INL/MIS-23-70913-Revision-0



# December 2022 NS&T Highlights

January 2023

Addison Marie Arave

Changing the World's Energy Future

Idaho National Laboratory

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INL/MIS-23-70913-Revision-0

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**Addison Marie Arave**

**January 2023**

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**Idaho Falls, Idaho 83415**

**http://www.inl.gov**

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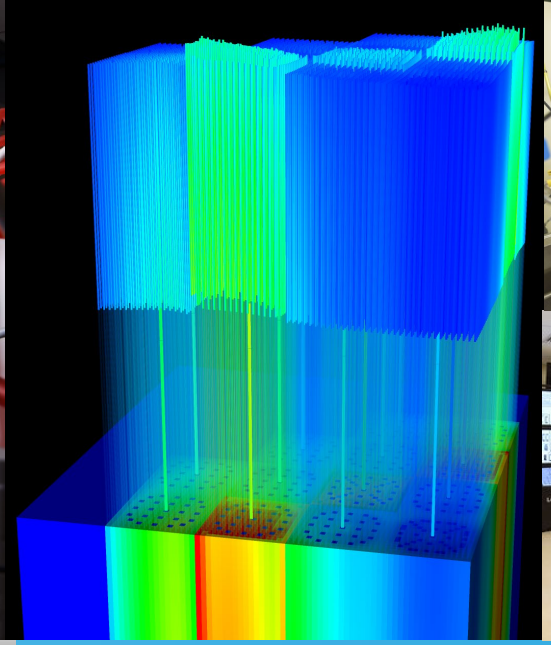
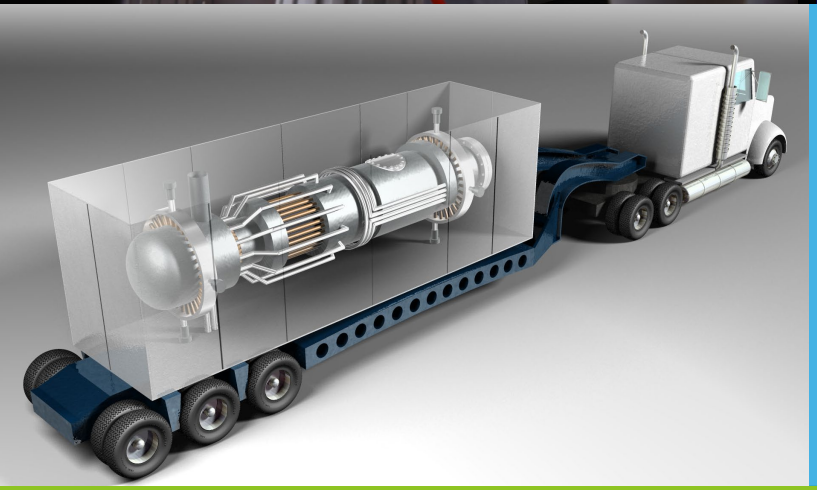
**U.S. Department of Energy**
**Under DOE Idaho Operations Office**
**Contract DE-AC07-05ID14517**



# Nuclear Science & Technology

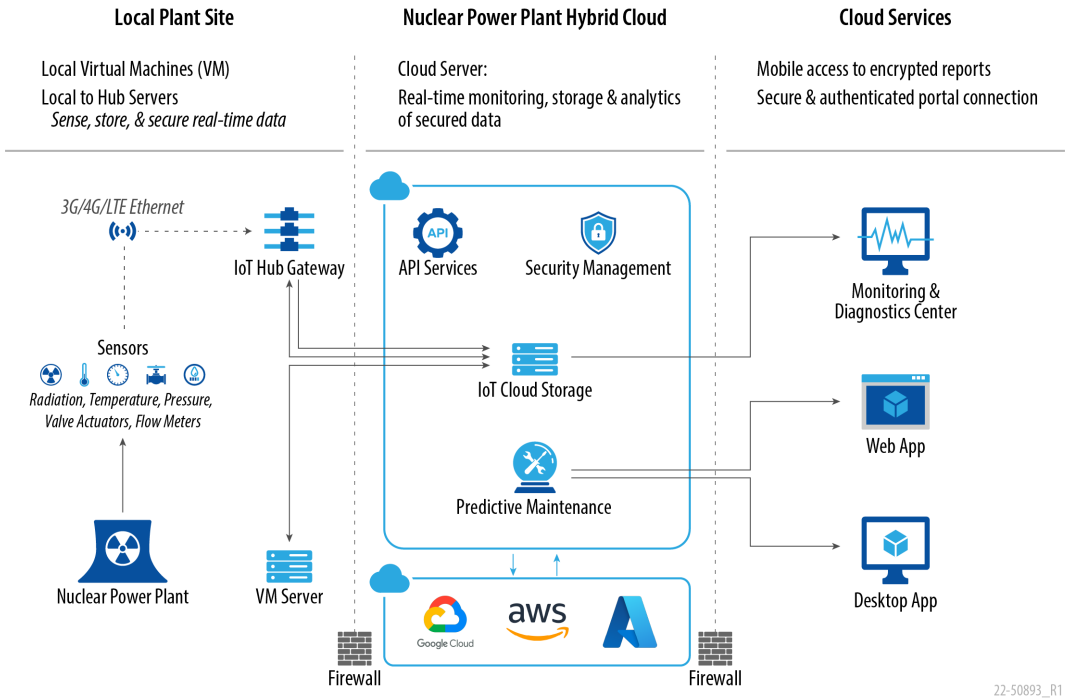
## December 2022 Highlights

Idaho National Laboratory

*DOE-NE Light Water Reactor Sustainability Program*

# Cloud Computing Shows Potential as a Cost-effective Alternative for Predictive Maintenance for the Current Reactor Fleet

- Light Water Reactor Sustainability Program researchers at Idaho National Laboratory (INL), Blue Wave AI Labs, and Oak Ridge National Laboratory (ORNL) completed a techno-economic analysis of cloud computing resources to evaluate the feasibility of transitioning from an onsite to a cloud-based predictive maintenance program.
- This effort concluded that there are significant advantages to moving the predictive maintenance-related data and applications to the cloud, such as improved security, adaptable computing/storage capabilities, broad network access, Internet of Things compatibility, and simplified application programming interface.
- This development would also feature improved situational awareness through expanded deployment of wireless sensors, along with a distributed antenna system.
- Regulatory requirements were considered for the transition from an onsite to cloud-based maintenance program for non-safety-related systems.




*Proposed high-level architecture of the hybrid cloud.*

**Title:** Development of a Cloud-based Application to Enable a Scalable Risk-informed Predictive Maintenance Strategy at Nuclear Power Plants INL/RPT-22-70543
**Authors:** Rita Appiah (INL), Cody Walker (INL), Vivek Agarwal (INL), Jonathan Nistor (BlueWave), Tom Gruenwald (BlueWave), Michael Muhlheim (ORNL), Pradeep Ramuhalli (ORNL)
**Link:** https://doi.org/10.2172/1906501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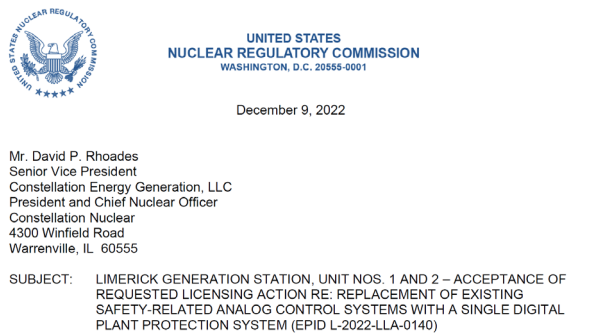
*DOE-NE Light Water Reactor Sustainability Program - Cooperative Research and Development Agreement with Constellation Energy Generation*

# Light Water Reactor Sustainability Program Research Supports License Amendment Request for Digital Upgrade

- Light Water Reactor Sustainability Program researchers, in collaboration with Constellation, Westinghouse, and Sargent & Lundy, produced four reports to support a safety-related digital instrumentation and control upgrade at Constellation's Limerick Generating Station. The reports address:
  - Human Factors Engineering (HFE) Program Planning and Management
  - Operating Experience Review
  - Function Analysis & Allocation and Task Analysis
  - Human-System Interface Style Guide
- The LWRS Program reports were provided to the U.S. Nuclear Regulatory Commission (NRC) by Constellation Energy in support of the Limerick digital upgrade License Amendment Request that was submitted to the NRC on September 26 and accepted on December 9.
- The NRC did not identify any HFE items in the License Amendment Request acceptance letter that needed additional information.
- In support of this activity, the Department of Energy is providing $50 million in a cost sharing project with Constellation Energy to digitalize the control room at the company's Limerick nuclear power plant.



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

December 9, 2022

Mr. David P. Rhoades
Senior Vice President
Constellation Energy Generation, LLC
President and Chief Nuclear Officer
Constellation Nuclear
4300 Winfield Road
Warrenville, IL 60555

SUBJECT: LIMERICK GENERATION STATION, UNIT NOS. 1 AND 2 – ACCEPTANCE OF REQUESTED LICENSING ACTION RE: REPLACEMENT OF EXISTING SAFETY-RELATED ANALOG CONTROL SYSTEMS WITH A SINGLE DIGITAL PLANT PROTECTION SYSTEM (EPID L-2022-LLA-0140)

*License Amendment Request Acceptance Letter From the NRC.*

*HFE Task Analysis Team including Constellation, INL, and Westinghouse.*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LWRS LIGHT WATER REACTOR SUSTAINABILITY

*DOE-NE Light Water Reactor Sustainability Program - Cooperative Research and Development Agreement with Constellation Energy Generation*

# INL Hosts Conceptual Verification of Limerick Safety-Related Instrumentation and Control Upgrade to Human-System Interfaces

- Conceptual verification (CV) occurs during the project design phase to ensure that human system interface (HSI) development is converging.
- CV for this particular project included an evaluation of HSIs that support manual operator actions impacted by the safety-related digital instrumentation and control upgrade project scope.
- In collaboration with Constellation, Westinghouse, and CORYS, INL prepared the facilities for and coordinated the execution of this evaluation during the week of December 5, 2022.
- Per the Nuclear Regulatory Commission License Amendment Acceptance letter, Constellation will submit the "Human Factors Engineering Conceptual Verification Results Summary Report" by February 9.
- Findings will improve HSI designs and set the stage for HSI Preliminary Validation scheduled for February 2023.

*Limerick Generating Station.*

*Human-system interface conceptual verification with plant operations personnel at INL Engineering Innovation Laboratory.*


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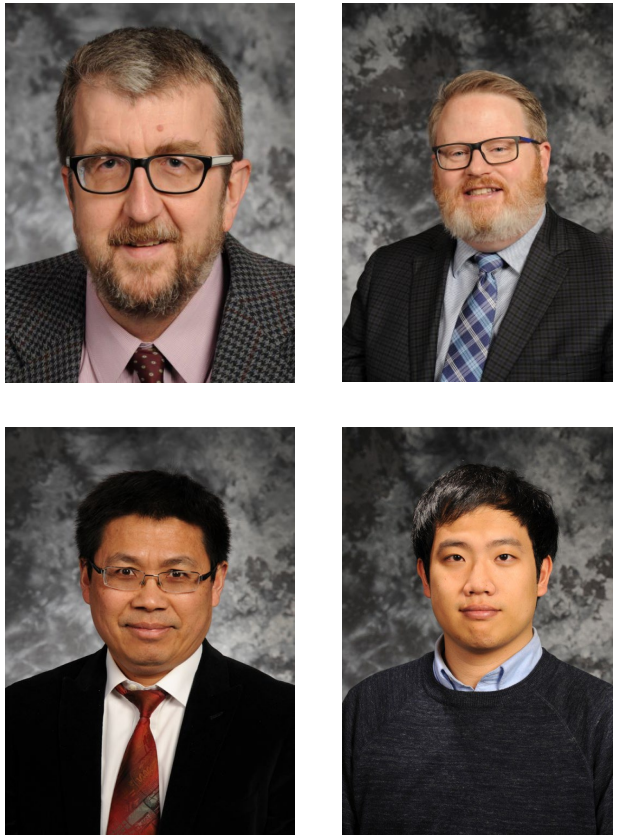
# Nuclear Science and Technology Employees Represent INL at the Asian Symposium on Risk Assessment and Management

- The INL Nuclear Safety and Regulatory Research (NSRR) Division has a strong presence in South Korea's nuclear industry and they participated heavily in the Asian Symposium on Risk Assessment and Management (ASRAM) 2022.
- At ASRAM 2022, Dr. Curtis Smith was invited to present a plenary speech on "Nuclear Safety and Regulatory Research and Development"; Dr. Ron Boring presented "Dynamic Human Reliability Analysis (HRA) with HUNTER (Human Unimodel for Nuclear Technology to Enhance Reliability)" in a special session; and Dr. Zhegang Ma provided "An Overview of 2020 U.S. Probabilistic Risk Assessment (PRA) Parameter Update and Its Impact on Internal and External Hazards PRA Model".
- Before and after ASRAM 2022, the INL team hosted several workshops with the nuclear regulators, industry representatives, and universities from South Korea.
  - This gave an opportunity to highlight INL's unique capability in risk assessment and human reliability analysis (including the "INL's HRA Data Collection Framework" by Jooyoung Park), introduce the United States' nuclear operating experience program, and the parameter estimates for probabilistic risk assessment.



*Dr. Curtis Smith (top, left), Dr. Ron Boring (top, right), Dr. Zhegang Ma (bottom, left) and Jooyoung Park (bottom, right).*

NUCLEAR SAFETY AND REGULATORY RESEARCH
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*U.S. Nuclear Regulatory Commission Nuclear Operating Experience Program*

# INL Presents Workshop to South Korean Industry on American Nuclear Operating Experience Program

- INL staff held a workshop for South Korean Nuclear Industry on December 5–6 in Daejeon, South Korea regarding the overall process within the operating experience program including discussion of various analyses, quality control activities, and a question-and-answer session with participants.
- Workshop participants included INL, Korea Atomic Energy Research Institute, and Korea Hydro and Nuclear Power.
- INL has been providing technical assistance to the Nuclear Regulatory Commission (NRC) in the areas of reliability and risk analysis, including the U.S. nuclear operating experience program, since the 1980s.
- The publication on Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants (NUREG/CR 6928), and its subsequent updates, provide U.S. industry-average parameter estimates for probabilistic risk assessment that are used by the nuclear industry, both national and international.
- South Korea is developing a nuclear operating experience program with the aim to create a Korean-specific data book similar to NUREG/CR 6928.

*Group photo of participants from the INL-South Korea workshop.*


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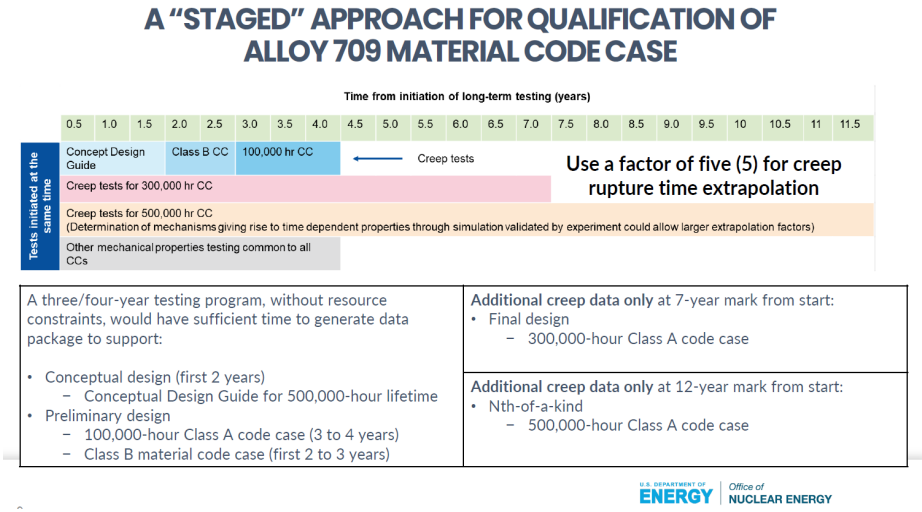
U.S.NRC
United States Nuclear Regulatory Commission
*Protecting People and the Environment*

# INL Nuclear Science and Technology Directorate Contributes to DOE-Office of Nuclear Energy Fast Reactor Program Review

- Nuclear Science and Technology directorate (NS&T) staff participate in the Department of Energy Office of Nuclear Energy (DOE-NE) 52 Fast Reactor Program Review at Argonne National Laboratory (ANL) December 13–15.
- Dr. Sam Sham provided an update on current and future advanced fast reactor materials research and development activities that are a collaborative effort between ANL, Oak Ridge National Laboratory, and INL.
- Dr. Sham's update included information on the status of America Society of Mechanical Engineers (ASME) staged code qualification and sodium compatibility study of Alloy 709.
- These efforts will help establish necessary data for an ASME Alloy 709 code case to support sodium fast reactor design and construction, and sodium compatibility data to support licensing and operation.
- Sanjay Mukhi, National Reactor innovation Center (NRIC) collaborations manager, furthered NRIC efforts in support of the ANL Mechanisms Engineering Test Loop facility—a critical sodium components testing facility for fast reactor research and development.
- Scott Ferrara from NS&T's Regulatory Development group collaborated on regulatory development efforts to provide a regulatory path for accelerated materials deployments for advanced reactor materials.





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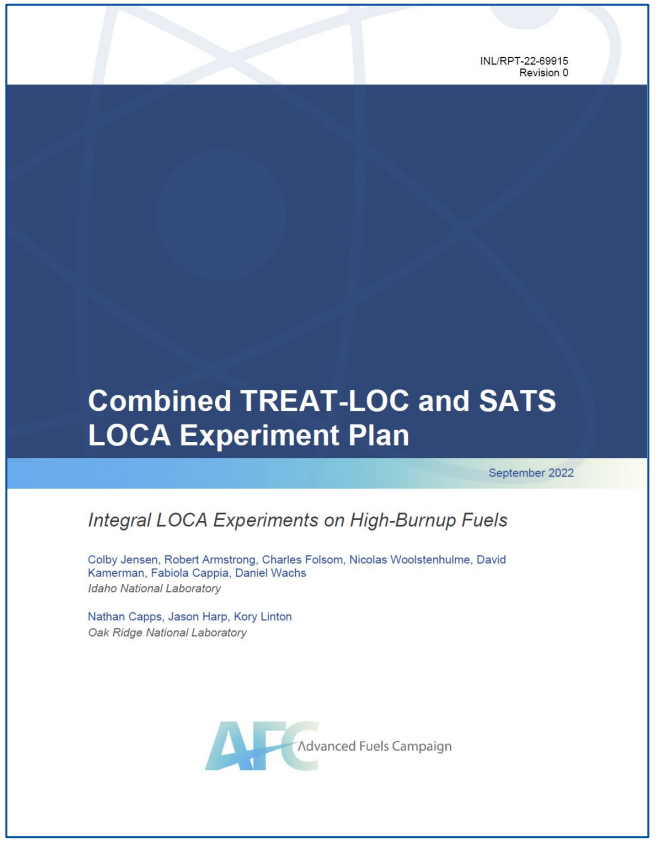
*DOE-NE Advanced Fuels Campaign*

# Advanced Fuels Campaign Consensus Loss-of-Coolant Accident Test Plan Presented at International Atomic Energy Agency Technical Meeting

- The presentation was given at the International Atomic Energy Agency Technical Meeting on Safety and Performance Aspects in the Development and Qualification of High Burnup Nuclear Fuels for Water-Cooled Reactors which was held in Vienna, Austria from November 15–18.
- The collaborative meeting included presentations from international research organizations, utilities, and regulators with participants from 21 countries.
- The Advanced Fuels Campaign consensus test plan details upcoming high-burnup integral Loss-of-Coolant Accident experiments to be performed in-pile at INL in the Transient Reactor Test (TREAT) Facility and out-of-pile at Oak Ridge National Laboratory in the Severe Accident Test Station.
- The systematic integration of in- and out-of-pile experiments aims to support light water reactor fuel burnup extension by achieving an improved understanding of fuel fragmentation, relocation, and dispersal.


INL/RPT-22-69915
Revision 0

Combined TREAT-LOC and SATS LOCA Experiment Plan

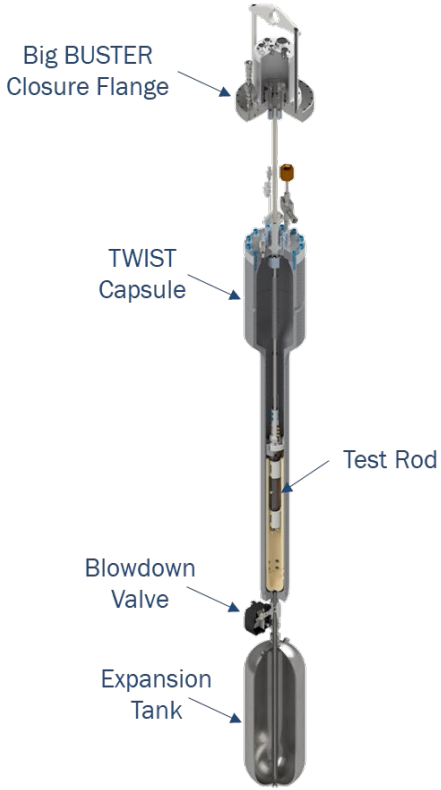
September 2022

*Integral LOCA Experiments on High-Burnup Fuels*

Colby Jensen, Robert Armstrong, Charles Folsom, Nicolas Woolstenhulme, David Kamerman, Fabiola Cappia, Daniel Wachs
*Idaho National Laboratory*

Nathan Capps, Jason Harp, Kory Linton
*Oak Ridge National Laboratory*

AFC Advanced Fuels Campaign




*Schematic of INL's Loss-of-Coolant Accident experiment vehicle; Transient Water Irradiation System for TREAT (TWIST).*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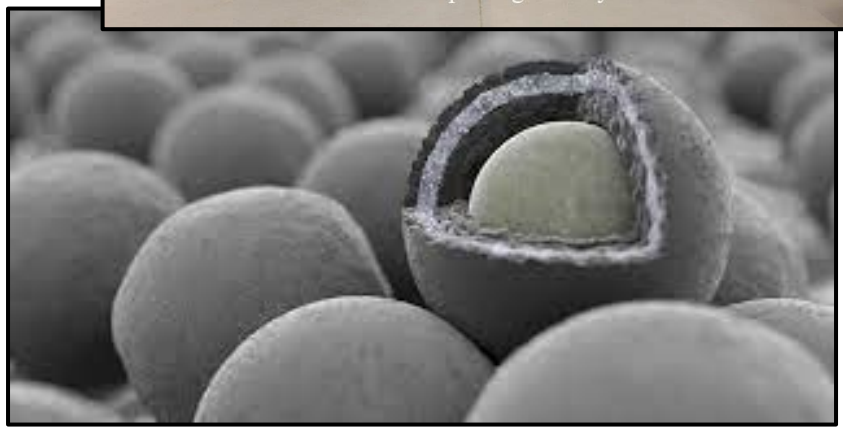
*Department of Defense - Strategic Capabilities Office Pele Program*

# BWX Technologies Begins Tristructural Isotropic Fuel Production for Pele Microreactor at the December 7, 2023 Event

- BWX Technologies (BWXT) announced it has reached production capable status for supplying tristructural isotropic (TRISO) fuel quantities to meet Department of Defense microreactor needs.
- BWXT is the nation's only licensed facility capable of producing TRISO fuel from high-assay low-enriched uranium (HALEU).
- This production is a culmination of over 20 years of research, development, and collaboration between BWXT, INL, Oak Ridge National Laboratory, DOE, and Department of Defense-Strategic Capabilities Office.
- INL awarded a contract of nearly $37 million to BWXT to manufacture TRISO fuel for the Project Pele core.


BWXT TRISO Compacting Facility Heat Treat Furnaces


*TRISO fuel particle showing protective layers of carbon and silicon carbide on a uranium oxycarbide fuel particle.*

REACTOR SYSTEMS DESIGN & ANALYSIS | SPECIAL REACTOR CONCEPTS
Justin.Coleman@INL.gov

# INL Researcher Dr. Jackson Harter Lectures at University of Wyoming

- On November 30, Dr. Jackson Harter gave a lecture at the University of Wyoming (UW) on morphological-informed, multiphysics, multiscale nuclear material modeling. Harter highlighted the importance of using true first-principles approaches and removing dependence on correlations and empirical formulae for nuclear fuel modeling.
- Research in nuclear energy is of particular interest to UW given the announcement of TerraPower's Natrium™ nuclear power plant (345 MWe sodium fast reactor) demonstration in Kemmerer, Wyoming.
- As part of this visit, Dr. Harter met with multiple UW faculty in the Chemistry, Chemical Engineering, Mechanical Engineering, and Physics departments; the School of Computing; and the UW co-director for the Nuclear Energy Research Center (NERC).
  - Harter plans to collaborate on this holistic methodology with UW faculty, other universities, and INL staff.



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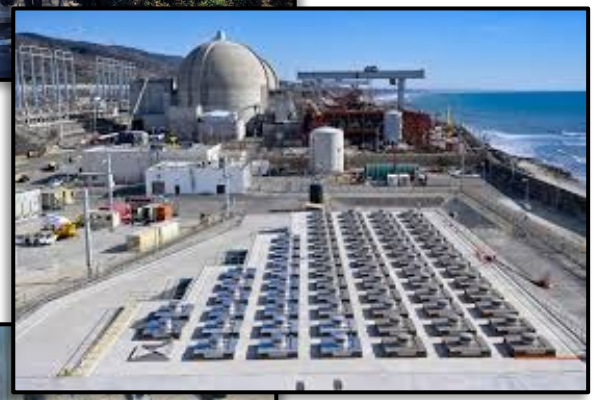
*DOE-NE Advanced Fuels Campaign*

# Advanced Fuels Campaign Reviews Accomplishments at Integration Meeting

- This annual meeting held December 6–9 featured major accomplishments from the Advanced Fuels Campaign for fiscal year 2022.
- The meeting included over 90 collaborators and presenters from the Department of Energy (DOE), the United States Nuclear Regulatory Commission (NRC), multiple national laboratories, industry, utility partners, and universities participating in the Nuclear Energy University Program.
- The annual meeting was held at the General Atomics campus in San Diego and included a tour of the DIII-D National Fusion Facility and the San Onofre Nuclear Generating Station (SONGS).
- SONGS is in the process of decommissioning, so the tour provided an opportunity to see the current stage of deconstruction and to visit the on-site spent fuel storage.

*Attendees of the Advanced Fuels Campaign meeting at the General Atomics campus in San Diego.*



*SONGS commercial power plant, currently undergoing decommissioning.*

*GA's experimental fusion device, DIII-D National Fusion Facility*

# Publications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- Zhang J., Yao T., Murray D., Di Lemma F., Zhuo W., Williams W., Teng F., Benson M.. 2023. "The formation mechanism of the Zr rind in U-Zr fuels." JOURNAL OF NUCLEAR MATERIALS. Vol. 572. https://doi.org/10.1016/j.jnucmat.2022.154057

# Patents

- Abderrafi M. Ougouag, R. Sonat Sen, and George W. Griffith. “Heat Transfer Systems for Nuclear Reactor Cores, and Related Systems,” US11508488B2. https://pat2pdf.org/patents/pat11508488.pdf