DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

CX Posting No.: DOE-ID-INL-23-054

SECTION A. Project Title: FY-24 LDRD Annual Projects

SECTION B. Project Description and Purpose:

Idaho National Laboratory's (INL's) core mission is to discover, demonstrate, and secure innovative nuclear energy solutions, clean energy options, and critical infrastructure. The INL Laboratory Directed Research and Development (LDRD) program engages researchers, leadership, and infrastructure to convert scientific and engineering ideas into scientific discoveries, research capabilities, research and development (R&D) programs, and deployed technology solutions. INL uses the LDRD program to develop core capabilities and achieve strategic initiatives in science and technology (S&T).

For the Fiscal Year (FY)-24, INL's LDRD program focuses on the laboratory's five strategic initiatives: INL's three emerging core capabilities; one new full core capability described below; growth in the net-zero program. In addition, INL encouraged the formation and submission of proposals that specifically address and establish INL's leadership position in creating a carbon-free energy future. Appendix A lists and describes individual FY-24 LDRD proposals for all initiatives and with research collaborations outside of INL.

1.0 Nuclear Reactor Sustainment and Expanded Deployment: INL focuses on sustaining and advancing reactor technology options ranging from small modular light water reactors (LWRs) to a suite of non-LWRs to the existing LWR fleet and expand the deployment of nuclear power. Near-term microreactor demonstrations and fast spectrum capabilities to accentuate strategies for mixed-technology nuclear future. Significant scientific advancements in materials and fuels are imperative to achieve reactor sustainment and deployment, as is the development of techniques, technologies, experimental testbeds, and capabilities that enable substantially lower operational costs and integration of advanced nuclear systems into non-baseload applications.

2.0 Integrated Fuel Cycle Solutions: Research at INL uses science, technology, and infrastructure to find solutions for the availability of special nuclear materials for fuel fabrication needs to support the demonstration of new advanced reactors, and the management and disposition of existing and future radiological waste materials. Developing a fuel cycle with inherent process transparency will reduce the risk of nuclear proliferation, so INL is focused on developing fuel cycle technologies that incorporate safeguards by design for the effective and efficient monitoring and verification of nuclear materials throughout the fuel cycle. INL supports proliferation risk reduction in the integrated fuel cycle through research that demonstrates simplified used nuclear fuel (UNF) recycling processes, develops and demonstrates real-time interrogation of UNF treatment processes, and demonstrates the direct chemical and physical immobilization options for UNF.

3.0 Advanced Materials and Manufacturing for Extreme Environments: INL missions require materials to operate in a wide range of extreme environments: radiation, thermal, mechanical, extreme deformation, and corrosive. To meet these requirements, new materials for application such as lightweight materials, next generation reactor components, and advanced survivability materials is a priority. Emerging materials include, but are not limited to, high entropy alloys, high temperature materials, metamaterials, and radiation-resistant alloys. The focus of this initiative is the growth of new national capabilities to design, develop, test, characterize, and manufacture these needed materials. The main goal is to develop capabilities for transformative materials design and advanced manufacturing for material functionality and durability in extreme environments.

4.0 Integrated Energy Systems: This initiative fosters sustained and expanded nuclear energy deployment and advances the integration of variable renewable energy sources onto the electric grid. The current nuclear fleet and next generation nuclear plants can be increasingly supportive of federal, local, and private sector decarbonization goals by optimizing the use of the high-quality heat generated by nuclear fission to support electricity production and industrial processes, such as hydrogen generation, production of potable water, and chemical manufacturing. INL conducts extensive simulation, optimization, real-time experimental demonstration, and full-scale testing to support the deployment of efficient, reliable, and resilient integrated energy systems for all energy use sectors.

5.0 Secure and Resilient Cyber-Physical Systems: INL seeks to transform the cyber-informed science and engineering of control systems in critical infrastructure and vital national security systems to advance their security and resiliency. Civilian and defense energy systems and critical infrastructure rely on the availability, security, and resiliency of digital command, control, computing, and communication systems. To assure the nation's security and prosperity, INL provides world-leading research, development, and deployment (RD&D) capabilities and delivers innovative solutions that enhance these critical systems' capabilities to protect, detect, respond, and recover from significant cyber and physical events.

6.0 Chemical and Molecular Science (emerging core capability): One of 25 DOE-recognized core capabilities, this capability represents the ability to conduct experimental, theoretical, and computational research to fundamentally understand chemical change and energy flow in molecular systems that provide a basis for the development of new processes for the generation, storage, and use of energy and for mitigation of the environmental impacts of energy use. Areas of research include atomic, molecular, and optical sciences; gas-phase chemical physics; condensed phase and interfacial molecular science; catalysis science; separations and analytical science; actinide chemistry; and geosciences.

7.0 Condensed Matter Physics and Materials Science (emerging core capability): One of 25 DOE recognized core capabilities, this capability represents the ability to conduct experimental, theoretical, and computational research to fundamentally understand condensed matter physics and materials sciences that provide a basis for the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and utilization. Areas of research include experimental and theoretical condensed matter physics, x-ray and neutron scattering, electron and scanning probe microscopies, ultrafast materials science, physical and mechanical behavior of materials, radiation effects in materials, materials chemistry, and bimolecular materials.

8.0 Computational Science (emerging core capability): The ability to connect applied mathematics and computer science with research in scientific disciplines (e.g., biological sciences, chemistry, materials, physics, etc.). A core capability in this area involves expertise in applied mathematics, computer science and in scientific domains with a proven record of effectively and efficiently utilizing high performance computing resources to obtain significant results in areas of science and/or engineering of interest to the Department of Energy and/or other Federal agencies. The individual strengths in applied mathematics, computer science and in scientific domains in concert with the strength of the synergy between them is the critical element of this core capability.

9.0 Plasma and Fusion Energy Sciences (full core capability): The ability to control, maintain, and utilize matter in the state of plasma across a range of conditions to conduct world-leading research. This includes low temperature plasmas which are utilized in applications such as microelectronics fabrication and nanomaterial synthesis and can have significant spinoff applications, and high temperature/high pressure plasmas, also known as burning plasmas, which are critical for developing the scientific foundation for fusion as a future energy source. This ability can be demonstrated across this entire range of plasma conditions in the operation of state-of-the-art experimental facilities that can support research on the fundamental physics of plasmas; in theory and advanced simulations which are critical to the full understanding of the plasma phenomena being studied and on how plasmas can be best controlled and utilized; and in enabling technologies that allow experiments to reach the necessary conditions where new discoveries can be made.

10.0 Net-Zero Carbon Emissions: The driving force behind INL's nuclear and other clean energy research and development is creating clean, scalable, and sustainable energy solutions to address national and global needs while reducing environmental impacts. INL will lead by example, committing to becoming a national carbon neutral prototype and achieving net-zero emissions in INL operations within the next 10 years. Achieving net-zero means drastically reducing onsite emissions and offsetting the limited residual emissions from activities that are impossible to decarbonize. This is a substantial and long-term commitment. INL will use technology innovations and partnerships, increased efficiencies, and novel approaches to demonstrate the path forward for establishing a clean energy economy.

GENERAL

The proposed laboratory activities include reasonably foreseeable actions necessary to implement the proposed action, such as radiological control and safety support; sample, chemical, and material transport; project closeout; waste management, transport, treatment, storage and disposal; maintenance, development, and demonstration of processes, instruments and detection; maintenance, calibration, transport, and use of analytical and research equipment; consulting and planning with sponsors and collaborators; and award of grants and contracts.

FACILITIES

The proposed LDRD projects leverage facilities across INL – the Advanced Test Reactor (ATR) Complex, Central Facilities Area (CFA), Critical Infrastructure Test Range Complex (CITRC), Materials and Fuels Complex (MFC), and the Research and Education Campus (REC). These facilities each host complementary resources and infrastructure to support research.

The primary focus of the ATR Complex is continued fuels and materials irradiation testing, nuclear safety research and nuclear isotope production. The ATR subjects experiment to a wide range of temperatures, pressures, and exposure to high levels of neutrons and gamma rays to determine how the materials will react in high-radiation environments. The ATR-Critical Facility (ATR-C) is a full-size, low-power, pool-type nuclear replica of the ATR, designed to evaluate prototypical experiments before the actual experiments are irradiated in the ATR.

CFA supports the Wireless Test Bed network, operations center, and the site-wide protection, emergency response, network and communications, transportation, and warehousing services for the Site campuses.

CITRC supports INL National & Homeland Security (N&HS) missions in developing solutions for security and resilience of critical infrastructure and advancing security solutions that prevent, detect and counter nuclear and radiological threats. This mission engages strategic partnership projects that include other federal agencies, national and international programs, and the energy industry.

MFC has facilities for fabricating, examining, and characterizing nuclear fuel and materials, as well as remotely handling and processing spent fuel and radioactive wastes. Projects at MFC primarily focus on developing innovative solutions for nuclear power technology, including nuclear fuel development, separations development, post-irradiation examination (PIE), and fast reactor development. The Analytical Laboratory (AL) houses shielded hot cells, air and inert atmosphere glove boxes, casting laboratories and related assets used for nuclear fuels and materials characterization, environmental sampling and analysis and other examination tasks. The Fuel Conditioning Facility (FCF) contains two adjacent hot cells, a mock-up area and shielded decontamination and repair area that support legacy spent fuel treatment, remote equipment development, cask receipt and related activities. The Fuel Manufacturing Facility (FMF) features a highly secure vault and two work rooms with glove boxes that allow for the receipt, storage, handling and inspection of fissionable material and the development of advanced nuclear fuels. The Transient Reactor Test Facility (TREAT) is an air-cooled, thermal test reactor maintained in standby status to support radioisotope dispersal device exercises, recovered spent fuel storage and potential future transient testing needs. Fuels and Applied Science Building (FASB) is a radiological facility that houses small hot cells, gloveboxes, hoods, and a variety of equipment that supports nuclear energy research and development. Advanced Fuels Facility (AFF)'s operations involve research and development primarily with uranium bearing fuels and associated surrogate materials to increase MFC's advanced fuel manufacturing capabilities. Radiochemistry Laboratory (RCL) houses several laboratories for aqueous separations science and technology, actinide chemistry, radiochemistry research, and metals and isotopic analyses on radioactive materials. Irradiated Materials Characterization Laboratory (IMCL). Electron Microscopy Laboratory (EML) is a user facility dedicated to materials characterization, using primarily electron and optical microscopy tools. Sample preparation capabilities for radioactive materials ensure that high quality samples are available for characterization. Engineering Development Laboratory (EDL)is used to fabricate, assemble, mockup and test various research, development, and production equipment. Hot Fuel Examination Facility (HFEF) is Idaho National Laboratory's flagship facility for conducting post-irradiation examinations of fuels and materials.

The Research and Education Campus is located in Idaho Falls and includes laboratories where researchers work on a wide variety of R&D projects. The campus includes numerous office, lab and support facilities, including the N&HS Laboratory & Training Facility, the Center for Advanced Energy Studies (CAES), the INL Research Center (IRC), the Energy Systems Laboratory (ESL), Energy Innovation Laboratory (EIL), the Collaborative Computing Center (C3), Cybercore Integration Center (CIC), and National and Homeland Security's University Boulevard (UB) 3 and 4. Activities in these facilities are highlighted below:

- The N&HS Laboratory & Training Facility offers a blend of low- and high-bay work areas and wet and dry lab space for technologies close to commercial deployment.

- CAES is a research and education consortium between INL, Boise State University, Idaho State University, University of Idaho, and University of Wyoming and provides a collaborative, multi-mission environment focusing on research including nuclear and materials science, geothermal energy systems, advanced manufacturing, and energy policy.
- The IRC houses more than 60 laboratories and was designed to allow easy lab space modification as research needs change over time. Scientists and engineers at the IRC conduct research in several different fields including materials science, biology, analytical chemistry, nondestructive battery evaluation, autonomous systems and geochemistry.
- The ESL supports R&D to reduce technical and economic risks associated with the deployment of new energy technologies in the areas of bioenergy research, energy storage and advanced vehicles, and energy systems integration.
- EIL houses INL researchers affiliated with Energy & Environment Science & Technology, Nuclear Science & Technology, and the Nuclear Science User Facilities. Laboratories at EIL support chemical sciences, nanotechnology, water chemistry, advanced microscopy, control systems, high-temperature testing, thermal hydraulics, materials testing and characterization, separations technology and advanced instrument training.
- The C3 is a facility where INL researchers, Idaho universities and industry can explore computer modeling and simulation to develop new nuclear materials, advance nuclear energy concepts and conduct a broad span of scientific research.
- The CIC supports research on security and resilience of the nation's critical infrastructure, including the power grid. The research focuses on developing the partnerships, people and innovations required to meet emerging threats from persistent, capable, well-resourced and highly motived cyber adversaries.
- University Boulevard 3 and 4 (UB3/4) contain engineering space that supports a wide range of work-for-others customers including programs for the departments of Defense and Homeland Security.

IMPACTS and ASPECTS

The proposed projects may result in emissions to the atmosphere of both chemicals and radionuclides; generating hazardous, mixed, radioactive low- level, transuranic (TRU), and industrial wastes. The total estimated sum of the generated TRU waste is less than 200 grams. The total estimated sum of low-level waste is to be <500 m^3. Samples for analysis or R&D work may be received from outside the INL or originate within the INL. Laboratory activities may result in excess samples or sample residues that project personnel must return to the generator or to INL personnel to manage and dispose. Project activities may retain wastewater from laboratory operations for characterization and management by Waste Generator Services (WGS) or may be disposed to laboratory drain systems in accordance with the appropriate sewage disposal regulations.

To complete some of the proposed work activities, it is necessary for projects to use the HFEF hot cell which contains both defense and nondefense related materials and contamination. Project materials will come into contact with defense related materials. It is impractical to clean out defense related contamination, and therefore, waste associated with project activities is eligible for disposal at the Waste Isolation Pilot Plant (WIPP). National Environmental Policy Act (NEPA) coverage for the transportation and disposal of waste to WIPP are found in Final Waste Management Programmatic Environmental Impact Statement [WM PEIS] (DOE/EIS-0200-F, May 1997) and Waste Isolation Plant Disposal Phase Supplemental EIS (SEIS-II) (DOE/EIS-0026-S-2, Sept. 1997), respectively. The 1990 Record of Decision (ROD) also stated that a more detailed analysis of the impacts of processing and handling transuranic (TRU) waste at the generator-storage facilities would be conducted. The Department has analyzed transuranic (TRU) waste management activities in the Final WM PEIS (DOE/EIS-200-F, May 1997). The WM PEIS analyzes environmental impacts at the potential locations of treatment and storage sites for TRU waste; SEIS-II addresses impacts associated with alternative treatment methods, the disposal of TRU waste at WIPP and alternatives to that disposal, and the transportation to WIPP.

After PIE, irradiated test pin segments and PIE remnants would be stored with similar DOE-owned irradiated materials and experiments at MFC, most likely in the HFEF or the Radioactive Scrap and Waste Facility (RSWF) in accordance with DOE's Programmatic SNF Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (FEIS) and ROD(DOE/EIS- 0203, 1995) and supplemental analyses (DOE/EIS-0203-SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (February 1996).

Ultimate disposal of the irradiated test pin segments and PIE remnants will be along with similar DOE-owned irradiated materials and experiments currently at MFC. Categorizing this material as waste is supported under Department of Energy Manual (DOE M) 435.1-1, Att 2, Item 45, which states "...Test specimens of fissionable material irradiated for research and development...may be classified as waste and managed in accordance with this Order [DOE O 435.1]."

Packaging, repackaging, transportation, receiving, and storing used nuclear fuel and R&D for used nuclear fuel management is covered by DOE's Programmatic Spent Nuclear Fuel (SNF) Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement (EIS) and Record of Decision (DOE/EIS-0203, 1995) and supplemental analyses (DOE/EIS-0203- SA-01 and DOE/EIS-0203-SA-02) and the Amended Record of Decision (February 1996). The analyses include those impacts related to transportation to, storage of, and research and development related to used nuclear fuel at the INL (see Tables 3.1 of the SNF Record of Decision (May 30, 1995) and Table 1.1 of the Amended Record of Decision [February 1996].

The environmental impacts of transferring LLW from the INL Site to the Nevada National Security Site were analyzed in the 2014 Final Site-Wide Environmental Impact Statement for the Continued Operation of the Department of Energy/National Nuclear Security Administration Nevada National Security Site and Off-Site Locations in the State of Nevada (DOE/EIS-0426) and DOE's Waste Management Programmatic EIS (DOE/EIS-200). The fourth Record of Decision (ROD) (65 FR 10061, February 25, 2000) for DOE's Waste Management Programmatic EIS established the Nevada National Security Site as one of two regional LLW and MLLW disposal sites.

The potential for transportation accidents was analyzed in the SNF EIS (Section 5.1.5 and Appendix I-5 through I-10).

SECTION C. Environmental Aspects or Potential Sources of Impact:

Air Emissions

Note: If this project or activity produces or causes air emissions, and it is not stated in this ECP how those emissions caused by this project or activity are exempt, then an APAD is required for documentation.

INL LDRD projects have the potential to generate small amounts of air emissions containing a variety of constituents. Each activity must meet state and Federal air emission regulations. Due to the nature of these LDRD projects, INL anticipates emissions will be minor and covered by existing APAD's for the individual facilities. The APAD establishes the appropriate maximum 24-hour and maximum annual emission limits for toxic pollutants used at the laboratory. Administrative controls based on inventory limits and independent Hazard Reviews for new programs would then be implemented to ensure that these limits would not be exceeded.

Discharging to Surface-, Storm-, or Ground Water

This ECP does not authorize direct discharge to ground water, surface water, or the ground surface. Storm water runoff may occur from parking lots.

No discharge is planned to occur out at the INL site.

No discharges are planned for off-site locations.

Disturbing Cultural or Biological Resources

Cultural: See attached table of proposals analysis as some of the proposal activities do not trigger Section 106 review and some have little to no potential to cause effects to historic properties.

Generating and Managing Waste

LDRD projects will generate waste, including office waste, Recyclable waste (machined scrap), industrial waste (e.g., gloves, non-hazardous hardware, ceramic-type pellets, lab pipettes, wipes, etc.), low-level waste (LLW), mixed LLW (e.g., from irradiated fuel salt and salt-facing components), hazardous waste from chemical solutions and solvents, and transuranic (TRU) waste from certain activities at the INL Site. The total estimated sum of the generated TRU waste is less than ~200 gram per year. The total estimated sum of low-level waste is to be ~500 grams. The total estimated sum of radioactive waste is estimated to be less than ~1 cubic meter. The total estimated sum of mixed waste is estimated to be less than ~1 cubic meter. Estimated industrial waste generated will be approximately 2 cubic meters (PPE, gloves, wipes, etc.,). Estimated Scrap metal (machined scrap) will be approximately 1 cubic meter.

Off-Site Locations: Locations off-site will have the potential to generate industrial waste, office waste, hazardous waste, and LLW. No TRU waste will be generated at off-site locations. From LWP-20000, research performed by INL personnel at offsite (non INL) locations must be performed with the same rigor as on-site work. To ensure such rigor is applied, an analysis must occur between the work performer and research line management using Form 420.15.

Off-Site Work Request – From LWP-20000 or IQ Work Smart Work Index - Define Scope and Identify Research Hazards and Mitigations, research performed by INL personnel at offsite (non INL) locations must be performed with the same rigor as on-site work. To ensure such rigor is applied, an analysis must occur between the work performer and research line management using Form 420.15, Off-Site Work Request." This form ensures NEPA is addressed at the designated off-site work location. If it is determined that the work controls are consistent with INL standards, research by the INL performer at the offsite location may be allowed. In the absence of a defined and structured work-control process, INL work-control processes should be applied.

Offsite activities would occur in facilities that are designed to operate to support proposed R&D projects and include all pollution prevention measures as required by all applicable federal, state, and local laws, regulations, and ordinances. It is anticipated that any potential environmental impacts as a result of the proposed activities from these facilities would be similar to what these facilities currently produce.

PCB waste could be generated when performing replacing or modifying electrical equipment/systems manufactured before 1982 or when disturbing building material such as applied paint, caulking, joint sealer, cable/wire insulation in buildings built before 1982.

Releasing Contaminants

When chemicals are used, there is the potential the chemicals could be spilled to air, water, or soil.

Using, Reusing, and Conserving Natural Resources

All materials will be reused and recycled where economically practicable. All applicable waste will be diverted from disposal in the landfill where conditions allow. Project description indicates materials will need to be purchased or used that require sourcing materials from the environment. Being conscientious about the types of materials used could reduce the impact on our natural resources. Project activities may release known greenhouse gases (GHGs) to the atmosphere and increase INL's energy use.

SECTION D. Determine Recommended Level of Environmental Review, Identify Reference(s), and State Justification: Identify the applicable categorical exclusion from 10 Code of Federal Regulation (CFR) 1021, Appendix B, give the appropriate justification, and the approval date.

For Categorical Exclusions (CXs), the proposed action must not: (1) threaten a violation of applicable statutory, regulatory, or permit requirements for environmental, safety, and health, or similar requirements of Department of Energy (DOE) or Executive Orders; (2) require siting and construction or major expansion of waste storage, disposal, recovery, or treatment or facilities; (3) disturb hazardous substances, pollutants, contaminants, or Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)-excluded petroleum and natural gas products that pre-exist in the environment such that there would be uncontrolled or unpermitted releases; (4) have the potential to cause significant impacts on environmentally sensitive resources (see 10 CFR 1021). In addition, no extraordinary circumstances related to the proposal exist that would affect the significance of the action. In addition, the action is not "connected" to other action actions (40 CFR 1508.25(a)(1) and is not related to other actions with individually insignificant but cumulatively significant impacts (40 CFR 1608.27(b)(7)).

References:

A9 "Information gathering, analysis, and dissemination", B1.24 "Property transfers", B1.31 "Installation or relocation of machinery and equipment", B3.6 "Small-scale research and development, laboratory operations, and pilot projects"

Justification:

A9 Information Gathering, Analysis, and Dissemination Information gathering (including, but not limited to, literature surveys, inventories, site visits, and audits), data analysis (including, but not limited to, computer modeling), document preparation (including, but not limited to, conceptual design, feasibility studies, and analytical energy supply and demand studies), and information dissemination (including, but not limited to, document publication and distribution, and classroom training and informational programs), but not including site characterization or environmental monitoring. (See also B3.1 of appendix B to this subpart.)

B1.24 Property transfers. Transfer, lease, disposition, or acquisition of interests in personal property (including, but not limited to, equipment and materials) or real property (including, but not limited to, permanent structures and land), provided that under reasonably foreseeable uses (1) there would be no potential for release of substances at a level, or in a form, that could pose a threat to public health or the environment and (2) the covered actions would not have the potential to cause a significant change in impacts from before the transfer, lease, disposition, or acquisition of interests.

B1.31 Installation or relocation of machinery and equipment. Installation or relocation and operation of machinery and equipment (including, but not limited to, laboratory equipment, electronic hardware, manufacturing machinery, maintenance equipment, and health and safety equipment), if uses of the installed or relocated items are consistent with the general missions of the receiving structure. Covered actions include modifications to an existing building, within or contiguous to a previously disturbed or developed area, that are necessary for equipment installation and relocation. Such modifications would not appreciably increase the footprint or height of the existing building or have the potential to cause significant changes to the type and magnitude of environmental impacts.

B3.6 Small-scale research and development, laboratory operations, and pilot projects. Siting, construction, modification, operation, and decommissioning of facilities for small-scale research and development projects; conventional laboratory operations (such as preparation of chemical standards and sample analysis); and small-scale pilot projects (generally less than 2 years) frequently conducted to verify a concept before demonstration actions, provided that construction or modification would be within or contiguous to a previously disturbed or developed area (where active utilities and currently used roads are readily accessible). Not included in this category are demonstration actions, meaning actions that are undertaken at a scale to show whether a technology would be viable on a larger scale and suitable for commercial deployment.

Is the project funded by the American Recovery and Reinvestment Act of 2009 (Recovery Act) ☐ Yes ☒ No

Approved by Jason L. Anderson, DOE-ID NEPA Compliance Officer on: 9/26/2023

Appendix A
FY-24 LDRD Projects listed by Initiative

Tracking number
ERP Number
Title
Project Description

1.0 Nuclear Reactor Sustainment and Expanded Deployment

24A1081-014FP
ERP ID 2763
High Throughput Alloy Fuel Development for Fast Reactors
This work will utilize advanced manufacturing methods to produce an array of samples for high-throughput characterization. This work will require the purchase of two additional hoppers for the Laser engineered net shaping (LENS) printer at the Advanced Fuel Facility (AFF) at Materials and Fuels Complex (MFC) as well as the raw powders needed for fabrication. Characterization work will involve X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM), Focused Ion Beam (FIB), Transmission Electron Microscope (TEM), and Differential Scanning Calorimetry (DSC) at MFC facilities. Additional work will involve computer modelling of the data.

24A1081-100FP
ERP ID 2839
Concepts for Establishing Fast Neutron Experiment Irradiation Capabilities to Accelerate Fission and Fusion Material R&D
This project, by using state-of-the-art models and new experimental data, will investigate the feasibility of candidate spectral modification methods, identify materials and ideal strategies for fast fission and fusion irradiation, and create verification and validation (V&V) data using dosimetry and diagnostics in the ATR-Critical facility (ATR-C) in various spectral regions of its core. This project will enrich understanding and predictive capabilities while laying the groundwork for bulk neutron irradiation of fuels and materials in fast fission reactor cores and fusion plant breeder blankets. The use of neutronic modeling and non-traditional spectral modification techniques can be used to create neutron spectra that are better suited to irradiation of advanced nuclear materials. Damage mechanisms of interest differ depending on the materials being tested. The work performed in this project will identify the criteria for success by finding and detailing beneficial combinations of damage phenomena, specimen materials, and spectra schemes. This scope involves collaboration research with Michigan Institute of Technology in accordance with their Standard Operating Procedures (SOP) found at https://ehs.mit.edu/.

24A1081-116FP
ERP ID 2814
Uncertainty Quantification Approach for Digital Twin-based
The main hypothesis this project aims to test is whether the proposed uncertainty quantification (UQ) approach can estimate the uncertainty of digital twin (DT) predictions in an autonomous control system with sufficient accuracy. Specifically, this proposal aims to determine and integrate the uncertainty of low-fidelity Modelica/Dymola models, machine learning (ML) surrogates, and information losses when the system is under cyber-attacks and operated beyond the training domain for virtual models. The acceptance/rejection of hypothesis is decided by comparing the estimations against the actual uncertainty, while the accuracy requirements are informed by the safety and reliability requirements of autonomous control systems. For validation data, since there are no currently operating reactors that incorporate a DT system for autonomous control, this work uses simulation results from high-fidelity Nuclear Energy Advanced Modeling and Simulation (NEAMS) tools and leverages existing experimental data from testbeds at Idaho National Laboratory (INL). This scope involves collaboration research with North Carolina State University in accordance with their Standard Operating Procedures (SOP) found at https://ehs.ncsu.edu/.

24A1081-143FP

ERP ID 2820
Optimizing Experimental Design to Accelerate Research, Development, and Demonstration (RD&D) on Nuclear Fuels To facilitating more rapid discovery and testing of new nuclear fuel materials, it is essential to optimally allocate the expensive experimental or computational resources such that the most information can be harvested. This project proposes to advance computational methodologies to identify and bridge the data gap to target the most informative experimental conditions under the Bayesian framework. Optimization of the experimental design will be achieved by maximizing the information gain of model parameters over the design space upon availability of future experiments. The developed experimental design framework will accelerate the research, design & demonstration (RD&D) of advanced nuclear fuel concepts by optimizing the experimental efforts. Impact of this work will not be limited to the nuclear fuel research community, but of general applicability to a broad range of nuclear problems.

24A1081-149FP
ERP ID 2791
Machine Learning based Correlation the Mechanical Properties of Sub-sized and Standard-sized Specimens Small-scale mechanical testing using sub-sized specimens is critical in the nuclear industry to accelerate irradiation tests, to gain knowledge of new materials during/after irradiation, and to ultimately accelerate materials qualification and deployment. However, the small size of a specimen causes the so-called “size effect”, which leads to different material behaviors in the microscale, mesoscale, and macroscale. The goal of this project is to correlate the mechanical properties of sub-sized specimens and those of standard-sized specimens using machine learning (ML). The objectives of this project are to: (1) build a database of materials properties, e.g., Charpy impact toughness, tensile, and creep properties, including detailed pedigree information for the selected materials. (2) identify and evaluate existing methods for properties prediction and develop ML methodologies that can be used for more accurate properties prediction under different test factors; (3) develop a correlation of sub-sized and standard-sized specimens under different conditions; (4) investigate the importance of different test factors to the corresponding mechanical properties, and eventually guide test matrix design and accelerate new material development. The selected materials for study include stainless steel 316, reactor pressure vessel steels, and Zircalloy. This project will deliver a correlation of the mechanical properties between sub-sized and standard-sized specimens based on ML models to accelerate materials qualification and deployment. This is extremely important for the development and qualification of structural materials for Generation IV nuclear energy systems where the long-term high temperature property is required, and accurate empirical extrapolation methods are needed.

24A1081-162FP
ERP ID 2858
Investigating the Cross-Roads of Multi-Physics Modeling and Advanced Experimentation? Techniques for Accelerated Molten Salt Reactor Deployment The present project is divided into two parts. First, a computational part, where computational modeling and simulation tools will be developed for performing the safety studies of Molten Salt Reactors. This work will lead to the characterization of the expected impurities in molten salt coolants during reactors operation. The second part is experimental work, in which small synthetic samples (on the order of the centiliter) of depleted-uranium-bearing molten salts will be formulated in the lab based on the impurity levels predicted by the numerical simulations. These samples will be used for measuring the thermophysical properties (density, thermal conductivity, specific heat, and viscosity) of the molten salt.

24A1081-193FP
ERP ID 2804
High Spatial Resolution Mapping of Retained Fission Gas
This LDRD work will be for the development of an instrument capability (using commercially available components) that will measure, and map retained krypton (Kr) and xenon (Xe) gas in non-radioactive uranium dioxide (UO2) surrogate materials, depleted UO2 samples, and 1µm cube sized irradiated UO2 fuel samples (which will contain low enough activity that they can be free-released from radiological control). The Kr and Xe gases will be extracted from the solid samples in a high-vacuum gas manifold system using focused laser light; either through diffusion (a nondestructive sampling method) or laser ablation (a minimally destructive sampling approach). Releasing Kr and Xe from a sample will potentially also release other elements alongside the Kr and Xe gases (such as water, hydrocarbons, cesium, iodine, and even uranium if laser ablation is employed as the sampling method). Release of these elements will be contained in the high vacuum gas manifold system, where reactive-metal getter pumps and cold traps will be employed to scrub out

everything released alongside the Kr and Xe. The cleaned Kr and Xe gas will then be introduced into a noble gas mass spectrometer for isotopic composition analysis.

24A1081-203FP
ERP ID 2840
Miniaturized Fracture Toughness Measurements for Structural Materials To measure fracture toughness of alloys, compact tension tests are commonly employed, and these tests have requirements on the minimum size to ensure that certain conditions regarding the material behavior are met. This project is developing an approach to minimize the required size of the sample material by employing electroplating, and potentially welding and cold spraying, to increase the effective size of sub-sized samples for fracture testing. Computational simulation will also be employed to aid in interpreting the experimental results. This scope involves collaboration research with University of California, Berkeley in accordance with their Standard Operating Procedures (SOP) found at https://ehs.berkeley.edu/ .

24A1081-205FP
ERP ID 2784
Economics Driven, Advanced Manufacturing Based Optimization of Fission Battery Mass Production Making fission batteries (FBs) economically competitive across various markets requires them to be mass produced in a factory. With FBs being in a pre-conceptual stage, it is still unknown where the bottlenecks and barriers in achieving mass production will lie. This project will attempt to answer the question: can mass producing FBs make them economically competitive enough, and if so, what is the most effective way to mass produce them? This question will be answered by first developing an integrated platform to model the mass production process of any FB. The platform combines techno-economics and cutting-edge production process design techniques to develop holistic, economics driven FB production process models that include fabrication, assembly, and quality control processes for its components, detailed factory layout, servicing facility choices, and their capital and levelized costs. By modeling a notional FB design on this platform, this project evaluates transformative approaches to FB production, and identifies bottlenecks in the production process. This project will enable any FB vendor or manufacturer to economically maximize FB mass production and quantify the benefits of advanced manufacturing (AM) in terms of FB production rates and levelized costs.

24A1081-222FP
ERP ID 2848
Event-Mode Imaging for Nondestructive Examination of Nuclear Fuels
This project performs proof-of-principle experiments to determine the utility of a new single-event based imaging technology to nondestructively examine highly radioactive nuclear fuels and materials in hot-cell environments. Development of this event-mode neutron imaging capability would provide deep and meaningful insights into the physical properties of nuclear fuels earlier in the post-irradiation examination process, thereby informing subsequent destructive processes and accelerating fuel qualification. This scope involves collaboration research with Technical University of Munich and Los Alamos National Laboratory in accordance with their Standard Operating Procedures (SOP) found at https://www.tum.de/en/about-tum/goals-andvalues/ sustainability and https://environment.lanl.gov/environmental-protection.

2.0 Integrated Fuel Cycle Solutions

24A1081-025FP
ERP ID 2828
Toward Zero Salt Waste Advanced Pyroprocessing (ZSWAP): In-situ Oxidant Salt Synthesis and Group Metal Drawdown with Restrictive Flow Electrochemical Cell This proposal is a Zero Salt Waste Advanced Pyroprocessing (ZSWAP) solution for advanced metal fuel cycle and an associated electrochemical process regulating molten salt electrolyte mixing kinetics. The ZSWAP enables perpetual use of molten salts for supporting advanced metal fuel cycle without incurring effluent salt waste. The achievement of this objective will lead to sustainable use of molten salt and may pave the way for the realization of ZSWAP in advanced metal fuel cycle. The feasibility and benefits of this process concept and its waste implications in the context of ZSWAP will be studied theoretically and through experimentation. This scope involves collaboration research with Penn State University in accordance with their Standard Operating Procedures (SOP) found at https://ehs.psu.edu/.

24A1081-089FP
ERP ID 2798
On-Line Salt Chemistry Management
The project proposes to design and manufacture halides salts sensors (HSS), develop the molten salt static testbed for HSS testing and data generation, train, and test HSS machine learning models based on data feedback, and establish a working digital twin framework to automate anomaly detection and sensor calibration. New equipment will be installed in EIL B208 or MFC-789, where the experiments will be carried out.

24A1081-122FP
ERP ID 2799
Molten Flow loop Testbed for Advanced Instrumentation and Material Testing
Flowing salt properties will be investigated using a natural circulation molten-salt flow loop equipped with instrumentation (furnaces, thermocouples etc). Specifically, the molten-salt flow loop will be observed to analyze the molten salt flow characteristics (thermal gradients and flow dynamics). Electrochemical and bubbler techniques will be used to evaluate salt properties. Corrosion samples of various metals and alloys will be introduced in the loop through the surge tank. Salt samples will be collected before, during, and after the corrosion tests to monitor the metal alloy corrosion. Various techniques (i.e., ICP analysis, spectroscopy techniques etc.) will be used to analyze the salt samples collected during and after the measurement; and surface characterization techniques (SEM, FIB, optical microscopy etc.) will be used for analysis of metal/alloy surface after the corrosion test. In addition to the corrosion samples, a specimen of stainless steel (SS) 316 pipe will be characterized after the loop operation to evaluate the corrosion during the operation. For salt and metal alloy characterization, the samples will be sent to various facilities including IRC and CAES. There will be facility modifications done at EIL C213 and Engineering Development Laboratory (MFC) to allow for argon supply and exhaust and routing of electrical power (208/240V maximum) as deemed necessary.

24A1081-144FP
ERP ID 2819
Proliferation Detection via Acoustic Monitoring of Pyroprocessing Equipment and Related (DAMPER) Systems This project focuses on using acoustic monitoring to advance detection techniques for Pyroprocessing in support of nuclear safeguards and nonproliferation. The usage of free air acoustic monitoring has been previously demonstrated at Idaho National Laboratory (INL) facilities such as the Advanced Test Reactor and the National Security Test Range. However, the proposed work revolves around a new deployment environment, the Fuel Conditioning Facility(FCF), that brings forward several questions regarding the performance of the technology in non-free air media. The confinement of the Pyroprocessing equipment to a heavily shielded hot cell, the atmosphere of the hot cell containing argon gas, and the radiation dose inside the hot cell are all new environments for acoustic monitoring.

University in accordance with their Standard Operating Procedures (SOP) found at https://ehs.psu.edu/.
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24A1081-147FP
ERP ID 2835
FASTER: Fieldable Analysis of Salt Through Expedited Radiochemistry
Technologies that enable near-real time isotopic analysis of advanced molten salt reactor (MSR) fuels are critically needed to safeguard these reactors, increase their operational efficiency, and enable their widespread deployment with confidence. To accomplish this, we propose to develop breakthrough approaches in highly radioactive molten salt sample dissolution and chemical separations. We will achieve this through:
1) Scientific advances in fundamental analytical chemical separations, enabling the achievement of extremely rapid, high-efficiency analytical separation approaches not currently available.
2) Development of a fieldable/hot cell compatible system designed specifically for near-real time chemical dissolution and separation of actinides and fission products from highly radioactive molten salt samples. The approach will then be employed to purify key actinide and fission product isotopes from highly radioactive (> 10 R/hr) uranium-plutonium (U-Pu) and uranium-thorium (U-Th) molten salt samples. Numerous publications and an invention are anticipated from this work. This scope involves collaboration research with Idaho State University Idaho Accelerator Center in accordance with their Standard Operating Procedures (SOP) found at https://www.isu.edu/ehs/.

24A1081-178FP
ERP ID 2821
Proliferation Risk Assessment of Pyroprocessing
This project will study the chemistry and electrochemistry of molten salts used for uranium electrorefining in Pyroprocessing applications of spent nuclear fuels. The study is limited to non-radiological salts containing surrogates for the actinides, and radiological salts containing uranium and transuranic. The work will be performed at the gram scale in gloveboxes (approximately 800 g of salt per experimental trail). Salt and metal samples will be collected for chemical analyses. There will be modification to gloveboxes of feed-throughs for electrical cables at facilities: MFC-765, MFC-787, MFC-768B, MFC-787, CFA-625 to provide electrical connections to new equipment inside the glovebox. This scope involves collaboration research with Idaho State University in accordance with their Standard Operating Procedures (SOP) found at https://www.isu.edu/ehs/.

24A1081-184FP
ERP ID 2774
Investigations into Irradiated Waste Form Performance for Fuel Cycle Technologies
Regardless of reactor type, research and development on the back-end of the fuel cycle, i.e., fuel disposition or recycling, remains an under-addressed issue. This project aims to explore the hypothesis that encapsulation in a stable and durable waste form with proven robustness in high radiation environments provides a viable path forward for immobilizing endof-life electro-refiner salt, used in the production of high assay low enriched uranium (HALEU) with the potential to be extended to other waste salts such as those from molten salt reactors. This research will explore novel aspects of waste form durability, including irradiation studies to simulate long-term viability in repository storage, characterization, and

comparison of material properties before and after irradiation. Characterization testing techniques could include scanning electron microscopy (SEM), transmission electron microscope (TEM), neutron radiography, and x-ray diffraction (XRD), while durability would be analyzed using long-term leaching tests as outlined in American Society for Testing and Materials (ASTM) standard C1285-14, thermal expansion using a dilatometer, and stability at elevated temperature using thermogravimetric analysis (TGA). These studies will have a significant impact on waste form research and development, including disposition options for Mk-IV electro-refiner salt, providing critical insight into the behavior of these materials in realistic environments over a longer time period than has been previously simulated.

3.0 Advanced Materials and Manufacturing for Extreme Environments

24A1081-006FP
ERP ID 2795
Solid Tritium Breeder for Fusion Enabled by Electric Field Assisted Sintering
The purpose of this project is to develop a new solid tritium breeder concept for fusion reactor systems. The synthesis of these materials will be performed using electric field assisted sintering to consolidate mixtures of metal and ceramic (non-nano) powders into solid cermets. The development of the synthesis process will be informed by MOOSE-based modeling tools, including MALAMUTE and TMAP-8, which will also be further developed over the course of the project. This scope involves collaboration research with Purdue University in accordance with their Standard Operating Procedures (SOP) found at https://www.purdue.edu/ehps/index.php.

24A1081-062FP
ERP ID 2802
Novel Synthesis and Examination of Uranium-Zirconium Carbonitride (UZrCN)
This research proposes three synthesis methods to produce uranium-zirconium carbonitride (UZrCN) that will potentially provide high-purity material. The first method is a solid-state diffusion process that utilizes advanced field assisted sintering of uranium nitride and zirconium carbide powders. The second is a direct casting of uranium, zirconium, and carbon under a nitrogen cover gas. The last method utilizes the infusion of cyanide gas into uranium zirconium (UZr) powder, taking advantage of the elevated kinetics of interstitial diffusion. The fabricated UZrCN will be tested under extreme prototypic environments such as hot hydrogen, carbon dioxide, and helium to evaluate fuel resilience. This scope involves collaboration research with University of Florida in accordance with their Standard Operating Procedures (SOP) found at https://www.ehs.ufl.edu/.

24A1081-172FP
ERP ID 2790
Advanced Structural Material with Corrosion-Resistant Cladding for Molten Salt Environment
Generation IV advanced fission and proposed fusion reactor designs will operate under unprecedented conditions. The reactor components are expected to experience high temperatures, harsh corrosive environments, and/or larger and harder neutron fluences than the current generation reactors. Traditional reactor materials often prove inadequate for long-term application in the advanced reactor designs, and this can increase the burden on materials reprocessing, decommissioning and disposal. Therefore, the objective of this project is to develop a state-of-the-art structural material with a good combination of corrosion resistance, impressive high temperature mechanical properties and irradiation tolerance for molten salt reactors. To achieve this,
(1) Alloy 709 with improved high temperature mechanical properties will be adopted as the base material;
(2) a yttrium doped- nickel (Ni)-molybdenum (Mo) material will be developed as a salt-facing cladding on top of Alloy 709 to enhance molten salt corrosion resistance;
(3) yttrium oxide (Y_2O_3) will be added to inhibit helium (He) swelling that is a concern for nickel-based material.
To validate our solution, electric field assisted sintering (EFAS) will be employed for fabricating a monolithic saltfacing material, and for cladding the salt facing material onto Alloy 709. High temperature molten salt corrosion and tensile testing, in combination with microstructure characterization will be performed for properties evaluation. Heliumion radiation and microstructure evaluation will be carried out to investigate the irradiation tolerance of the produced material. Successful completion of this project will deliver advanced structural material with corrosion-resistant cladding for fluoride molten salt reactors and demonstrate the application of state-of-the-art processes and testing methodologies. This scope involves collaboration research with University of Michigan in accordance with their Standard Operating Procedures (SOP) found at https://ehs.umich.edu/.

24A1081-200FP
ERP ID 2776
Characterization, Modeling, and Validation of the Impact Dynamics of Structural Microreactor Materials
This project will develop an explicit dynamic capability within the Multiphysics object-oriented simulation environment (MOOSE). This will involve extensive mechanical characterization of different grades of graphite at high strain rates and the development of a material model to predict its behavior. In addition, explicit dynamic capabilities will be implemented, improved, and validated within MOOSE, including contact, performant element types, and critical time step evaluation. Validation will include the comparison of Taylor anvil experiments against code predictions.

4.0 Integrated Energy Systems
24A1081-084FP
ERP ID 2823
Recycling Critical Raw Materials from Used Solid Oxide Electrolyzers
This project is to integrate Idaho National Laboratory's (INL)'s capabilities in biomass pre-processing, critical raw materials (CRM) recycling, and solid oxide electrolyzers (SOEs) manufacturing to develop a physio-electrochemical strategy for recovering and recycling the CRM from end-of-life SOEs manufacturing waste assisted by techno-economic assessment (TEA) and life cycle assessment (LCA). The success of this project will reinforce INL's Department of Energy (DOE)'s hydrogen production portfolio and offer the potential to further reduce costs addressing the Hydrogen Shot's cost target of $1/kg by 2031, while also developing a sustainable supply chain alternative for critical materials.

24A1081-098FP
ERP ID 2827
Integrated Heterogeneous Structure of High-Entropy-Alloy/Reactor for High-Throughput Chemical Synthesis via In-Situ Carbon-Dioxide Hydrogenation
In this proposal, there will be fabrication of an integrated electrochemical cell with high-entropy alloy (HEA) and densified proton conducting electrolyte for CO2 conversion to methanol. The HEA will act as the catalyst for CO2 conversion and the densified electrolyte acts as the HEA support. This electrochemical cell will work at the temperature lower than 400 °C. This scope involves collaboration research with University of Oklahoma and University of Idaho in accordance with their Standard Operating Procedures (SOP) found at https://compliance.ouhsc.edu/ehso and https://www.uidaho.edu/dfa/division-operations/ehs.

24A1081-101FP
ERP ID 2777
Impurities in Lithium-ion Batteries: Troublemakers or Troubleshooters.
The Proposal 24A1081-101FP studies the current supply for battery manufacturing, as well as the impact of materials grade on the battery performance and battery manufacture cost. The project is a combination of lab experiments and computer modeling. A new tool will be developed through this project to accelerate the assessment of minerals and materials for battery cathodes through correlation of material impurities and battery performance. Also, involves research with Center for Advanced Energy Studies.

24A1081-118FP
ERP ID 2824
Direct CO2 Capture from Seawater Using Flowing Electrode Capacitive Deionization Strategy based on 2D Materials
This project aims to address CO2 capture from seawater using flowing electrode capacitive deionization (FE-CDI). Functionalized two-dimensional materials will be synthesized by Boise State and be used as flowing electrodes in a slurry. An electric potential will be applied within the anode and cathode of a dual membrane electrochemical cell to mobilize the carbon ions out of sea water. Synthetic sea water will be used where the goal is to remove the carbonates and bicarbonates from the seawater and concentrate these carbon sources in a solid form, either as calcium carbonate or magnesium carbonate. This scope involves collaboration research with Boise State University in accordance with their Standard Operating Procedures (SOP) found at https://www.boisestate.edu/policy/facilities-planning-campussafety/policy-title-environmental-health-and-safety/.

24A1081-209FP

ERP ID 2775
The Development of Aqueous Zinc-Manganese Oxides Batteries for Long-Duration Energy Storage
Comparing with lithium ion and flow battery technologies, aqueous zinc (Zn)/manganese oxide (MnO2) batteries are highly desirable owing to their low-cost, high safety and high energy density; however, cycling stability is a major hurdle for large-scale adoption. In this project, in order to target long duration and address those issues, the different failure mechanisms leading to capacity decay need to be distinguished first. And then, rational aqueous electrolyte design will be discovered in zinc ion batteries. The ion solvation structure of electrolytes will be tuned to enable the formation of solid-electrolyte interphases (SEIs) on zinc anode surface and cathode-electrolyte interphases (CEIs) on the cathode surface to enhance the stability of both electrodes.

5.0 Secure and Resilient Cyber-Physical Systems

24A1081-009FP
ERP ID 2825
Programable Hardware Authenticity Self Evaluation (PHASE)
The applied science of cyber-physical phenomenologies central to this proposed research is key to the discovery of important insights and development of new capabilities. Researchers will attempt to discover how to realize detector functions or sensors within the FPGA fabric that enable self-monitoring of side-channel emissions such as temperature, voltage, and electromagnetic interference. Aggregated data will then be used to attempt to validate the integrity of the FPGA hardware/configuration pair based on side-channel signatures observed. If successful, this research will enable self-monitoring of side-channel emissions of existing FPGA platforms as an additional security element to detect compromise. This scope involves collaboration research with Montana State University and Drexel University in accordance with their Standard Operating Procedures (SOP) found at https://www.montana.edu/policy/environmenthealth-safety/ and https://drexel.edu/research/compliance/environmental-health-safety/.

24A1081-011FP
ERP ID 2826
Artificial Neural Network Enabled Decode of Gigabit Ethernet (AN^2 EDGE)
In order to prove this hypothesis, researchers will attempt to develop and train machine learning algorithms to enable decode of full-duplex network signals as they appear when passively observed. This applied cyber-physical research will leverage bleeding-edge cyber science to countervail physical phenomena resulting from the superposition of electromagnetic waves. Success will allow passive capture and decode of data from Gigabit Ethernet and related communication protocols without prior knowledge of what either endpoint has transmitted. The resulting new technology will enable a completely passive device to interface with and collect data from all communications networks without risk to critical systems resulting from disturbance or delay of signals. This scope involves collaboration research with Montana State University in accordance with their Standard Operating Procedures (SOP) found at https://www.montana.edu/policy/environment-health-safety/ .

24A1081-024FP
ERP ID 2852
Directional MAC with Spread Spectrum Network Discovery
This project researches methods in fully directional communications to reduce the impact of interference and detection to external nodes. Most of the work will be in simulation software. The final phase of the project will include field testing out of the INL site where temporary directional antennas will be used on tripods that sit in the back of the truck to prove out communication methods developed as part of this LDRD. This scope involves collaboration research with University of Idaho in accordance with their Standard Operating Procedures (SOP) found at https://www.uidaho.edu/dfa/division-operations/ehs.

24A1081-049FP
ERP ID 2770
Detecting UNclassified Electromagnetic Signals (DUNES) for Secure Wireless Communication Using Open Set Recognition
The idea of ultra-wideband (UWB) communications for short ranges i.e., up to a few tens of meters, has been around since the 1990s. In the period of 2002 to 2006, the federal communications commission (FCC) allocated 7.5 GHz of

spectrum for unlicensed use of UWB. Since then, despite many efforts by the industry, UWB deployment has never reached its predicted potential. This is partly because of disagreements on the best approach for UWB waveforms. This proposal suggests an alternative technology based on filter banks and explores the advantages of filter bank communications when compared to previously suggested technologies. For this research, there will be development of signal processing algorithms for filter bank UWB (FB-UWB) and designs of a prototype system that demonstrates the approach using off-the-shelf software radio platforms. This proposed system will provide significantly higher data rates than commercially available UWB, and orders of magnitude lower transmit power than conventional wireless technologies, such as Wi-Fi and Apple Airdrop. Moreover, the broad past experiences with filter banks efficiently design and develop these algorithms and prototype. Using filter banks for UWB is a transformative technology that will revolutionize the earlier thoughts on UWB and become a serious contender for any future development in this field. FBUWB
will provide resiliency and assurance to the government communication portfolio due to the unique capabilities it offers over conventional wireless technologies and other proposed UWB technologies.

24A1081-061FP
ERP ID 2779
Filter Bank Ultra-Wideband Communications
The idea of ultra-wideband (UWB) communications for short ranges i.e., up to a few tens of meters, has been around since the 1990s. Despite many efforts by the industry, UWB deployment has never reached its predicted potential. This proposal suggests an alternative technology based on filter banks and explores the advantages of filter bank communications when compared to previously suggested technologies in UWB. For this research, there will be development of signal processing algorithms for filter bank UWB and design a prototype system that demonstrates the approach using an off-the-shelf software radio platform. This approach will allow significantly higher data rates than commercially available UWB, and orders of magnitude lower transmit power than conventional wireless technologies, such as Wi-Fi and Bluetooth. This scope involves collaboration research with University of Utah in accordance with their Standard Operating Procedures (SOP) found at https://oehs.utah.edu/.

24A1081-220FP
ERP ID 2847
AskSoftly: Combining Multiple Language Models with External Information Storage to Increase Binary Software Analysis Capabilities at Scale
Software analysis is a time-consuming process that requires the analyst possess expertise in one or multiple programming languages and the knowledge of how to reverse-engineer said languages. The goal of this project is to develop a solution that can reduce the analysis time required for large software collections, which can contain millions of samples, from multiple months to weeks. This will be achieved by developing automatic analysis pipelines that combine the natural language query and reasoning capabilities of Large Language Models (LLMs) with databases of semantic information representations and software analysis tools. This project focuses on data analysis at scale and will require minimal materials other than sufficiently powerful computing hardware. This scope involves collaboration research with University of Wyoming in accordance with their Standard Operating Procedures (SOP) found at https://www.uwyo.edu/safety/index.html.

6.0 Chemical and Molecular Science (emerging core capability)

24A1081-012FP
ERP ID 2788
Development of a Predictive Model for Organic Diluent Radiolysis
Liquid organic molecules in used nuclear fuel reprocessing solvent systems are constantly exposed to ionizing radiation which leads to the destruction of the solvent and its organic solutes, with the formation of degradation products. The understanding of the fundamental chemistry of these short-lived organic radicals is minimal, which limits the ability to predict and control organic liquid radiolysis under process conditions. To address this fundamental knowledge gap, this project will couple irradiation experimental techniques (steady-state and time resolved) with mechanistic computer modeling and simulation for the elucidation, characterization, and quantification of the processes underpinning transient organic radical reactivity and kinetics at the molecular level in irradiated dodecane, a prototypical nuclear fuel cycle

solvent. Validation of the predictive computer model will be achieved by comparing the experimental data for radiation driven degradation of neat dodecane, as well as for typical organic ligand systems in dodecane under gamma irradiation with the model predictions. Overall, these data, models, and new knowledge will improve the quantitative understanding of fundamental radiation-driven processes that affect the formation and chemical behavior of transient radicals in liquid organic media. This scope involves collaboration research with Brookhaven National Laboratory, California State University Long Beach, and University of Notre Dame in accordance with their Standard Operating Procedures (SOP) found at https://www.bnl.gov/esh/index_e.php , https://www.csulb.edu/beach-building-services/environmental-healthand-safety, and https://facilities.nd.edu/services/utilities-and-maintenance/environmental-health-and-safety-programs/ .

24A1081-050FP
ERP ID 2781
Predicting Radiation-Induced Plutonium Redox Chemistry using Multi-scale Modeling Methods
This research goal is to develop an experimentally supported mechanistic multi-scale computer model for the prediction of radiation-induced plutonium ion redox chemistry in aqueous solutions. To achieve this goal, quantitative experimental data is needed for the change in concentration of individual Pu ion oxidation states as a function of the initial Pu oxidation state, absorbed dose, radiation quality, and solution composition. These data will be acquired through the preparation of various plutonium solutions and then irradiating them with a combination of ex situ gamma and electron beam, and in situ alpha radiolysis techniques. This scope involves collaboration research with Brookhaven National Laboratory in accordance with their Standard Operating Procedures (SOP) found at https://www.bnl.gov/esh/index_e.php .

7.0 Condensed Matter Physics and Materials Science (emerging core capability)

24A1081-015FP
ERP ID 2771
Self-Learning Kinetic Monte Carlo Simulations of Radiation Damage in Nuclear Fuels
A fundamental understanding of the effects of irradiation on thermo-physical and mechanical properties of nuclear materials (e.g., thermal conductivity for nuclear fuels and ductility for structural materials) requires precise knowledge of the nature and population of point defects and small defect clusters therein. Direct experimental visualization of these small-scale defects using high-resolution scanning transmission electron microscopy (HRSTEM), however, remains a challenging task. Recently, self-learning kinetic Monte Carlo (SLKMC) simulations have emerged as a powerful computational tool for predicting long-time evolution of irradiation-induced defects with full atomistic fidelity, which can reach experimental timescales not accessible by classical molecular dynamics (MD) simulations. The goal of this project is to leverage the state-of-the-art SLKMC techniques to predict defect evolution in irradiated uranium dioxide (UO2) and uranium mononitride (UN) fuels. For both materials, neural network-based machine learning interatomic potentials (MLIPs) will be developed to speed up the unbiased sampling of the complex potential energy surfaces (PESs) of defect clusters formed under irradiation, which is needed for on-the-fly generation of events (pathways and associated energy barriers for defect migration and reaction) during SLKMC simulations without the need for a priori knowledge. The MLIP potentials will retain the accuracy of first-principles calculations while being many orders of magnitude faster. Model validation will be performed using experimental data from the literature and existing Basic Energy Science (BES) programs at Idaho National Laboratory (INL). This project fits well with INL's BES engagement strategy and will provide a powerful new modeling capability to strength the BES-materials program at INL.

24A1081-119FP
ERP ID 2785
Unconventional superconductivity in doped epitaxial samarium nitride
The team of researchers at Idaho National Laboratory research center (IRC) plan to synthesize thin films of samarium nitride and study their physical properties. The systems that will be used are located in laboratories IRC-C5 and IRC-C6. There will be usage of high-purity samarium metal that is completely contained in an ultra-high vacuum chamber and evaporate small amounts of it to combine with a nitrogen plasma and form the thin films on small substrates that measure 10 mm by 10 mm. This whole process is fully contained, and substrates and samples are only handled when entering and leaving the vacuum chamber. This scope involves collaboration research with Texas A&M University, Benemerita Universidad Autonoma de Puebla, Universidad Nacional autonoma de Mexico, Lawrence Berkeley National Laboratory in accordance with their Standard Operating Procedures (SOP) found

at https://ehs.tamu.edu/, https://www.buap.mx/, https://www.unam.mx/, and https://ehs.lbl.gov/.

8.0 Computational Science (emerging core capability)

24A1081-206FP
ERP ID 2859
Advancing Digital Engineering and Multiphysics Models of Irradiation Experiments
The proposed project involves the development of computational models and a computational framework to improve the engineering analyses of irradiation experiments. The work in this project will be purely computational and devoted to computational code developments.

9.0 Plasma and Fusion Energy Sciences (full core capability)

24A1081-087FP
ERP ID 2813
Multiphysics High-Fidelity Modeling of Plasma Facing Components
The engineering processes taking place in the plasma facing components (PFCs) of a fusion reactor are complex, making their design challenging. The goal of this project is to develop the first open-source, fully integrated multiscale computational framework for full scale, three dimensional (3D) PFC modeling: Fusion ENergy Integrated multiphys-X (FENIX). This framework will (i) enable identifying the main degradation mechanisms of PFCs, (ii) alleviate challenges early in the design process, and (iii) support effective design/optimization iterations. Moreover, FENIX will facilitate quantifying uncertainties associated with different physics, and therefore identify key areas where improvements are most impactful, making FENIX a strategic asset for the fusion community. To achieve these goals, FENIX will synergistically leverage Multiphysics Object-Oriented Simulation Environment (MOOSE) tools, which are well established in the fission energy space. This scope involves collaboration research with North Carolina State University and University of Illinois Urbana-Champaign in accordance with their Standard Operating Procedures (SOP) found at https://ehs.ncsu.edu/ and https://cam.illinois.edu/policies/fo-18/.

24A1081-195FP
ERP ID 2818
Development of Tightly Coupled Multiphysics Simulation Workflows for Fusion Reactor Magnet Design and Engineering. This proposal is the development of new capability within the Multiphysics Object-Oriented Simulation Environment (MOOSE) to accurately simulate the tightly coupled electromagnetic-thermomechanical (EM-TM) response of the magnet assemblies and structures within a modern fusion reactor to perform safety and performance evaluation. There are several gaps in the current set of MOOSE modeling capabilities for this type of multiphysics problem. New material models that represent the electromagnetic and thermomechanical properties of the structure are required, as well as a high-fidelity, transient magnetic field solver suitable for large-scale, high magnetic field strength scenarios. This scope involves collaboration research with North Carolina State University and University of Illinois Urbana-Champaign in accordance with their Standard Operating Procedures (SOP) found at https://ehs.ncsu.edu/ and https://cam.illinois.edu/policies/fo-18/.

10.0 Net-Zero Carbon Emissions: no FY-24 LDRD projects met this initiative.