DOE-ID NEPA CX DETERMINATION
Idaho National Laboratory

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SECTION A. Project Title: FY-21 LDRD Projects

SECTION B. Project Description and Purpose:

INL uses LDRD investments to accelerate advanced nuclear energy Research, Development, and Demonstration (RD&D), develop integrated fuel cycle solutions, accelerate advanced integrated energy systems, develop advanced materials and manufacturing processes for extreme environments, and improve the security and resilience of cyber-physical systems across critical infrastructure systems. LDRD is a relatively small, but vital DOE program that allows INL and other DOE laboratories to select a limited number of RD&D projects. It works to: 1) maintain the scientific and technical vitality of INL, 2) enhance INL's ability to address future DOE missions, 3) foster creativity and stimulate exploration of forefront S&T, 4) serve as a proving ground for new research, and 5) support high-risk, potentially high-value RD&D. Determining LDRD and other RD&D investments relies on alignment with the Laboratory's science and technology (S&T) initiatives.

The Laboratory ensures that LDRD program goals and objectives are aligned with DOE Order 413.2C, Chg 1, and that the LDRD portfolio is managed with integrity and transparency. All LDRD projects go through a rigorous proposal review and selection process, and ongoing projects applying for renewal are contingent on a progress report review process. These steps ensure that LDRD investments are continually aligned with INL's vision, mission, and S&T initiatives, and are technically sound, innovative, cutting-edge RD&D projects.

INL's five strategic S&T initiatives are described below:

> *Nuclear Reactor Sustainment and Expanded Deployment*. INL works to develop and qualify new nuclear fuels, design and enable testing and demonstration of a microreactor by early 2024, and leads the National Reactor Innovation Center (NRIC). INL's efforts contribute to enabling the U.S. to regain and sustain leadership in advanced reactor technologies.
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> *Integrated Fuel Cycle Solutions*. INL develops integrated fuel cycle solutions to sustain the current reactor fleet and enable its expansion and replacement with advanced reactors.
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> *Advanced Materials and Manufacturing for Extreme Environments*. INL focuses on advanced materials and manufacturing solutions for use in extreme environments, including advanced nuclear reactors, integrated energy systems, defense systems, and space applications. INL, often in partnership with industry, seeks to discover and advance materials that must function in extreme environments for instrumentation and energy technologies.
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> *Integrated Energy Systems*. INL researches and demonstrates methods to harness and use a variety of forms of nuclear energy products (radiation, heat, and electrons) in conjunction with energy products from other clean-energy sources to accelerate the deployment of an economy based on clean, reliable, and sustainable energy.
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> *Secure and Resilient Cyber-Physical Systems*. INL advances automated-control solutions for vital systems and critical infrastructure through its control systems cybersecurity capability. INL's threat analysis and consequence-based risk prioritization with embedded, component, and system security RD&D for critical process technology develops automated threat responses and resilient systems that limit the physical effects of cyberattacks.

Fiscal Year (FY) 2021 LDRD investments offer the potential to achieve INL's five S&T initiatives by focusing on its long-term objectives and key S&T drivers. Additionally, strategic investments enable researchers to conduct early-stage exploratory research to foster innovation through collaborative RD&D, while providing science and engineering opportunities for students and postdocs. The FY 2021 LDRD research projects are summarized below:

Nuclear Reactor Sustainment and Expanded Deployment

144 – Flash Neutron Radiography at TREAT to Examine Two-Phase Flow – MFC (U510)
Flash neutron and X-ray radiography have been applied in a variety of fields to understand high-speed dynamic events, some of which often cannot be explored any other way. This project will develop and analyze the performance of an experimental facility for flash neutron radiography utilizing the Transient Reactor Test (TREAT) facility and apply this capability to proof-of principle two-phase flow experiments. A high-speed digital neutron imaging system will be developed for installation in TREAT's neutron radiography station where proof-of-principle bubbly flow experiments will be performed. The system will consist of a high-speed digital camera optically coupled to a quickly decaying neutron scintillator screen placed in the beam behind an experiment apparatus. The proof-of-principle measurements are designed to measure nucleation site density at the time of critical heat flux at high pressures, which is needed for modeling and simulation validation.

This project will be completed at the Transient Reactor Test (TREAT) Facility. Radiation shielding materials (polymer sheets, lead bricks), cameras and optics, aluminum hardware, computer(s), other electronics will be purchased. The lead is powder-coated for safer handling and will not be a waste product; it will continue being used at the TREAT Facility beyond this project.

155 – Demonstrating Fueled-Salt Irradiation Capability to Support Reactor Deployment – NS&T (C601)
Licensing and operating Molten Salt Reactors (MSR) requires an understanding of (1) the source term, radiation chemistry, and gas generation; (2) unanticipated irradiation-induced corrosion effects; and (3) the impact of burnup on thermophysical properties, all of which can be deduced through

irradiation testing. Idaho National Laboratory (INL) proposes to leverage its expertise in chloride salt chemistry, as well as its Neutron Radiography Reactor (NRAD) facility, to conduct fuel-bearing chloride salt irradiation and to fill in the knowledge gaps pertaining to salt chemistry under irradiation. Utilizing NRAD will enable the testing of fissile-bearing salt (not possible at equivalent university reactors) while accelerating experiment timelines compared to the Advanced Test Reactor (ATR).

The majority of the project will take place at various locations on the MFC campus including Hot Fuels Examination Facility (HFEF), Irradiated Materials Characterization Laboratory (IMCL), Engineering Development Laboratory (EDL), Mockup Shop, Fuels and Applied Science Building (FASB), Analytical Lab (AL), and Neutron Radiography Reactor (NRAD). Other INL locations include Energy Innovation Laboratory (EIL) and North Holmes Laboratory (NHL) at the Research Education Campus (REC). Ammonium Chloride (solid), uranium (metal-solid), uranium chloride (solid), and sodium chloride (solid) are needed for fuel synthesis, and acetone (liquid) and ethanol (liquid) will be used for general cleaning purposes. The uranium will be irradiated in NRAD. All wastes generated will be in a solid phase. An electronic control system will be purchased to control a furnace that will be fabricated at INL. There is also a possibility of purchasing (along with other projects at INL) a fission gas monitoring system (FGMS) to place in the basement of HFEF.

253 – Informative Design of High-Temperature Metal Hydride Moderators in Microreactors – NS&T (C610)

Micro nuclear reactor research centers on compact reactors that operate at relatively low power (<20MWth), at high temperatures (~800°C), with passively safe designs for deployable electricity and/or industrial process heat. The keys to the compactness of these reactors are the high-power density core design and the utilization of dense neutron moderators. Because hydrogen is an effective moderator, materials with high hydrogen number density are considered as candidates for neutron moderators. The challenge with hydride moderators is ability to retain hydrogen as a metal hydride at elevated temperatures. Escape of hydrogen from the moderator can affect the criticality of the reactor, posing a potential safety concern via hydrogen reactivity, reduced thermo-mechanical properties, and unplanned modification of macroscopic cross sections. This challenge can be addressed by developing metal alloy hydrides with high hydrogen binding energies, using the first principles simulations and confirmatory experiments. Therefore, the proposed action (i) computationally develops alloy hydrides which minimize hydrogen transport and maximize its retention, (ii) measures microstructures and material properties of the developed alloy hydride(s) essential for the licensing of these reactors, and (iii) investigate the possible effects of irradiation on these critical properties by performing a small set of screening ion irradiations. First principles techniques will be used to downselect the best option for pure and alloy-based hydrides based on hydrogen binding energy and thermophysical properties. The density functional theory (DFT) and *ab initio* molecular dynamics (MD) simulations will explore materials with the optimum hydrogen binding energy and thermal properties with the additions of various elements to improve hydrogen behavior. Downselected candidates will be subjected to screening ion-irradiations and post-irradiation property measurements to generate data essential to utilizing these alloy hydrides in microreactors.

The project locations for this proposal include Center for Advanced Energy Studies (CAES), TRA-666, FASB (optional), and IRC. Cleaning agents for the metallic samples (ethanol and acetone) will be used. There will be purchases made specific to this project: ConFlat fitting components, button heater, and Swagelok components.

Integrated Fuel Cycle Solutions

153 – A Combinatorial Modelling & Simulation and Separate Effect Test Approach to Investigate Unknown Microstructural Evolution in Metallic Fuel Pin– MFC (U510)

This project proposes to use modeling and simulation (M&S) and separate effect studies to improve current knowledge and models assessing advance fuel behavior. This project will use BISON simulations and an extensive literature and/data review to inform a series of high throughput separate effect tests (SET) aimed at evaluating metallic fuel axial swelling and "fluff" structure development and evolution. The fluff structure is a porous structure formed at the top of the fuel that affect source term release and has an impact on core reactivity (thus on core loading and reactor shut down). The matter of its formation and its stability under steady state and transients' conditions is not understood. The data and literature review will leverage on the on-going inter-laboratories effort on database construction for advance reactor system and will provide a set of parameters and boundaries conditions for these phenomena. Based on the database variables correlation, a first model will be developed. The model will be implemented in BISON and used to inform a series of high throughput SETs, aimed at validating the developed hypothesis. This combinatorial study will be used to improve and extend BISON models, and to predict a suite of bonding conditions for fuel safety.

The location of this project is at MFC and Rensselaer Polytechnic Institute. The first year of the project will be focused on modelling and the results will determine the specific facility at MFC (either FASB, IMCL, EML, Experimental Fuels Facility (EFF), Advanced Fuels Facility (AFF). Radioactive material will be used in the form of metallic fresh and irradiated fuel (U-Zr, U-Pu-Zr). Polishing compounds and cleaning medias will be used. No new equipment will be purchased for this project. Mixed waste and TRU waste will be generated only at MFC. The amount of TRU waste generated is explained in Part II. Work at Rensselaer Polytechnic Institute will involve database review and modeling (no experimental work).

161 – Microwave-assisted Digestion of Nuclear Materials– MFC (U410)

The use of microwave-assisted digestion has clear advantages when compared to the open systems currently used for dissolution of nuclear materials, including lower digestion time (significantly increasing sample throughput), better recovery for volatile elements and being a cleaner sample preparation technique, which enhances the quality of the analytical results. It is also more reproducible and predictable, as the digestion efficiency in a closed system is better monitored by parameters such as temperature and pressure, and not only to the visual confirmation of presence or absence of solid material.

The main goal of this work is to develop and implement new microwave digestion technologies for nonirradiated dissolutions in the AL at MFC to improve sample dissolution capability and the ability to reach lower detection limits.

The dissolution methods for several materials will be developed evaluating several acid types and acid mixtures (nitric, hydrochloric, hydrofluoric and boric acids will be used) with one of the most recent microwave digestion systems, a Milestone UltraWAVE. This system is equipped with a single reaction chamber (SRC), where the digestion flasks are contained inside a larger reaction vessel, which is then pressurized with 40 bar of N_2. With the SRC, temperatures up to 300°C and pressures up to 199 bar can be achieved, increasing the digestion efficiency for several materials. A systematic evaluation of temperature, pressure, sample mass and acid concentration are necessary for the development and validation of methods.

Chemical used include inorganic acids (nitric, hydrochloric, hydrofluoric, boric and sulfuric) which will be used for dissolution using a microwave digestion system. The acids (concentrated or diluted) + samples will be heated using microwave-induced heating in a closed pressurized system, with pressure varying from 40 to 199 bar. In addition to the acid, uranium materials such as uranium metal and uranium oxide (U3O8) in pieces or chunks will be digested. Depending on availability, U-Mo, U-Zr, U-N materials may also be digested. The UltraWAVE will be installed in a benchtop configuration, inside a Radiological Buffer Area.

200 – Traveling Molten Zone Refining Process Development for Innovative Fuel Cycle Solutions – NS&T (C420)
The proposed project aims to confirm the phase behavior and develop a thermal treatment process to rapidly extract actinides from spent metallic fuels. A traveling molten zone system with induction heating will be used for both purposes. The project anticipates that one rapid pass of the molten zone from the bottom to the top of the metallic rod incorporating species of spent metallic fuels will realize the expected immiscible layer formation and provide species partitioning data. It will also demonstrate an actinide extraction process by concentrating the impurities at the top segment of the rod and leaving the actinide species behind as the bulk rod.

This project will occur at MFC, at EFF-west. A variety of chemicals and metals will be utilized including uranium (depleted), cerium, strontium, sodium, and cesium metals. Alloys will be made of the mentioned metals with various composition by melting and consolidating. The leftover uranium, cerium, strontium, sodium, cesium metals may need to be disposed as low-level waste but may also be reused. The zone melting furnace will be the sole equipment purchase.

205 – Modeling and Measurement of Gas Transport in Nuclear Fuels – NS&T (C650)
The modeling of axial gas transport needs to be implemented to improve the BISON fuel performance code developed at INL. Model validation will be accomplished by comparing the predictions with data obtained from an out-of-pile separate effects apparatus. The proposed prototype will investigate the time to equilibrium of the gas pressure due to different manufactured pathways using surrogates that mimic the different stages of irradiation. In support of the experimental efforts, BISON will be used to guide experiment design. The project outcomes will provide the United States with unique capabilities and modeling techniques

The modeling will occur mostly via remote locations and telecommuting with occasional visits to MFC Research Collaboration Building (RCB) and IRC. A flow meter, pump, and pressure monitoring hardware will be purchased for the project.

Advanced Materials and Manufacturing for Extreme Environments

140 - Accelerating Pathways to Actinide Materials Discovery Through Combinatorial Deposition – EES&T (B612)
The proposed action takes a materials-library approach to synthesize a wide range of actinide systems utilizing a staged framework of thin film fabrication, characterization, transport analysis, and *ab initio,* physics-based modeling and simulation.

The project will be located at IRC (laboratories C10, C6, B3) and University collaborators at Boise State University, University of Utah, and University of California Riverside. Thin films of depleted uranium dioxide, thorium dioxide, and mixed uranium/thorium dioxide will be synthesized at the University of Utah and then characterized at INL. These materials and their properties and structure will be characterized using a variety of methods at INL. Light cleaning solvents will only be used for purposes of sample cleaning (acetone, methanol).

142 - Assessment of Neutron Irradiation Tolerance of Semi-Coherent Nano-Lamellar Structures – MFC (U520)
The objective of this seed project is to elucidate the role of semi-coherent nano-lamellar structures on the defect evolution and phase stability of intermetallic titanium aluminides under irradiation, with the long-term objective of applying this understanding to design irradiation tolerant materials for advanced nuclear energy systems. Intermetallic titanium aluminides exhibit low neutron activation, high specific strength, excellent oxidation, corrosion, and creep resistance at elevated temperatures, and have potential for applications in advanced fission and fusion reactors. The proposed action studies the defect evolution and phase stability of titanium aluminides with semi-coherent $\alpha 2/\gamma$ nano-lamellar interfaces under neutron irradiation.

This project is a collaboration between the INL (IMCL and EML facilities at MFC) and a reactor lab at MIT. Radioactive stainless steels and titanium alloys will be utilized. The metal specimens will be irradiated in MIT reactor, and shipped back to MFC at INL for characterization. The samples will be characterized in confined vacuum systems, including scanning electron microscope and transmission electron microscope in IMCL and EML. After the completion of the projects, the samples will be kept in NSUF library at INL for other researchers to access in the future.

143 - An Innovative Approach for Accelerated Irradiation Studies of Materials – MFC (U520)

The objective of this project is to develop an innovative approach to accelerate irradiation studies of materials in nuclear reactors. The proposed action develops an innovative in-pile approach to accelerate irradiation damage studies of materials in research reactors without creating neutron atypical damage. Boron neutron capture (BNC) therapy is used to locally treat invasive tumors such as brain tumors and recurrent head and neck cancer. In this project, the concept of BNC method will be used to develop high-throughput neutron capture radiation (NCR) testing capability. It is proposed to use $Boron^{10}$ (B^{10}) and Lithium (Li^{6}) based lithium boron oxide glass as neutron converter and $Uranium^{235}$ (U^{235}) based fuel to trigger fission reactions and create damage in the target materials. Thermal neutrons are absorbed by B^{10} and Li^{6}, and the resulting nuclear capture and fission reactions yield high-energy alpha particles. This approach provides isotropic irradiation environments with neutrons, alpha particles and fission fragments, and dramatically accelerates in-pile irradiation flux. Irradiation-induced microstructure using the proposed method will be benchmarked using well-studied stainless steels after neutron irradiation. As a demonstration, this project also seeks to create metastable high-entropy alloys from long-range ordered intermetallic compounds by metastability engineering using irradiation as an asset. Molecular dynamics (MD) simulations will be performed to study irradiation-induced disordering of intermetallic compounds and its effects on mechanical properties.

This project is a collaboration between the INL (IMCL and EML facilities at MFC) and a reactor lab at MIT. Radioactive stainless steels and titanium alloys will be utilized. The metal specimens will be irradiated in MIT reactor, and shipped back to MFC at INL for characterization. The samples will be characterized in confined vacuum systems, including scanning electron microscope and transmission electron microscope in IMCL and EML. After the completion of the projects, the samples will be kept in NSUF library at INL for other researchers to access in the future.

152 – Development and Demonstration of Spatial Correlation Techniques Among Diverse Data Sets – MFC (U520)
INL is currently focused on improving fuel and materials characterization techniques by upgrading existing capabilities such as visual examination, neutron and X-ray radiographic and tomographic imaging, metrology, scanning electron microscope (SEM) and transmission electron microscope (TEM) imaging, focused ion beam tomography, and optical microscopy, amongst others. The proposed action will help improve imaging data analysis by developing a technique for quantitative data extraction from images while also establishing the ability to integrate multiple data sets to provide researchers with a more robust picture of material properties by correlating information obtained from different techniques.

The location of this project will be performed at RCB where the project primarily involves data analysis on computers. The data itself is collected from various instruments at IMCL and the NRAD reactor. No chemicals or radioactive materials will be used within the scope of this project.

194 – Natural Gas to Chemical Intermediate by Single-Step Synthesis Using Tubular Ceramic Catalytic Membrane Reactor – EES&T (B622)
Non-oxidative aromatization of natural gas (ANG) is a promising chemical process that can synthesize aromatics and hydrogen for downstream conversion processes, which increases process efficiency by improving selectivity and avoiding the separation process. In this proposal, a tubular ceramic catalytic membrane reactor (CMR) with embedded innovative catalysts is proposed for intensification of this process that can result in high and prolonged aromatic yields by applying electrochemical potential. The CMR can overcome thermodynamic reaction equilibrium by introducing electrochemical energy to shift selectivity towards heavier aromatics. By incorporating ANG reaction into CMR with similar carbon efficiency to large and optimized Fischer-Tropsch plants, this direct conversion approach can be adapted to the size of a natural gas field with flexibility for chemicals synthesis.

The project is located at EIL (C313, C312, C212) and IRC (B103). Tetrammineplatinum nitrate, Alpha Aesar, gallium nitrate, zeolite, and some oxides and carbonates ($BaCO_3$, ZrO_2, CeO_2, $Y2O_3$, NiO) will be used. No radioactive material will be used for this project. To support this project an electrical furnace was purchased to provide heating for the reaction which will be located at IRC.

195 – A Fundamental Investigation of the Current Leakage Mechanism and Relevant Harsh Environmental Chemistries in Solid Oxide Materials – EES&T (B611)
The proton-conducting solid oxide electrolysis cell (p-SOEC) is an electrochemical ceramic electrolyzer that produces hydrogen and oxygen simultaneously by water splitting reaction at intermediate temperatures (400~600˚C), which are closer to the thermal temperatures of nuclear plants. The fast hydrogen production rates have been achieved by optimizing the electrode/electrolyte materials and microstructure, which shows promise for commercializing this technology. The proposed action develops a state-of-the-art and high throughput atomic/electronic scale computational framework. The computational work will be supplemented by an in-house experimental validation at INL via relevant p-SOEC fabrication, characterization, and performance analysis.

The simulation portion of the project will be performed from Collaborative Computing Center (C3) and EIL buildings and the experimental portion will be performed in EIL-C313, C212. Many chemicals will be utilized including; NiO, $BaCO_3$, Y_2O_3, CeO_2, ZrO_2, and $Pr(NO_3)_3$, $Ni(NO_3)_2$, and $Co(NO_3)_3$. In addition, some ethanol mixed with NiO, $BaCO_3$, Y_2O_3, CeO_2, ZrO_2 powders may be left over as waste.

199 – Data-Driven Failure Diagnosis and Prognosis of Solid-State Ceramic Membrane Reactor under Harsh Conditions Using Deep Learning Technology with Internal Voltage Sensors – EES&T (B622)

The proposed action develops a novel method to investigate *in situ* effects of different components (e.g. anode, electrolyte, cathode) on the degradation behavior in a solid state ceramic membrane reactor (SCMR) by embedding micro-voltage sensors into the interface between different components to monitor current response and collect impedance electrochemical data during operation. These sensors will enable simultaneous fault diagnosis based on state-of-the-art artificial intelligence (AI) technology (i.e. stacked sparse autoencoder, grid long short-term memory and physics-informed neural networks). In this proposed work, a well-established high temperature steam electrolysis process using a solid oxide electrolysis cell (SOEC) developed at INL will be used as a case study. By collecting data and developing the key features of the sensors, the project will observe degradation trends during operation and use this data to predict reactor failure under harsh operating conditions. With the completion of this project, a critical failure diagnostic tool will be developed for electrochemical membrane reactors for use as high-temperature electrochemical hydrogen production systems, helping reveal the underlying degradation mechanism and develop the relevant mitigations.

The location for this project is EIL C212. Small amounts (~2g/month) of silver paste will be used as a collecting material. Air emissions include argon (~ 60 ml/min), O_2 (~5ml/min) and H_2 (~10ml/min).

220 – Modular Designs for Facilitated Transport Membranes in Olefin Production – EES&T (B622)

This project focuses developing scaling and demonstrating membrane modules based on facilitated transport membranes (FTMs) that will separate and concentrate ethylene from the effluent of the INL electrochemical non-oxidative deprotonation process (ENDP), which potentially targets INL oxidative coupling of methane process (OCMP) and steam cracking olefin production processes.

Two main tasks are envisioned: 1) Fabricating and testing new FTMs that include electrochemical and chemical methods for silver ion stabilization, and 2) designing and testing modular designs that can be piloted. Based on the understanding gained from the parametric laboratory membrane fabrication and performance testing, a scalable process to fabricate large surface area membrane modules will be determined to help accelerate pilot plant tests of ENDP with the new membranes.

The location of this project is at EIL and the University of Toledo. Most preparatory chemistry will be done at EIL C312 and some of the analytical spectroscopy will be done at EIL C318. No experiments will be conducted at the University of Toledo, but INL will be sending polymer membranes and other chemicals to their laboratories. Chemicals that are planned to be used are custom polymers using primarily polydimethysiloxane (PDMS), but other polymers could be used including polyamides, polyethylene oxides, and polyglycols. Organic solvents will be used (hexanes, tetrahydrofuran, toluene, and dimethylacetamide) to dissolve the polymers. No radioactive materials will be used for this project. Hazardous waste will be generated in small quantities (gram and milliliters). Two to five grams of silver (I) will be used at the University of Toledo. University of Toledo will be responsible for the waste that is generated at their facilities and will follow their procedures.

222 – In Situ Positron Annihilation Spectroscopy for Characterizing Irradiation Induced Defects – MFC (U510)

The proposed action is a proof of principle study for a new positron annihilation spectroscopy (PAS) capability that uses neutrons to 1) induce damage while, 2) generating positrons to analyze the defect evolution in nuclear fuels and materials. PAS is sensitive to low vacancy concentration (~1014 cm^{-3}) and small defect size (sub nanometer). Therefore, it is capable of nondestructively probing the formation of vacancy defects under neutron doses well below 1 dpa. If successful, this research will provide first-hand information on defect dynamics at the onset of neutron damage.

This project is a collaboration between the INL facilities (EIL, IRC, MFC HFEF, FASB, and IMCL) and North Carolina State University. Chemical use is limited to cleaning agents such as ethanol and isopropyl alcohol. Positron/gamma sealed button source (Na-22, ~10 µCi) and irradiated metal samples (not rad at EIL) with very low activity will be part of this project. Equipment needs may include gamma detectors and various electronics.

237 – Spectral Observation Convolutional neural networK (SPOCK) – NS&T (C620)

This project proposes a method to analyze collected radiation spectra using advanced, scalable deep learning. This concept will be developed by training Sawtooth on real-world and simulated gamma-ray spectra generated at the INL IRC Physics Laboratory. Ultimately, due to the broad range of possible spectroscopy scenarios, it must be determined if analysis can be trained on simulated training data sets in order to be functional in real-world measurements.

Physical work will be performed at IRC IF638-115, while calculations/computational work will be performed remotely and at the Collaborative Computing Center (C3). Only small radiation check sources that are kept and controlled at the IRC IF638 facility will be used for this project. These sources include gamma-ray and beta emitting sources such as Cs-137, Co-60, mixed Gamma gamma-ray sources, and Sr-90 beta particle sources. All sources are certified and sealed. Sources will be placed in various configurations on detector systems located at the IF638-115 spectroscopy laboratory.

249 – Large Scale Spark Plasma Sintering Process and Die Design– EES&T (B612)

This project has five areas of work: 1) SPS Pyrolysis, Carbonization, and Graphitization, 2) Vacuum Impregnation System Design and Fabrication, 3) 3D Printing of Carbon-fiber SPS Tooling, 4) Die Assembly Manufacturing, and 5) SPS Die Experimental Testing and Validation.

Task 1: SPS Pyrolysis, Carbonization, and Graphitization

Instead of using radiative heating, the proposed action uses the Spark Plasma Sintering (SPS) system as the source of heat and energy. The proposed action involves inserting the mesophase pitch impregnated carbon fiber parts into SPS die assemblies and performing pyrolysis, carbonization, and perhaps graphitization directly. The project also builds custom die assemblies with gas flow ports and passages to condense and drain the liquid-rich effluent (primarily this will be low molecular weight paraffins). To increase the carbon conversion efficiency of the resin, carbon black will be mixed into the mesophase pitches. Carbonization will occur in the die assemblies where only heat is applied to the impregnated preforms, as compared to direct flow of electric current through the impregnated preforms. Small scale (parts <20mm diameter) conversion testing, using INL's smaller scale SPS devices will be performed in parallel with Task 2 to develop heating profiles and effluent analysis/measurement. Once these techniques and approaches are established, the large DCS-800 system and dies will be modified.

Task 2: Vacuum Impregnation System Design and Fabrication

The intended filler material to be used in this impregnation system will be a mesophase binder pitch. There exist numerous, functional designs in the literature to guide this development effort. The project does not anticipate needing to use over-pressures of gas to impregnate the simple shape forms discussed in this proposal, but the design review of the system (completed by February 2021) will drive the necessary capabilities. The key design feature of this device will be the ability to evacuate the part while introducing a low-viscosity, but high carbon conversion density, pitch into the pyrolyzed 3DP CF part.

Task 3: 3D Printing of Carbon-fiber SPS Tooling Precursors
INL will subcontract and collaborate with the Idaho-based startup Continuous Composites, Inc (CCI), located in Coeur d' Alene Idaho. This work will be laid out in 4 basic phases: (P1) rectilinear block and resin development, (P2) small, 75mm part size, die assembly printing, (P3) medium, 150mm part size, die assembly printing, and (P4) large, 200mm part size, die assembly printing. In P1, the focus will be on printing unidirectional (Uni) and quasi-isotropic (QI) rectilinear blocks for pyrolysis and densification testing, while also developing and selecting appropriate resins that are UV-curable, locally during printing, and fully convertible to carbon during pyrolysis without significant shape change. These parts will be examined using INL's X-ray computed tomography (XCT) capabilities.

Task 4: Die Assembly Manufacturing
The goal of this portion of the project is to manufacture the final C-C die assemblies. The first step is the development of the densification process, where pyrolyzed and impregnated 3DP CF blanks are carbonized in the SPS. The initial impregnation and carbonization experiments will be evaluated via XCT, Archimedes density, X-ray diffraction, Raman spectroscopic analysis, microscopic analysis to determine the density distribution, overall density, graphite quality (D/G ratio of the graphite), and local pore and fiber distributions, respectively. The impregnation steps will be repeated until further density improvements are not found, or until greater than 92% Archimedes density is achieved whereby closed porosity is achieved. The temperature and time profiles for carbonization and densification of these parts will be optimized through rigorous Design of Experiments.

Task 5: SPS Die Experimental Testing and Validation
This final phase of the project will be performed using actual SPS experimental apparatuses, including INL's SPS to achieve the pressures and current densities necessary to determine the operational parameters of the C-C, C-SiC, and Mersen 2160/Tokai G535 graphite die assemblies. The die assemblies will be tested electrothermally, mechanically, and for burst/crush strength. The electrothermal testing will consist of heating rate tests of 20, 100, 400 K/min using conductive and non-conductive powder samples. The thermal gradients across the face of the densifying samples will be monitored by an array of thermocouples arranged radially out from the center of the plunger assembly, while the process control will be provided by a temperature measurement located ~3-5mm from the outside edge of the sample inside the die assembly itself. The burst/crush strength tests will be performed in situ during SPS testing only on the inert, non-conductive powder system. These tests are most appropriately done above or equal 873K where SPS testing has shown graphite die assemblies to be more failure resistant than at room temperature. Slow loading rates to failure will be conducted at increasing temperatures to determine the comparable die assembly strengths between the materials of interest. These tests will only be performed on the large die assemblies at increasingly high temperatures up to 1473K, where further temperature increases would risk damaging the SPS apparatus.

The project is located at IRC and ESL. Chemicals to be used include a carbon mesophase pitch for impregnating carbon-fiber preforms. It is a mixture of hydrocarbon compounds that is solid at room temperature and melts at around 200-300C. The project will melt the material inside the SPS system to impregnate the carbon-fiber preforms. That structure will then be heated to very high temperature which decomposes the hydrocarbons into carbon/graphite. Industrial waste will be generated from this project in the form of cleaning supplies and shop towels.

256 – Advanced Manufacturing of Novel Nuclear Fuels and Structural Components – MFC (U170)
This project seeks to address design and materials challenges focused on advancing understanding of components and fuel systems fabricated by the Laser Additive Manufacturing (LAM) process. The micromechanical properties and phenomenological behavior of advanced fabricated materials will be examined.

This project investigates and finalizes the co-manufacturing of cladding materials and uranium-zirconium fuels using the Optomec MR-7 system.

The project will be carried out at MFC in AFF and FASB and the radioactive materials that will be unitized are depleted metallic uranium alloyed with zirconium. The uranium-bearing material will be processed into powder and then subjected to laser-based heating. Uranium-bearing materials will be subjected to laser-based heating within the confines of a glovebox.

257 – Nanostructuring of Uranium Based Metallic Fuels via Spark Plasma Sintering – MFC (U170)
The proposed project aims to demonstrate the *proof-of-concept* of a novel nanostructured metallic fuel for advanced reactors. The project utilizes nanosized uranium mononitride (UN) particles embedded within a uranium-molybdenum (U-Mo) metallic matrix as a model system. The project will establish a first principles guided route to synthesize the (U-Mo)/UN nanocomposite fuel, develop a powder consolidation process of the fuel feedstock using pulsed-electric-field assisted sintering (FAST), i.e. Spark Plasma Sintering (SPS), evaluate solid fuel behavior under ion irradiation, verify the mitigation of FCCI and establish the baseline thermal conductivity of the novel fuel. Unlike previous attempts to mitigate FCCI in metallic fuels by modifying the alloy chemistry, the proposed approach utilizes the atomic structure and chemistry of nanoscale metal/ceramic interfaces.

Hands-on aspects of the project will be carried out at MFC in EFF and AFF. Computer modeling and simulation aspects of the project will be carried out at the University of Idaho. Depleted metallic uranium alloyed with molybdenum will undergo arc melting, milling and sintering.

285 - In-Situ High Temperature Radiation-Induced Metal Cation Redox Chemistry – NS&T (C410)

Due to the complexity of designing *in-situ* capabilities for high temperature irradiation measurements in aqueous solutions, there are only a few radiation chemistry studies in the literature under hydrothermal conditions (>100°C). This project aims to address this critical knowledge gap by establishing state-of-the-art, *in-situ* high temperature irradiation capabilities at INL to investigate the radiation-induced aqueous redox chemistry of a series of multivalent metal ions relevant to a nuclear fuel cycle, i.e., iron (Fe), aluminum (Al), chromium (Cr), and uranium (U). The experimental data will be incorporated into accurate, predictive, mechanistic models for the radiation-induced behavior of these metal ions from ambient to hydrothermal conditions using complementary kinetic and thermodynamic modeling techniques.

The majority of the project will be performed at INL between EIL, Radiochemistry Laboratory (RCL), and FASB. Offsite work will be performed at Brookhaven National Laboratory and The University of Notre Dame Radiation Laboratory. The chemicals required for this project are standard commercial acids, bases, and metal ions. These will be dissolved in water, gamma irradiated, with changes in solution composition measured using a variety of techniques. All radioactive sources will be sealed sources. Hazardous waste will be generated form this project at INL. The amounts used at off-site locations are milliliters of solution and millimolar metal ions. No radioactive waste will be generated off-site. All additional chemical waste will consist of aqueous solutions of no radioactive metals, which will be disposed of in accordance to the respective laboratories (*Brookhaven National Laboratory, Notre Dame Radiation Laboratory, and Canadian Nuclear Laboratories*) waste generation and disposal procedures.

Integrated Energy Systems

198 – Deep Reinforcement Learning and Decision Analytics for Integrated Energy Systems – EES&T (B682)
To meet carbon emission goals, new ways to integrate energy systems to maximize efficiency are being sought. A leading solution is to couple a nuclear power plant (NPP) to dispatchable hydrogen generation plants in a way that thermal and electrical power from the nuclear plant can be used to produce hydrogen when grid electricity demand and prices are low. These systems exhibit nonlinear behavior that must be managed across a wide range of time scales to account for weekly and seasonal power imbalances. The complexities and non-linearities in the shorter time scales inevitably involve numerous dependent and some semi-independent agents and constraints that cannot be managed with conventional control systems because they require a detailed and robust model of the system behavior, which may not be available for many situations.
This project will develop a novel deep reinforcement learning (DRL) approach that is capable of managing either distributed or tightly coupled multi-agent systems. DRL is a promising artificial intelligence (AI) methodology for system control. It utilizes deep neural networks (DNN) for automatic system representation, modeling, and end-to-end learning.

The first two years of the project is to conduct research, development and simulations using computers. No lab experiments will be conducted. Computer work will be done at EIL and Engineering Research Office Building (EROB) with collaboration with the University of Toledo who will also be performing research and simulations. For the third year, of this project, some validation work may be conducted in Energy Storage Laboratory (ESL) by using the Digital Real Time Simulator. No chemicals or radioactive material are going to be used.

218 – Methane Upgrading Using Dynamic Energy Supply – EES&T (B623)
Research Plan: This project is divided into three specific aims that will focus on *i*) mitigating deactivation through catalyst architectural strategies, *ii*) identification of catalyst regeneration strategies for different coke species, and *iii*) bench scale cycling trials and technoeconomic analysis. Experimental methods and instrumentation described below are available in the *Catalysis and Transient Kinetic Laboratory*; with the exception of atomic layer deposition.

Objective 1, Catalyst Deactivation. Zeolite supported molybdenum catalysts will be prepared at INL and carburized using straightforward methods as described in the literature. Nanodomains of Fe, Ni, Pt (and similar metals) will be added using cycles of atomic layer deposition (ALD). ALD equipment is not presently available at INL and samples will be sent to Forge Nano (Louisville, CO). The role of different carbon collector species will be examined in Temporal Analysis of Products (TAP) titration experiments and using density function theory calculations (DFT).

Incremental titration of deactivation kinetics will be measured using TAP multipulse experiments with methane on different catalysts using temperature ramps to determine the impact of start-up dynamics. It is anticipated that the catalyst will require some accumulation of a pool of radical hydrocarbon reaction intermediates prior to the observation of benzene products.

This project will investigate changes in the intermediate pool using pump/probe pulsing of hydrogen and methane in different delay timing. It is anticipated that hydrogen will play a role in mitigating coke formation (this is expanded in Objective 2 when we examine regeneration).

Objective 2, Catalyst Regeneration. Reversible and irreversible coke formation must be distinguished. From different temperature-programmed methane and hydrogen/methane pulsing regimes, the proposed action will characterize post-reaction samples *ex situ* using thermal gravimetric temperature programmed oxidation (TPO) to determine if there are multiple coke species with different binding strengths. TAP pulse response experiments of hydrogen and carbon dioxide will be conducted in addition to studies with carbon monoxide and water. Surface coverage dependent reaction rate constants will be developed for different elementary steps on catalysts with different coke content
Objective 3, Bench Scale Cycling and Technoeconomic Analysis. A bench-scale tubular reactor will be modified for programmed cycling between deactivation and regeneration conditions. High performing catalyst samples from TAP studies will prepared in larger quantities to be proven at bench-scale operating conditions for longer time-on-stream studies. These results will be corroborated with microkinetics of deactivation and regeneration derived from TAP experiments in Objective 1 and 2.

Process simulation will be conducted using Aspen software based on microkinetic reaction rate details provided by TAP and bench scale operating conditions. Technoeconomic analysis will be executed at the demonstration scale (10 kg/day) and CAPEX (capital expenditure) and OPEX (operating expenditure) will be carried out at the production scale.

This project will take place at EIL C111. Chemical use includes both catalyst precursors, catalysts, and reactant gases. Catalyst precursors include metal salts and solvents (generally Mo is the only metal) which will be mounted on zeolite (silicoalumina phosphate) materials. The catalysts are powder sized solid materials. They will be tested in different reactor scenarios where they contact methane or hydrogen gas to produce benzene. Benzene is a by-product of the processes, but is not expected to be released to air, rather it will be trapped in a condenser for liquid disposal.

Secure and Resilient Cyber-Physical Systems

146 – Unattended Operation through Digital Twin Innovations – EES&T (B654)
A digital twin tool will enable reduced costs and risk through integration of the disparate systems used in the design, construction, and operation of microreactors and next generation reactors. This proposal will use the Microreactor AGile Non-nuclear Experimental Testbed (MAGNET) as a case study to develop a digital twin with a single heat pipe test article, providing the capabilities of remote monitoring and unattended operation (autonomous control) of the system. This twin will be developed through integration of Deep Lynx (a data warehouse technology), the Multiphysics Object-Oriented Simulation Environment (MOOSE), physical asset sensors, and physical asset controls. The team will also perform AI model training and experimentation to determine what models and features are most important for enabling intelligent autonomous control and evaluate and determine best practices for digital twin cyber security.

The location of this project is located at C3 and the Bonneville County Technology Center (BCTC). The proposed work involves testing the MAGNET single heat pipe test article, and no chemicals or radioactive materials are needed. Furthermore, there is no plan to purchase any equipment and no emissions or discharges will occur.

191 – Scalable Framework of Hybrid Modeling with Anticipatory Control Strategy for Autonomous Operation of Modular and Microreactors – NS&T (C200)
The proposed project will develop and validate a scalable framework that uses hybrid modeling (physics-based and AI techniques) and anticipatory control techniques to enable emerging reactors to regulate their operations, take optimized control actions in a semi-autonomous manner (or autonomous, in the case of microreactors), aid operators, and proactively protect against potential anomalies, such as load variations, plant component degradation, unanticipated design basis events, cyber incidents, or other external events. The team will collaborate with modular and microreactor vendors to validate the framework and expand its applicability to other reactor systems across various reactor designs. The team will also perform a cost-benefit analysis to estimate the savings achievable by automation and its impact on the operation and maintenance (O&M) of plant systems.

This project will use INL's HPC capabilities and Human System Simulation Laboratory located in EIL.

225 –Development of Scalable Design Optimization Parameters for Bi-Component Protective Systems– N&HS (D100)
The specific objectives in this proposed project are to examine and quantify the effects of ceramic/titanium alloy intercomponent bonding on the optimal projectile/target areal density ratio and the component relative mass fraction. The bonding methods to be used are an INL- developed metallurgical bonding process, an organic adhesive, and a control group without inter-component bonding. Additionally, the dynamic behavior due to impact such as propagation of mechanical waves will be characterized and quantified via Digital Image Correlation (DIC) or via X-ray Phase-Contrast Imaging (PCI). Concurrent numerical simulation efforts will use the experimental data gathered from these two tasks as input calibration data to populate a larger dataset.

This project will take place at the National Security Test Range (NSTR) and at IRC. Ballistic metals and a polymer epoxy are the only materials needed for this study.

239 – Shock Wave Mitigation in Metal Materials Through Advanced Manufacturing Processes– N&HS (D100)
This project will create strategically oriented microstructures allowing the attenuation and dissipation of shock waves in large-impulse tolerant and shock mitigating materials. The key objective is to understand what forming processes and associated processing parameters influence microstructure to become oriented to dissipate shock wave energy. Equal channel angular extrusion (ECAE), rolling, and welding will be explored. After processing a material through the mentioned processes, crystallographic orientation texturing will be evaluated with Orientation Imaging Microscopy (OIM) while shock wave attenuation and dissipation will be documented using the planar impact shock experiments. A modeling and simulation effort will be completed to explore the shock response of systems to predict material systems that offer the largest attenuation and dispersal of an incident shock wave. Then materials, materials processing methodologies, and system designs will be chosen, processed and bonded together to form a layered system for comparison with a monolithic material. These will be shocked, and the shock wave propagation will be monitored.

Three primary tasks will be executed to accomplish the research objective.

Task 1 – Development of Favorable Texture and Mechanical Properties

To orient the microstructure, ECAE, multi-material welding capabilities at IRC, and commercially available rolling systems will be used The ECAE system at IRC can process rectangular bars up to 7/8” x 7/8” x 6”. However, to process plates, a new die will be designed and fabricated. Selected materials will be processed while adjusting parameters and observing the change on the microstructure.

Rolling can produce highly textured materials and aids in aligning grain boundaries. This process will be explored to fine tune the oriented microstructures to guide wave propagation and dissipation. Rolling may be executed at a commercial facility such as Niagara Specialty Metals Inc.

A multi-wire welder at IRC will be used to create functionally graded materials. During welding, the crystals orient themselves based on the maximum temperature gradient and are deposited in the molten material pool forming mechanical impedances across the thickness of the plate.

Once the material is processed, the microstructure will be characterized using Orientation Imaging Microscopy (OIM) to characterize and evaluate the microstructure texture. The OIM will inform each material process to establish a relational database of processing routes with observed microstructures and the extent of crystallographic texturing. This database will document the material processing parameters that yield the microstructure, as indicated from modeling and simulation. A Split-Hopkinson Pressure Bar will be used to capture dynamic stress/strain properties from the unoriented and oriented microstructure materials for comparison.

Layering dissimilar material is another path to manipulating shock wave transmission. Materials currently considered for the high-speed layer are copper, steel and aluminum. Materials currently under consideration for the low speed layer are tin, zinc, and brass Table 1 lists several materials and their material sound speed that are considered for this work.

Table 1. Selected speeds for potential layering materials

Material	Longitudinal Wave Speed
Copper	4800
Steel	5900
Aluminum	6400
Tin	3300
Brass	4700
Zinc	4200

After the parameters controlling microstructure orientation are understood and the materials for the testing package are selected, the testing package will be constructed and tested. Materials will be processed individually according to microstructure orientation and bonded together Materials could also be potentially roll bonded, brazed and soldered, or a stack of ECAE plates could be processed together. In addition, the materials may be bonded together then subjected to additional processing to further develop a favorable shock response. The Split-Hopkinson Pressure Bar will be used to capture dynamic stress and strain properties from processed testing packages.

Task 2 – Modeling & Simulation (M&S) of Material Systems

The goal of the modeling and simulation effort is to aid in the selection of materials for testing the package used for the ballistic testing. The modeling and simulation effort will be completed in parallel with Phase 1 activities. The modeling software to be used in this effort will be the either Alegra (Sandia National Laboratory hydrocode) or ALE3D (Lawrence Livermore National Laboratory hydrocode). The continuum modeling and simulation will consist of two materials in a serial stack subjected to a large impulse load from a flyer plate. The geometry used for the model will be a 20 mm diameter flyer plate impacting a 20 mm diameter target article.

Task 3 – Characterization of the Shock Response of Material Systems

The bonded multilayer samples will be studied at the National Security Test Range (NSTR) using a powder driven or explosively driven flyer plate. High-speed imaging (to capture macroscale behavior of the test package), Photon Doppler Velocimetry (to capture the shock speed in the material), and a force sensor (to capture force transmission to the rear of the test package) will be used to characterize the material response to shock loading. The performance of the testing packing will be benchmarked against a comparable monolithic material.

Timeline

Year 1

- Revive ECAE equipment, design and build die for ECAE processing plate
- Construct and execute material modeling and simulation
- Begin processing materials – ECAE-process two materials; deposit a composition gradient using the multi-wire welding equipment; down-select and roll two materials to achieve microstructure and crystallographic alignment.
- Characterize microstructures of the processed plates.

Year 2

- Optimize processing materials based on characterization results from Year 1
- Construct testing packages
- Conduct experimental flyer plate testing on testing packages.

The location of the project will be held at multiple locations (IRC, Sandia National Lab or Lawrence Livermore National Lab (only for computer modeling), and NSTR. The project will only generate metallic scrap waste as a result of material processing that yield undesirable results in the material. Additionally, greases and lubricants will be used during material processing and small amounts of acid etchants for revealing metal microstructure during metallographic sample preparation (generally, acid etchants).

SECTION C. Environmental Aspects or Potential Sources of Impact:

Air Emissions

Several of these LDRD projects are expected to generate a small amount of air emissions in a variety of constituents. Due to the nature of these LDRD projects, emissions will be minor and covered by existing APAD's for the individual facilities.

A small amount of fission product gases (<< than a milligram) will be released within the main cell at HFEF. Those gases would then exit the HFEF ventilation/exhaust stack.

Minor amounts of NOx, Cl2, and acid vapors will be generated during activities at the MFC AL.

At AFF, EFF, and FASB off-gassing that occurs as a result of heating uranium components is contained within a glovebox that is connected to a radiological facility exhaust system that processes the exhaust through in-line HEPA filters prior to being emitted to the air.

Proposed activities will generate small amounts of air emissions at EIL in the form of benzene, ethylene, ethane, methane, C2 hydrocarbons, and CH4, CO2, Ar (~ 60 ml/min), O2 (~5ml/min) and H2 (~10ml/min). In addition, unreacted methane and hydrogen gas will be exhausted from the TAP reactor. There will be no flaring or chemically reacting of these gases.

NSTR: Air emissions are expected to include fugitive emissions and emissions from non-road mobile generators (emissions from mobile generators are not regulated since the generator will be in place less than one year.

Discharging to Surface-, Storm-, or Ground Water

Proposed activities have the potential to discharge chemicals to the Idaho Falls Sewer System. No planned discharges are planned to occur out at the site. No discharges are planned for off-site locations.

Disturbing Cultural or Biological Resources

For projects that occur out at MFC and NSTR, there is the potential to disturb cultural resources that are eligible the National Register of Historic Places or un-surveyed areas.

Generating and Managing Waste

LDRD projects will generate waste, including office waste, industrial waste (e.g., gloves, non-hazardous hardware, ceramic-type pellets, machining scrap, 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 desert Site. The total estimated sum of the generated TRU waste is about 2 cubic feet.

Off-Site Locations: Locations off-site will have the potential to generate industrial waste, office waste, hazardous waste, 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." 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.

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 to 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: 10 CFR 1021 Appendix B to subpart D, Item B3.6, "Small-scale research and development, laboratory operations, and pilot projects", B1.24 "Property Transfers" and B1.31 "Installation and relocation of machinery and equipment".

Final Environmental Assessment for Expanding Capabilities at the National Security Test Range and the Radiological Response Training Range at Idaho National Laboratory (DOE/EA-2063, January 2019)

Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement 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 (1996)

Final Environmental Impact Statement for the Waste Isolation Pilot Plant (DOE/EIS-0026, October 1980) and Final Supplement Environmental Impact Statement for the Waste Isolation Pilot Plant (SEIS-I) (DOE/EIS-0026-FS, January 1990)

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, September 1997)

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, December 2014).

Justification: The proposed R&D activities are consistent with CX B3.6 "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); 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 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.",

B1.31, “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), provided that 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." and,

B1.24, "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."

NEPA coverage for explosives and ballistic testing at the NSTR is found in the Final Environmental Assessment for Expanding Capabilities at the National Security Test Range and the Radiological Response Training Range at Idaho National Laboratory (DOE/EA-2063)

After Post-Irradiation Examination (PIE) in the modular hot cell in FCF, irradiated of molten salt systems and PIE remnants will be stored with other similar DOE-owned irradiated materials and experiments at MFC, most likely in the Hot Fuels Examination Facility (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 molten salt systems 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 Order (DOE O) 435.1, Att. 1, Item 44, which states “…Test specimens of fissionable material irradiated for research and development purposes only…may be classified as waste and managed in accordance with this Order...”.

NEPA coverage for the transportation and disposal of waste to Waste Isolation Pilot Plant (WIPP) are found in the 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 ROD also stated that a more detailed analysis of the impacts of processing and handling TRU waste at the generator-storage facilities would be conducted. The Department has analyzed TRU waste management activities in the Final Waste Management Programmatic Environmental Impact Statement (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.

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.

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

Approved by Jason Sturm, DOE-ID NEPA Compliance Officer on:02/04/2021