MPACT
Materials Protection Accounting and Control Technologies

U.S. DEPARTMENT of ENERGY | Office of Nuclear Energy

FY2025 QUARTER 2 NEWSLETTER

Materials Protection Accounting and Control Technologies (MPACT) Quarterly Newsletter

In This Issue:

Program Manager Note

In the last newsletter I talked in a bit more detail about what MPACT does and how we decide what activities to pursue. I ended the newsletter with an invitation to send us your ideas for possible future MPACT activities, and I would like to repeat that invitation now. I am often asked about what type of technology MPACT is interested in pursuing. There is no easy answer! Within our mission space (front and back-end of the domestic U.S. fuel cycle), we seek technology that supports Material Control & Accountancy (MC&A). Historically, MPACT has developed physical protection technologies for U.S. fuel cycle facilities. More recently we have focused less on the "control" portion of MC&A due to increased private sector work in this area. We currently focus most of our efforts on accountancy. When most people think about nuclear material accountancy, they naturally think about "counting." That can be item counting, non-destructive assay measurements, analytical chemistry approaches, etc. But there are likely an infinite number of additional methods that may be applied to account for nuclear material. These alternative methods could include process control technologies coupled with process material measurements, these may be applications of LIBS (Laser Induced Breakdown Spectroscopy) or LAS (Laser Absorption Spectroscopy), or new application of Raman spectroscopy, UV-VIS, new neutron and gamma sensitive semiconductors or scintillators with operational capabilities in harsh environments (think recycling hot cells). Have an idea? Drop me an email! If I can't answer your question, I have a National Technical Director who loves to geek-out on technology.

My focus for the rest of this newsletter will be to mention some things I find interesting going on right now and some conferences and workshops coming up where MPACT will have a presence. Starting at the beginning (of the fuel cycle), construction continues at LANL on the Low Enrichment Fuel Fabrication Facility (LEFFF - https://www.lanl.gov/media/publications/national-security-science/2024-winter/fuels-of-the-future). LEFFF will produce fuels for U.S. advanced reactors and offers an opportunity to develop and test safeguards-by-design concepts. MPACT is working with LEFFF on domestic safeguards concepts as well as measurement technology development. LEFFF will also collaborate with our sister organizations in international security and safeguards, further offering an opportunity for DOE programs to assist U.S. fuel cycle developers to gain a leg up on domestic and international regulatory requirements should their business take them beyond the U.S. market.

There are several conferences in 2025 that I am excited about. In February of this year MPACT participated in the Conference on Nuclear Training and Education. MPACT training personnel went to provide an update on MPACT training activities and to develop near and long-term MPACT training goals through interactions with nuclear training colleagues and stakeholders. Also in February, MPACT presented work related to unattended holdup monitoring at the INMM Pebble Bed and TRISO Fueled Reactors Nonproliferation Workshop. Next up MPACT will participate in the Methods and Applications of Radioanalytical Chemistry (MARC March 23-28, 2025) presenting on recent research using the High Efficiency and Resolution Microcalorimeter Spectrometer (HERMES-700) instrument. MPACT will also participate in the annual ANS Conference (June 15-18, 2025) as well as in the August Annual INMM Conference (INMM August 24-28, 2025). If you get a chance and are interested, please introduce yourself to any of the MPACT researchers presenting at these conferences. Our researchers would love to tell you more about their work and will be giving away MPACT-logo stickers, water bottles, and notebooks!

Thanks for reading our quarterly newsletter!

Tansel Selekler

MPACT FEDERAL PROGRAM MANAGER

Principal Investigator Profile: *Don Kovacic, Nuclear Engineer* OAK RIDGE NATIONAL LAB

Don Kovacic is a nuclear engineer with over 35 years of experience in design, operations, safety, and nonproliferation issues for nuclear energy covering regions in the United States, Europe, Africa, the Middle East, and Asia. He has held positions as a Project Engineer at Commercial U.S. PWRs, BWRs, Eastern European PWRs, and VVERs.

He is currently a Distinguished R&D Engineer with the Oak Ridge National Laboratory and is a Principal Investigator on projects supporting the IAEA, NNSA, US DOE, and US NRC to identify licensing issues, policies, concepts, and approaches for applying domestic and international nuclear safeguards, along with safety and security for advanced reactors and fuel cycle facilities (i.e., the "3S" approach).

Don is currently working with advanced reactor and fuel cycle facility designers such as Kairos Power, X-Energy, TerraPower, Ultra Safe Nuclear Corporation (Now Standard Nuclear), and others developing nuclear material control and accounting programs as part of the deployment of advanced high temperature TRISO fueled reactors, microreactors, and molten salt reactors. For the MPACT program, Don has been leading a multi-laboratory team focusing on identifying challenges and technical solutions for material control and accounting for the manufacture (or synthesis) of advanced nuclear reactor fuels.

Don has served as a senior advisor in Washington, DC for the NNSA Office of Nonproliferation and Arms Control from 2008 - 2010 as well as a Cost-Free Expert for the IAEA's Nuclear Infrastructure Group in the Department of Nuclear Engineering working with embarking countries implementing the Milestones Approach from 2010 - 2013.

Don is also the Regional Laboratory Lead for the he NA241 International Nuclear Safeguards Engagement Program responsible for engaging with 40+ countries in Sub-Saharan Africa.

Principal Investigator Profile: *Prof. Alex Bataller* NORTH CAROLINA STATE UNIVERSITY

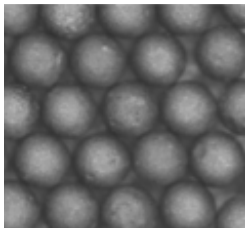
Dr. Bataller received his B.S. in Engineering-Physics from the University of Arizona in 2007, followed by his Ph.D. in Physics from the University of California, Los Angeles (UCLA) in 2014. Following his graduate studies, Bataller was the laboratory director of the Putterman research group at UCLA from 2014-2015. Prior to his joining the Department of Nuclear Engineering at NC State in 2019, Bataller was a postdoctoral fellow at NC State in the Department of Physics from 2015-2017 and a research assistant professor from 2017-2019. Dr. Bataller's research group specializes in the application of ultrafast laser techniques for probing matter in extreme environments with a particular focus on molten salts for advanced nuclear energy applications. Molten salt research topics include thermophysical property characterization and their microscopic origins, ultrafast photochemistry of solvated electrons, THz spectroscopy, and plasma engineering for nuclear material accountancy.

MPACT Technical Update Highlight – *TRISO Fuel Fabrication MC&A*

ORNL, LANL, and SNL has been working on a technical R&D plan to address the nuclear material control and accounting (MC&A) needs for advanced reactor fuel fabrication facilities. It reviewed and evaluated the current US advanced fuel fabrication landscape and proposed MC&A methods and compared them with current US Nuclear Regulatory Commission (NRC) regulations. Several gaps were identified regarding how these fuel fabrication facilities can meet MC&A goals. Those goals were then prioritized. The purpose of this report is to identify measurement types and measurement locations for tristructural isotropic (TRISO) fuel manufacturing that can be used for MC&A.

US TRISO fuel manufacturers were engaged in this effort and the results presented can be applied broadly to all TRISO fuel manufacturing since many of the processes are similar. Specifically, LANL is collaborating with Kairos Power to provide fuel for the Hermes demonstration reactor. As LANL prepares to bring the Low Enriched Fuel Fabrication Facility (LEFFF) online, preliminary material balance areas (MBAs) and key measurement points (KMPs) for the TRISO process have been identified. ORNL collaborated with Ultra Safe Nuclear Corporation (Now Standard Nuclear) to perform holdup measurements to identify potential material accumulation and determine strategies for measurement locations and methods. Furthermore, nondestructive analysis (NDA) and destructive analysis (DA) were conducted on materials collected at specific points in the fabrication process to identify potential measurement technologies and determine the accuracy of those measurements.

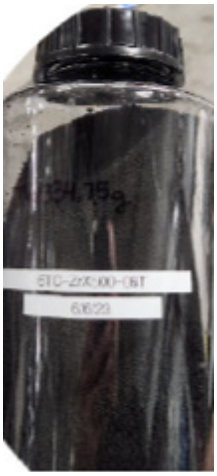
TRISO fabrication process flow material measurements. Samples received from USNC and are being analyzed via Mass Spec, Davis Gray, Titration, Raman Spectroscopy, and Laser Fluorescence Spectroscopy.
(Courtesy of Oak Ridge National Laboratory)



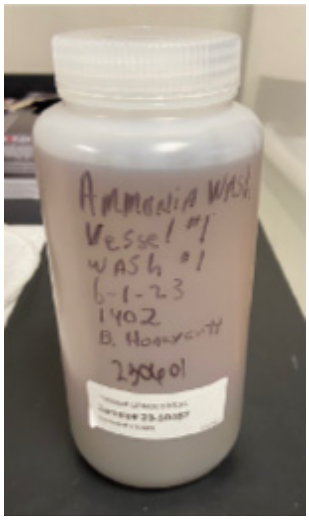
Dense Kerels

ADUN

Dry Gel Spheres

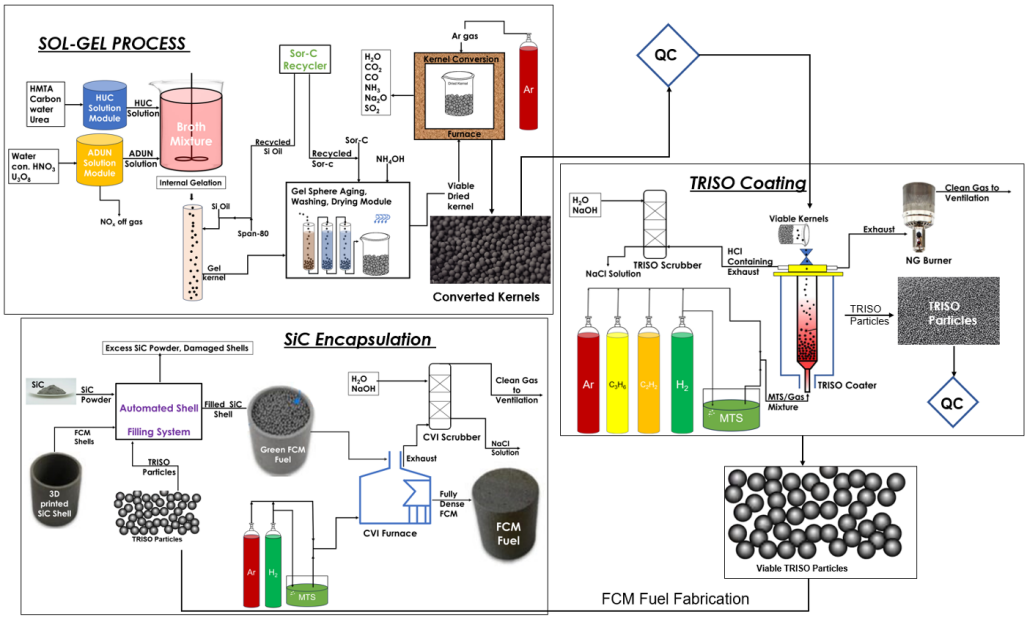


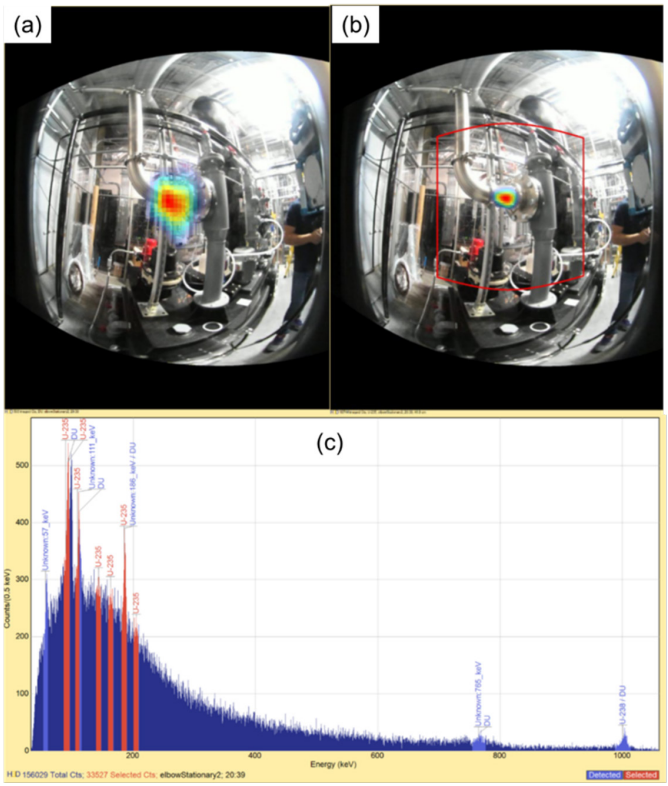
TRISO Particles



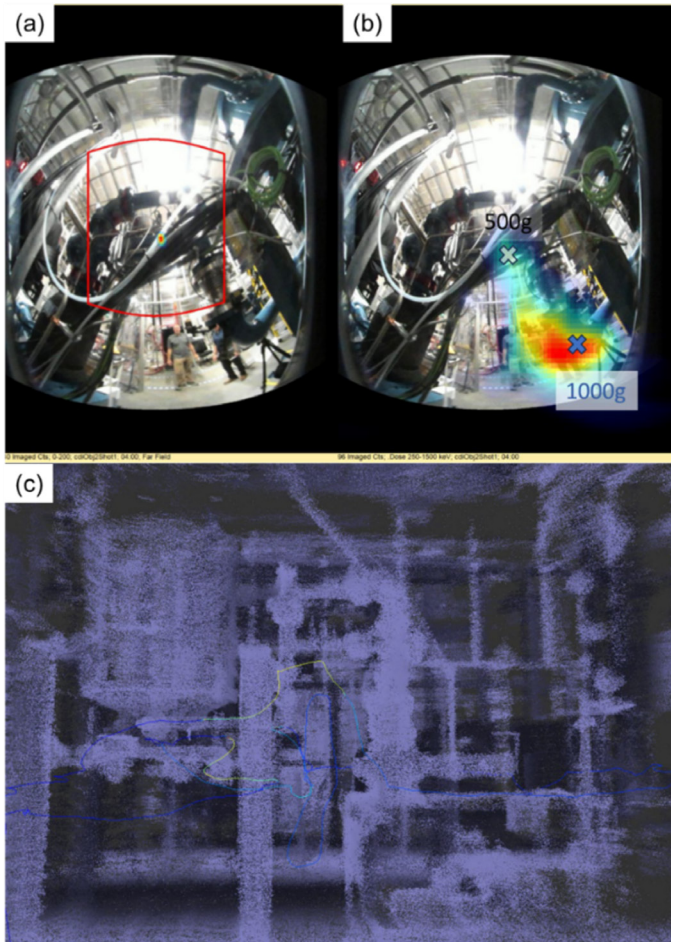
Ammonia Wash

A generic flow diagram for manufacturing of fully ceramic microencapsulated TRISO fuel.

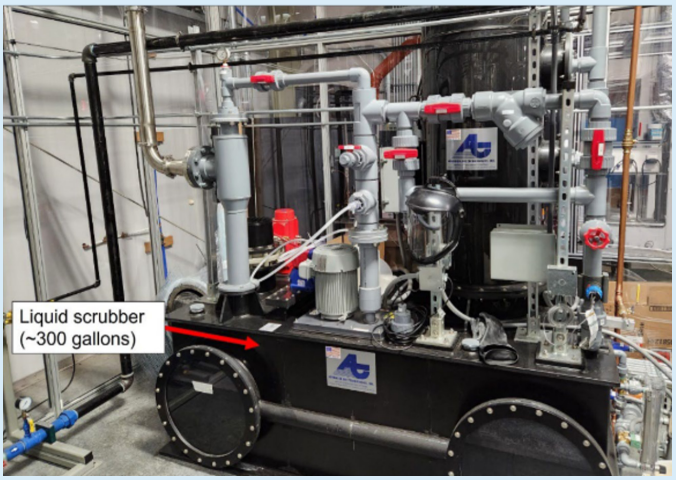




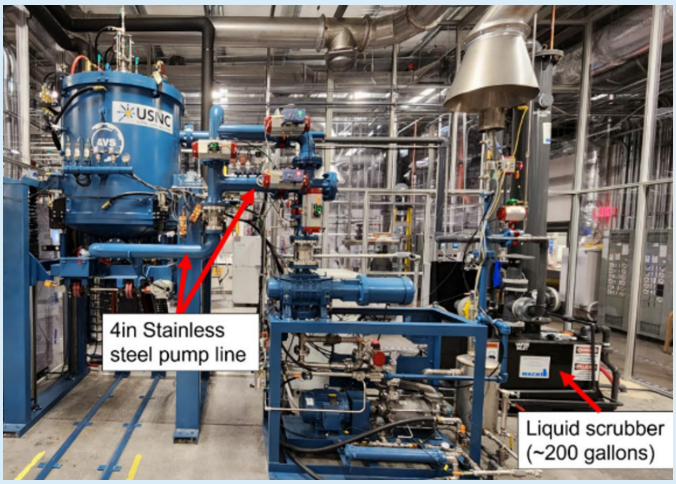
(a) Compton image of ^{238}U gamma-rays. (b) *Coded aperture image of ^{235}U gamma-rays and uranium x-rays. The reconstructed object is extended, larger than one image pixel, in the lateral dimension.* ***(c)*** *Recorded gamma-ray spectrum.*



(a) Coded aperture image of low-energy gamma-rays and x-rays. *The 1 kg source is outside the coded aperture field-of-view.* ***(b)*** *Compton image of high-energy gamma-rays.* ***(c)*** *3D dose rate map of the CVI. Note that reconstructions in (b) are noisy because of the limited, 4-minute dwell time. Both the 500 g (top center) and 1 kg (bottom right) samples are visible in the associated Compton reconstruction. Note that the apparent source strength at the detector location is the multiplication of source mass/surface area, shielding attenuation, and $1/r_2$.*



SiC coating system scrubber tank.

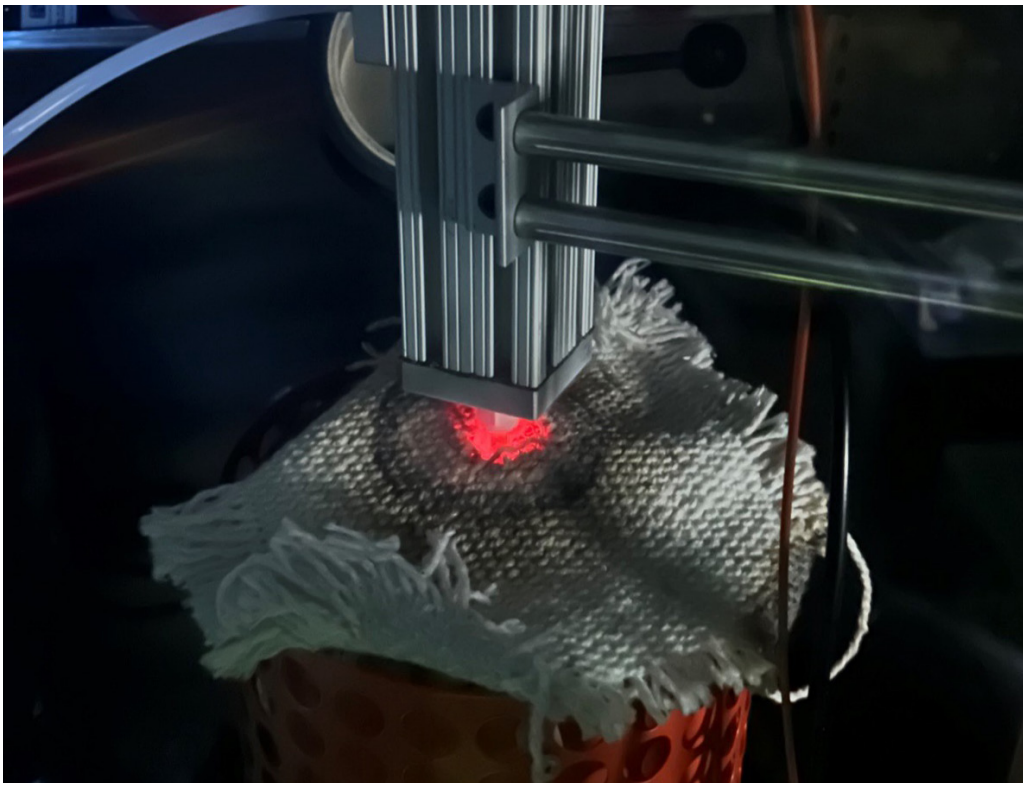


CVI system for production of final fuel form.

MPACT Technical Update Highlight – *Plasma-Bubble Spectroscopy*

The development and commercialization of advanced nuclear reactors utilizing molten salts introduces new challenges for nuclear material accountancy. Among them is the inherent mobility of nuclear material in a liquid state. Elemental and isotopic sensors for real-time monitoring could help address this challenge by providing accurate material quantification. However, the extreme conditions found in molten salt reactors and pyroprocessing facilities (i.e., high temperature, corrosion, and radiation) have impeded many conventional analytic techniques from future deployment. But new challenges stimulate new innovations, and researchers are exploring alternative methods and robust sensor designs. With support from the DOE under the MPACT program, Prof. Bataller's research group at NC State has developed a novel plasma-based sensor that combines the analytic capabilities of an atmospheric glow discharge with the robust architecture of a bubbler. The overall method, which we've called "Plasma Bubble Spectroscopy", has been demonstrated on a variety of liquid systems that include aqueous solutions, liquid metals, and molten salts. For the latter, elemental detection limits have been demonstrated at the ppb level and narrow spectral linewidths enable isotopic differentiation of the lightest and heaviest elements (e.g., tritium and uranium).

An important goal for the plasma sensor is to demonstrate its performance on complex, "real world" salts that contain many heavy elements. This demonstration will be performed on salts from the Hot Fuel Examination Facility (HFEF) at Idaho National Laboratory (INL) in collaboration with Dr. Ammon Williams. The NC State research team, composed of graduate students Kayla Hahn, Davis Bryars, Munmun Jahan, and Alina Jugan, has recently developed a new version of the sensor called the Submerged Plasma for Isotopic Differentiation and Elemental Resolution (SPIDER) that will be used for the HFEF tests. The SPIDER probe features a simplified architecture with off-the-shelf feedthroughs and low-cost, robust materials, which has helped reduce experimental setup times from days to hours. With the SPIDER probe developed and a new radiation laboratory at NC State, upcoming experiments will be performed to characterize many more salt species, including uranium salts. These efforts will culminate in a first-of-a-kind measurement at INL that will bring us one step closer to online material accountancy of molten salts.



Photograph of the SPIDER probe at NC State performing real-time measurements on molten LiCl-KCl-CeCl3. A red glow from the plasma discharge can be seen emanating from the sensor head.

MPACT Contacts

TANSEL SELEKLER
Federal Program Manager
tansel.selekler@nuclear.energy.gov

MICHAEL BROWNE
National Technical Director
mcbrowne@lanl.gov

COLIN CARROLL
Deputy National Technical Director
ccarroll@bnl.gov

JACKI WALSH
Control Account Manager
jacquelyn.walsh@lanl.gov

The MPACT newsletter is prepared by INL in coordination with all MPACT labs.

Idaho National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratories, Argonne National Laboratory, Oak Ridge National Laboratory, Brookhaven National Laboratory, Los Alamos National Laboratory.

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