt dynamics** – Enables prediction of processing performance from melter feed composition/additives, allows manipulation of performance by changes in additives, and provides capability to respond to WTP melter processing issues rapidly and efficiently.
- **Integrated melter modeling** – Once built and validated, modeling tools and simulations are often more efficient than physical testing and can be run prior to testing to ensure the right tests are designed and executed.

PNNL Scope, cont’d

- **Melter offgas testing capability** – Complete and demonstrate Adaptive Vitrification Evaluation System (AVES) offgas testing capability. System will allow generation and testing of representative melter offgas from short duration tests.
- **Glass former testing and evaluation** – The raw material supply chain will continue to change throughout the life of the WTP. Efficient evaluation and qualification of glass formers will remain key to maintaining full throughput operations and avoiding potential issues.

INL Scope

- Integrated melter model development: Improve the fidelity of the integrated melter model to describe the relevant physics occurring in the molten glass, melter atmosphere and cold cap, as well as their interfaces. Continue to develop and incorporate submodels to represent the complex, coupled electromagnetic, hydrodynamic, chemical and thermal phenomena. Identify data that can be used to develop sub-models for incorporation into the integrated melter model for melters at various scales.
  - Implement new cold cap sub-model in integrated melter model:
  - Implement an improved representation of plenum gases in the integrated CFD model:
  - Develop CFD model of full-scale LAW melter
  - Validate computational models
  - Assist with the development of a test melter system
- UCT Prague Pass Through

SRNL Scope

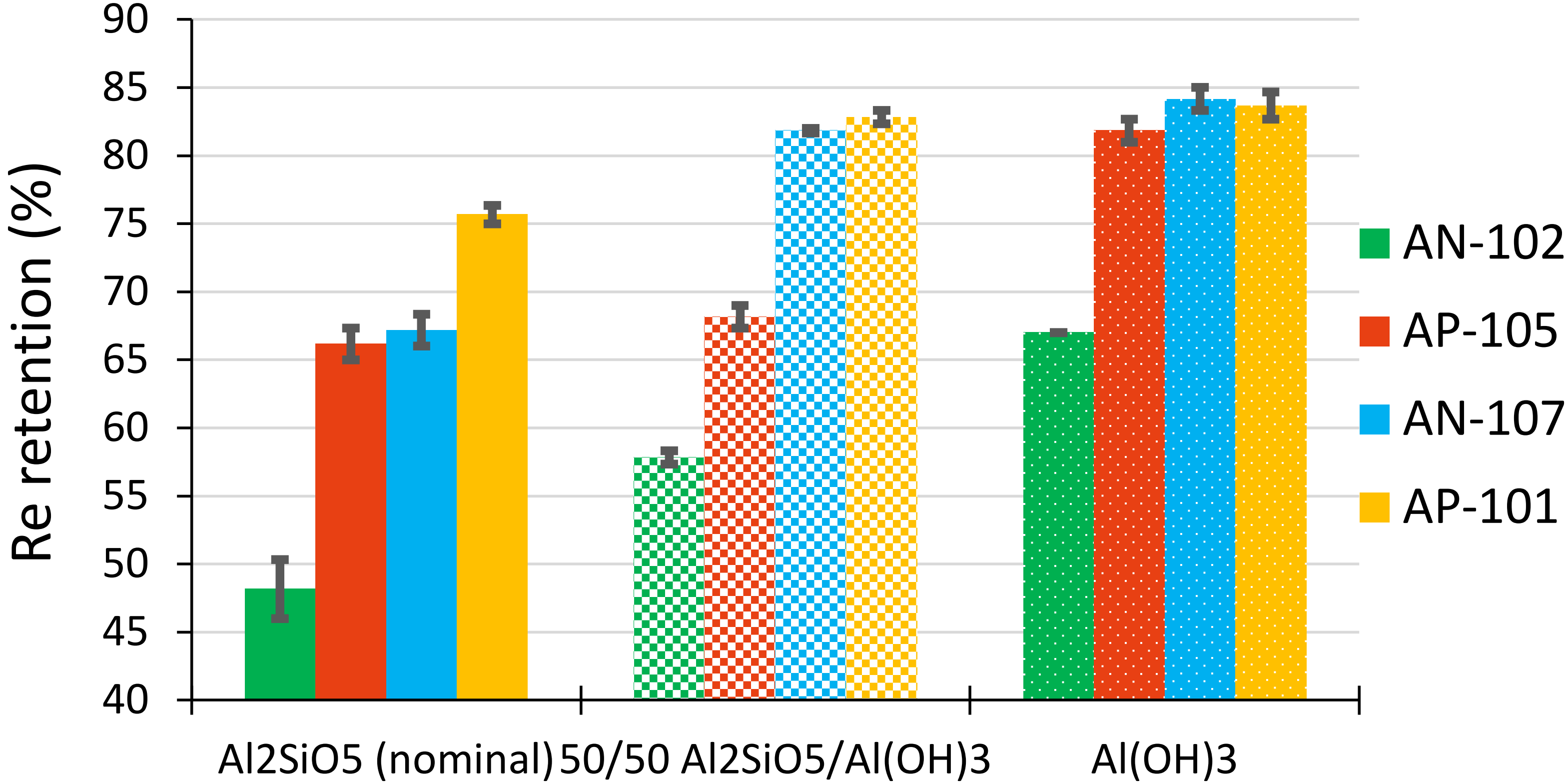
- **Sample Analysis:** SRNL provides support for PNNL in generating LAW and HLW glass property-composition data.
- **Nepheline Crystallization Studies:** SRNL continues to develop the Structural Integrity of Residual (SIR) glass model developed in FY20 by investigating the influences on chemical durability caused by altering the composition/concentration of minor components.
- **Refractory Corrosion: P**erformed jointly with PNNL to estimate the degradation rate of melter refractory block and materials. It is known that the predictive life of melter refractory block is conservative, as demonstrated by performance of these materials such as in the Defense Waste Processing Facility (DWPF)
- **Production and Performance of High Sulfur Concentration Waste Glasses:** provide further insight into the practical aspects of glass production with high sulfur loading. Thus far there has been a disparity between the thermodynamic solubility limit in laboratory crucible testing and the measured retained sulfur content in large scale test reactors, with larger retention values corresponding to larger scale testing.
- **Crystal Tolerant Glasses:** Experiments utilizing the full scale, room temperature WTP HLW melter riser system have demonstrated a degree of robustness to pouring despite accumulations of particles in the throat and riser.

University of Chemical Technology Scope

- **Development of advanced cold cap model – cold cap bottom and conversion rate:** Current work on the cold cap addresses factors affecting the heat transfer from the molten glass into the cold cap using the boundary layer theory to develop a relationship estimating the melting rate of feeds with different compositions.
- **Development of advanced cold cap model – foaming in the presence of water vapor:** The morphology of the foam layer at the cold cap bottom and the temperature at the foam bottom-melt boundary is directly related to the melting rate.
- **Development of advanced cold cap model – LAW feeds:** Developed a mathematical model that reasonably estimates the melting rate and the temperature profile in the HLW waste feed cold cap.
- **Cold cap formation – interaction between slurry and cold cap, cold cap rheology:** One of the problems resulting in the deficiency of current batch melting models is that they do not include feed rheology, or simulate the flow of reacting materials using apparent viscosities or other empirical parameters.
- **Collaboration with INL on cold cap model implementation:** The ultimate goal of cold cap studies is to incorporate the advanced cold cap model in the full CFD glass melter model as its integral component.

(Modest ORP funding results in more significant financial support from the Czech Ministry of Education, Youth and Sports Project)

Effect of Al source on Tc/Re retention



University of Nevada – Reno Scope

- The team has developed a non-friable, carbon foam material with iodine capture capacity of ~813 mg I per g of sorbent.
- The mechanical robustness, compatibility with the components in the off-gas, ease of fabrication, and commercial availability of the base material, has allowed this material to be downselected for further study in a pre-pilot-scale system.
- The goal of this effort is to deliver a procurement specification by establishing the performance bases; engineering the carbon foam to have the potential to be implemented into the primary and guard beds for the removal of mercury, I_2 and acid gases (HCl and HF). A pre-pilot-scale system to test the mercury, iodine and acid gas sorption capacity in a simulated LAW off-gas (composition of off-gas provided in the mechanical data sheet for the activated carbon adsorber 24590-LAW-MVD-LVP-00003) is operational.

Washington State University & Rutgers Scope

- The **first** part of the task description is to research the **suppression of foaming** in the melt due to changes in the redox behavior.
- The **second** part of the task description is to research means to **increase Na_2O and SO_3 loading** in glass to avoid salt segregation in the melter.
- The **third** part of the task description focuses on **increasing the solubility of volatile radionuclides** in LAW glasses (*i.e.*, Technetium and halides (Cl and ^{129}I))
- The **fourth** part of the **suppressing crystallization in LAW glasses**. Generally, crystallization is not considered to be a problem in LAW glasses. However, the addition of some oxides, for example, ZrO_2 and/or SnO_2 to these glasses, in a pursuit to increase their chemical durability (measured by vapor hydration test), tends to promote crystallization.
- The **fifth** part of the task description focuses on **controlling K-3 refractory** corrosion to increase the melter lifetime. K-3 refractory corrosion will be a major problem during the vitrification of DF-LAW.

CRESP Scope

- The goal of our project is the selection of test(s) that are more reproducible and at least as easy to implement as compared to the current tests (e.g., ASTM C1663-09 & ASTM C1285-14), and (most importantly) are more representative of performance under the conditions in the Integrated Disposal Facility. Recent contaminant release science has concluded that:

  Waste testing should provide information about potential contaminant release from a waste in the context of the anticipated disposal or utilization conditions. Thus, testing should reflect the range of conditions (e.g., pH, water contact, etc.) that will be present in the waste and at its interface with its surroundings during the long term.

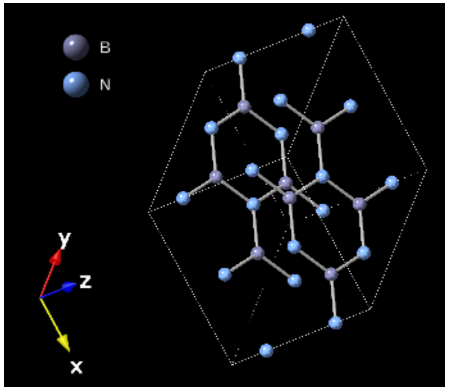
- Testing and evaluation of resulting low activity vitrified waste (LAW glass) must be used as part of a performance assessment to estimate the rate and extent of glass corrosion and release of radionuclides for periods from 1,000 to 10,000 years.

Sheffield-Hallam University Scope

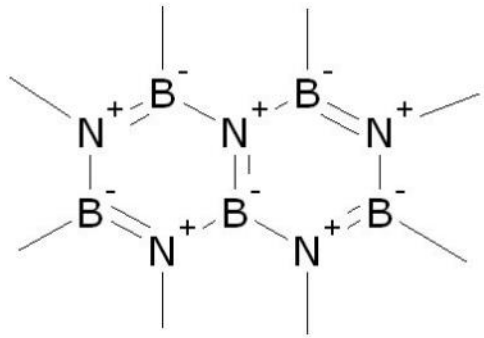
- **Integrated durability across HLW canister with nepheline**. Hanford waste glasses are currently conservatively limited to compositions that do not appreciably form nepheline [$NaAlSiO_4$] tied to potential impacts on chemical durability of glass.
- **Density of Hanford glass melts.** Density of quenched crucible melts of simulated and actual waste glasses have been effectively modelled. However, very limited data exist on melt density. Since control of melter operation relies on glass level which in-turn relies on melt density in the melter, understanding how composition and temperature impact melt density is of import to WTP plant operation.
- **Viscosity model expansion**. Empirical models correlating Hanford waste glass composition to viscosity have found significant success with relatively low uncertainty and scientifically understandable component effects. However, these models are based on viscosity measurements in the temperature range from roughly 950 to 1250°C and extrapolation to higher viscosity (lower temperature) is not viable.

(15-20k/student per annum 3-year duration)

Boron Nitride: an alternative to organic reductants



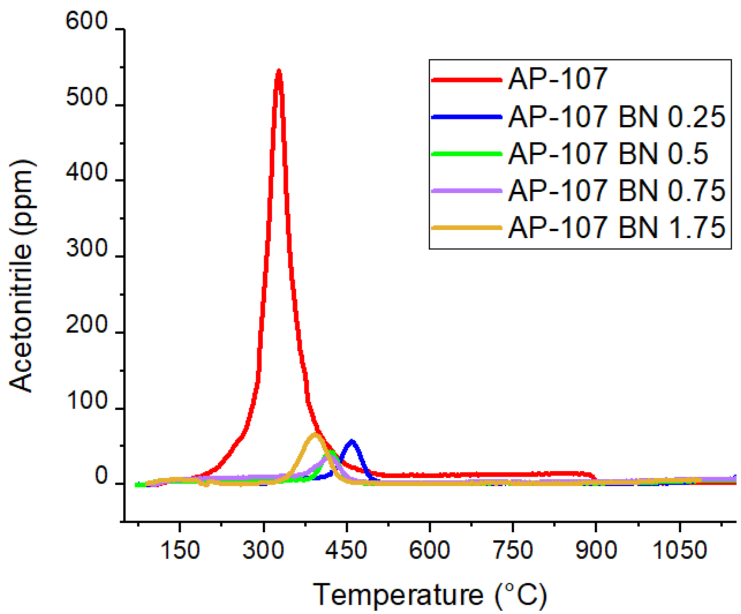
Crystal structure of BN.

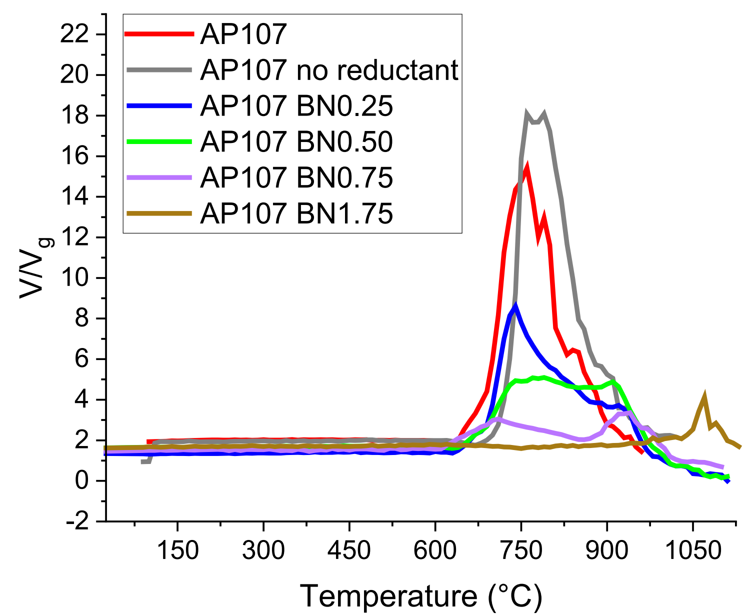


Designed AP-107 feeds at molar ratio "BN/N" = 0.25, 0.50, 0.75, 1.75*

Each time removing the necessary amount of H_3BO_3 glass-former to ensure the same theoretical total boron in the glass

**1.75 is the maximum before H_3BO_3 would be negative.*





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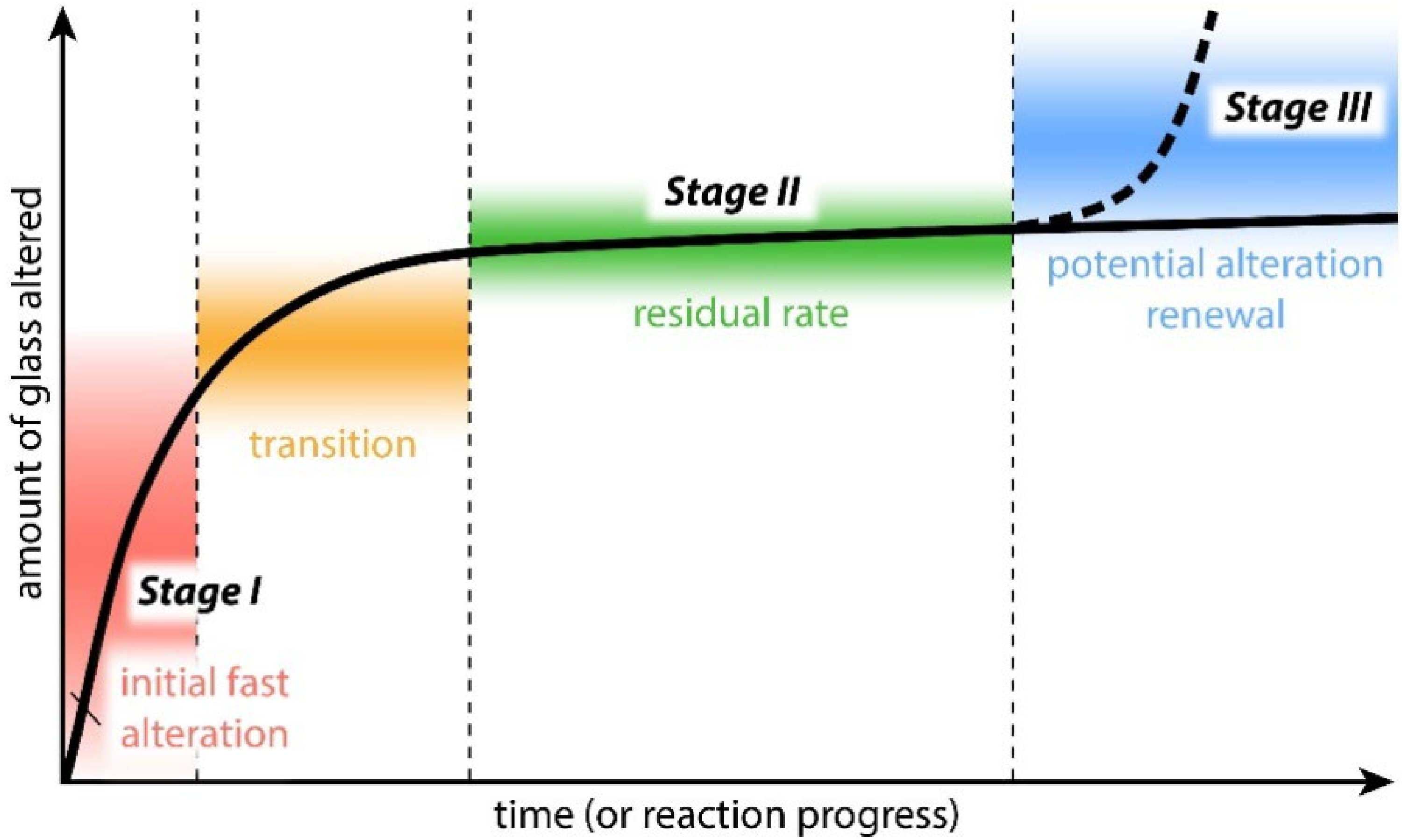
Balance of Mission Treatment Projections

	BNI/WTP Baseline Models	2008 TUA Baseline	2013 TUA Baseline	2013 TUA with Caustic and Oxidative Leaching Eliminated
HLW Canisters	18,400	14,838	8,223	13,534
LAW Containers	145,000	91,400	79,465	65,151
Total Canisters and Containers	163,000	106,238	87,688	78,685

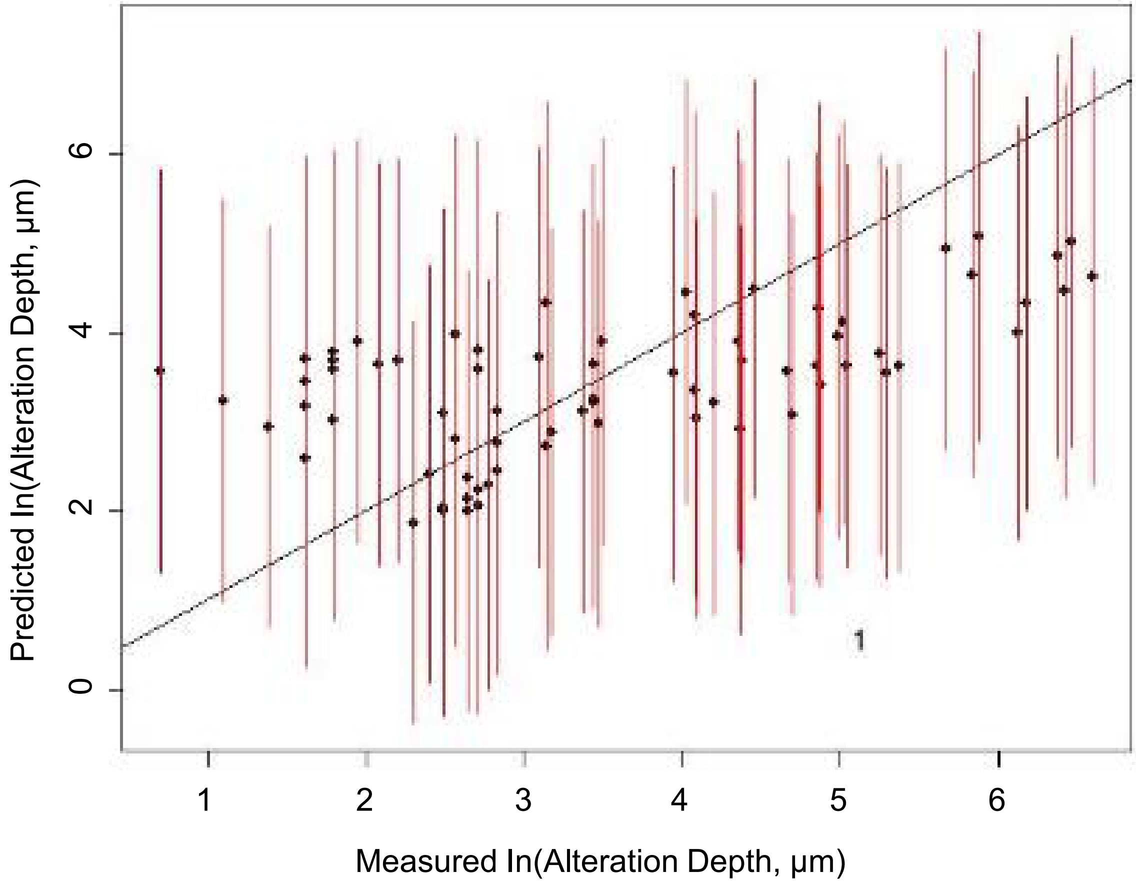
Adaptive Vitrification Evaluation System (AVES)

Glass Durability



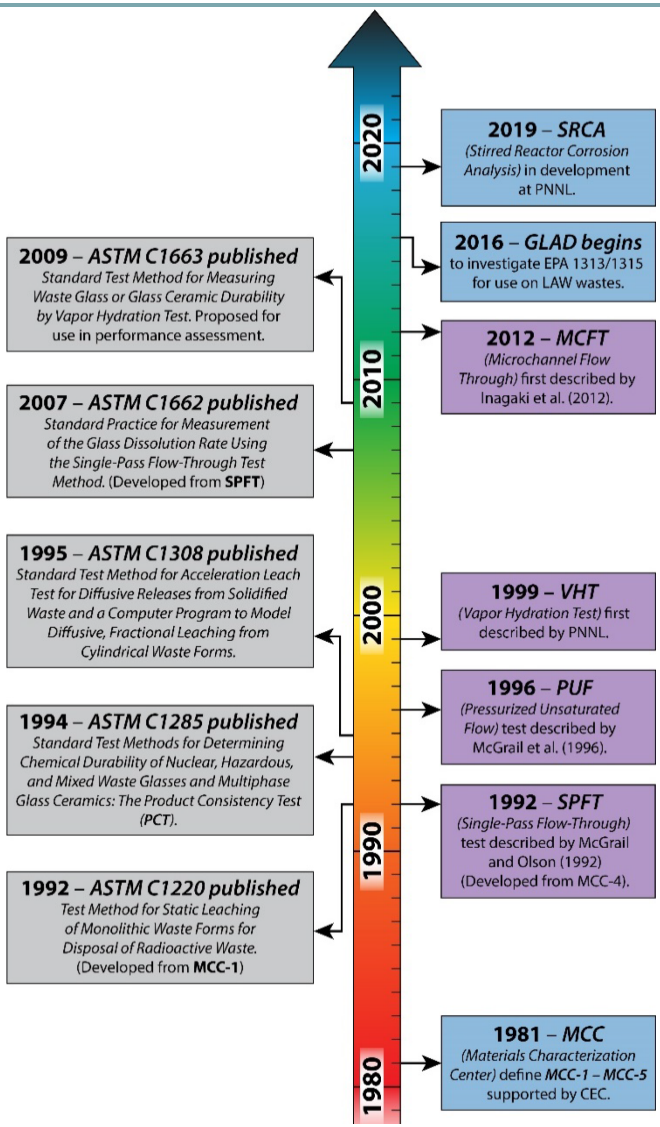
The general behavior of glass dissolution can be described in three major stages.

Vapor Hydration Test



2.2.2.17.3, "The glass corrosion rate shall be measured using at least a seven (7)-day vapor hydration test run at 200°C." The measured glass alteration rate shall be less than 50 grams/(m^2 day)."

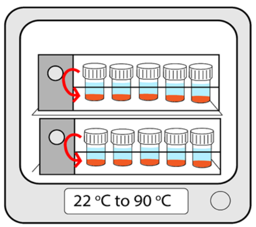
Durability Tests

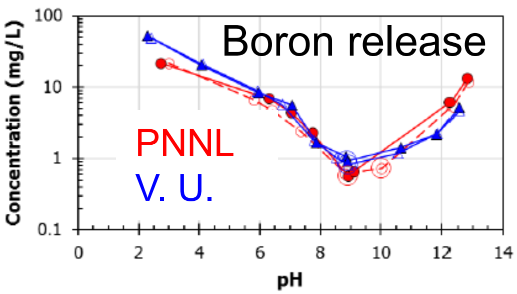


ASTM: *American Society for Testing and Materials International*
CEC: *Commission of European Communities*
MCC: *Materials Characterization Center*

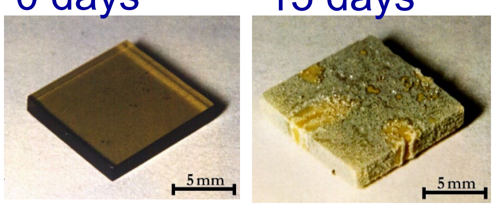
ASTM proc. | *development* | *documentation*

Combined Task Objectives





0 days   15 days



The GLAD Project

Aim: to design a new test for LAW glass using existing EPA test for hazardous component leaching

The Hillfort Project

Aim: to validate the chosen low temperature test against natural analogues from 1,500-year-old Swedish Hillforts

GLAD Project steps:

- Develop a low temperature glass corrosion test
- Confirm reproducibility between PNNL, Sheffield, and V. U.
- Exchange the high uncertainty VHT for new test

Hillfort Project steps:

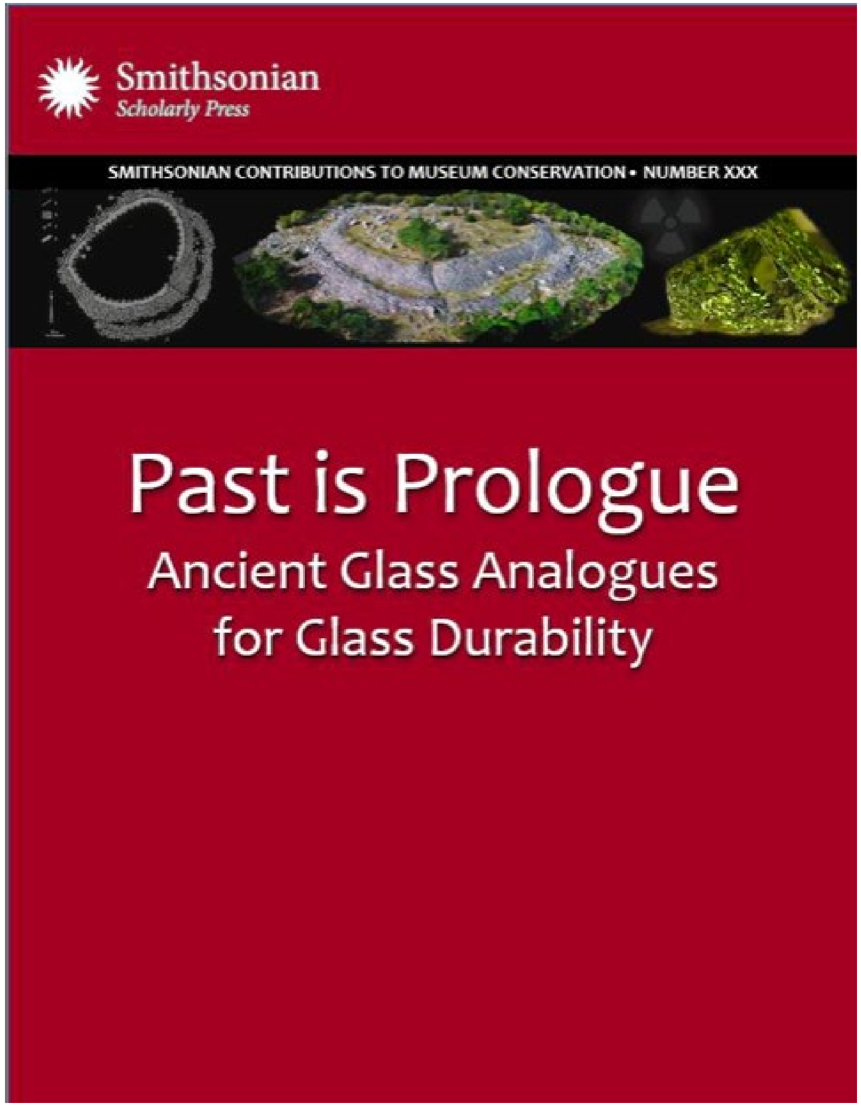
- Take glass samples from Swedish Hillfort
- Study corrosion and local environment
- Make glass of identical composition

Both projects then lead to:

Apply test to Hillfort glasses and document findings

Impact: alteration model to replace VHT in LAW facility, Increases operational windows, provides operations flexibility, and direct link to IDF disposal

Glass Leaching Assessment for Durability Success



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What if?

- Sludge treatment in PT Facility is primarily driven by desire to effectively leach and wash the HLW fraction of tank waste
    - Caustic leaching to remove primarily Al
    - Oxidative leaching was to remove Cr
    - Washing to remove primarily Na and S and leached Al and Cr
    - All driven to reduce the amount of glass produced to reduce mission length and cost of HLW glass management
- Several recent developments bring into question if sludge treatment in PT Facility is the optimal RPP flowsheet option
    - New glass development efforts have shown that significant improvements in Al, Cr, Na, and S loadings are likely, eliminating the PT Facility requirements
    - Flowsheet models currently project HLW melters idle for large fractions of the mission (balancing throughput between LAW and HLW is the goal)
    - Sludge treatment in the PT Facility is the single largest cause for technical issues and throughput challenges, negatively impacting plant startup schedule

Thank You

"If the reactor blows up, jump in the middle of it and save yourself a lot of trouble."

General Leslie R. Groves, Jr. to Colonel Franklin T. Matthias
Oral history of WII Hanford, S.L. Sanger, 1995, pp 77.

1) Challenges with vitrification of Hanford High-Level Waste (HLW) to borosilicate glass – An overview, A. Goel, J. S. McCloy, R. Pokorny, A. A. Kruger, Journal of Non-Crystalline Solids: X 4 (2019) 100033

2) Hanford Low-Activity Waste Vitrification: A Review, J. Marcial, B. J. Riley, A. A. Kruger, C. E. Lonergan, J. D. Vienna, invited by the Journal of Hazardous Materials, in press.

3) Forty years of durability assessment of nuclear waste glass: A review of standard methods, C. L. Thorpe, A. J. Fisher, S. A. Walling, R. J. Hand, N. C. Hyatt, C. Pearce, J. Neeway, A. A. Kruger, M. Schweiger, D. S. Kosson, C. L. Arendt, J. Marcial, C. L. Corkhill, npj Materials Degradation, (2021) 5:61

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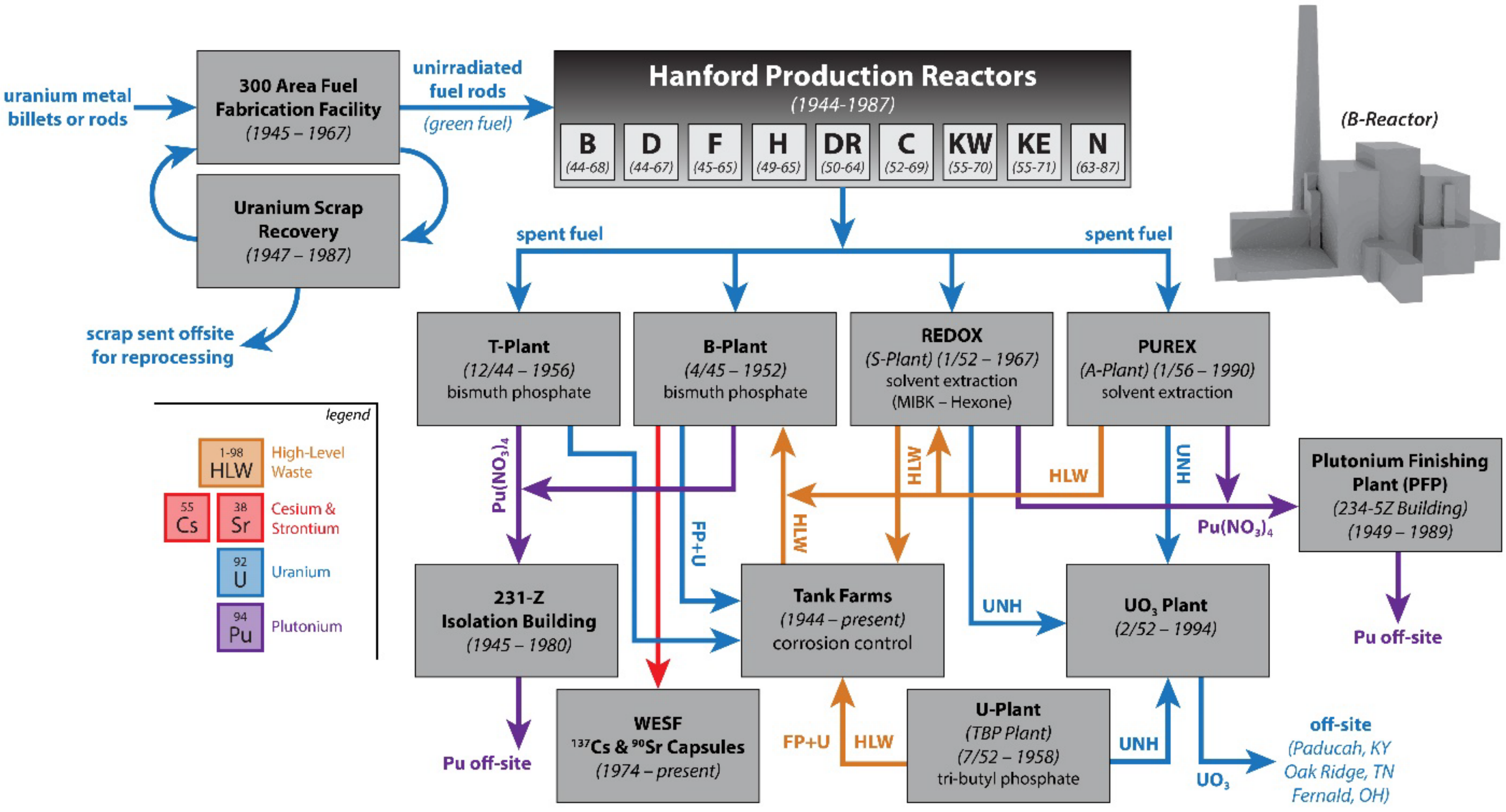
Summary of glass property constraints, the associated limits, and the driver for why the limit exists.

Property	Limit	Driver	
Melt viscosity at 1150°C (η_{1150})	$2 \le \eta_{1150} \le 8$ Pa·s	Process efficiency, mixing, and corrosion	
Melt viscosity at 1100°C (η_{1100})	$\eta_{1100} \le 15$ Pa·s	Pouring and idle process efficiency	
Melt electrical conductivity at 1100°C (ε_{1100})	$\varepsilon_{1100} \ge 10$ S·m^{-1}	Power delivery to the melt	
Melt electrical conductivity at 1200°C (ε_{1200})	$\varepsilon_{1200} \le 70$ S·m^{-1}	Current density on electrodes	
Melt crystal content at 950°C (C_{950})	$C_{950} \le 1$ vol%	Melter pour spout pluggage	
6-d Monofrax K3 refractory corrosion (k_{1208})	$k_{1208} \le 0.00102$ m	Melter lifetime	
Sulfur solubility/sulfur concentration (S/C)	S/C ≥ 1	Excessive corrosion of melter components	
Product consistency test (PCT) response normalized Na, B, and Si releases ($NL_{[Na,B,Si]}$)	$NL_{[Na,B,Si]} \le 2$ g·m^{-2}	Reduce risk of excessive corrosion rate in the Integrated Disposal Facility (IDF), Specification 2.2.2.17	
Vapor hydration test (VHT) response (r_a)	$r_a \le 50$ g·m^{-2}·d^{-1}	Reduce risk of accelerated corrosion in the IDF, Specification 2.2.2.17	
Phase changes during slow cooling in the container	No significant impact to performance	Ability to satisfy disposal criteria	
Waste classification (W_C)	W_C ≤ class C	Demonstrate waste is incidental to reprocessing, Specification 2.2.2.8	
^{90}Sr activity	^{90}Sr ≤ 20 Ci·m^{-3}	Demonstrate waste incidental to reprocessing (WIR), Specification 2.2.2.8	
^{137}Cs activity[(a)]	^{137}Cs ≤ 3 Ci·m^{-3}	Demonstrate WIR, Specification 2.2.2.8	
^{137}Cs activity[(a)]	^{137}Cs ≤ 0.3 Ci·m^{-3}	Contact maintenance dose, Section C.7	
Container surface dose rate (D_S)	$D_S \le 500$ mrem·h^{-1}	Container handling, Specification 2.2.2.9	
Land disposal restrictions (LDR)	Satisfy petition	IDF acceptance criteria, Specification 2.2.2.20	
(a) There are two ^{137}Cs constraints in the contract. One is required for waste disposal while the other for contact maintenance. The higher limit determines the maximum that can be put in glass while the lower can potentially be exceeded on a case-by-case basis if process safety can otherwise be assured.			

Waste Treatment and Immobilization Plant Site

Aerial photograph of WTP facing west taken June 2022.

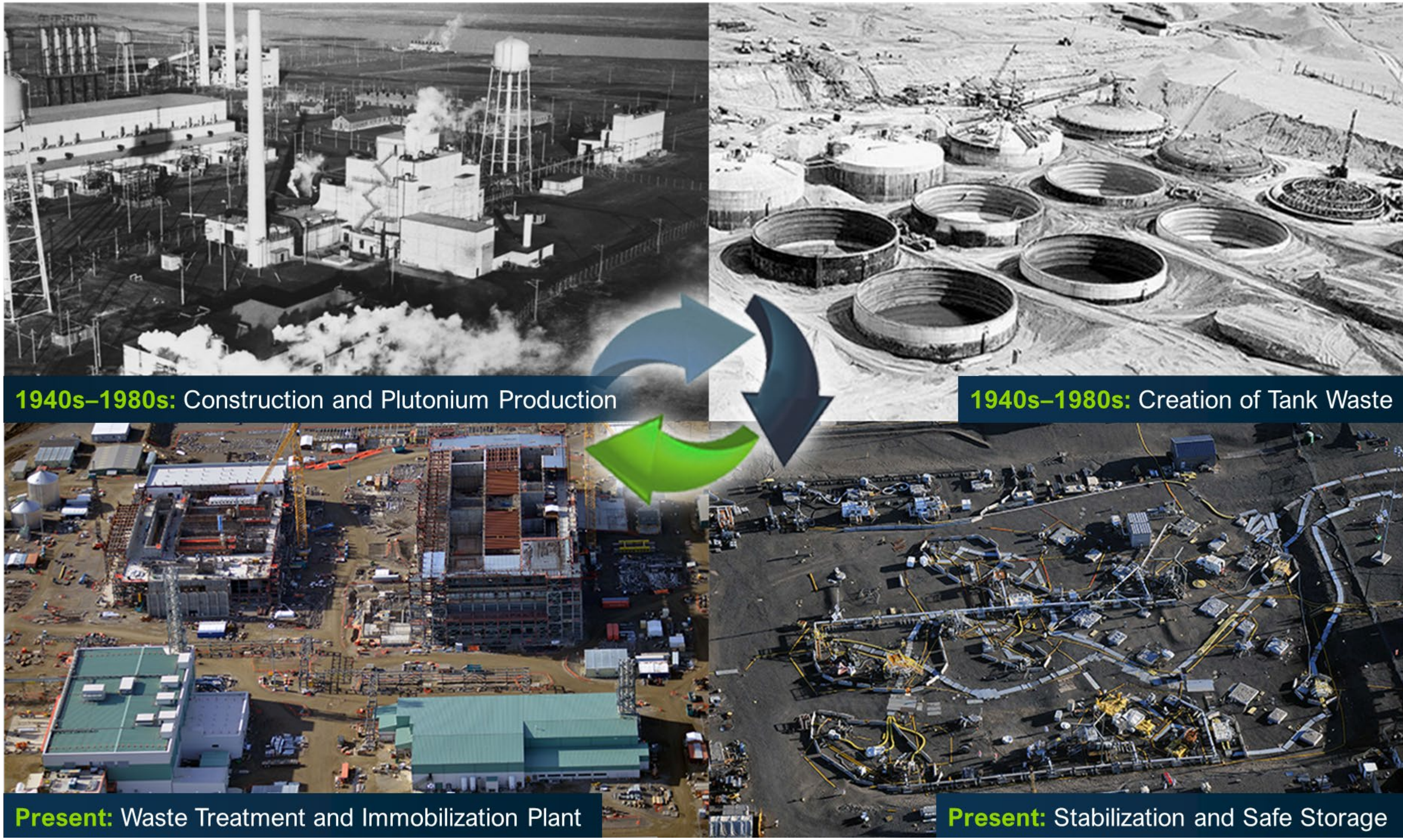
Generation of Hanford Tank Wastes



[this drawing was modified from DOE/RL-2000-43]

9 reactors; 4 fuel reprocessing flowsheets; 100,000 MT fuel processed

Hanford Site Historical Overview



Dirk's laws of Hanford

- *Grout is dead!* Long live grout!
- *Cheaper, better, faster* is almost never any of these
- *Saving money* is really really expensive (and time consuming), especially at the start
- *Magic bullets* aren't!
  - *Corollary: Cheap fixes aren't either!*
  - *Corollary: Neither are 'temporary' solutions, or 'quick' fixes!*
- *Really neat ideas* never are
  - *Corollary: They tend to be really expensive, time consuming, and immensely profitable*
- There is never enough time or money to do the job right
  - *Corollary: There is ample of both to do it over and over and over…*
- *Temporary is temporary* → Until it becomes permanent
  - *Corollary: Everything is "temporary" at Hanford*
- Whenever things get hard → start over
  - *Corollary: Things <u>always</u> get hard*

OREGON DEPARTMENT OF ENERGY

Glass Science Activities

ORP Glass Science Activity	Program Objective	Impact or Desired Result on the Mission
• ORP Glass Program	• Broaden glass compositional region of acceptable glasses • Reduce Complexity or eliminate caustic dissolution in PT	• Reduce WTP Mission Duration • Provide greater WTP operational design flexibility • Improve Process Equipment Reliability • Meet Waste Disposal Criteria • Improve Cost Efficiency (Operations, Maintenance, Mission)
• Update HLW glass models • Increase Al_2O_3 concentrations • Increase Cr_2O_3 concentrations • Develop alternative nepheline formation model	• Reduce PT Process Reduce or eliminate oxidative leaching in PT; minimize carry-over Pu • Increase tolerance for SO_3 & sodium WL in LAW	• Offer Flexibility in the Feed Vector • Increase Waste Loading (WL)
• Update LAW glass models • Increase SO_3 solubility	• Increase Na_2O concentrations in glass while maintaining process and product performance requirements	• Offer Flexibility in the Feed Vector • Reduce the LAW Effluent • Increase WL, reduce need for supplemental treatment • Cross-over: may be applicable to DWPF washing strategies • Cross over: could support DWPF glass formulation efforts assuming Na_2O management is still an issue for future operations with SWPF

Glass Science Activities (Cont.)

ORP Glass Science Activity	Program Objective	Impact or Desired Result on the Mission
• Improve Single-Pass Tc retention	• Simplify Supplemental Treatment • Reduce Secondary Waste	• Reduce the LAW Effluent
• Cold cap & Melter Modeling • Development of LSM/RLSM (cold and radioactive) For cold cap dynamic studies • Provide key input for modeling and understanding of waste feed-to-glass processes • Tc volatility / retention	• Develop and validate models to define testing needs and assist in plant operations • Provide key input for modeling and understanding of waste feed-to-glass processes • Support to IDF PA – partitioning of Tc in off-gas system	• Reduce the LAW Effluent • Provide process information for glass model development • Reduce uncertainty and risk in design underpinning and operations • If validated ahead of when needed, models can provide efficient first cut at plant issue resolution and lower cost of testing
• Demonstrate alternative glass contact refractory	• Identify a refractory that offers needed durability • Understand build-up of certain materials of interest melter or offgas (Cs, SO_3 salts, halides)	• Eliminate the dependence on a single source for melter K3 and E brick refractory • Mitigate or avoid impact to plant availability

Facilities Existing (or Planned) at Waste Treatment and Immobilization Plant

Facility Name	Abbreviation	Description
Pretreatment Facility	PT Facility	Receives waste and separates it into low-activity waste (LAW) and high-level waste (HLW)
Low-Activity Waste Facility	LAW Facility	Receives LAW, mixes with glass forming chemicals (GFC), vitrifies mixture to form immobilized low-activity waste (ILAW) glass, treats process gases
High-Level Waste Facility	HLW Facility	Receives HLW, mixes with GFCs, vitrifies mixture to form HLW glass, treats process gases
Analytical Laboratory	LAB	Analyzes samples from Waste Treatment and Immobilization Plant (WTP) operations, supplies data for safe operations, qualifies glass for disposal
Tank-Side Cesium Removal Facility (operated by Tank Operations Contractor)	TSCR	Removes radioactive Cs, Sr, and transuranics and delivers decontaminated LAW to LAW Facility
Effluent Management Facility	EMF	Evaporates LAW liquid effluents into concentrated and diluted streams for recycle and treatment/disposal, respectively
Supplemental LAW Treatment (to be designed and built)	SLAW	Operation to treat LAW fractions over the treatable fraction

Tank Waste Chemical Constituents from Best Basis Inventory

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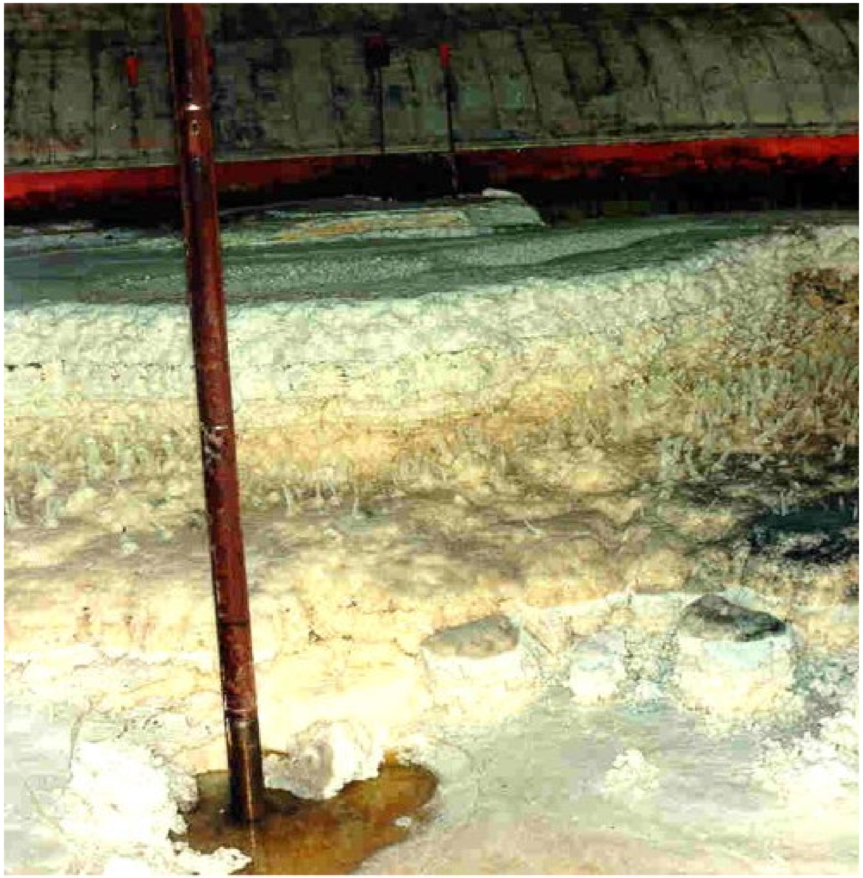
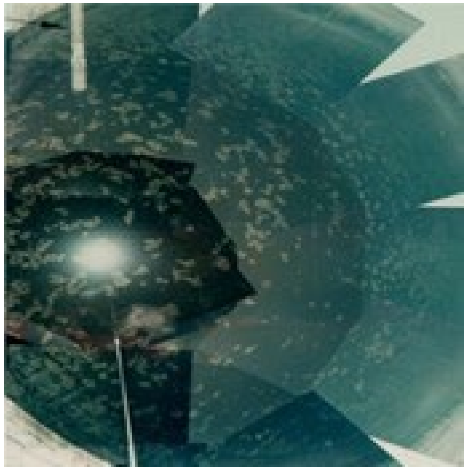
Ion	Mass Percentage	Primary Process Contributing
NO_3^-	35.2	Nitric acid additions from fuel dissolution, Bismuth Phosphate Process (BPP), Reduction Oxidation (REDOX), and Plutonium Uranium Extraction (PUREX)
Na^+	31.8	Neutralizing, corrosion control, and solvent wash
NO_2^-	8.2	Corrosion control
CO_3^{2-}	6.7	Atmospheric absorption and solvent wash
Al^{3+}	5.6	Cladding removal and REDOX
PO_4^{3-}	3.2	BPP, THOREX (Thorium Extraction), cesium (Cs) / strontium (Sr) recovery
SO_4^{2-}	2.3	BPP, REDOX, PUREX, Cs/Sr recovery
$C_2O_4^{2-}$	1.0	Oxalate precipitation
TOC	0.8	Several
F^-	0.8	Cladding removal, BPP, REDOX
Fe^{3+}	0.8	PUREX, BPP, REDOX, corrosion product
K^+	0.7	U recovery, solvent wash, neutralization, corrosion control
Cl^-	0.6	Chemical impurity, U recovery
Si^{4+}	0.5	Diatomaceous earth, PUREX, REDOX
U^{4+}, U^{6+}	0.4	BPP
Cr^{3+}, Cr^{6+}	0.4	BPP, corrosion control, corrosion products
Bi^{3+}	0.4	BPP
Zr^{4+}	0.3	Cladding removal
Ca^{2+}	0.2	Several
Other	0.1	Includes nearly the entire periodic table

Tank Waste Characterization / Feed Control to Waste Treatment and Immobilization Plan



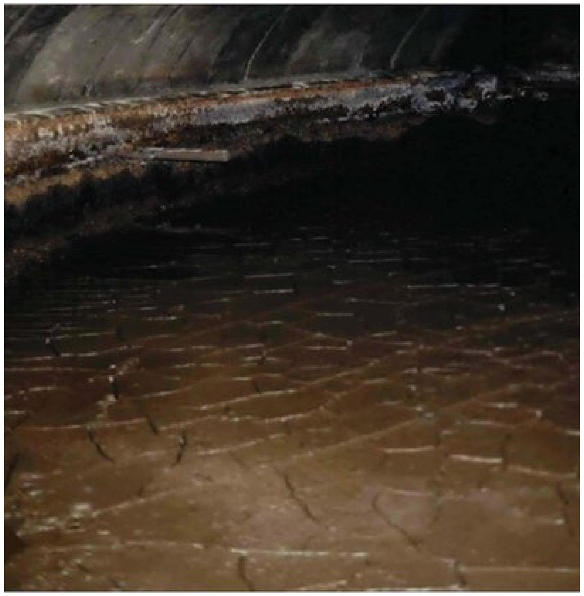
Saltcake – 23 million gallons

Sludge – 12 million gallons

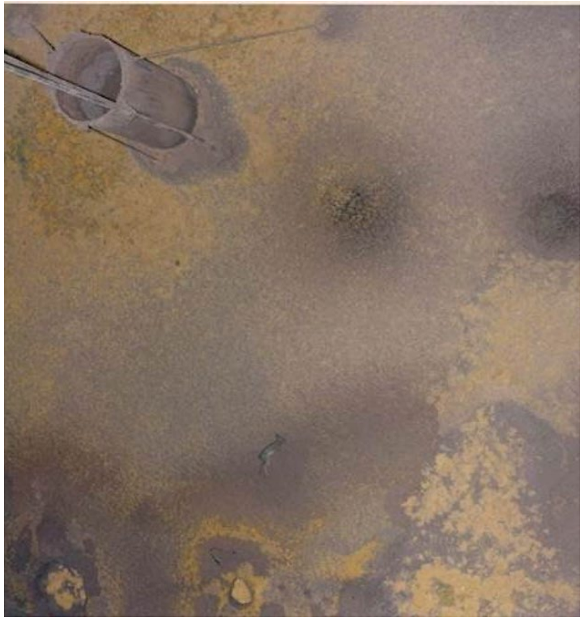


Supernate – 21 million gallons

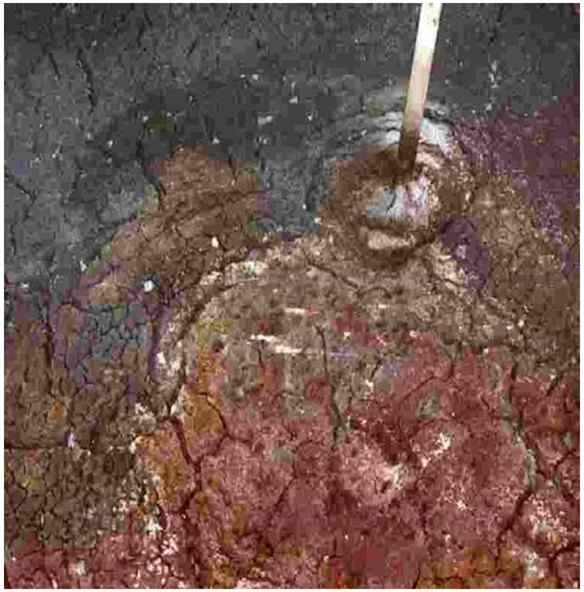
Sludge



Sludge – Tank T-111

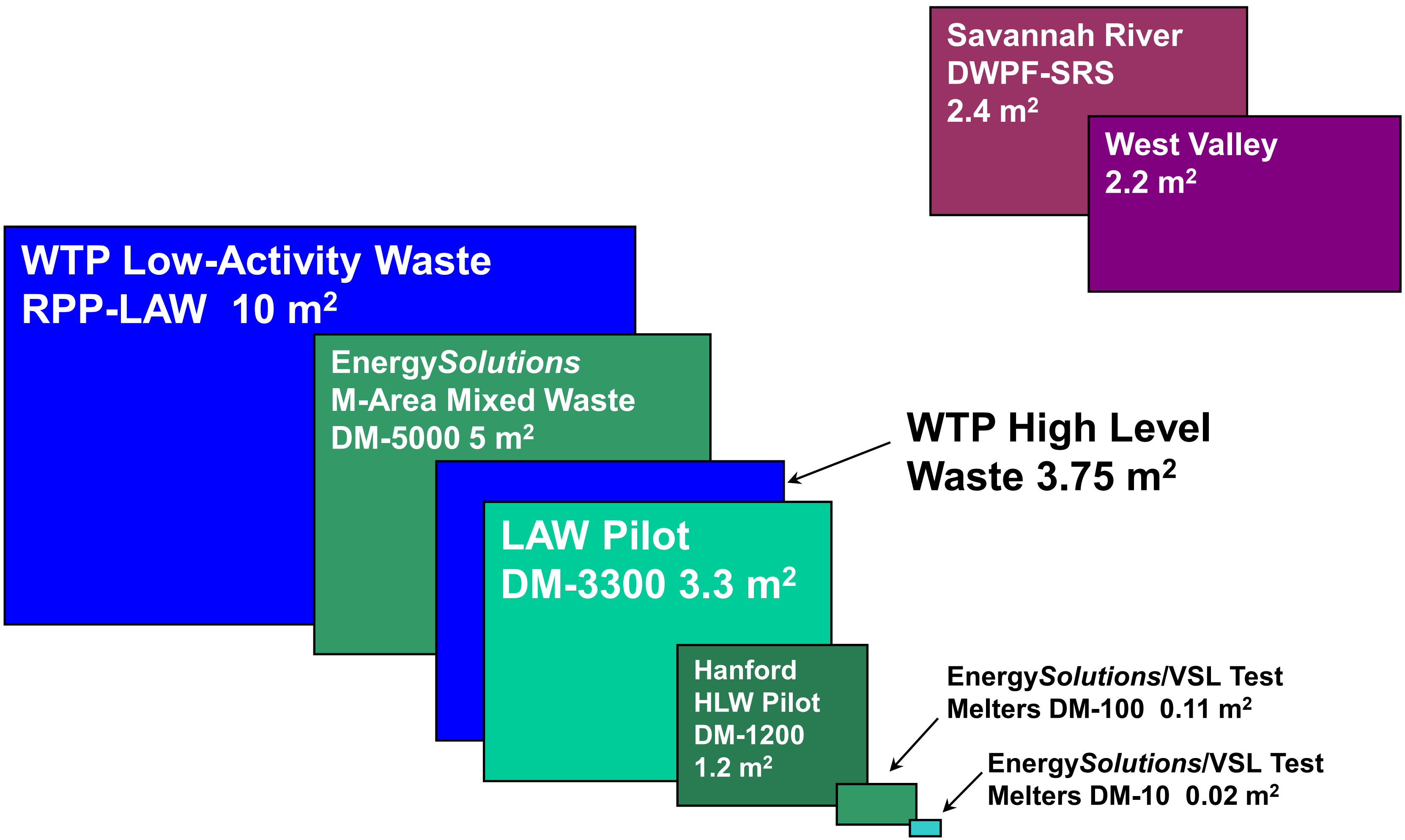


Sludge and critter – Tank SX-114



Sludge – Tank S-112

Melter Scale Comparison



U.S. DEPARTMENT OF ENERGY | OFFICE OF ENVIRONMENTAL MANAGEMENT

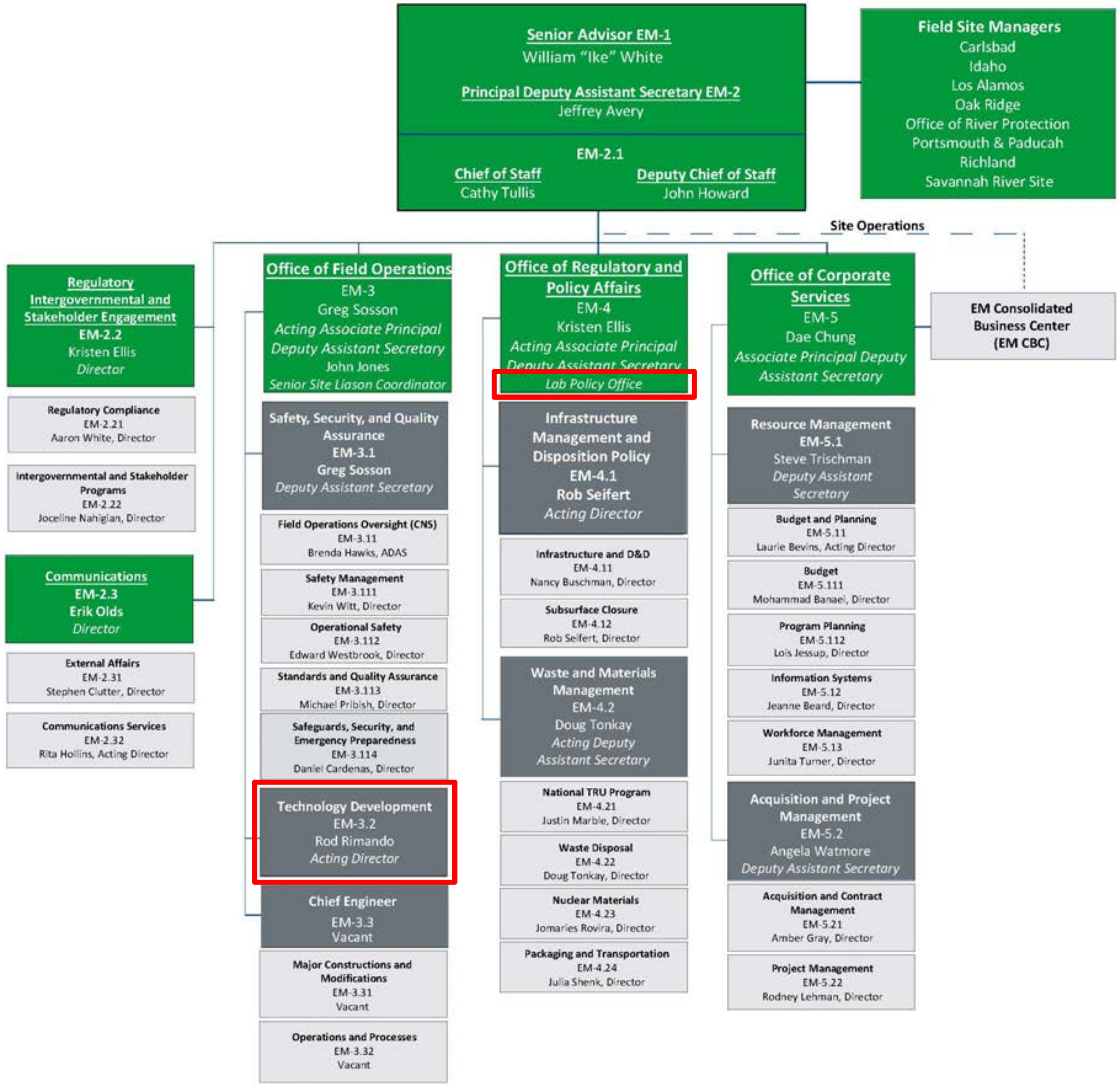
Projects Relevant to R&D Roadmap for Hanford Tank Waste Mission Acceleration that are funded by EM Office of Technology Development

Rodrigo Rimando, Director (Acting)

Office of Technology Development (EM-3.2)

August 28, 2023

EM Headquarters



Current TDO Tanks Projects: Hanford

Current Projects Relevant to R&D Roadmap for Hanford Tank Waste Mission Acceleration			
Name	**Performer**	**Funding**	**Roadmap Crosswalk**
Evaluation of Technology for Retrieval of Tank Waste	SRNL	$300K	WR&T-3
Real-Time, In-Line Monitoring (RTIM) for HLW Applications	SRNL, PNNL, LANL	$500K	WT-1
Evaluation of Technology for Destruction of LDR Organics in Hanford Tank Waste	SRNL	$200K	PS-5, WT-10
Abatement of Mercury and Iodine in WTP LAW Off-Gas Streams	PNNL	$500K	PS-9, IM-5
Technetium and Iodine Removal from Real Waste	PNNL	$325K	PL-6/7, IM-3
Aluminum/Phosphate Dissolution Processing for HLW Sludges	PNNL	$300K	PS-3
Contaminant Sequestration	SRNL	$500K	SW-1
Multiphase Waste Form Performance Collaboration with Australian Nuclear Science and Technology Organization (ANSTO)	PNNL	$300K	IM-10
Metal-Organic Framework Glass Waste Form	SRNL	$600K	IM-1/10
Cementitious Material Studies-Continuous Improvement of Cement Waste Form Technology	SRNL	$250K	
Radioactive Glass Waste Form Studies	SRNL, PNNL	$300K	
Consolidated Waste Glass Database	SRNL, PNNL	$300K	
Hydrogen Recombiner Catalyst	SRNL	$160K	

Note: Period of performance is typically 12 months.

TDO Tanks Projects: Seeding Quick Wins

Evaluation of Technology for Retrieval of Tank Waste

SRNL will assemble a team of SMEs to study low-water or dry-retrieval methods. "Seed" funding of $300K was provided to support **Quick Win** for **SST Retrieval Infrastructure to Enable Flexible, Timely Waste Mobilization**.

Real-Time, In-Line Monitoring (RTIM) for HLW Applications

This multi-lab effort provides $100K to SRNL to collaborate with CRESP and other labs on FTIR spectroscopy $200K to PNNL on Raman spectroscopy; and $200K to LANL on Laser-Induced Breakdown Spectroscopy. This "seed" funding of $500K supports **Quick Win** for **Sample Reduction using Material Balance and Real-Time, In-Line Monitoring Approaches for HLW Applications**.

Evaluation of Technology for Destruction of LDR Organics in Tank Waste

SRNL was provided $200K to study methods of destroying organic constituents present in some Hanford tanks that would prevent disposing low-activity waste off-site under Land Disposal Restrictions (LDR). Initiating this study would assemble a team to better understand the inventory of organics present and methods such as hydrogen peroxide oxidation or catalytic oxidation to destroy organics that may end up in grout. This supports **Quick Win** for **LDR Organics Characterization and Removal/Destruction**.

TDO Tanks Projects: Separations

Abatement of Mercury and Iodine in WTP LAW Off-Gas Streams

PNNL will investigate sorbents for the capture of mercury and iodine in off-gas systems to prevent bypassing of these contaminants to the facility off-gas stack, the Liquid Effluent Treatment Facility and/or Effluent Treatment Facility. This sorbent would potentially replace a baseline sorbent (Kombisorb BAT-37) and would capture Hg and I separately or both together and offer a clear path to conversion into a durable waste form.

Technetium and Iodine Removal from Real Waste

PNNL will test commercially available ion exchange material for their ability to remove technetium and iodine in processing tank waste, using actual Hanford waste samples currently available in the lab. The best performing material from batch tests would be evaluated in column tests to determine relevant parameters for deployment, such as breakthrough curves. Technetium and iodine are the contaminants in tank waste that account for over 99% of the risk in a non-treatment, or “no action”, scenario. Removal of these species from low activity waste would relieve constraints on the disposal performance of alternate waste form options (such as grout) or, in the case of vitrification, would reduce the quantity of glass produced when these volatile species are recycled from the off-gas stream.

Aluminum/Phosphate Dissolution Processing for HLW Sludges

PNNL will conduct experiments to support direct-feed high-level waste concept scenarios. It investigates dissolution of solids material, aluminum and phosphate compounds that would not need to be processed at WTP HLW Vitrification Facility, thereby reducing the amount of HLW for processing and consequently the total number of HLW canisters produced. The dissolved material could be processed at WTP LAW Vitrification Facility.

TDO Tanks Projects: Waste Forms

Contaminant Sequestration

SRNL will study mechanisms for the retention of contaminants in grouted waste forms. The study consists of three tasks: (1) understanding the reaction chemistry for sequestration of organo-mercury (i.e., methyl mercury) compounds in grout; (2) studying getters that would retain iodine and technetium in grout; and (3) developing means to sequester other contaminants of concern such as organics, nitrates and ammonia, which do not typically react with grout-forming materials.

Multiphase Waste Form Performance Collaboration with Australian Nuclear Science and Technology Organisation (ANSTO)

PNNL will collaborate with Australian Nuclear Science and Technology Organisation (ANSTO) to explore the durability of multiphase waste forms such as glass/ceramics using tools and techniques available to both countries. These waste forms could offer greater waste loading and processing versatility for consideration, if their performance were understood and bounded.

Metal-Organic Framework Glass Waste Form

SRNL will develop and test the use of metal-organic frameworks to capture pertechnetate and iodine and to demonstrate the production of a glass waste form product from this material. Previous testing of similar materials at Savannah River Site simulant tank waste revealed fast kinetics and selectivity over competing ions. It was also shown that this material can be compressed to form a glass at room temperature. This work will develop other candidate compounds specific to technetium and mercury removal, investigating kinetics, selectivity and removal efficiency from waste streams, and also demonstrate the production of a stable glass waste form.

TDO Tanks Projects: Roadmap Crosswalks

Cementitious Material Studies-Continuous Improvement of Cement Waste Form Technology

SRNL will evaluate the use of coal ash material stored at SRS for use as a waste form ingredient, rather than sending this material to a landfill. Characterization of coal ash material would consider such aspects as chemical composition, particle size and hydration, and these are variable for ash from different sources. SRNL will also coordinate with Oklahoma State University in the use of machine learning to characterize this type of fly ash material for cementitious application.

Radioactive Glass Waste Form Studies

This SRNL-PNNL collaboration will evaluates several standard test methods for glass durability and corrosion. The product consistency test used for compliance does not correlate to actual durability performance. A range of glass compositions relevant to Hanford low-activity waste glass will be tested with erosion/corrosion determined by analysis of surface alteration, with standard test methods of interest being evaluated (such as vapor hydration testing). This would attempt to tie standard test methods to glass performance in the Integrated Disposal Facility.

TDO Tanks Projects: Roadmap Crosswalks

Consolidated Waste Glass Database

This SRNL-PNNL collaboration will compile existing data for glass formulation and properties from national labs and universities and will assess the quality assurance level. The initial database was completed, and follow-on work would recommend and carry out quality assurance testing needed on data.

Hydrogen Recombiner Catalyst

SRNL is funded for this testing, which affects design-basis limitations in operations related to hydrogen flammability. Hydrogen is generated by radiolysis of water in waste tanks and process vessels. This task would investigate the efficiency of the use of catalysts in the vapor space to prevent the buildup of free hydrogen. The catalyst would be used to recombine or re-oxidize the hydrogen under controlled conditions.

OFFICE OF ENVIRONMENTAL MANAGEMENT

Continuing TDO Tanks Projects: Hanford

Newly Funded Continuation Projects Relevant to R&D Roadmap for Hanford Tank Waste Mission			
Name	**Performer**	**Funding**	**Roadmap Crosswalk**
Evaluation of Technology for Retrieval of Tank Waste	SRNL	$300K	WR&T-3
Real-Time, In-Line Monitoring (RTIM) for HLW Applications	SRNL, PNNL, LANL	$500K	WT-1
Evaluation of Technology for Destruction of LDR Organics in Hanford Tank Waste	SRNL	$200K	PS-5, WT-10
Abatement of Mercury and Iodine in WTP LAW Off-Gas Streams	PNNL	$600K	PS-9, IM-5
Technetium and Iodine Removal from Real Waste	PNNL	$425K	PL-6/7, IM-3
Aluminum/Phosphate Dissolution Processing for HLW Sludges	PNNL	$300K	PS-3
Contaminant Sequestration	SRNL	$500K	SW-1
Multiphase Waste Form Performance Collaboration with Australian Nuclear Science and Technology Organization (ANSTO)	PNNL	$300K	IM-10
Metal-Organic Framework Glass Waste Form	SRNL	$600K	IM-1/10
Cementitious Material Studies-Continuous Improvement of Cement Waste Form Technology (FY2022 focused on coal ash. FY2023 will focus on fly ash.)	SRNL	$250K	
Radioactive Glass Waste Form Studies	SRNL, PNNL	$300K	
Consolidated Waste Glass Database	SRNL, PNNL	$300K	
Hydrogen Recombiner Catalyst	SRNL	$160K	

New TDO Tanks Projects: Hanford

Newly Funded Projects Relevant to R&D Roadmap for Hanford Tank Waste Mission Acceleration			
Name	**Performer**	**Funding**	**Roadmap Crosswalk**
Optimizing Tc-99 and Cr(VI) Retention in Grouts Using Ferrous Iron	PNNL	$395K	SW-1
The Behavior of Non-pertechnetate Forms of Technetium in Grout	PNNL	$425K	SW-1
Mitigation of Contaminant Release from Residual Tank Waste	PNNL	$490K	TC-6
Continuous Improvement of Cement Waste Form Technology - Measurement of Ultra-Low Relative Permeability for Grout	SRNL	$350K	IM-13
Coatings for Bubbler Life-Extension	SRNL	$200K	IF-4, IM-2
Ultrasonic Denitrification of Radioactive Waste Streams	PNNL	$370K	PL-8
Increased Hanford Tank Sidewall Integrity Inspections with Robotic Guided Wave & Magnetic Flux Leakage Sensors	PNNL	$1,670K	IF-2, WR&T2a
Deployment of In-Line Sampling in Tank Farms	PNNL	$300K	WT-1
TMFD Online Alpha Monitors	SRNL	$300K	TC-4, WR&T-8
Continuous Improvement of Cement Waste Form Technology - Replacement of Fly Ash with Natural Pozzolans	SRNL	$300K	

TDO Projects: Supplemental Treatment/Grout

Optimizing Tc-99 and Cr(VI) Retention in Grouts Using Ferrous Iron

PNNL will expand on previous studies to retain Tc and Cr within a grout form. Previous studies have all used Fe(OH)2 to control redox conditions but loses reduction capacity with exposure to air. This effort utilizes other forms of Fe(II) that are stable against air oxidation and evaluates capture of Tc and Cr from waste streams through contact tests, characterization (spectroscopic methods) of the iron complexes, and grouting demonstration.

The Behavior of Non-pertechnetate Forms of Technetium in Grout

This PNNL-SRNL collaboration will study the leaching of Tc in grout as a function of redox transformation. Ionic Tc exists in valences from +1 to +7, which have different stability and leaching behavior. NMR will be used to track Tc speciation in liquid prior to grouting, during curing, after solidification, and in leachate.

Mitigation of Contaminant Release from Residual Tank Waste

PNNL and FIU will develop chemical compounds to sequester contaminants of concern (U, Tc, Pu, Cr) in grout forms. Candidate reagents are zero-valent iron (ZVI), sulfur-modified ZVI, and phosphorous-modified ZVI. Sequestration testing will result in a down-select of reagents and saturated leach testing will evaluate retention.

Continuous Improvement of Cement Waste Form Technology - Measurement of Ultra-Low Relative Permeability for Grout

SRNL will improve measurements of permeability on high-performing grout for use in waste encapsulation and improve models for performance assessments. Computational methods will be used to analyze laboratory data on low-porosity grout material.

TDO Tanks Projects: Processing

Coatings for Bubbler Life-Extension

SRNL will improve lifetime for bubblers currently used for mixing glass in vitrification. These are currently switched out approximately every 6 months, resulting in process down-time. Ceramic materials are more resistant to glass corrosion and the project would focus on these. The project includes literature search for relevant chemical properties, bubbler failure mechanism study, materials testing and scale-up testing.

Ultrasonic Denitrification of Radioactive Waste Streams

PNNL will explore the use of high-power focused ultrasound to break down nitrates and nitrites to molecular nitrogen. Hanford LAW contains large amounts of these nitrogen compounds which are handled by a melter off-gas system. Unfocussed low frequency systems are commercially available for treating wastewater systems. In this testing, a liquid waste simulant stream will be monitored by pH probes and off gas streams will be monitored with a gas analyzer.

TDO Projects: Characterization & Monitoring

Increased Hanford Tank Sidewall Integrity Inspections with Robotic Guided Wave & Magnetic Flux Leakage Sensors

This PNNL-SRNS collaboration is focused on sensors, robotics and inspection service companies to improve methods for inspection of double shell tank primary walls. Task 1 uses Guided Wave Phased Array (GWPA) sensors and machine learning for large coverage of tank areas. Task 2 would work on electromagnetic acoustic transducer (EMAT) sensors and robotic systems. Task 3 would test and qualify commercially available magnetic flux leakage (MFL) sensors. This is the first year of a multi-year project and would begin initial work on all three tasks: to model GWPA sensors for curved surface inspection, fabricate sidewall test plates and complete a basic MFL sensor demo.

Deployment of In-Line Sampling in Tank Farms

PNNL will design and fabricate a large-scale flow cell necessary to couple real-time monitoring (Raman Spectroscopy) into a process line. This is the interface between techniques developed in the roadmap quick win for in-line monitoring and deployment in an actual system. Ideal dimensions, flow rates and other parameters will be identified for optimal and stable signals.

TMFD Online Alpha Monitors

SRNL will increase the maturity of tension metastable fluid detectors (TMFD) for use as a real-time alpha monitor. These have been developed and studied within the last decade and are blind to beta and gamma. A current prototype will be scaled down and tested using Cs-137 in simulant and actual waste. The project will be coordinated with Purdue University.

TDO Tanks Projects: Roadmap Crosswalks

Continuous Improvement of Cement Waste Form Technology - Replacement of Fly Ash with Natural Pozzolans

SRNL will evaluate the use of natural pozzolans as a potential replacement for fly ash and blast furnace slag in cementitious waste forms (SRS Saltstone, Hanford ETF and potential Hanford supplemental treatment). Pozzolans are a broad class of siliceous and aluminous materials. Samples will be obtained from representative sources in Idaho, Nevada, Oregon and Georgia and analyzed for chemical composition, particle size and other relevant properties. Based on composition and minerology, two of the pozzolans will be evaluated for processing using Hanford Cast Stone and SRS Saltstone formulations. Other ingredient adjustments will be considered to prepare quality baseline samples. Waste loading, soluble ion and redox sensitive leaching, porosity and hydraulic conductivity will be measured.

Closing Remarks

- **TDO-Funded Tanks Projects**
  - **Discrete and short-duration tasks with specific deliverables**
  - **Are mapped to and differentiated from “Roadmap” activities**
  - **Deliverables (e.g., final reports) can be made available**
  - **Follow-on work can be considered for FY 2024 funding**
- **Laboratory leads**
  - **SRNL: Michael Stone**
  - **PNNL: Tom Brouns**

ARPA-E | Waste Treatment Innovations

Robert Ledoux, Program Director
Jenifer Shafer, Program Director
Bill Horak, Program Director

August 28, 2023

REDUCE
imports

REDUCE
emissions

IMPROVE
efficiency

IMPROVE
radioactive waste management

IMPROVE
energy infrastructure resilience

What Makes an ARPA-E Project?

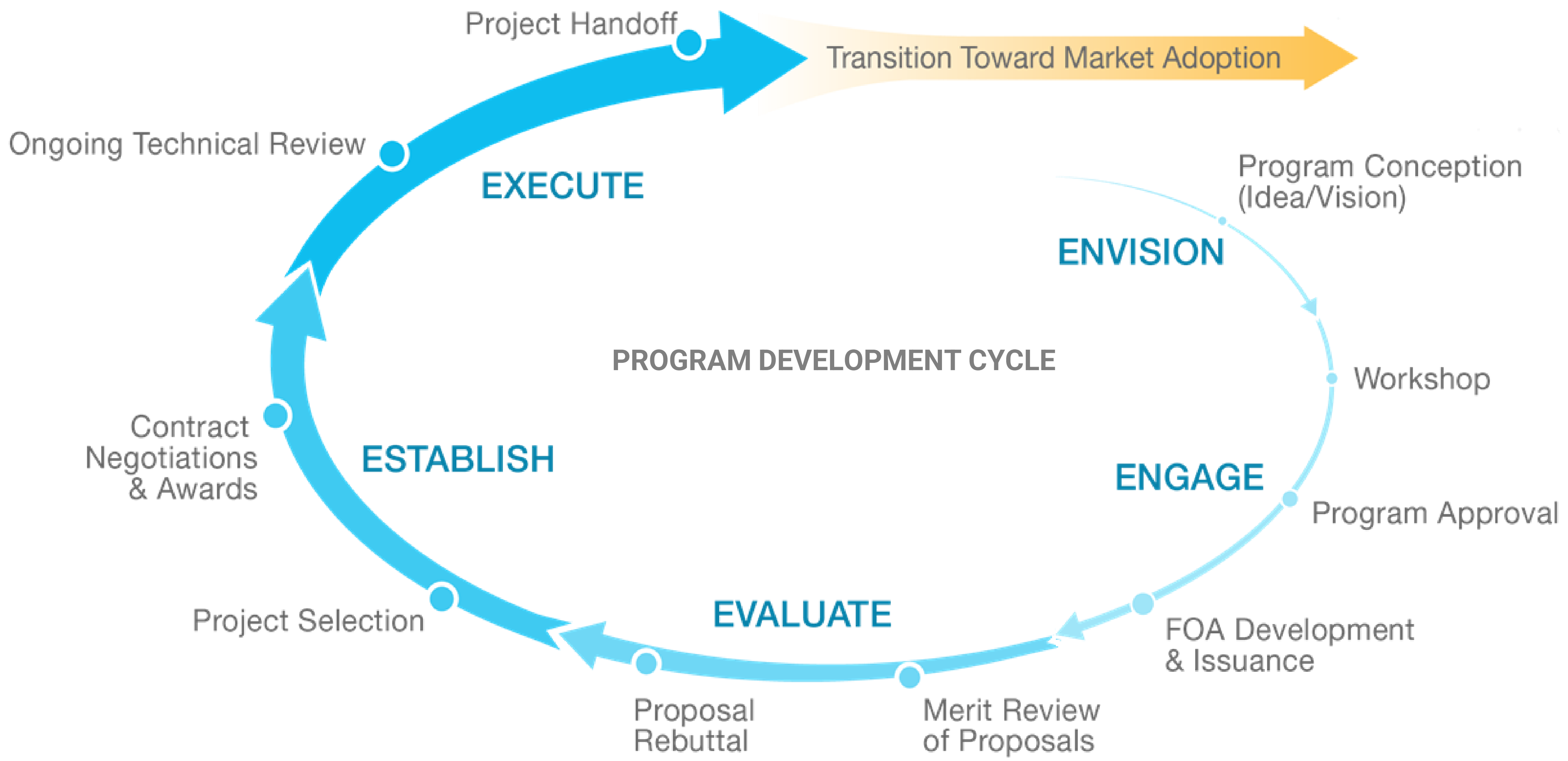
IMPACT
- High impact on ARPA-E mission areas
- Credible path to market
- Large commercial application

TRANSFORM
- Challenges what is possible
- Disrupts existing learning curves
- Leaps beyond today's technologies

BRIDGE
- Translates science into breakthrough technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

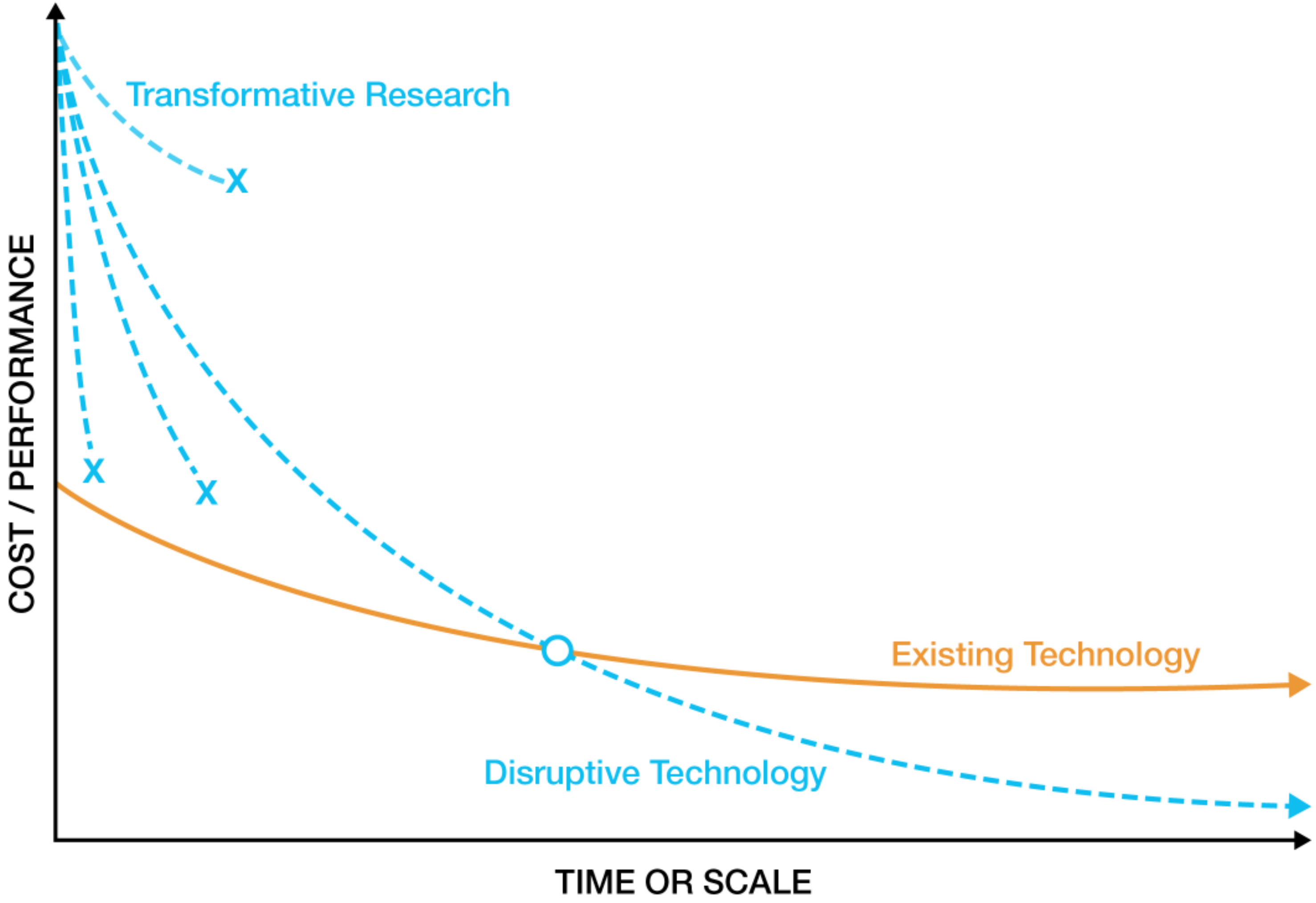
TEAM
- Comprises best-in-class people
- Cross-disciplinary skill sets
- Translation oriented

ARPA-E Development Cycle



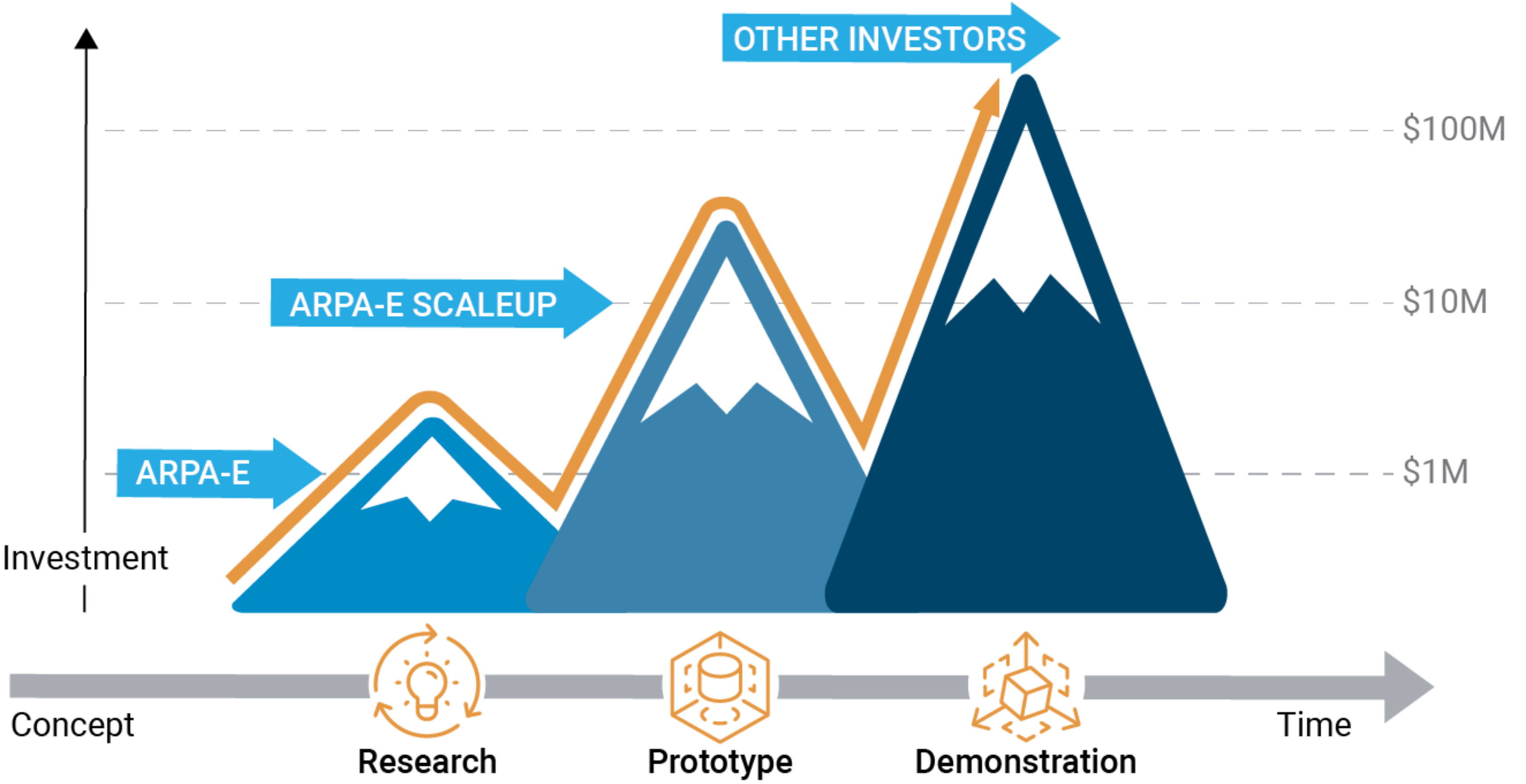
arpa·e
CHANGING WHAT'S POSSIBLE

We are high-risk, high reward...



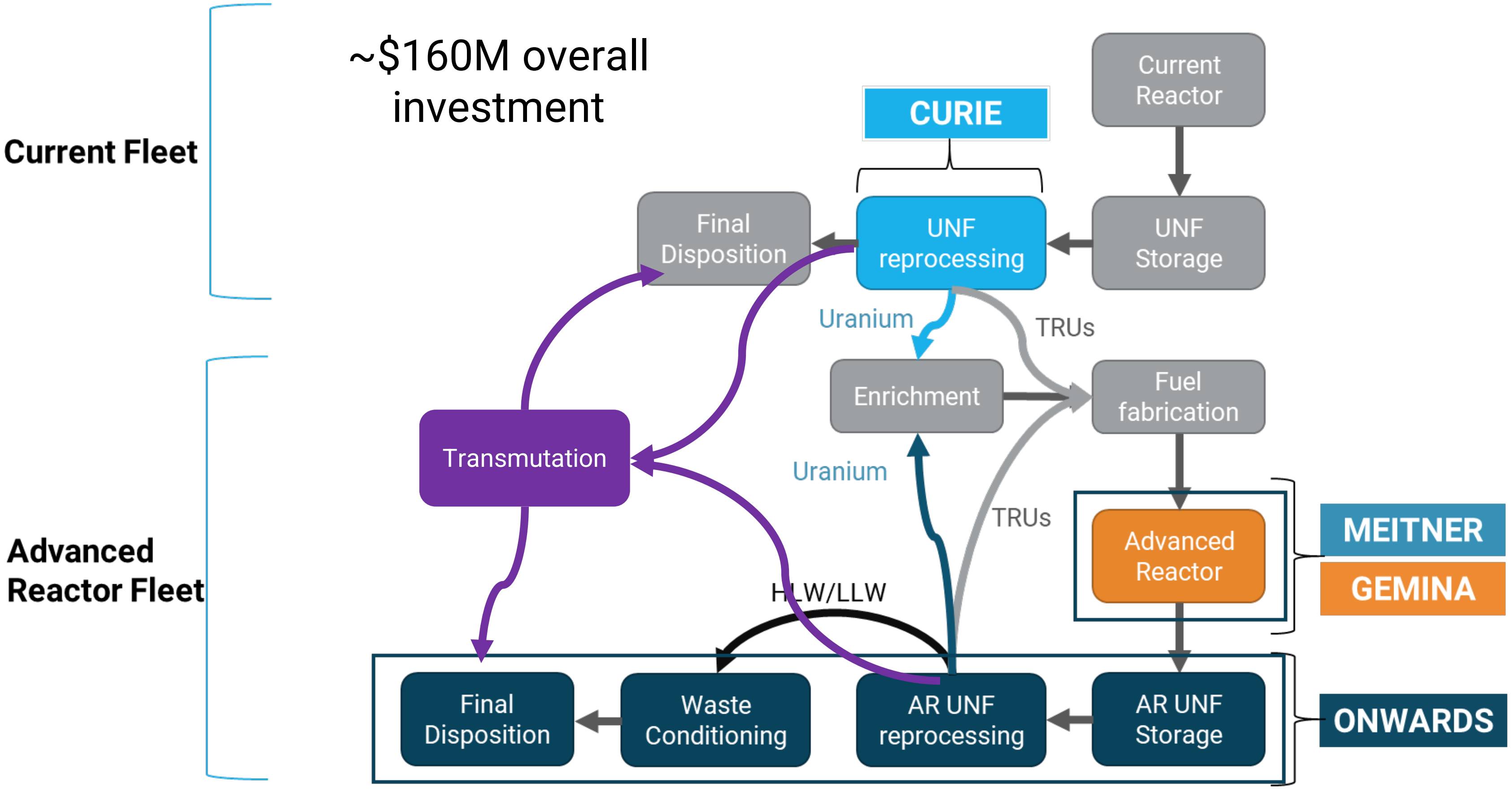
CHANGING WHAT'S POSSIBLE

ARPA-E Creates a "Mountain of Opportunity" for energy technology



ARPA-E Advanced Nuclear Fission Portfolio

- Fission
  - MEITNER (2018)
    - Can we greatly reduce AR CapEx?
  - GEMINA (2020)
    - Can we greatly reduce AR OpEx?
  - ONWARDS (2021)
    - Can we greatly minimize the disposal impact of AR wastes?
  - CURIE (2022)
    - Can we improve the cost and monitoring of UNF reprocessing?
  - Transmutation
    - Active area of program development



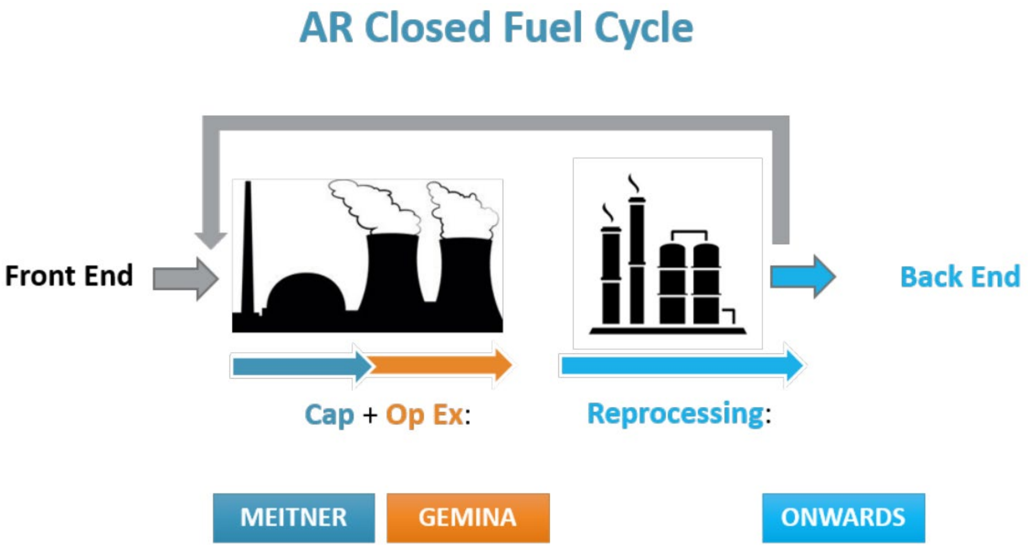
Attentive to commercialization & deployment

ONWARDS (Optimizing Nuclear Waste and Advanced Reactor Disposal Systems)

- **Goal:** Develop technologies to **significantly minimize the disposal impact** of wastes from ARs while maintaining disposal costs in the range of **$1/MWh**

ONWARDS seeks to support the development of technologies that enable:

- **10x reduction in waste volumes or repository footprint with no weakening of safeguards standards**
  - **Better than 1% accuracy in fissile mass measurement in UNF processing in high-radiation backgrounds**
- **No pure fissile material streams produced during processing (< 0.1% actinides by mass in waste streams)**
- **High performance waste forms for AR HLW across multiple disposal environments.**



ONWARDS | arpa-e.energy.gov

The production of new waste streams is required to be minimal relative to a once-through fuel cycle and have an established path to a robust waste form or final disposition.

ONWARDS Talking Points

10x reduction in waste volumes and repository footprint

Waste forms for AR used nuclear fuel (UNF) across multiple fuel cycles and disposal environments

Recycling of UNF with no pure Pu streams for new fuel stock with integrated safeguard sensors

ONWARDS Project Teams

Process Solutions

- OKLO — Argonne National Laboratory, Deep Isolation, INL Idaho National Laboratory, Finsterle GeoConsulting LLC
- orano — Oak Ridge National Laboratory, Pacific Northwest National Laboratory
- TerraPower — INL Idaho National Laboratory, SRNL Savannah River National Laboratory, NM State
- INL Idaho National Laboratory — The University of Utah
- BYU — INL Idaho National Laboratory
- Stony Brook University — The University of Tennessee Knoxville, MIT Massachusetts Institute of Technology, X-energy, Saint-Gobain
- Rensselaer

Waste Form Solutions

- Rutgers — Washington State University, Alfred University, Missouri S&T, University of South Carolina, Pacific Northwest National Laboratory, SRNL
- Citrine Informatics — Pacific Northwest National Laboratory, UNT
- Deep Isolation — Berkeley University of California, Berkeley Lab, NAC International

Safeguards Solutions

- GE Research — Hitachi, INL Idaho National Laboratory, Idaho State University, Lumitron Technologies

ONWARDS: Brigham Young University

BYU BRIGHAM YOUNG UNIVERSITY — INL Idaho National Laboratory — PYRO LAB

Project Title:

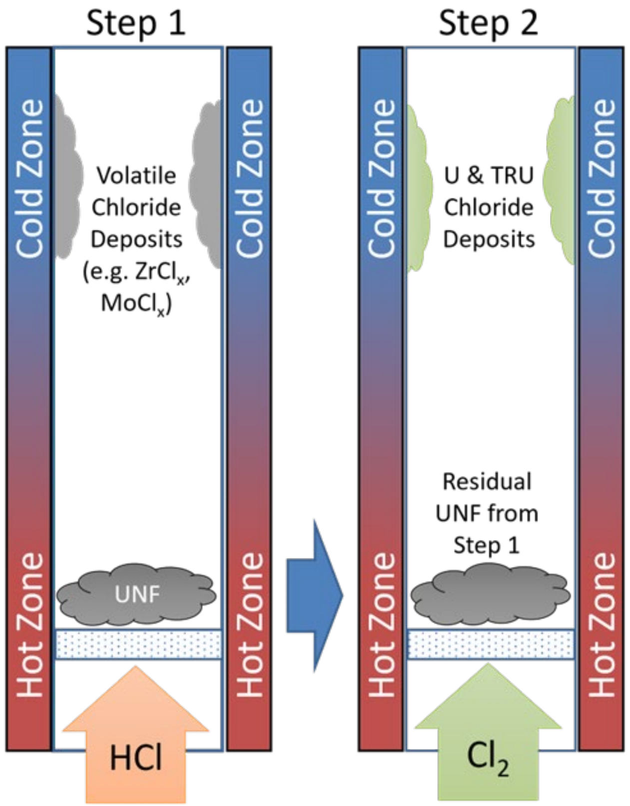
Two-Step Chloride Volatility Process for Reprocessing Used Nuclear Fuel from Advanced Reactors

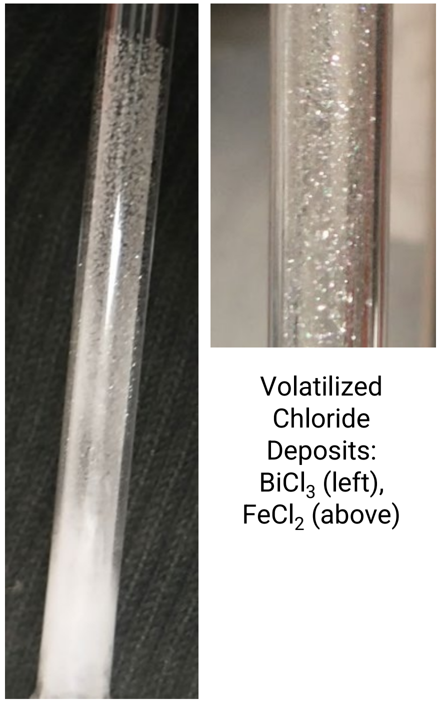
PI:

Devin Rappleye, BYU, drapp@byu.edu
Robert Hoover, INL

Project Outcomes:

Two-Step Chloride Volatility (TSCV) co-recovers uranium & transuranic elements (TRU) from the used nuclear fuel (UNF) of advanced reactors (AR) at an equivalent rate of ≥1 kg/day while reducing waste (~5% of UNF) by minimizing solvents and recycling process gases.





Volatilized Chloride Deposits: $BiCl_3$ (left), $FeCl_2$ (above)

Cost reduction by using a solventless separation scheme and recycling gases

ONWARDS: Citrine Informatics, Inc.

CITRINE INFORMATICS

UNIVERSITY OF NORTH TEXAS

Pacific Northwest NATIONAL LABORATORY

Project Title:

Halogen-related Advanced Waste forms through Artificial Intelligence Integration (HAWAII)

PI:

Dr. James Saal
jsaal@citrine.io

Project Outcomes:

Novel molten salt reactor waste forms with >3x reduction in volume, improved durability, and >50% reduction in facility costs.

CONVENTIONAL TECHNOLOGY
[GLASS-BONDED SODALITE]

- >3x reduction in volume
- >50% reduction in CapEx and O&M costs
- Improved durability and other properties

NEW TECHNOLOGY
[PHOSPHATE GLASS, PROPOSED]

Key takeaway: AI-driven dehalogenated phosphate waste form design

ONWARDS: Deep Isolation

Project Title:

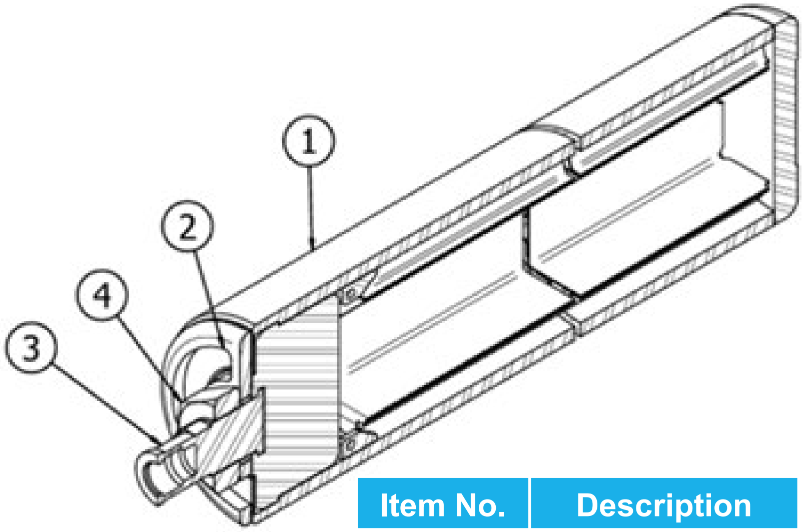
UPWARDS: Universal Performance Criteria and Canister for Advanced Reactor Waste Form Acceptance in Borehole and Mined Repositories Considering Design Safety

PI:

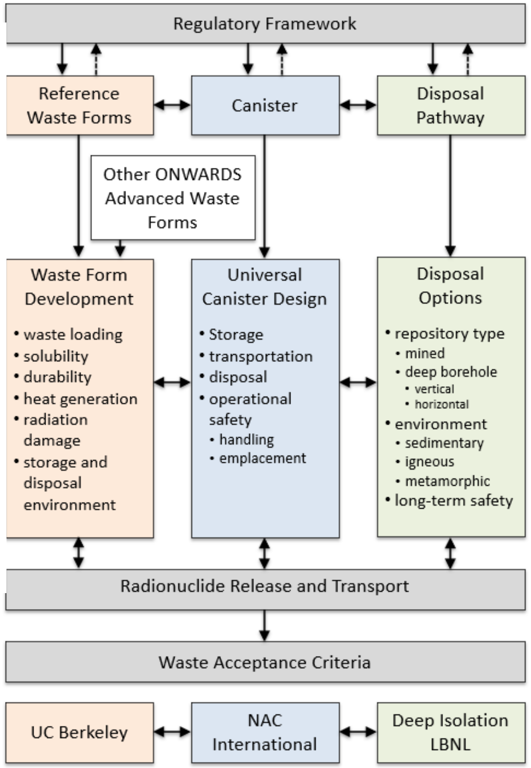
Jesse Sloane, PE
jesse@deepisolation.com

Project Outcomes:

Provide an integrated waste management system for the disposition of advanced reactor (AR) waste forms compatible with both mined and deep borehole disposal.



Item No.	Description
1	Canister Assembly
2	Cover Ring
3	Lift Adapter
4	Jam Nut



Key takeaway: Universal Canister System to Dispose of Multiple AR Waste Streams

ONWARDS: Idaho National Laboratory

Project Title:

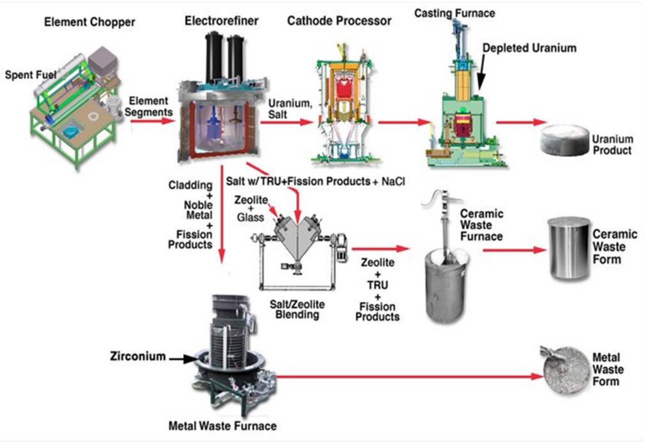
Traveling Molten Zone Refining Process Development for Innovative Fuel Cycle Solutions

PI:

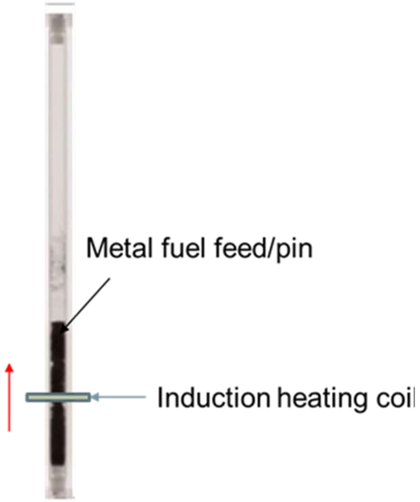
Dr. Tae-Sic Yoo
Tae-Sic.Yoo@inl.gov

Project Outcomes:

Disruptive metal fuel reprocessing concept based on heat treatment without utilizing any chemical or solution



Conventional Technology



Envisioned Technology

Key takeaway: Rapid Metal Fuel Reprocessing only with Heating

ONWARDS: Oklo Inc.

OKLO Argonne NATIONAL LABORATORY INL Idaho National Laboratory DEEP ISOLATION®

Project Title:

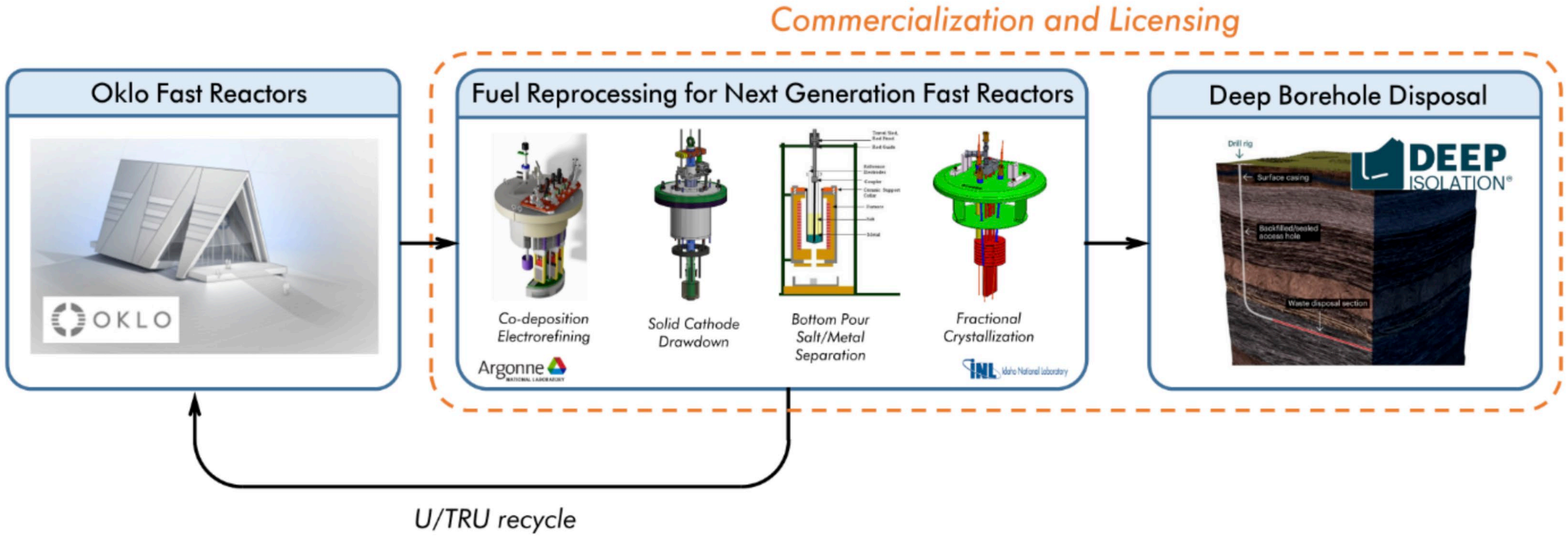
Enabling the Near-Term Commercialization of an Electrorefining Facility to Close the Metal Fuel Cycle

PI:

John Hanson
john@oklo.com

Project Outcomes:

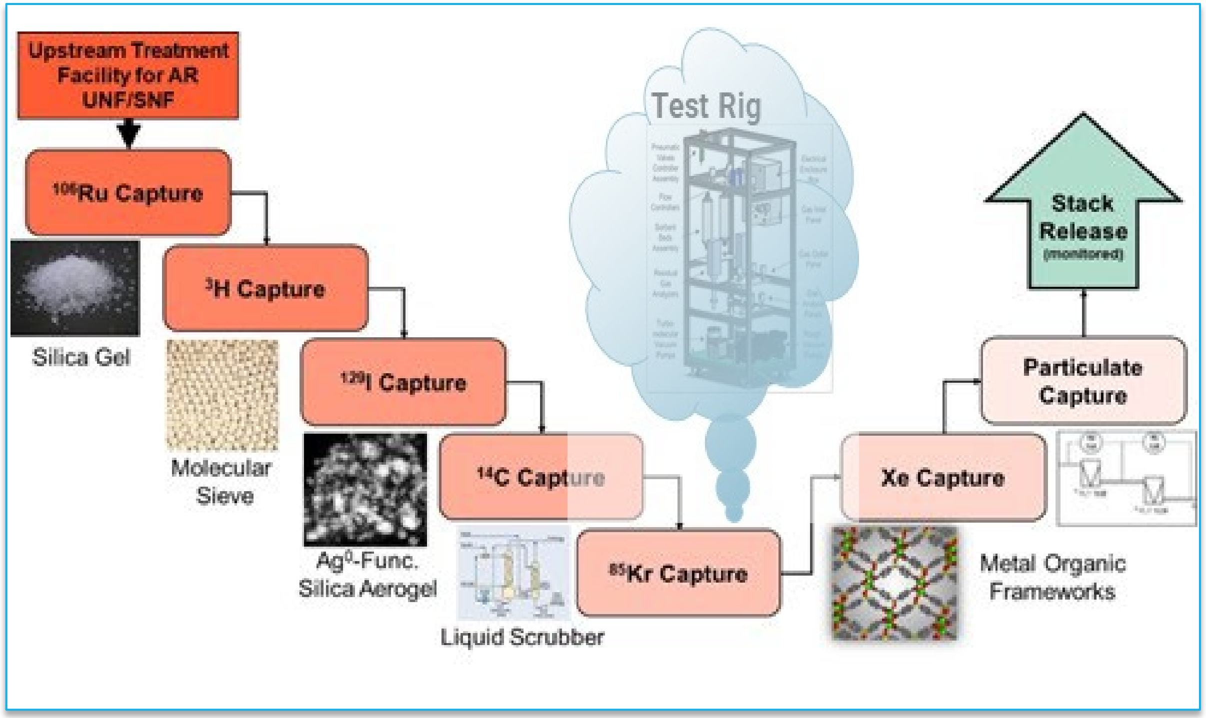
Industrialize key electrorefining facility processes, develop a commercial licensing basis for the facility, and develop a final waste disposal strategy utilizing deep borehole disposal



Key takeaways: Significantly improve advance reactor fuel economics, reduce ultimate waste volume, and close the fuel cycle through commercial fuel recycling

ONWARDS: Orano

Pacific Northwest NATIONAL LABORATORY | MCL INC MATERIALS & CHEMISTRY LABORATORY, INC. | orano | OAK RIDGE National Laboratory | Chimie Paris ParisTech



Project Title:

A Modular Off-Gas Treatment System for Advanced Reactor Used Nuclear Fuel Treatment

PI:

Dr. Sven Bader
Sven.Bader@orano.group

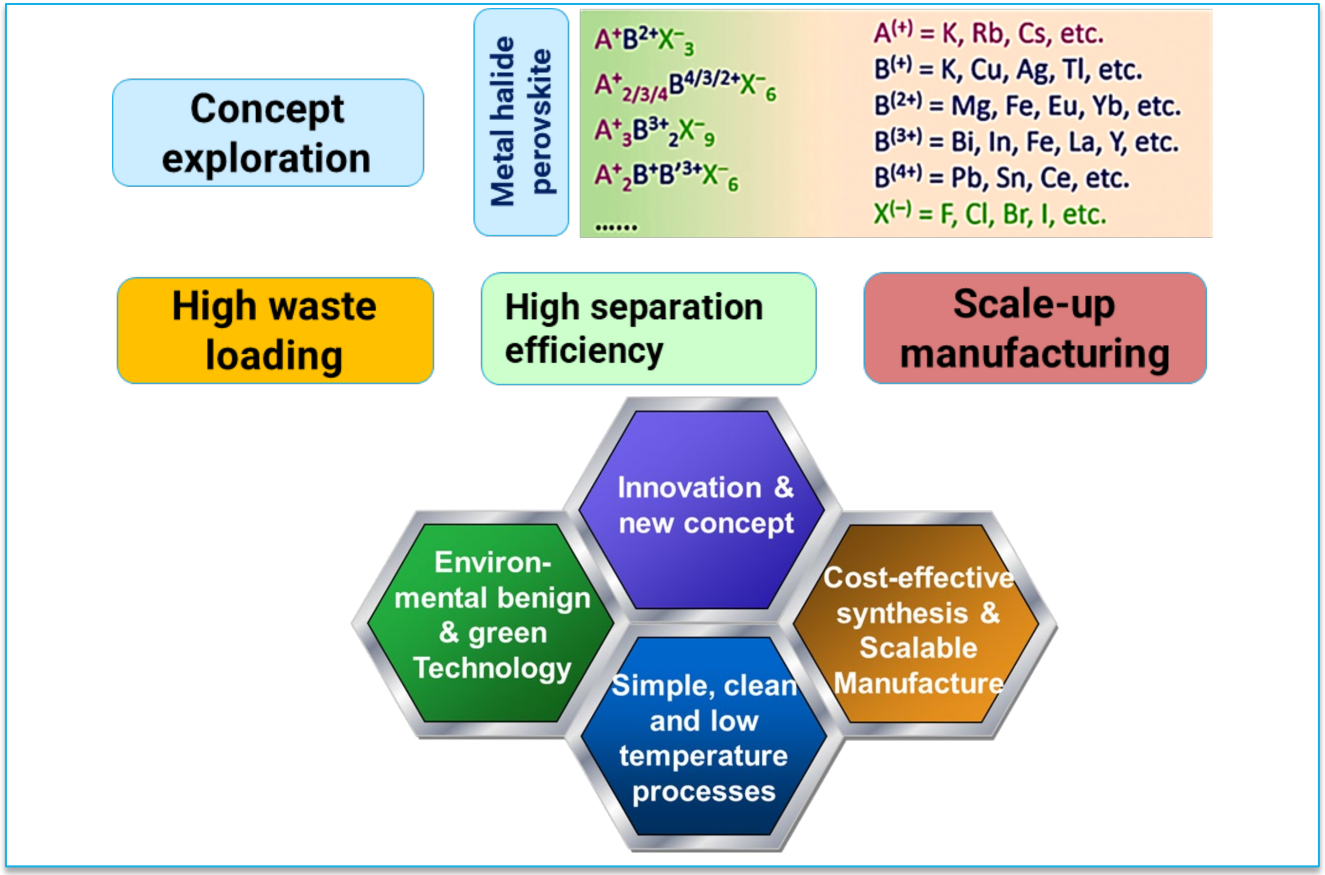
Project Outcomes:

Flexible and modular off-gas treatment system for all advanced reactor UNF/SNF treatment facilities with state-of-the-art treatment, industrialization & lifecycle management with MOF testing

Key takeaway: Treatment of off-gases to ensure regulatory limits are satisfied

ONWARDS: Rensselaer Polytechnic Institute

Rensselaer



Project Title:

Metal-Halide Perovskites as Innovative and Cost-Effective Fluoride Salt Waste Forms

PI:

Jie Lian
lianj@rpi.edu

Project Outcomes:

Simply, low temperature and cost effective solution-based processes for recovering ^{7}Li and separating fluoride salt waste

Key takeaway: Separate Fluoride Salt Wastes and Recycle LiF

PACE-FORWARD: Rutgers University

RUTGERS THE STATE UNIVERSITY OF NEW JERSEY · WASHINGTON STATE UNIVERSITY · Alfred University · MISSOURI S&T · UNIVERSITY OF South Carolina · Pacific Northwest NATIONAL LABORATORY · SRNL SAVANNAH RIVER NATIONAL LABORATORY

Project Title:

PACE-FORWARD: Pioneering **a Ce**rmet Wasteform **for** Disposal of **W**aste Streams from **A**dvanced **R**eactors

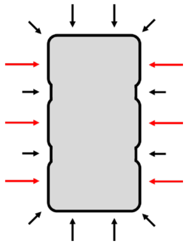
PI:

Prof. Ashutosh Goel, Rutgers University
ag1179@soe.rutgers.edu

Project Outcomes:

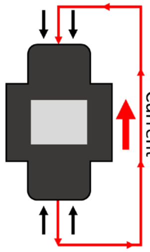
Demonstration of near-scale production of cermet wasteforms to apply for immobilization of wastes from advanced reactor types

Advanced reactor waste streams
Halide salts – Molten salt reactors
Metallic wastes
Carbon (graphite) – TRISO fuels

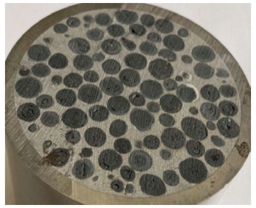


Waste pre-treatments
Halides to oxyhalides
Carbon/graphite to carbides

Mix with metallic waste stream



Hot Isostatic Pressing (HIP)	or	Spark Plasma Sintering (SPS)
High temperature, High pressure		High temperature, Medium pressure
Sealed canister – No off-gas systems		Extremely rapid processing (< 1 hour)



Durable cermet wasteform capable of immobilizing multiple waste streams from a range of reactor designs

*Key takeaway: Convert wastes to stable ceramics at low temperature, mix with metallic wastes, form final **cermet** wasteform*

ONWARDS: TerraPower

TerraPower INL SRNL NM STATE

Project Title:

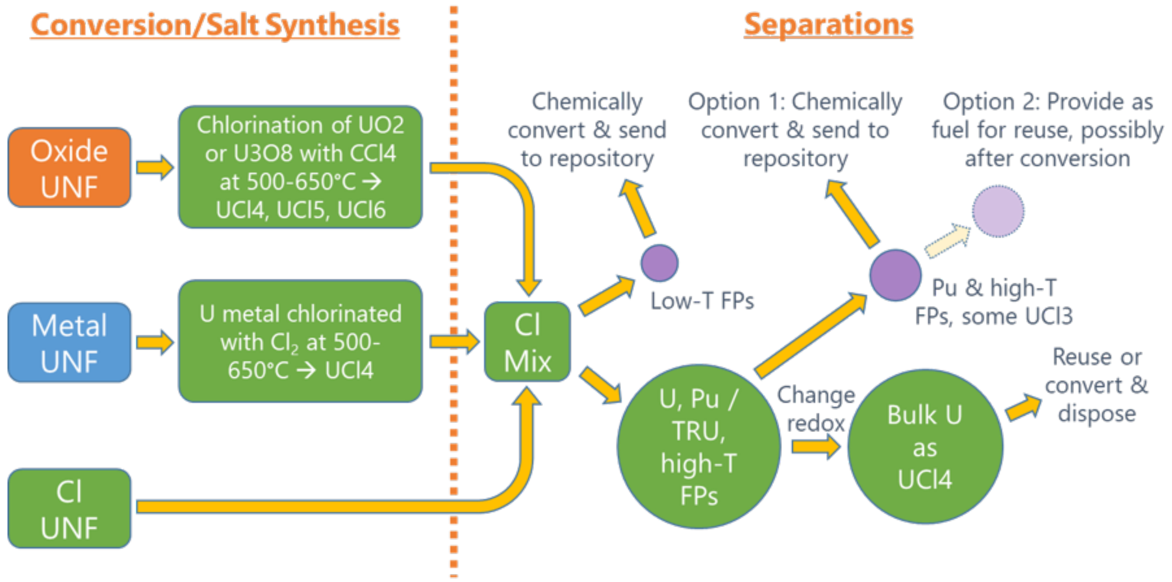
Chloride-Based Volatility for Waste Reduction and/or Reuse of Metallic-, Oxide- and Salt-Based Reactor Fuels

PI:

Dr. Perry Motsegood
pmotsegood@terrapower.com

Project Outcomes:

Volatility-based separations to enable bulk recovery of U for reuse or disposal at a reduced cost compared to deep geologic repositories, while Pu will be comingled with fission products



Key takeaway: Recover uranium from UNF through chloride volatility

CURIE (Converting UNF Radioisotopes Into Energy)

Goal: Enable commercially viable reprocessing of used nuclear fuel (UNF) from the current light water reactor (LWR) fleet by resolving key gaps/barriers in reprocessing ***technologies***, ***process monitoring***, and ***facility design***

Global Metrics

1. significantly (i.e., at least an order of magnitude) reduce the volume of LWR HLW requiring permanent disposal,
2. maintain disposal costs in the range of 0.1¢/kilowatt-hour (kWh)[4],
3. provide a 1¢/kWh[5] fuel cost for a 200 metric tons heavy metal (MTHM)/yr n^{th}-of-a-kind (NOAK) facility,
4. in situ SNM process monitoring approaches that predict, within 1% uncertainty and under representative conditions, the post-process material accountancy, and
5. development of UNF separations which do not produce pure plutonium streams

CURIE

CURIE | arpa-e.energy.gov

Main CURIE Talking Points

Make reprocessing economically viable

Demonstrating "real time" materials accountancy and process monitoring has cost benefit

Provide an opportunity for US technical leadership in the national security space

CURIE Project Teams

Separations

- The University of Alabama at Birmingham; Oak Ridge National Laboratory
- Argonne National Laboratory; Deep Isolation; Oklo; Case Western Reserve University
- The University of Utah; University of Nevada, Reno; Idaho National Laboratory; Virginia Tech
- Idaho National Laboratory; PennState; University of Nevada, Reno
- Oak Ridge National Laboratory; CURIO; Sandia National Laboratories; Idaho National Laboratory; Pacific Northwest National Laboratory; Spectra Tech Inc.
- Mainstream Engineering (Solutions Through Advanced Technology); Idaho National Laboratory
- Argonne National Laboratory; Case Western Reserve University

Safeguards/MC&A

- GE Research; orano; Lumitron Technologies; Sandia National Laboratories
- Northeastern University; UNT; GE Research; University of Michigan; Idaho National Laboratory
- University of Colorado Boulder; Idaho National Laboratory; Los Alamos National Laboratory; NIST National Institute of Standards and Technology U.S. Department of Commerce
- VCU; NVE; NuVision Engineering; Pacific Northwest National Laboratory

Systems Analysis

- TerraPower (A Nuclear Innovation Company); EPRI Electric Power Research Institute; Oak Ridge National Laboratory; Deep Isolation; Southern Company

***Projects in green boxes also include equipment design**

CURIE: University of Colorado, Boulder

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY U.S. DEPARTMENT OF COMMERCE

Los Alamos NATIONAL LABORATORY

INL Idaho National Laboratory

Project Title:

Achieving 1 % Assay of Special Nuclear Materials in 2 Minutes with Microcalorimeter-Array Gamma-Ray Spectroscopy

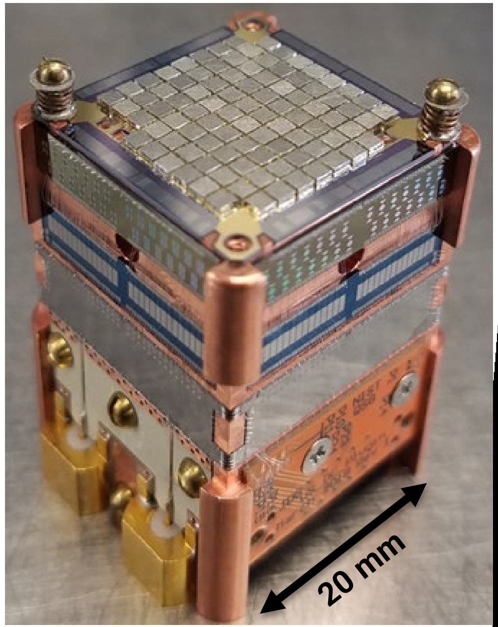
PI:

Dan Becker
daniel.becker@colorado.edu

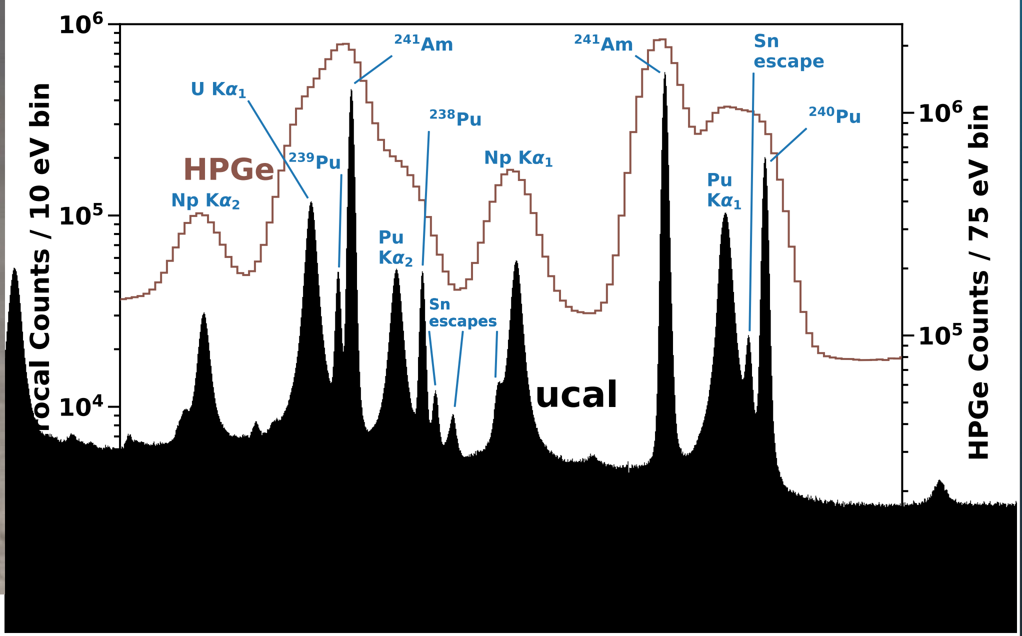
Project Outcomes:

Microcalorimeter submodule featuring 20x improvement in detector speed, and demonstration using pyroprocessing samples from INL

96-pixel microcalorimeter submodule



Superior energy resolution of microcalorimeters allows separation of closely spaced gamma-ray peaks, enabling Pu isotopic assay to within 1 %



Key takeaway: Faster microcalorimeters enable better approaches to nuclear materials accountancy and control at lower operating cost

Argonne NATIONAL LABORATORY

Case Western Reserve University EST. 1826
think beyond the possible

Project Title:

Radioisotope Capture Intensification Using Rotating Packed Bed Contactors

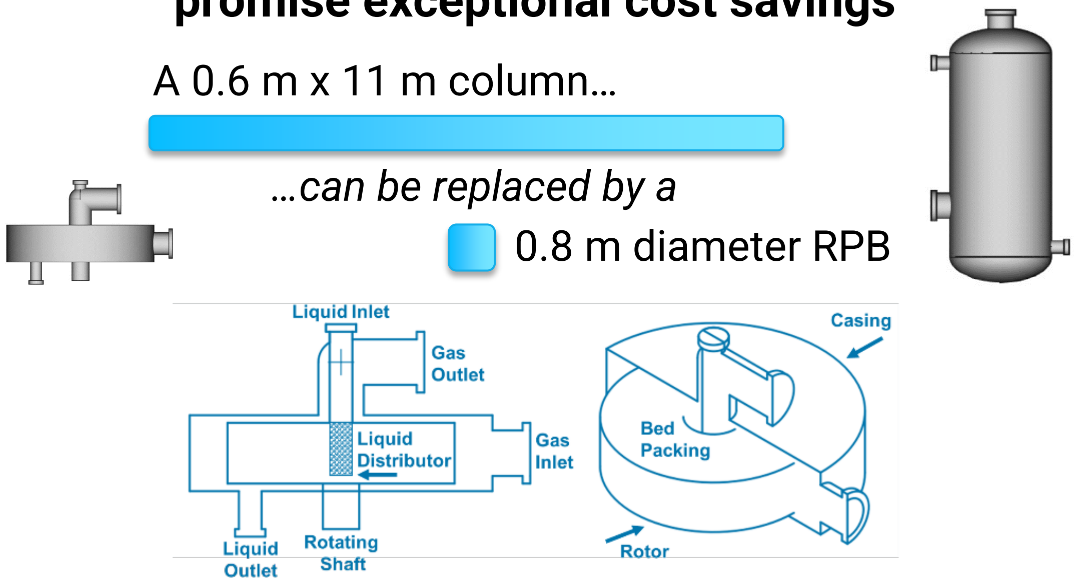
PI:

Dr. Anna G. Servis
aservis@anl.gov

Project Outcomes:

Development and demonstration of PACER RPBs for consecutive solid-liquid, liquid-liquid, and gas-liquid separations

Exceptional plant volume reductions promise exceptional cost savings



Key takeaway: Novel separations engineering could decrease facility size, waste, and, ultimately, cost

CURIE: General Electric Research

GE Research · LUMITRON TECHNOLOGIES · Sandia National Laboratories · orano · HITACHI

Project Title:

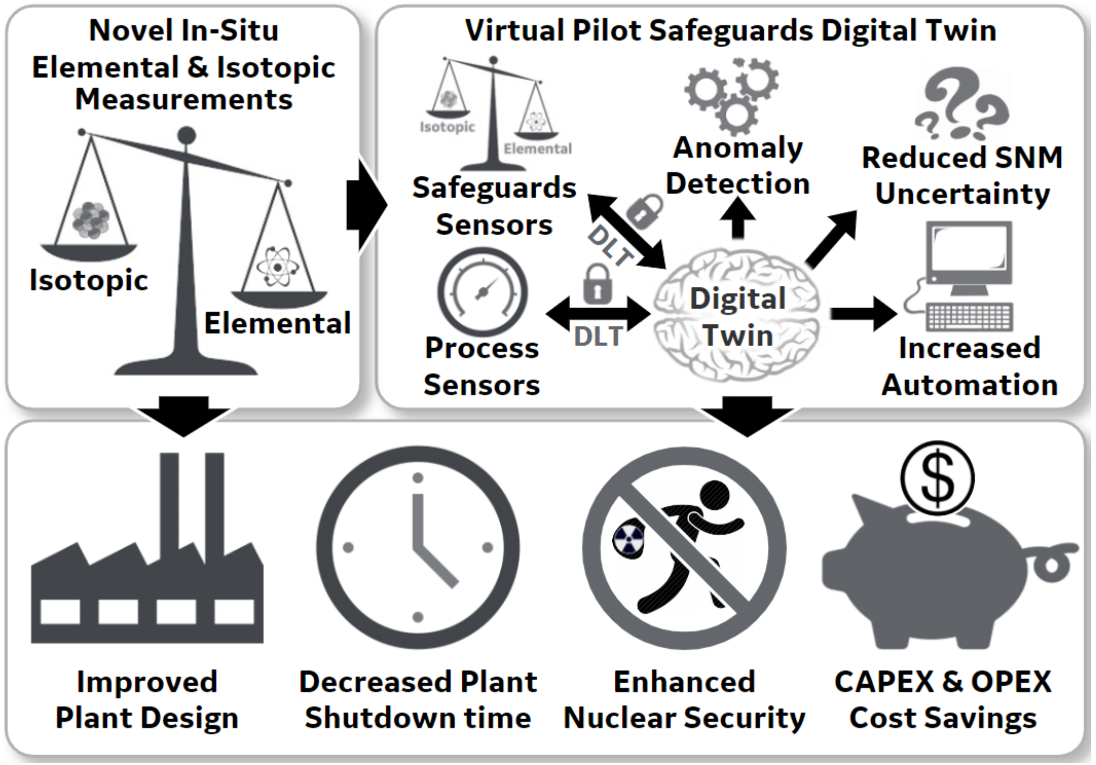
MONOCHROMATIC ASSAY YIELDING ENHANCED RELIABILITY (MAYER)

PI:

Dr. Bogdan Neculaes
Bogdan.neculaes@ge.com

Project Outcomes:

Deliver a revolutionary safeguards solution to improve the economics for aqueous nuclear reprocessing, consisting of : a) novel in situ sensors; b) digital twin (DT) – for real-time probabilistic risk assessment and anomaly detection; and c) distributed ledger technology (DLT) – to ensure data transparency and integrity.



Key takeaway: Improve the economics for aqueous reprocessing of spent nuclear fuel.

CURIE: Mainstream Engineering

Solutions Through Advanced Technology
MAINSTREAM ENGINEERING

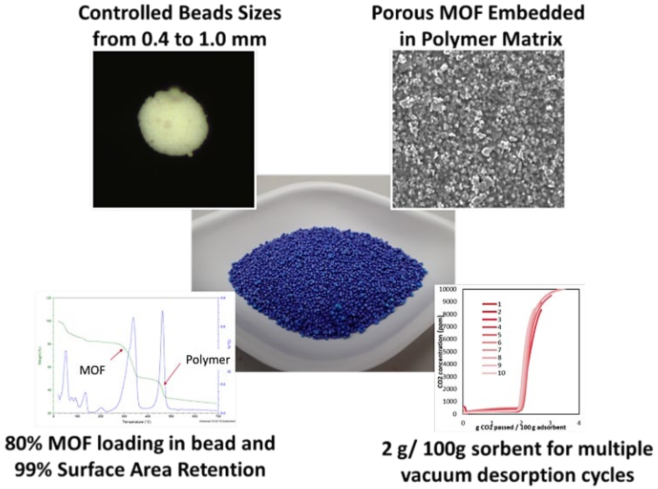
Idaho National Laboratory

Project Title:

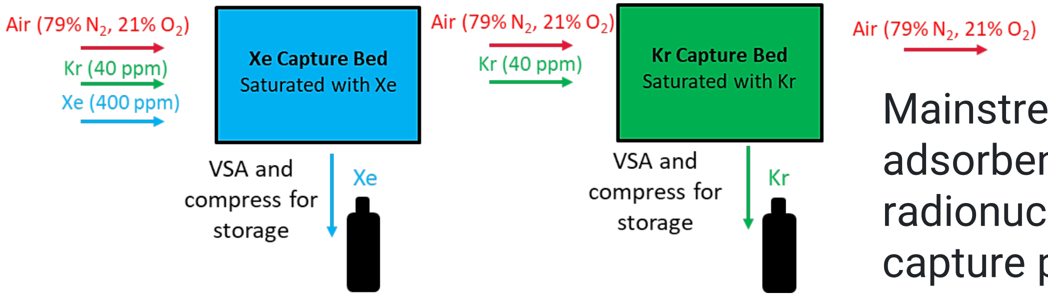
Improved Volatile and Semi-volatile Radionuclide Off-Gas Management

Project Outcomes:

Decrease facility costs, simplify off-gas logistics, and reduce facility energy needs while **capturing >99.9% of volatile radionuclides**



Mainstream's MOF based encapsulated adsorbents



Mainstream's adsorbent-based radionuclide off-gas capture process

Key takeaway: Capture off-gas releases economically

CURIE: NuVision Engineering

Pacific Northwest NATIONAL LABORATORY

Project Title:

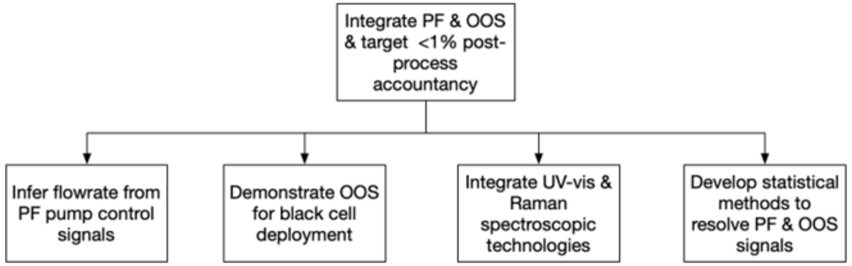
MODULAR POWER FLUIDICS AND ONLINE OPTICAL SPECTROSCOPY FOR REPROCESSING PLANT CONTROL AND ACCOUNTANCY

PI:

David Lashley
Lashley@nuvisioneng.com

Project Outcomes:

- Reducing the facility footprint and number of facility operations
- Process and production designs that improve economics and security
- Providing enhanced opportunities for safeguarding
- Leveraging modularization of unit operations and use of advanced manufacturing techniques



Fluidic Mixing, Pumping & Sampling with Online Spectroscopy………

……..In an Integrated Modularized System

Key takeaway: Coupled Technologies Drive Step Change in Process

Questions

Thank You!

August 28, 2023

If it works…

will it matter?

Questions?

Send email to:

EM-LabCall@em.doe.gov

Or contact:

Dr. Ming Zhu
EM Senior Advisor for Laboratory Policy
Ming.Zhu@em.doe.gov
(301) 903-9240