

Gateway for Accelerated Innovation in Nuclear February 2018 Highlights Report

GAIN NEAMS Workshop for MSR Developers

February 27-28: **GAIN NEAMS MSR Workshop.** Nuclear Energy Advanced Modeling and Simulation (NEAMS) developers met with representatives of the Molten Salt Reactor (MSR) Technology Working Group (TWG) at Argonne National Laboratory (ANL) to provide a hands on training experience with NEAMS codes. All MSR vendors were represented at the working meeting. Topics included fuel performance modeling, systems analysis, computational fluid dynamics, neutronics, structural mechanics, flow-induced vibration, and work flow management. The meeting culminated with an executive session on March 1 that provided vendors with an opportunity to provide feedback to NEAMS leadership. Such input is valuable for NEAMS to set programmatic priorities that are commensurate with vendor needs.

Status of GAIN NEAMS NRC Modeling and Simulation Integration Effort

In anticipation of the Nuclear Regulatory Commission (NRC) license review of advanced non-light water reactor designs, a new inter-agency agreement was initiated early in FY 2018 between INL and NRC to support the development and validation of NRC's evaluation model for advanced non-LWR designs. In particular, this agreement expands code development for MOOSE-based applications (i.e., Pronghorn, MAMMOTH, and Rattlesnake) for the analysis of gas-cooled reactors and also includes the BISON nuclear fuel performance code for use in non-light water reactor designs. The resulting evaluation model will be composed of both NRC legacy codes and new MOOSE-based tools developed under DOE's NEAMS program.

This NRC effort on modeling and simulation has been greatly expanded to include BISON-TRACE coupling to look at coping times for Accident Tolerant Fuel (ATF) concepts. A meeting was held October 17-19, in Bethesda, Maryland at NRC to discuss coupling NRC's TRACE system/safety analysis code to BISON, the NEAMS nuclear fuels performance modeling and simulation tool and to provide NRC staff training on MOOSE/BISON.

As a result of this meeting, a MOOSE-Wrapped Application, called **Blue CRAB (Comprehensive Reactor Analysis Bundle)**, named by NRC, was stood up to couple MOOSE tools (Pronghorn, MAMMOTH, Rattlesnake, BISON) and NRC tools (TRACE , PARCS, MELCOR). Under Blue CRAB, TRACE and BISON are now compiled under one executable capable of interleaved execution and information exchange. Blue CRAB can spawn single or multiple instances of TRACE (good for probabilistic analysis, PRA). BISON and TRACE are now coupled through continuous heat flux with BISON 2D r-z axisymmetric heat structure. Future work includes implementation of TRACE 1.5 D heat structure with BISON 1.5D heat structure; MOOSE adaptive mesh consistent with TRACE for LOCA events; and incorporate cladding displacements from BISON. GAIN, NEAMS, and NRC are working together to understand the ramifications of using modern DOE tools to support regulatory needs.

Legacy Information

February 21: The **Bibliography of Publications on Experimental Breeder Reactor (EBR-II)**, Revision 5, dated August 1992, was reviewed and approved for external release. The document, published by Argonne National Laboratory, covers EBR-II publications from 1955 through August of 1992. It is available on the GAIN Website, Resources Tab, under Fast Reactor.

February 26: The **TREAT Experimental Relational (TREXR) Database** website is now accessible from all Department of Energy laboratories. TREXR provides web access to valuable legacy information from past testing of nuclear fuels and materials in TREAT, including published articles, technical reports, and data from tests and post-test examinations. There are presently 20 users in the national lab space. In order to allow US industry and educational institutions access to protected TREXR content, an additional layer of security is being added: multifactor user authentication (MFA) using Duo. Duo user licenses have been ordered and are expected to arrive in early March. Once licenses are available, Duo MFA will be implemented for all TREXR users. Then, users from US industry will be able to access TREXR content by authenticating with an Argonne collaborator account (username/password combination) and Duo (via smartphone app or landline callback).

February: A meeting was held with Tennessee Valley Authority (TVA) to evaluate the potential value in archived records from the **Clinch River Breeder Reactor (CRBR)** project. Three ORNL senior staff, with experience on CRBR project and knowledge of the archived reports, met with TVA to go through a number of the records boxes to determine whether the reports were of value, and whether they are already part of the national archive. It was determined that there were documents in the sample set that were not available elsewhere, which included a number of reports from the designer and developer organizations that were part of the licensing submittal to NRC. Based on the review, it is highly likely that the reports will be of value to the fast reactor developers. The path forward to create electronic records of the reports will be developed.

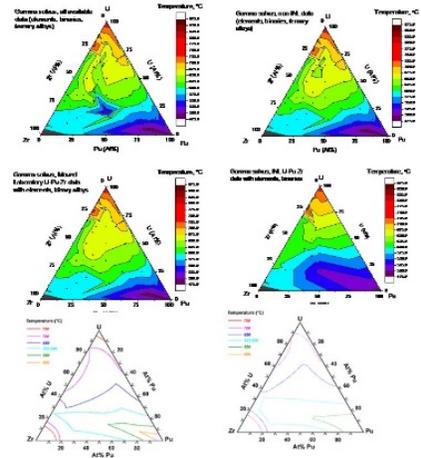
Outreach

On February 15, Rita Baranwal presented GAIN to the **Rolls-Royce NAYGN (North American Young Generation in Nuclear)** chapter meeting, which was held at Robert Morris University (RMU) in Pittsburgh, PA. Attendees included employees from Rolls-Royce, Westinghouse, University of Pittsburgh, and RMU students.

On February 21, Rita Baranwal presented GAIN updates at the **U.S. NIC Advanced Reactor Summit** in College Station, Texas. Over 200 attendees participated in summit, which included presentations from industry, government, and laboratories, as well as tours of Texas A&M University facilities.

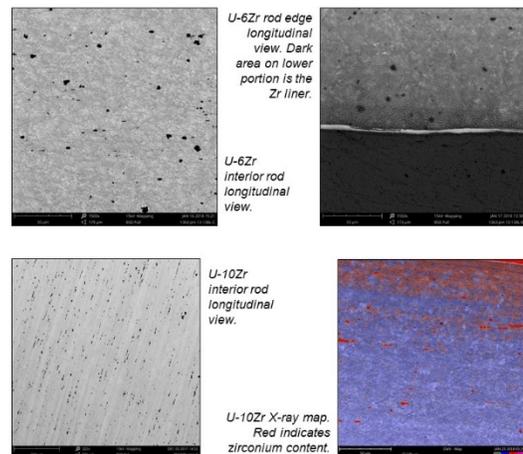
February Technical Advances

INL. The Metallic Fuels Handbook is produced each year to summarize and capture current state of the art in metallic fuel properties and characteristics. A new feature of the 2018 Handbook will be the incorporation of ternary plots generated with Origin software. The new plots will make it easier to compare and understand data from complex alloys (U-Pu-Zr alloys shown in the figure). The data combine experimental results from different sources to produce new insights into metallic fuel behaviors that is not possible using traditional 2-D plots. This work is supported by the Nuclear Technology R&D (NTRD) Program.

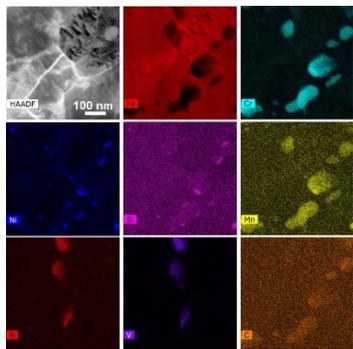


INL. Tested AGR 3/4 compact with the FACS furnace. The test involved heating the compact in the fuel accident condition simulator (FACS) furnace to a peak temperature of 1200°C, while collecting fission products released from the compact for subsequent analysis. One of several features of Advanced Gas Reactor (AGR)-3/4 that sets it apart from AGR-1 and AGR-2 is the incorporation of 20 designed-to-fail (DTF) particles in each compact. The fuel kernels in the DTF particles were coated with a thin (20 μm thick) pyrocarbon layer, having high anisotropy such that the coating is likely to fail during the irradiation, resulting in up to 20 exposed kernels per compact. One of the main goals of this test was to assess the retention of fission products in the exposed kernels and the surrounding graphitic matrix material comprising the compact.

INL. Microstructure characterization on extruded rods was completed. The Advanced Fuels Campaign is investigating extrusion as a fabrication process for advanced metallic fuels. Co-extrusion of Zr/U-Zr fuel rods has been shown to be a feasible approach for fuel fabrication for high burn-up and advanced fuel. Samples were taken from the beginning, middle, and end of the sectioned extruded rods. SEM characterization showed expected deformed grain structure in the longitudinal view, although it was much less noticeable in the U-6Zr versus the U-10Zr composition. A zirconium content gradient seen from the fuel next to the liner material was substantially higher than the interior of the fuel.



ORNL. Three potential flow paths were identified for converting spent light water reactor (LWR) fuel into fluoride salts for use as feed to the Muons accelerator driven reactor. Material balances yielding fuel compositions are near completion, after which ORNL will work with Muons to determine if any of the flowsheets are not viable due to inclusion of elements in the feed that may have unacceptably adverse impacts on reactor neutron economy.



INL. Characterization of neutron-irradiated HT9 steels. HT9 is a high-chromium martensitic steel with demonstrated performance in fast reactors as fuel cladding and duct material. Irradiation induces the formation of dislocations, voids, precipitates, and segregation, which affect the mechanical behavior of HT9. **Microstructural characterization was performed on HT9 steel** irradiated at the Advanced Test Reactor (ATR) to 5 dpa (displacement per atom) at 550°C. This work was supported by the Nuclear Science User Facilities (NSUF) program with University of Illinois Urbana-Champaign.

Scanning transmission electron microscopy (STEM) image and energy dispersive spectroscopy (EDS) maps showing Ni-Si segregation at grain boundaries and (Cr, Mn)

carbides and vanadium nitride precipitates in irradiated HT9. High-angle annular dark-field (HAADF) STEM, iron (Fe), chromium (Cr), nickel (Ni), silicon (Si), manganese (Mn), nitrogen (N), vanadium (V), and carbon (C)

ORNL. New accident tolerant fuel (ATF) cladding, conceived, developed, manufactured, and tested at ORNL, has been manufactured by Global Nuclear Fuels (GNF) into lead test assemblies, and shipped to Southern Nuclear Operating Company for trials in Edwin I Hatch plant. The FeCrAl cladding, called IronClad (see figure), will be the first developed through DOE's Enhanced ATF program to be installed in a commercial nuclear reactor. The new alloy was designed from scratch with a diverse team that included experts in nuclear engineering, materials science, radiation effects, corrosion, thermomechanics, and alloy fabrication. The new cladding was tested at ORNL's High Flux Isotope Reactor and INL's Advanced Test Reactor, as well as the Halden research reactor in Norway.



Articles of Interest

February 6: The **House Committee on Energy and Commerce, Subcommittee on Energy** held a hearing to discuss the challenges facing America's nuclear infrastructure, including advanced reactor development. The hearing was called "DOE Modernization: Advancing the Economic and National Security Benefits of America's Nuclear Infrastructure." Key topics of interest included:

- National security implications associated with U.S. nuclear leadership and a domestic nuclear energy industry
- Outlook for domestic and international development of nuclear energy and application of nuclear technologies
- Challenges and opportunities maintaining the components of a domestic nuclear fuel cycle
- Options to develop and deploy advanced nuclear technologies.

Several hearing witnesses provided statements, including

- Victor McCree, Executive Director of Operations, NRC
- Ed McGinnis, Principal Deputy Assistant Secretary, DOE-NE
- Ashley Finan, Policy Director, Nuclear Innovation Alliance
- Maria Korsnick, President and CEO, Nuclear Energy Institute
- Mark Peters, Director, Idaho National Laboratory

Highlights from the hearing covered SMR commercialization, deployment schedule, and funding; high-assay LEU and test reactors; deployment of US SMRs overseas; and NRC fee reform. *Reference: 2/9/2018 Advanced Reactors Front and Center at House Committee Hearing on Nuclear Energy | Hogan Lovells – JDSupra, <https://www.jdsupra.com/legalnews/advanced-reactors-front-and-center-at-24687/2/6>*

February 8: NEI published an interview with **Jeffrey Binder, Associate Laboratory Director for Argonne National Laboratory's (ANL) energy and global security directorate**. He discussed the importance of DOE's national laboratories to the future of nuclear industry's ability to remain competitive technologically and economically. Below are two excerpts from the article specific to ANL.

“Argonne has a deep understanding of reactor design and the advanced computational modeling and simulation tools that can help quicken the pace of development and regulatory approval. Our experimental facilities for qualifying materials and components under extreme conditions, such as the Advanced Photon Source, are state-of-the-art. Finally, Argonne has a thorough grasp of the licensing environment and the necessary technical expertise required to make a strong licensing case for advanced nuclear technologies.”

In addition to sodium reactor research, “Argonne makes important contributions to the development of several other types of advanced reactors and fuel cycles. At a more basic level, Argonne has a significant manufacturing science and engineering initiative aimed at developing materials qualified for extreme conditions much more quickly.”

“One outgrowth of that is a facility for observing the effects of radiation damage in situ while it's happening. People are also looking at innovative manufacturing techniques for nuclear fuels and nuclear materials that would allow faster production of components for nuclear systems that may contain fissile material and also have control systems and sensing capabilities built in. Another area that we are looking into is applying the capabilities of the Advanced Photon Source to observe the microstructural behavior of nuclear materials that have been in nuclear environments, so we can model how they behave.”

“There is still research to do with sodium-cooled reactors involving advanced materials and components such as pumps and improved sensing and diagnostic systems to afford better control of sodium environments. The fuels and overall fuel cycles for sodium-cooled reactors are also of interest to our researchers.”

“Sophisticated supercomputers like Argonne's Mira, located at the Argonne Leadership Computing Facility, help researchers more quickly enhance the efficiency and reliability of nuclear energy by supporting more robust modeling, better simulations and more accurate predictions. We have people developing higher-resolution modeling tools for designing various reactor technologies. These researchers have the opportunity to build the next generation of tools. We are also studying machine learning and artificial intelligence approaches. Our ability to store and manipulate large data sets has changed dramatically in the last 10 years, facilitating physical insights that would have been unimaginable only a decade ago.”

Reference: 2/9/2018 Argonne's Jeff Binder on How Tech Can Revitalize Nuclear Energy - Nuclear Energy Institute. <https://www.nei.org/News-Media/News/News-Archives/2018/Argonne-s-Jeff-Binder-on-How-Tech-Can-Revitalize-N 3/3>.

GAIN Look Ahead

<i>FY 2018 Date(s)</i>	<i>Title</i>	<i>Location</i>	<i>GAIN's Role</i>
March 6:	Nuclear Innovation Week: Third Way Advanced Reactor Summit	Longview Gallery, Washington DC	Attend
March 7:	Nuclear Innovation Week: NEI R&D Summit	Longview Gallery, Washington DC	Attend
March 8-9:	Nuclear Innovation Week: Enabling Advanced Reactors for the Market (GAIN Symposium)	GWU, Washington DC	Organize, Present, Manage
March 11-15:	TMS 2018 Annual Meeting & Exhibition	Phoenix Convention Center, Phoenix, AZ	Tech Chair, Booth
March 12:	NEI ARWG Meeting	North Bethesda Marriott, Bethesda, MD	Attend
March 13-15:	Regulatory Information Conference (RIC)	North Bethesda Marriott, Bethesda, MD	Present, Attend
March 25-28:	MIT Symposium	Boston, MD	Attend
March 27-28:	Int'l SMR & Advanced Reactor Summit	Westin Buckhead, Atlanta GA	Present, Attend, Booth
April 18:	GAIN Executive Advisory Committee (EAC) Meeting	INL Meeting Center, Idaho Falls, ID	Organize, Manage, Tours
April 24:	NRC Public Briefing on Advanced Reactors	Rockville, MD	Attend
April 25-26:	NRC-DOE Workshop on Advanced Reactors	North Bethesda Marriott, Bethesda, MD	Attend
May 2:	ANS-NRC Advanced Reactors Standards Workshop	North Bethesda Marriott, Bethesda, MD	Attend
May 10:	GAIN HTR Symposium	INL, Idaho Falls, ID	Organize, Attend
May 15-16:	NIC – Western Nuclear Supply Chain Mtg	INL, Idaho Falls, ID	Attend
May 21:	NAYGN National Conference	Atlanta, GA	Present, Attend
June 5-6:	Digital I&C Workshop	ANL, Chicago, IL	Present, Attend
June 12:	NEI ARWG	NEI Office, Washington DC	Present, Attend
June 14:	Generation Atomics Workshop	INL, Idaho Falls, ID	Organize, Attend
June 17-21:	ANS Annual Meeting	Marriott Philadelphia Downtown, Philadelphia, PA	Present, Attend

For questions or additional information, please contact Lori Braase, GAIN, lori.braase@inl.gov.

