

Materials Protection, Accounting, and Control Technologies FY 2023 Overview – August 2023

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National Technical Director

LA-UR-23-30880

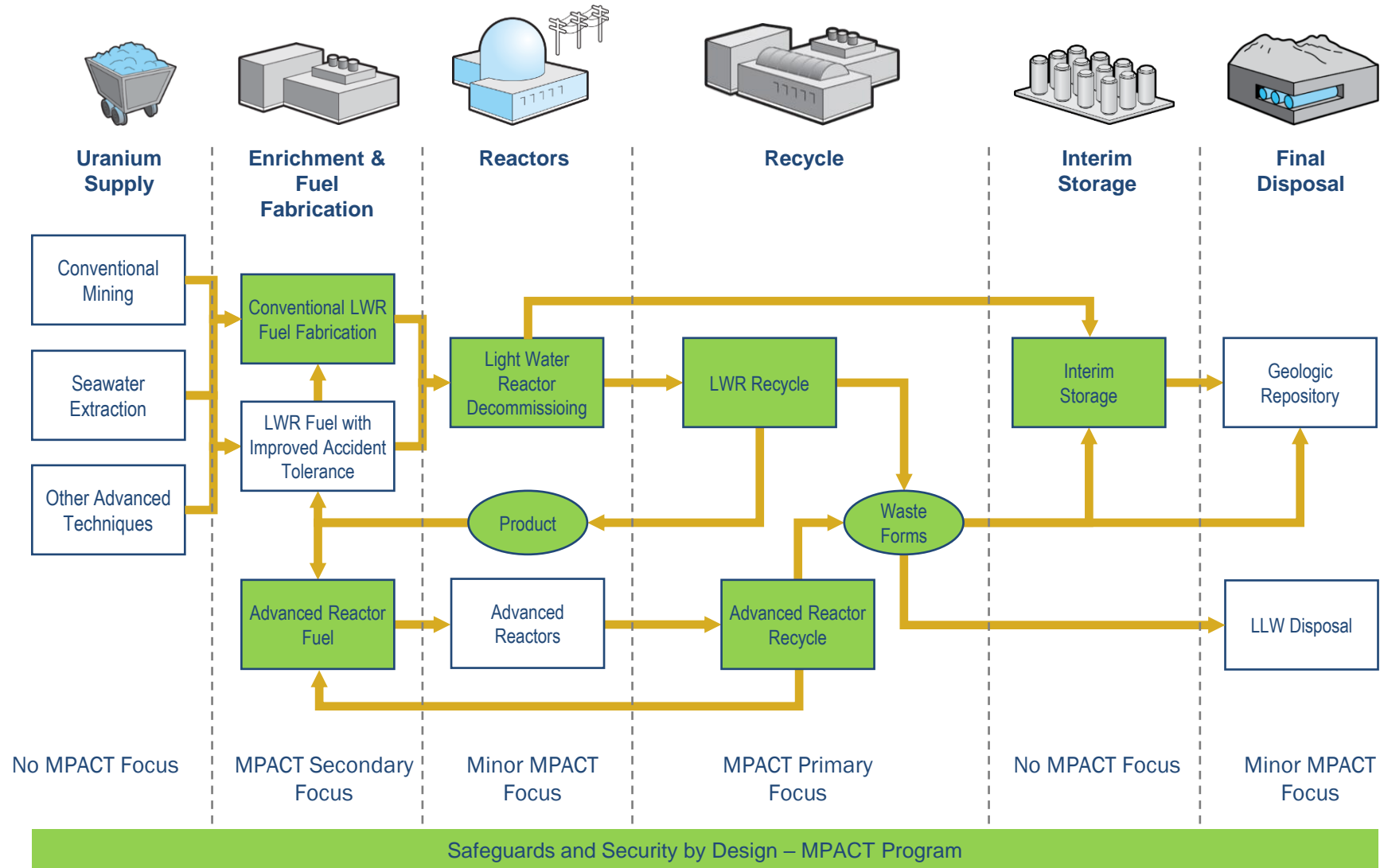


U.S. DEPARTMENT OF
ENERGY

Mission

The Materials Protection Accounting and Control Technologies (MPACT) campaign supports the U.S. advanced fuel cycles technology developers to effectively and economically address nuclear MC&A (Material Control and Accounting) requirements.

MPACT Fuel Cycle Focus



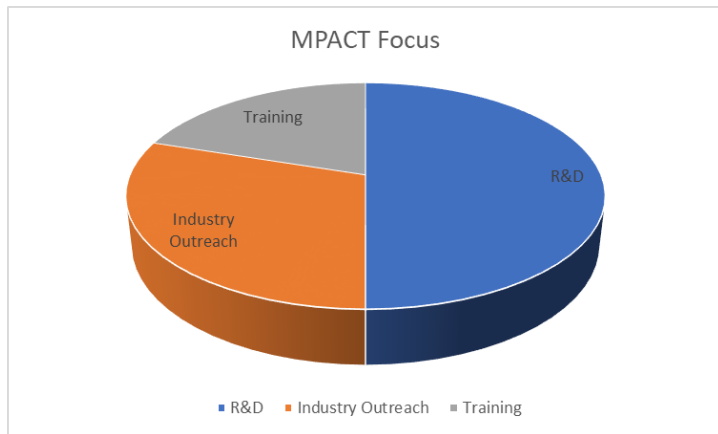
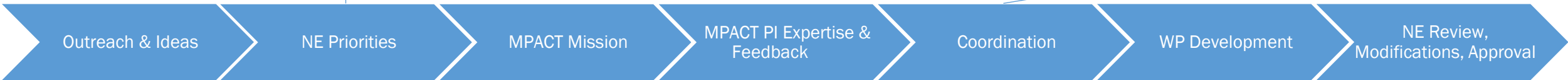
MPACT Activity Flow

NE Mission:
Advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs

NE Goals:

- 1.Enable continued operation of existing U.S. nuclear reactors.
- 2.Enable deployment of advanced nuclear reactors
- 3.Develop advanced nuclear fuel cycles.
- 4.Maintain U.S. leadership in nuclear energy technology
- 5.Enable a high-performing organization.

- DOE/NE Advanced Reactor Safeguards (ARS)
- DOE/NNSA Office of International Nuclear Safeguards
- DOE/NNSA Office of International Nuclear Security
- DOE/NNSA Office of Defense Nuclear Nonproliferation R&D
- DOE Advanced Research Projects Agency-Energy (ARPA-E)
- DOE/NE Materials Recovery and Waste Form Development (MRWFD)
- DOE/NE Advanced Fuels (AF)
- Nuclear Regulatory Commission (NRC)
- DOE/NE & DOE/NNSA U Assurance



MPACT Mission:
The Materials Protection Accounting and Control Technologies (MPACT) campaign supports the U.S. advanced fuel cycles technology developers to effectively and economically address nuclear materials control and accounting (Material Control and Accounting) requirements.

- Nuclear Energy University Program (NEUP)
- Small Business Innovation Research (SBIR)

FY23 MPACT Activities:

5 Front-End
10 Back-End
2 SG Training

MPACT Long-Term Campaign Objectives

Long-Term Objectives:

- Focus MPACT R&D to meet high-challenge goals:
 - MPACT tools that balance technology development with end-user applications
 - Cradle-to-grave domestic safeguards
 - Shift from discrete to real (or near-real) time accountancy

MPACT 3-year High-level Milestones (FY 2024-2026)

Develop **Demonstrate** **Deploy**

- Microcalorimeter integrated with Idaho National Laboratory analytical lab activities (**Deploy**)
- Molten salt sampler installed in processing facility (**Demonstrate**)
- Molten salt alpha detector (Nuclear Energy University Program) for MPACT or Advanced Reactor Safeguards & Security campaign (**Demonstrate**)
- Industry support through Nuclear Material Control and Accounting efficiencies, capability improvements, or training programs (**Develop, Demonstrate & Deploy**)
- Consolidate, update, and post safeguards performance models for general use (**Deploy**)
- Run Plutonium Multiplicity Scrap Counter with materials from fuel cycle development (**Deploy**)
- Test industry-developed (Small Business Innovation Research) argon hot cell γ spectroscopy for MPACT and Material Recovery and Waste Form Development campaigns (**Demonstrate**)

NEUP Awards

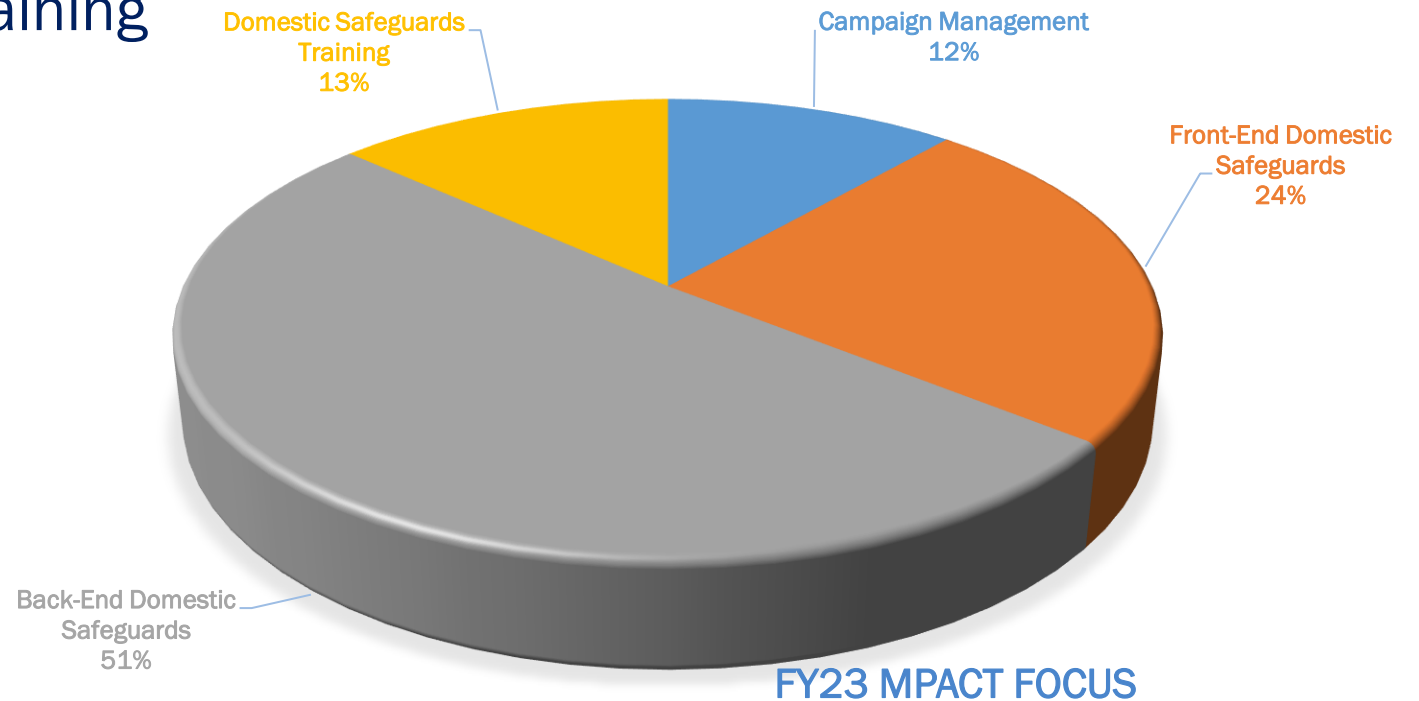
Project Number	Title	Lead University	Completion Date
18-15043	Integration of Nuclear Material Accounting Data and Process Monitoring Data for Improvement on Detection Probability in Safeguarding Electrochemical Processing Facilities	Oregon State University	12/29/2022
20-19939	Gallium Oxide Schottky Diode Detectors for Measurement of Actinide Concentrations from Measured Alpha Activities in Molten Salts	Ohio State University	12/29/2023
21-24307	Plasma-Bubble Spectroscopy: A Method for Real-Time Material Quantification in Molten Salts	North Carolina State University	12/29/2024
22-27159	Materials Accountancy During Disposal and Waste Processing of Molten Salt Reactor Fuel Salts	Texas A&M University	12/29/2024
22-27288	Advancing Nuclear Material Accountancy of TRISO-fueled pebbles using fast and accurate gamma-ray spectroscopy	Colorado University	12/29/2024
23-xxxxx	An Integrated Elemental and Isotopic Detector for Real-Time Molten Salt Monitoring	North Carolina State University	XX/XX/202X
23-xxxxx	Development of a Thin-Layer Electrochemical Sensor for Molten Salt Reactors and Fuel Cycle Processes (cross-cut with ARS)	Brigham Young University	XX/XX/202X

SBIR Awards

Award Number	Title	Institution	Project Period
DE-SC0020950	High Count Rate, High Temperature Neutron/Gamma Detector for Advanced Reactors (Phase 2)	Radiation Monitoring Devices, Inc., Watertown, MA	08/23/2021 - 08/22/2023
DE-SC0021765	Ruggedized, High-Resolution CZT Spectrometer for Operation in Inert Hot Cells (Phase 2)	H3D, Inc., Ann Arbor, MI	08/22/2022 - 08/21/2024
DE-SC0022767	A New Semiconductor Material, LiInGaSe ₂ , for Neutron Detection (Phase 1)	Radiation Monitoring Devices, Inc., Watertown, MA	6/27/2022 - 3/26/2023
DE-SC0022711	High Signal-to-noise Pixelated CZT Directional Spectrometer for Generalized Hold-Up Measurements (Phase 1)	H3D, Inc., Ann Arbor, MI	6/27/2022 - 3/26/2023
DE-SC0022817	High Rate Neutron Detector For Nuclear Material Control and Accounting (Nuclear Material AccountancyC) (Phase 1)	Proportional Technologies, Inc. Houston TX	6/27/2022 - 3/26/2023
DE-SC0022768	Hardcell: A Robust Sensor Head For Hot Cell Nuclear Material Accounting And Control (Phase 1)	Radiation Monitoring Devices, Inc., Watertown, MA	6/27/2022 - 3/26/2023
	No FY23 Phase 1 Release 2 Awards Made / 2 FY23 Phase 2 Awards and 1 FY23 Phase 2A Award		

MPACT Activity Structure

- FY23 MPACT Focus Areas:
 - Program Management
 - Front-End Domestic Safeguards
 - Back-End Domestic Safeguards
 - Domestic Safeguards Training



MPACT Front-End Domestic Safeguards

Develop	Demonstrate	Deploy
Enrichment Plant Safeguards		
Fuel Fabrication – Modeling		
Advanced Reactor Fuel Fabrication		
	Fuel Fabrication – Holdup	
		Fuel Fabrication - Standards

MPACT Fuel Fabrication - Modeling

Domestic Safeguards Need

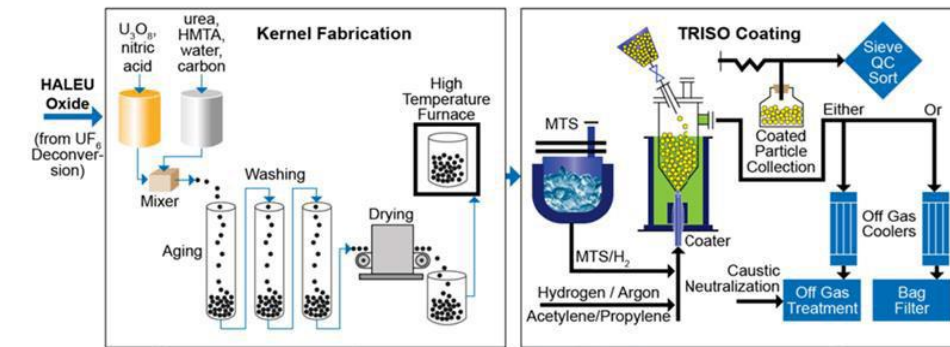
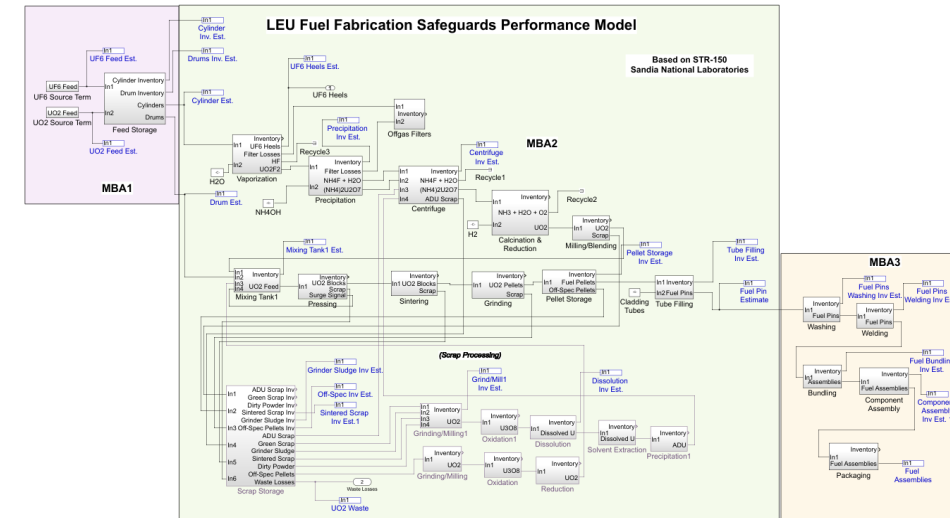
Several advanced reactor designs utilize TRISO fuel in multiple forms. There are no current Material Control and Accounting approaches for TRISO fuel fabrication.

Work Scope

Develop a TRISO fuel fabrication facility model including options for different inputs (UF6 cylinders or UO2 oxide powder) for versatility. The key task in FY23 is to start building in the Material Control and Accounting system with appropriate measurements in the process. The material balance area structure will be designed along with preliminary Standard Error of Inventory Difference (SEIF) analysis. Nuclear vendor engagements will be pursued to help validate the model assumptions

Accomplishments (completed & planned)

M4 (9/15/23) - Draft report describing the TRISO fuel fabrication model



MPACT Fuel Fabrication - Holdup

Domestic Safeguards Need

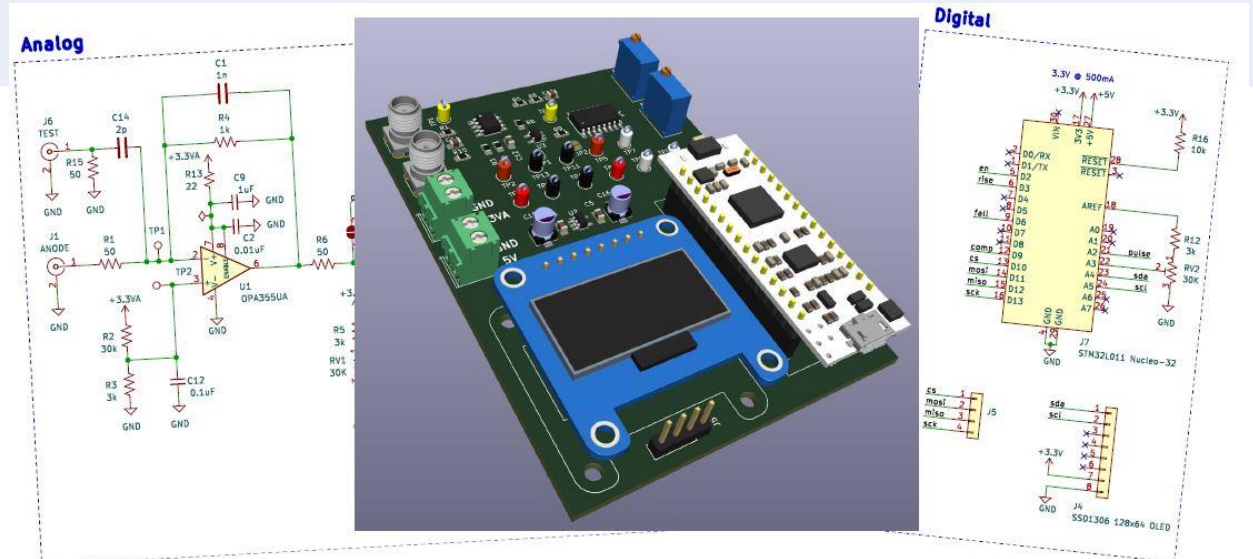
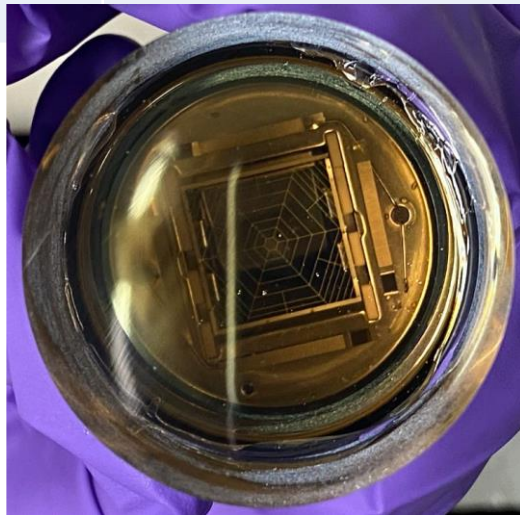
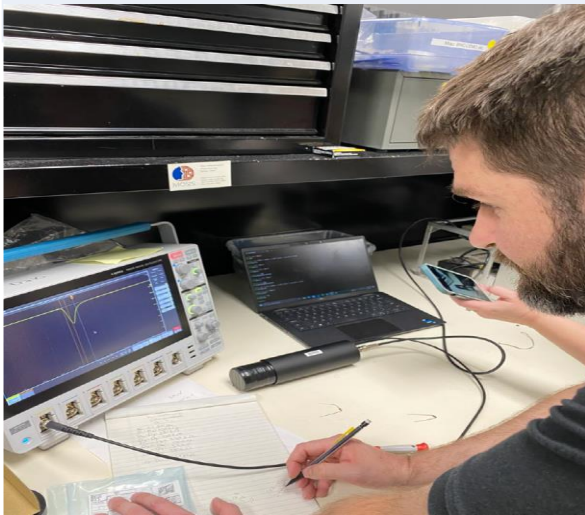
U.S. LWR fuel fabrication facilities have identified holdup issues that affect timely Material Control and Accounting and criticality safety determinations. There are currently 21 relevant NRC issue notifications related to concerns about the resiliency of the various nuclear fabrication facilities to issues that may arise, such as an inadvertent accumulation of Special Nuclear Material (SNM - holdup).

Work Scope

Develop a real or near-real time holdup monitor to enable continuous measurement of inadvertent accumulation of SNM.

Accomplishments (completed & planned)

M2 (8/31/23) – Summary report on ventilation ductwork monitor vendor installation.

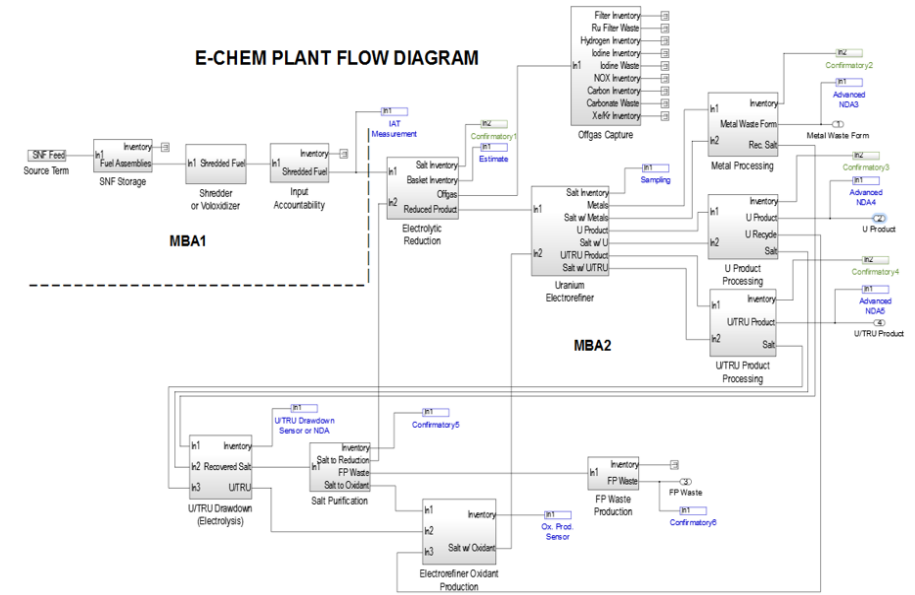


MPACT Back-End Domestic Safeguards

Develop	Demonstrate	Deploy
Pyroprocessing Safeguards and Security By Design: Lessons Learned & Include SG in New Designs		
Domestic Safeguards Performance Models: Recycling Facilities		
Molten Salt Sampling & Analysis		
	Molten Salt Sampler	
	Electrochemical Recycling Acoustic Interrogation for Nuclear Material Accountancy	
	Electrochemical Recycling Radioisotope Spiking for Nuclear Material Accountancy	
	Molten Salt Process Monitoring/Nuclear Material Accountancy Tests	
		Microcalorimeter Operation and Evaluation at Idaho National Laboratory
		Domestic Safeguards Performance Models: Migrate to Repository
		Plutonium Scrap Multiplicity Counter Commercialization

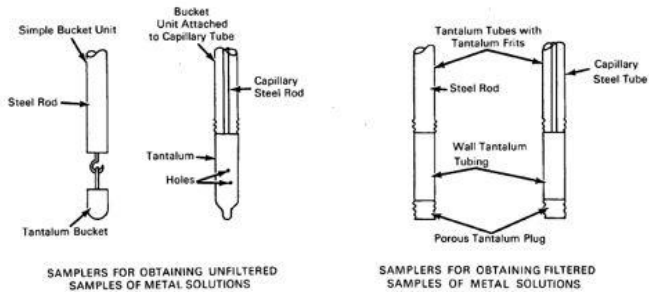
MPACT Modeling: Recycling Facilities

<p>Domestic Safeguards Need</p>	<p>Advanced fuel cycles require domestic safeguards development beyond traditional LWR approaches. Modeling</p>
<p>Work Scope</p>	<p>Develop domestic safeguards performance models for U.S.-relevant recycling flowsheets.</p>
<p>Accomplishments (completed & planned)</p>	<p>Complete domestic safeguards performance models for pyroprocessing, CoDCon, UREX, UREX+, PUREX, and ZIRCEX. Update models with any available data from R&D across the complex.</p>



MPACT Molten Salt Sampler

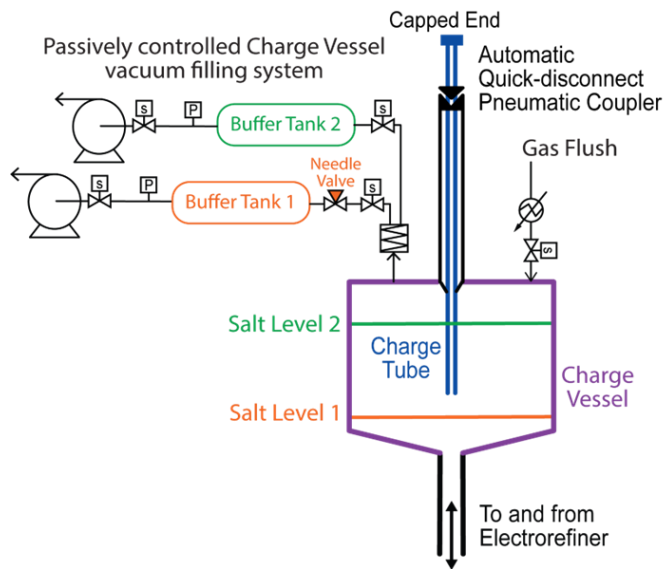
<p>Domestic Safeguards Need</p>	<p>Current on-line, at-line, or off-line molten salt sampling techniques demonstrate higher uncertainties than needed for Material Control and Accounting use.</p>
<p>Work Scope</p>	<p>Develop a salt sampling technique that reduces uncertainties associated with the sampling process and enables advanced analysis of the analyte.</p>
<p>Accomplishments (completed & planned)</p>	<p>First salt sampler developed and delivered to Idaho National Laboratory by the end of FY23.</p>



Winsch, I.O., ANL-7088 (1965)

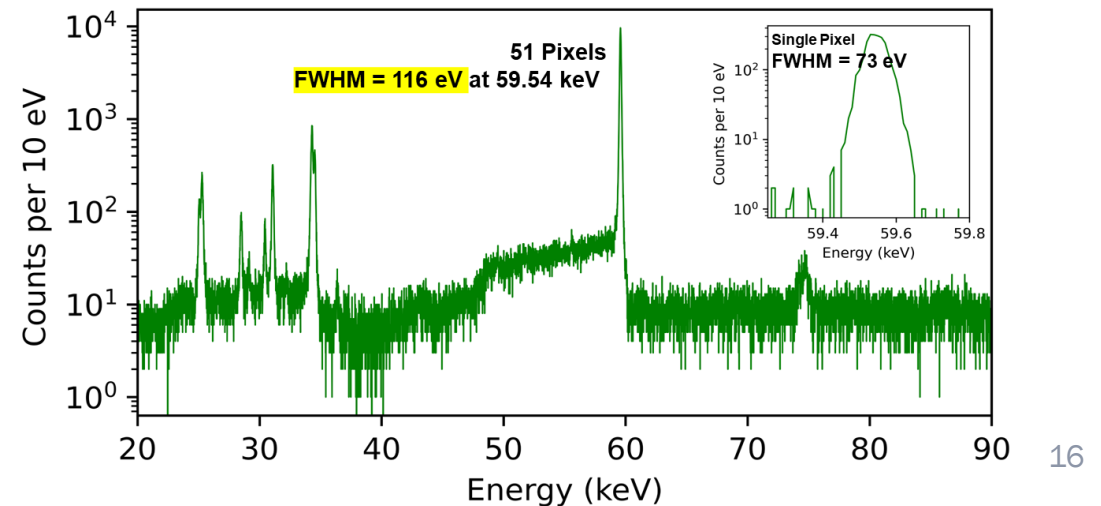


Gallaher, R. B. Operation of the sampler-enricher in the Molten Salt Reactor experiment. No. ORNL-TM--3524. Oak Ridge National Lab., 1971.



MPACT Microcalorimeter Operation and Evaluation at INL

Domestic Safeguards Need	Advanced fuel cycle R&D often requires analytical chemistry techniques to determine when to move from one process step to another. These techniques are time and cost intensive. A rapid yet comparable precision technique to reduce analytical chemistry dependence can support both the development of these processes as well as their Material Control and Accounting.
Work Scope	Develop and install a microcalorimeter in the INL analytical laboratory to off-load appropriate sample analysis and facilitate process and Material Control and Accounting R&D and processing operations.
Accomplishments (completed & planned)	FY23 objectives are to incorporate microcalorimeter into analytical lab operations and develop sample procedures and analysis consistent with analytical lab QA/QC processes.



MPACT Domestic Safeguards Training

Develop	Demonstrate	Deploy
Safeguards Practitioner Development		
	Statistics for Nuclear Material Control and Accounting Course Offering	

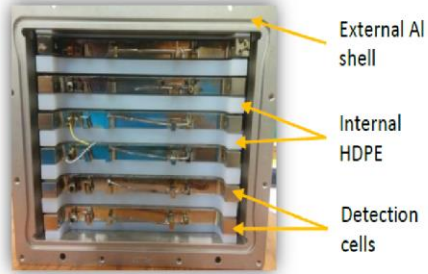
Safeguards & Security By Design (SSBD): MPACT Milestone 2020

- The Materials Protection Accounting and Control Technologies (MPACT) working group completed a 2020 Milestone to demonstrate **Safeguards and Security by Design (SSBD)** for next generation nuclear facilities.
- The 2020 milestone is encompassed in a **Virtual Facility Distributed Test Bed** that incorporates measurement technologies, data from field testing, and mod/sim tools to demonstrate SSBD.
- The milestone used an **electrochemical processing facility** as an example, but the tools can be extended to other fuel cycle facilities. The results will be published in a special issue of the Journal of Nuclear Material Management (Spring of 2021).
- The effort concluded with preliminary material control and accountancy and physical protection system designs, and also several SSBD recommendations.

MPACT Milestone 2020: Journal Papers

- 9 papers published in a special issue of the Journal of Nuclear Material Management (Spring 2021)
 - Papers include contributions from 4 National Laboratories (ANL, INL, LANL, SNL) and 6 universities under coordinated Nuclear Energy University Program (NEUP) activities (Oregon State University, Virginia Polytechnic University, University of Tennessee, Ohio State University, University of Utah, University of Colorado)
- MPACT is applying Milestone 2020 framework to other NE fuel cycle R&D processes to facilitate domestic safeguards and security by design as well as answer questions that may come up in broader fuel cycle analysis.

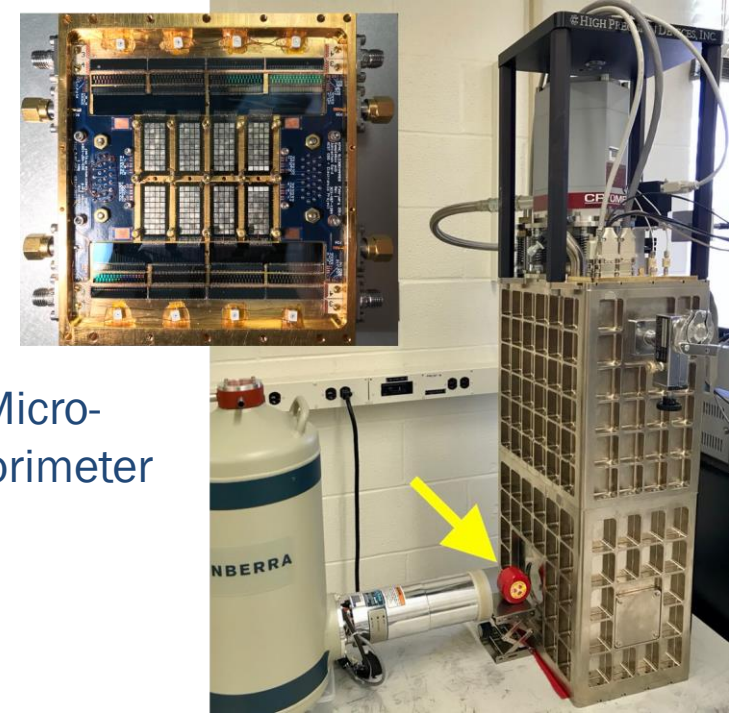
MPACT Milestone 2020: Material Control and Accounting R&D



High Dose Neutron Detector

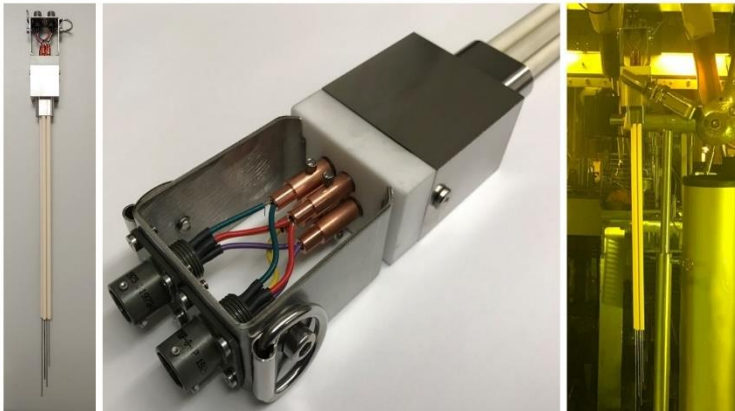


Triple Bubbler

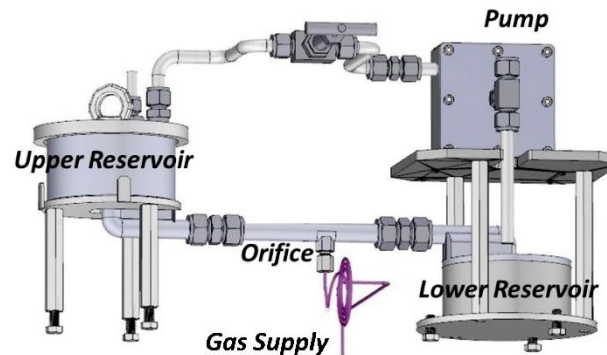


Micro-calorimeter

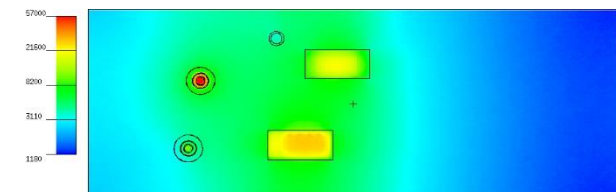
Voltammetry Sensor



Sample Extractor



Hot Cell Flux Mapping



MPACT FY24 Plans

Front End

- Continued technology development to support LWR fuel fabrication
- Advanced reactor fuel fabrication Material Control and Accounting technology & modeling development

Back End

- Material Control and Accounting technology & modeling for recycling flowsheets
- Industry engagement/MPACT technology application

Domestic Safeguards Education

- Additional statistics for Nuclear Material Control and Accounting course offering
- Safeguards practitioner development
- Develop Fundamental Nuclear Material Control Plan guidance documents

MPACT Industry Engagement

- General MPACT program overview (this call)
- Follow-up discussions in specific activities can be arranged
- Areas where MPACT can support industry development:
 - Assistance in taking a Safeguards and Security by Design approach to meet domestic regulatory requirements
 - Modeling to support Material Control and Accounting
 - Technology development/application to specific Material Control and Accounting challenges
 - Training to build Material Control and Accounting workforce
 - Coordination with other DOE programs to support interface with advanced reactors as well as international nuclear safeguards
- Welcome industry feedback on areas where MPACT can assist
- Please do not hesitate to reach out – MPACT and its technical resources are happy to discuss domestic safeguards challenges!