FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

U. S. Department of Energy

Idaho Operations Office

Fiscal Year 2020 Consolidated Innovative Nuclear Research

Funding Opportunity Announcement:
DE-FOA-0002128

Announcement Type: Initial - August 20, 2019
AMENDMENT 0001 (8/26/2019)

CFDA Number: 81.121

Informational Webinar: August 6-8, 2019
(Video links and presentations are available at www.neup.gov)

Issue Date: August 20, 2019

Letter of Intent (Mandatory only for NSUF Applications)
Due Date: September 4, 2019 at 7 p.m. ET

R&D/NSUF Pre-Applications (Mandatory except for IRPs)
Due Date: September 24, 2019 at 7:00 p.m. ET

NSUF Preliminary Statement of Work
Due Date: November 21, 2019 at 7:00 p.m. ET

NSUF Final Statement of Work
Due Date: January 23, 2020 at 7:00 p.m. ET

Full R&D Applications
Due Date: February 11, 2020 at 7:00 p.m. ET

IRP Applications
Due Date: February 11, 2020 at 7:00 p.m. ET

NOTE: Deadlines are the dates/times by which DOE must receive the specified submittal

AMENDMENT 0001: The purpose of this amendment is to:

- Clarify that the page limit for pre-applications technical narratives is 3-pages;
- Correct hyperlinks to the NSUF Statement of Work Template; and,
- Clarify letter of support timing and upload location for MS-NE-1 and MS-NE-2 workscopes.

Registration Requirements

There are several one-time actions applicants must complete in order to submit an application in response to this Announcement (e.g., obtain a Dun and Bradstreet Data Universal Numbering System (DUNS) number, register with the System for Award Management (SAM) and create an account on NEUP.gov. Applicants who are not registered with SAM should allow up to five weeks to complete this requirement. It is suggested that the process be started as soon as possible.

If an applicant has not already done so, it must:

1. Obtain a DUNS number. DUNS website: http://fedgov.dnb.com/webform.

2. Register with the SAM. SAM website: https://www.sam.gov/SAM/.

3. Create an account on NEUP.gov using the 'Sign In' tab in the top right hand corner. To create an account; 1) Click "Create a new account"; 2) fill out the required information and click "Create User"; 3) Fill out the information in the "My Information" section.

Questions

Questions regarding the **content of the funding opportunity announcement** must be submitted using the contact information found on page Part VII, Section B of this FOA. DOE will try to respond to a question within three (3) business days, unless a similar question and answer have already been posted on the website.

Application Preparation

Applicants must prepare the application package and application forms from the NEUP.gov website: **https://neup.inl.gov/SitePages/Home.aspx**

Additional instructions are provided in Section IV of this FOA.

Application Submission

Electronic applications and instructions are available at the NEUP website. To access these materials, (1) go to www.NEUP.gov, (2) select "Sign In" from the top right hand corner of the screen, (3) enter your user credentials, (4) select "Applications" from the menu, and (5) click on "Create New Application" for the type of application you are creating. Apply at www.NEUP.gov. If you have any questions about your registration, contact the INR Integration Office at 208-526-1602 or at neup@inl.gov.

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LIST OF ACRONYMS

CFDA	Catalog of Federal Domestic Assistance
CFA	Call for Full Applications
CFR	Code of Federal Regulations
CINR	Consolidated Innovative Nuclear Research
COI	Conflict of Interest
CTD	Crosscutting Technology Development
DE	Department of Energy (FOA Number)
DOE	Department of Energy
DUNS	Data Universal Numbering System
FC R&D	Fuel Cycle Research and Development
FFATA	Federal Funding and Transparency Act of 2006
FFRDC	Federally Funded Research and Development Center
FOA	Funding Opportunity Announcement
FSRS	FFATA Subaward Reporting System
FWP	Field Work Proposal
FY	Fiscal Year
GAIN	Gateway for Accelerated Innovation in Nuclear
HTGCR	High-temperature Gas-cooled Reactor
ID	Identification
IRP	Integrated Research Project
LOI	Letter of Intent
LWRS	Light Water Reactor Sustainability
M&O	Management and Operating
M&TE	Measuring and Test Equipment
MOOSE	Multiphysics Object Oriented Simulation Environment
MS	Mission Supporting
MSI	Minority Serving Institution
MSR	Molten Salt Reactor
NCE	No Cost Extension
NE	Office of Nuclear Energy
NEAMS	Nuclear Energy Advanced Modeling and Simulation
NEET	Nuclear Energy Enabling Technologies
NEUP	Nuclear Energy University Program

NFML	NSUF Nuclear Fuels and Materials Library
NRC	Nuclear Regulatory Commission
NSUF	Nuclear Science User Facilities
NNSA	National Nuclear Security Administration
PD	Program Directed
PDF	Adobe Portable Document Format
PIE	Post-irradiation Examination
PI	Principal Investigator
POC	Point of Contact
PS	Program Supporting
QA	Quality Assurance
R&D	Research and Development
RC RD&D	Reactor Concepts Research, Development and Demonstration
RPA	Request for Pre-applications
SAM	System for Award Management
SF	Standard Form
SMR	Small Modular Reactors
SOW	Statement of Work
URG	Under Represented Group
U.S.	United States

PART I – FUNDING OPPORTUNITY DESCRIPTIONS

A. STATEMENT OF OBJECTIVES

This Funding Opportunity Announcement (FOA) is for Consolidated Innovative Nuclear Research (CINR) and is thus referred to in this document as the "CINR FOA".

A.1 Background and Objectives

The Department of Energy's (DOE) Office of Nuclear Energy's (NE) mission is to advance U.S. nuclear power in order to meet the nation's energy needs by:

1.) Enhancing the long-term viability and competitiveness of the existing U.S. reactor fleet;
2.) Developing an advanced reactor pipeline; and,
3.) Implementing and maintaining the national strategic fuel cycle and supply chain infrastructure.

All applications submitted under this FOA must demonstrate a strong tie to at least one of these 3 priorities.

NE conducts crosscutting nuclear energy research and development (R&D) and associated infrastructure support activities, to develop innovative technologies that offer the promise of dramatically improved performance for its mission needs as stated above, while maximizing the impact of DOE resources.

The DOE has established a Gateway for Accelerated Innovation in Nuclear (GAIN) team, which has been working closely with the advanced nuclear design community to identify R&D objectives and work scopes that may be appropriately addressed through DOE programs. Several of the work scopes contain explicit language as guidance, but there are many additional work scopes that, at least tangentially, address needs identified in technology specific workshops. Work scopes that may be addressed in activities funded under this FOA are identified in Part IX, Appendices A-C, below. Generally speaking, applications that offer flexibility or provision for addressing measurements, materials, and conditions relevant to private sector developers of fast-spectrum reactors (lead-cooled, sodium cooled, and gas cooled), molten salt reactors (MSR), or high-temperature gas-cooled reactors (HTGCR) are encouraged.

NE strives to promote integrated and collaborative research conducted by national laboratory, university, industry, and international partners under the direction of NE's programs, and to deploy innovative nuclear energy technologies to the market in order to meet the strategic goals and optimize the benefits of nuclear energy. NE funds research activities, through both competitive and direct mechanisms, as required to best meet the needs of NE. This approach ensures a balanced R&D portfolio and encourages new nuclear power deployment with creative solutions to the universe of nuclear energy challenges. This FOA addresses the competitive portion of NE's R&D portfolio, as executed through the Nuclear Energy University Program (NEUP), Nuclear Energy Enabling Technologies (NEET) Crosscutting Technology Development (CTD), and the Nuclear Science User Facilities (NSUF). NEUP utilizes up to 20% of funds appropriated to NE's R&D program for university-based infrastructure support and R&D in key NE program-related areas: Fuel Cycle Research and Development (FC R&D),

Reactor Concepts Research, Development and Demonstration (RC RD&D), and Nuclear Energy Advanced Modeling and Simulation (NEAMS). NEET CTD supports national laboratory and university-led crosscutting research. By establishing the NSUF in 2007, DOE-NE opened up access to material test reactors, beam lines, and post-irradiation examination facilities to researchers from U.S. universities, industry, and national laboratories, by granting no-cost access to world-class nuclear research facilities.

While this FOA specifies many of NE's current and upcoming R&D priorities, NE reserves the right to respond to potential shifts in R&D priorities during Fiscal Year (FY) 2020 that may be driven by events, policy developments, or Congressional/budget direction. Further, NE reserves the right to fund all or part of an application to this FOA.

A.2 Major NE Funded Research Programs

A.2.1 Fuel Cycle Research and Development (FC R&D) Program

The mission of the FC R&D program is to develop used nuclear fuel management strategies and technologies to support meeting the federal government responsibility to manage and dispose of the Nation's commercial used nuclear fuel and high-level waste and to develop sustainable fuel cycle technologies and options that improve resource utilization and energy generation, reduce waste generation, enhance safety, and limit proliferation risk.

The program's vision is that by mid-century, strategies and technologies for the safe, long-term management and eventual disposal of U.S. commercial used nuclear fuel, and any associated fuel cycle technologies that enhance the accident tolerance of light-water reactors and enable sustainable fuel cycles are demonstrated and deployed. Together, these technologies and solutions support the enhanced availability, affordability, safety, and security of nuclear-generated electricity in the United States.

Current challenges include the development of high burn-up fuel and cladding materials to withstand irradiation for longer periods of time with improved accident tolerance; development of simplified materials recovery technologies, waste management (including storage, transportation, and disposal), and proliferation risk reduction methods; and development of processes and tools to evaluate sustainable fuel cycle system options, and to effectively communicate the evaluation results to stakeholders.

A.2.2 Reactor Concepts Research, Development and Demonstration (RC RD&D) Program

The RC RD&D program conducts research and development (R&D) on existing and advanced reactor designs and technologies to enable industry to address technical challenges with maintaining the existing fleet of nuclear reactors, and to promote the development of a robust pipeline of advanced reactor designs and technologies, and supply chain capabilities. Program activities are designed to address technical, cost, safety, and security issues associated with the existing commercial light water reactor fleet and advanced reactor technologies, such as small modular reactors (SMRs), fast reactors using liquid metal coolants, and high temperature reactors using gas or liquid salt coolants.

A.2.3 Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program

The mission of the NEAMS program is to accelerate early-stage development of advanced reactor concepts and enable improved economics of new and existing designs, by providing leading-edge computational tools to U.S. industry. The primary program objective is to develop and deploy these predictive tools and methods to industry, academia, and government, including the Nuclear Regulatory Commission (NRC), for research, analysis, design and regulatory acceptance of advanced reactor and fuel cycle systems These advanced computational tools employ scalable simulation methods, on high performance computing architectures in combination with a science-based, mechanistic approach to physics modeling to allow scientists and engineers to better understand reactor materials properties and coupled phenomena in nuclear energy systems. Consequently these tools span length scales from atomic to mesoscale to continuum, and time scales from picoseconds to seconds to days, and are currently being used to move certain advanced reactor concepts forward to commercialization in several key ways, including design optimization, which is required to fully realize the economic and technological advantages of those concepts. NEAMS capabilities also support development of advanced nuclear fuels, design and analysis of nuclear fuel experiments, and expansion of NRC confirmatory analysis capabilities in the advanced reactor area.

A.2.4 Nuclear Energy Enabling Technologies (NEET) Crosscutting Technology Development (CTD)

The NEET CTD program conducts R&D in crosscutting technologies that directly support and enable the development of new and advanced reactor designs and fuel cycle technologies. These technologies will advance the state of nuclear technology, improve its competitiveness, and promote continued contribution to meeting our Nation’s energy and environmental challenges. The activities undertaken in this program complement those within the RC RD&D and FC R&D programs, and support the Department of Energy’s (DOE) Office of Nuclear Energy’s (NE) mission to advance U.S. nuclear power in order to meet the nation's energy needs by: 1) enhancing the long-term viability and competitiveness of the existing U.S. reactor fleet; 2) developing an advanced reactor pipeline; and, 3) implementing and maintaining the national strategic fuel cycle and supply chain infrastructure. The knowledge generated through these activities will allow NE to address key challenges affecting nuclear reactor and fuel cycle deployment with a focus on crosscutting innovative technologies.

A.2.5 Nuclear Science User Facilities (NSUF)

DOE-NE funds access to world-class capabilities to facilitate the advancement of nuclear science and technology. This mission is supported by providing access, at no cost to the user, to state-of-the-art experimental irradiation testing and Post-Irradiation Examination (PIE) facilities as well as technical assistance, including the design and analysis of reactor experiments. This unique model is best described as a distributed partnership with each facility bringing exceptional capabilities and expertise to the relationship, including reactors, beamlines, state-of-the-art instruments, hot cells and, most importantly, expert technical leads. Together, these capabilities and people create a nation-wide infrastructure that allows the best ideas to be proven using the most advanced capabilities. Through NSUF, researchers and their collaborators are building on current knowledge to better understand the complex behavior of materials and fuels under irradiation.

The NSUF allows research teams to obtain access to designated capabilities at various unique facilities provided on the NSUF website at https://nsuf.inl.gov/

Part I, Section B.2 of this FOA describes application options for projects requiring NSUF capabilities.

NOTE: Applicants may request funding fro NSUF "Access Only" projects and/or joint NSUF access combined with R&D funding. Applicants requesting R&D financial support with a joint request for NSUF access will be limited to the work scopes in NSUF-1 and FC-2.5. Work scopes in eligible areas have been tailored to align NSUF capabilities with focused NE program and mission priorities. Applicants requesting NSUF Access Only will apply to the NSUF-2 work scope, a broader work scope focused on NE mission priorities and also tailored to align with NSUF capabilities.

A.2.6 NSUF Fuels and Materials Library

The NSUF Nuclear Fuels and Materials Library (NFML), which is owned by DOE-NE and curated by the NSUF, is a collection of specialized information and nuclear fuel and material specimens from past and ongoing neutron irradiation test campaigns, as well as real-world components retrieved from decommissioned power reactors, and donations from other sources. The NFML can be accessed at https://nsuf-infrastructure.inl.gov/Browse/Materials. In order to continue the expansion of the NFML, any specimens created as the result of an awarded NSUF neutron irradiation project will be added to the NFML. The project lead will be given exclusive rights to the specimens for a three-year period of PIE following completion of the neutron irradiation portion of the project. The specimens will be listed as *Not Available* in the NFML throughout the three-year exclusivity period. In order to populate the NFML, the NSUF program office may recommend irradiating a larger number of specimens than required for an awarded project. These extra specimens, not subject to the three-year exclusivity period, will be added to the NFML and made available for further research immediately after the completion of irradiation. Principal Investigators (PIs) of all future awarded applications requesting specimens from previous awarded neutron irradiation tests will be put in contact with the original PI(s) for potential collaboration. Although collaboration with original PI(s) is encouraged, permission from the original PI(s) to use previously generated materials that are currently *Available* in the NFML is not required.

B. FUNDING OPPORTUNITIES

DOE is seeking applications from U.S. universities, national laboratories, and industry to conduct Program Supporting (PS), Mission Supporting (MS), and NSUF-supported nuclear energy-related research to help meet the objectives of the major NE-funded research programs.

Specifically, this FOA contains three separate funding opportunity areas defined as follows:

B.1 U.S. University-led PS/MS R&D Projects

These funding opportunities are available to U.S. university-led teams. In general, PS R&D is focused more directly on programmatic needs and is defined by the statement of objectives developed by the responsible programs. PS R&D, and within NSUF affiliated work scopes, must be focused and responsive to the representative statement of objectives, which is not specific to a

discipline but can be limiting as defined by the project objective. In comparison, MS R&D is generally more creative, innovative, and transformative than PS R&D, but it must also support the NE mission. MS R&D activities could also produce breakthroughs in nuclear technology or could include research in the fields or disciplines of nuclear science and engineering that are relevant to NE's mission, but may not fully align with the specific initiatives and programs represented by PS objectives. U.S. university PIs are invited to propose research projects in response to this area of the FOA, and the associated PS and MS work scopes contained in Part IX, Appendix A.

B.2 U.S. University-, National Laboratory-, or Industry-led PS R&D Projects

These funding opportunities are available to teams led by U.S. university, national laboratory, or U.S.-incorporated industry PIs. U.S. university or national laboratory PIs can apply as lead PI to any work scopes in Part IX, Appendix B. Proposed research projects in response to this area of the FOA should meet the objectives of the NEET CTD program, and within the NSUF work scopes, meet the identified objectives of the RC RD&D, FC R&D, and NEET CTD programs as described in the work scopes contained in Part IX, Appendix B of this FOA.

B.2.1 Note for Nuclear Science User Facilities Access Projects

NSUF access project applications require a Letter of Intent (LOI) in addition to the pre-application and, if invited (see Part V, Section B.1), a full application. NSUF access project applications will also require a feasibility review and readiness review in addition to the relevancy and technical reviews. Important aspects of NSUF access applications are described in Appendix D and should be seriously considered when preparing applications. It is strongly recommended that all potential proposers review the contents of the NSUF website for vital information at http://nsuf.inl.gov.

The NSUF does not provide funding to the PI to support salaries, tuition, travel, or other costs typically supported via NE Program R&D funds.

DOE intends to fully fund all awarded NSUF access projects for the entire duration of the project, subject to any conditions or limitations contained in the award instruments. NSUF access project attributes include:

- U.S. university PIs may apply for NSUF access with a joint request for R&D financial support as stated in the FC-2.5 work scope.
- U.S. university, national laboratory and industry PIs may apply for NSUF access with a joint request for R&D financial support as stated in the NSUF-1 work scope.
- Academic, national laboratory, and industry PIs may apply for NSUF access without a joint request for R&D financial support as stated in the NSUF-2 work scope.

Eligible work scopes for a NSUF R&D project are found in Part IX, Appendix A & Appendix B, and applications must comply with the provisions of Part IX, Appendix D. **Since NSUF projects involving reactor neutron irradiation and PIE combined may last up to seven years in duration, greater flexibility in the R&D funding distribution can be established in order to better accommodate the actual resource allocation requirements of the project.** Those applications requesting research support, though limited to a total of three years of funding, may

request a project period of performance to spread the funding over the entire length of the project. For irradiation only, PIE only, and beamline applications, a standard continuous funding profile should remain adequate. The PIE phase of all NSUF projects is limited to three years in duration. R&D funding shall not be utilized to directly supplement activities funded by NSUF.

B.2.2 NSUF Readiness

Applicants must demonstrate readiness for NSUF access. In the NSUF pre-application, a summary of readiness is required. In the full application, a detailed description of readiness is required. Applications that do not adequately demonstrate readiness will not be considered for selection. Awarded projects that are found to not be ready for NSUF access may be cancelled.

The following items must be completed prior to requesting NSUF access:

- Development and qualification of fabrication techniques, processes and methods;
- Pre-irradiation characterization (physical, mechanical, thermal, chemical and other applicable properties);
- Material interaction studies (at irradiation conditions); and,
- Corrosion studies (at irradiation conditions).

A plan for delivery of fuel or material must be addressed with specific attention to the following:

- Structural and cladding materials for neutron irradiation must be supplied to NSUF three months after project initiation (provide supplier commitments and lead times) in order for the material to be machined to proper sample configuration prior to encapsulation.
- For previously irradiated fuels and materials not residing in the NSUF NFML, the location (as specific as possible), condition, provenience, pedigree, radioactivity levels, isotopic content, material composition, configuration, ownership, and any other available information that will be needed in order to ship and/or prepare the fuel or material for examination must be identified.
- For fuels and materials residing in the NSUF NFML, identify the specific specimen(s).
- For any fuels or materials supplied for the purpose of neutron irradiation, the applicant must own and have full authority to transfer ownership and title (free of any liens, claims of ownership, or other liabilities) to DOE.
- For fuels or materials coming from other DOE programs (not NSUF), a statement of program commitment is required.

NSUF will not support preliminary fuels, materials, or instrumentation development work, i.e., development must be at the irradiation testing stage. Projects whose relevancy is based solely or primarily on fusion energy needs will not be considered. Applications must include a list of publications that resulted from previous NSUF supported projects.

Projects not requiring R&D financial support may apply for NSUF access only work scopes in response to this area of the FOA and the associated work scope contained in Part IX, Appendix B of this FOA, wherein only access to capabilities are sought to perform research in nuclear science.

Additional information on the NSUF process is included in Part IX, Appendix D.

NOTE: Access to NSUF capabilities will require agreement and final signature to the User Agreement (copy provided in Part IX, Appendix E).**The terms and conditions of the User Agreement are non-negotiable, and failure to accept the terms and conditions of the User Agreement will terminate processing and review of the NSUF-1, NSUF-2, and FC-2.5 applications.** In order to ensure compliance throughout the application review process, applicants must indicate in the Letter of Intent (LOI) and full application submission that the User Agreement has been read, understood, and the terms and conditions are accepted. Further, submission of a pre-application and a full application indicates the applicant will comply with and agree to the terms and conditions of the User Agreement. Upon award of an NSUF supported project, the User Agreement must be signed before activities will begin on the project.

B.3 U.S. University-led IRP Projects

IRPs comprise a significant element of DOE's innovative nuclear research objectives and represent the PD component of the NE strategy to provide R&D solutions most directly relevant to the near-term, significant needs of the NE R&D programs. IRPs are significant projects within specific research areas. IRPs are intended to develop a capability within each area to address specific needs, problems, or capability gaps identified and defined by NE. These projects are multidisciplinary and require multi-institutional partners. IRPs may include a combination of evaluation capability development, research program development, experimental work, and computer simulations. IRPs are intended to integrate several disciplinary skills in order to present solutions to complex systems design problems that cannot be addressed by a less comprehensive team.

Although a proposing team must be led by a lead university PI and include at least one additional university collaborator, the proposed project team may include multiple universities and non-university partners (e.g., industry/utility, minority-serving institution (MSI), national laboratory, underrepresented group, and international). U.S. university PIs are invited to propose research projects in response to this area of the FOA and the associated PD work scopes contained in Part IX, Appendix C of this FOA.

As described above, work scopes for the respective FOA areas may be found in the Part IX appendices to this FOA as follows:

- Appendix A: "Work scopes for U.S. University-led Program and/or Mission Supporting R&D Projects." R&D support and associated NSUF access can only be proposed in specific work scopes.
- Appendix B: "Work scopes for U.S. University-, National Laboratory-, or Industry-led Program Supporting R&D Projects" R&D support and associated NSUF access and NSUF Access Only can be proposed in specific work scopes.
- Appendix C: "Work scopes for U.S. University-led Program Directed Integrated Research Projects (IRP)."

Table 1. FY 2020 Work scope Overview

Work Scope Code	Appendix	NSUF Funds?	Led by:			Work Scope Title
			University	National Laboratory	Industry	
RC-1	A	No	X			Innovative New Structural Materials for Molten Chloride Salt Fast Reactor Applications
RC-2.1	A	No	X			Micro-reactor Deployment Markets
RC-2.2	A	No	X			Validation of Micro-reactor Modeling and Simulation Tools
RC-2.3	A	No	X			Micro-reactor Technology Development and Maturation
RC-3	A	No	X			Liquid Metal-cooled Fast Reactor Technology Development and Demonstration to Support Deployment
RC-4.1	A	No	X			TRISO Fuel Buffer Layer Behavior During Neutron Irradiation
RC-4.2	A	No	X			Robust Individual TRISO-Fueled Pebble Identification Method for Ex-Core Evaluation
RC-5	A	No	X			Experimental Validation of High Temperature Gas Reactor (HTGR) Simulations
RC-6.1	A	No	X			Optimized Fluoride Salt Pipe Joints for Fluoride Salt-cooled High Temperature Reactors
RC-6.2	A	No	X			Pump Scaling Technology for Fluoride Salt-cooled High Temperature Reactors
RC-7.1	A	No	X			Digital Instrumentation and Control
RC-7.2	A	No	X			Virtualized Distributed Control Systems for Nuclear Power Plants
RC-7.3	A	No	X			Reducing Human Factor Uncertainty Using Artificial Intelligence in Operation and Maintenance of Nuclear Power Plants
RC-8	A	No	X			Evaluation of Physical Phenomena Data Impact and Improvements
RC-9	A	No	X			Elucidating how the water chemistry affects the corrosion sensitivity of pristine stainless steel in nuclear power plants
RC-10.1	A	No	X			Technologies to Support SMR Development and Commercialization
RC-10.2	A	No	X			SMR Market Analyses

Work Scope Code	Appendix	NSUF Funds?	Led by:			Work Scope Title
			University	National Laboratory	Industry	
RC-10.3	A	No	X			SMR Economic Analyses
FC-1.1	A	No	X			Nuclear Fuel Cycle Chemistry
FC-1.2	A	No	X			Electrochemical Separations
FC-1.3a	A	No	X			Waste Forms Development and Off-Gas Capture: Iodine Immobilization from Caustic Scrubber Solution
FC-1.3b	A	No	X			Waste Forms Development and Off-Gas Capture: Salt Waste Recycle and Immobilization
FC-2.1	A	No	X			NDE Techniques for Assessing Integrity of Coated Cladding Tubes
FC-2.2	A	No	X			Investigations of Carbide and Nitride Fuel Systems for Advanced Fast Reactors
FC-2.3	A	No	X			High-throughput and/or Micro-scale Post-irradiation Examination Techniques to Support Accelerated Fuel Testing
FC-2.4	A	No	X			Maintaining and Building upon the Halden Legacy of *In Situ* Diagnostics
FC-2.5	A	Yes	X			NSUF Separate Effects Testing in TREAT using Standard Test Capsules
FC-3	A	No	X			Materials Protection, Accounting and Control Technology
FC-4.1	A	No	X			Spent Fuel and Waste Disposition: Disposal
FC-4.2	A	No	X			Spent Fuel and Waste Disposition: Storage & Transportation
MS-FC-1	A	No	X			Understanding, Predicting, and Optimizing the Physical Properties, Structure, and Dynamics of Molten Salt
MS-FC-2	A	No	X			Understanding the Structure and Speciation of Molten Salt at the Atomic and Molecular Scale
NEAMS-1	A	No	X			Development of Generalized Multigroup Cross Sections for Arbitrary Reactor Geometries
NEAMS-2	A	No	X			Near-Wall Gas-Flow Correlations in Pebble Bed Reactors
NEAMS-3	A	No	X			Molten Salt Chemistry Modeling
MS-NEAMS-1	A	No	X			SAM Baseline Development
NE-1	A	No	X			Nuclear Energy-Cyber Security Research Topics and Metrics Analyses
NE-2	A	No	X			Integrated Energy Systems Design and Modeling

Work Scope Code	Appendix	NSUF Funds?	Led by:			Work Scope Title
			University	National Laboratory	Industry	
NE-3	A	No	X			Transformational Challenge Reactor R&D
MS-NE-1	A	No	X			Integral Benchmark Evaluations
MS-NE-2	A	No	X			Nuclear Data Needs for Nuclear Energy Applications
MS-NE-3	A	No	X			Mission Supporting Grand Challenge
NEET-1	B	No	X	X		Advanced Methods for Manufacturing
NEET-2.1	B	No	X	X		Advanced Control Systems
NEET-2.2	B	No	X	X		Big Data, Machine Learning, and Artificial Intelligence
NEET-2.3	B	No	X	X		Advanced Sensors and Communication
NSUF-1.1	B	Yes	X	X	X	Testing of Advanced Materials for Sensors and Advanced Sensors for Nuclear Applications
NSUF-1.2	B	Yes	X	X	X	Irradiation Testing of Materials Produced by Innovative Manufacturing Techniques
NSUF-1.3	B	Yes	X	X	X	Nuclear Materials Discovery and Qualification Initiative
NSUF-2.1	B	Yes	X	X	X	Core and Structural Materials
NSUF-2.2	B	Yes	X	X	X	Nuclear Fuel Behavior and Advanced Nuclear Fuel Development
NSUF-2.3	B	Yes	X	X	X	Advanced In-reactor Instrumentation
NSUF-2.4	B	Yes	X	X	X	High Performance Computing at Idaho National Laboratory
IRP-RC-1	C	No	X			Infrastructure to Support MSR Research & Development
IRP-NEAMS-1.1	C	No	X			Thermal-Fluids Applications in Nuclear Energy
IRP-NEAMS-1.2	C	No	X			Multiscale Nuclear Fuel Performance

PART II – AWARD INFORMATION

A. TYPE OF AWARD INSTRUMENT

DOE anticipates awarding cooperative agreements under this CINR FOA, with the exception of awards to national laboratories, which will be funded through field work proposals (FWPs) and NSUF Access Awards which will be funded through an NSUF User Agreement.

B. ESTIMATED FUNDING

The estimated amounts identified for each of the FOA areas are specified below. Funding for all awards is contingent upon the availability of funds appropriated by Congress for the purpose of this program.

B.1 U.S. University-led PS/MS R&D Projects

DOE currently estimates that it will fund approximately $40 million in awards for this FOA area.

B.2 U.S. University- or National Laboratory-led PS R&D Projects

DOE currently estimates that it will fund approximately $7 million in awards for this FOA area.

B.2.1 Nuclear Science User Facilities Projects

DOE currently estimates that it will fund approximately $10 million in award value for this FOA area.

B.3 U.S. University-led PD IRP Projects

DOE currently estimates that it will fund approximately $11 million in awards for this FOA area.

C. MAXIMUM AND MINIMUM AWARD SIZE

Maximum and minimum award sizes are identified for the four FOA areas below:

C.1 U.S. University-led PS/MS R&D Projects

Ceiling (i.e., the maximum amount for an individual award made under this area):

- PS: up to $800,000 (3-year project), except as explicitly noted in individual work scopes.
- MS: up to $400,000 (3-year project), except as explicitly noted in individual work scopes.

Floor (i.e., the minimum amount for an individual award made under this area): None.

C.2 U.S. University- or National Laboratory-led PS R&D Projects

Ceiling (i.e., the maximum amount for an individual award made under this area):

- PS: up to $1,000,000 (3-year project), except as explicitly noted in individual work scopes.
- NSUF: up to $500,000 (3-year project) for R&D funding, except explicitly noted in individual work scopes.

Floor (i.e., the minimum amount for an individual award made under this announcement): None.

C.2.1 Nuclear Science User Facilities Projects

Ceiling (i.e., the maximum amount for an individual award made under this area):
Irradiation/PIE Project: $4,000,000 NSUF Access Value (up to a 7-year project).

Floor (i.e., the minimum amount for an individual award made under this announcement): None.

C.3 U.S. University-led IRP Projects

Ceiling (i.e., the maximum amount for an individual award made under this area):

- PD: up to $5,000,000 (3-year project), except as explicitly noted in individual work scopes

Floor (i.e., the minimum amount for an individual award made under this announcement): None.

D. EXPECTED NUMBER OF AWARDS

The number of awards for each of the four FOA areas is identified below. The number of awards is dependent on the size of the awards. DOE reserves the right to make more or fewer (or even no awards) depending on funding availability and/or the quality of the applications.

D.1 U.S. University-led PS/MS R&D Projects

DOE anticipates making approximately 40 awards under this area.

D.2 U.S. University- or National Laboratory-led PS R&D Projects

DOE anticipates making approximately 7 awards under this area.

D.2.1 Nuclear Science User Facilities Projects

DOE anticipates making approximately 10 awards under this area.

D.3 U.S. University-led PD IRP Projects

DOE anticipates making approximately 1 award per IRP work scope area.

E. ANTICIPATED AWARD SIZE

The anticipated award size for each of the three FOA areas are identified below. (Amounts represent anticipated maximum per award.)

E.1 U.S. University-led PS/MS R&D Projects

DOE anticipates that awards will be up to $800,000/award for PS projects and up to $400,000/award for MS projects (except as explicitly stated in individual work scope areas).

E.2 U.S. University- or National Laboratory-led PS R&D Projects

DOE anticipates that R&D awards will be up to $1,000,000/award (except as explicitly stated in individual work scope areas).

E.2.1 Nuclear Science User Facilities Projects

DOE anticipates that award access value (funds not provided to the PI) will fall within the following ranges:

- Irradiation only: $500,000 to $3,500,000, typically up to 3 year duration.
- Irradiation /PIE: $500,000 to $4,000,000, up to 7 year duration.
- Beamline or PIE only: $50,000 to $750,000, typically up to 3 year duration.

E.3 U.S. University-led PD IRP Projects

DOE anticipates that awards will be up to $5,000,000 except as stated in the individual work scopes.

F. PERIOD OF PERFORMANCE

DOE anticipates making awards for up to three years for each area with the exception of awards involving NSUF access***, which may take up to seven years if neutron irradiation and PIE is requested.*** Assuming DOE makes awards under this FOA by September 2020, funded projects shall begin no later than October 1, 2020. Proposing different start dates for the project and budget periods may make the application ineligible for award; if a different project start date other than October 1, 2020, is absolutely necessary for the successful performance of the project, it must be fully documented and justified in the application for consideration by DOE.

G. TYPE OF APPLICATION

DOE will accept only new applications for each of the three areas defined in Part I, Section B of this FOA. Applications made to previous FOAs will not be considered. Previous applications can be resubmitted as a new application to this FOA.

PART III – ELIGIBILITY INFORMATION

A. ELIGIBLE APPLICANTS

This FOA is open to U.S. universities, national laboratories, and industry.

Research consortiums may be composed of diverse institutions including academia, national laboratories, non-profit research institutes, industry/utilities, and international partners. Research teams should strive to achieve the synergies that arise when individuals with forefront expertise in different methodologies, technologies, disciplines, and areas of content knowledge approach a problem together, overcoming impasses by considering the issue from fresh angles and discovering novel solutions.

This FOA provides award opportunities to United States owned entities. United States means the several States, the District of Columbia, and all commonwealths, territories, and possessions of the United States.

United States-owned entity means an entity that is either -

(i) A United States-owned entity; or

(ii) Incorporated or organized under the laws of any State and has a parent company which is incorporated or organized under the laws of a country which -

(a) Affords to the United States-owned companies opportunities, comparable to those afforded to any other company, to participate in any joint venture similar to those authorized under the Act;

(b) Affords to United States-owned companies local investment opportunities comparable to those afforded to any other company; and

(c) Affords adequate and effective protection for the intellectual property rights of United States-owned companies.

DOE has restricted eligibility for award in accordance with 2 Code of Fedearl Regulation (CFR) 910.126(b). This eligibility restriction does not apply to subrecipients, subawards, vendors, or team members of the prime/lead applicant.

DOE-NE strongly encourages diversifying its research portfolio through effective partnerships with industry, underrepresented groups, and MSI, which may receive funding support from the project. International partners are encouraged to participate; however, no U.S. government funding will be provided to entities incorporated outside of the United States, or to a foreign government or any entity owned or controlled by a foreign government. Foreign government ownership means direct ownership of the applicant entity, its parent organization (e.g., trust, holding company, corporation, etc.), and any and all other entities in the corporate structure regardless of the applicant entity's place of incorporation and operation. DOE-NE will evaluate the benefit and contribution of any such proposed partnerships as part of its program relevancy evaluation and scoring.

In Appendix A and C, non-university collaborators, in composite, can have no more than 20% of the total funds provided by the government.

A collaborator is an individual that makes a defined, material contribution that is critical to the success of the project and/or contributing to joint publications. Any individual appearing in the project summary, technical narrative, benefit of collaboration, coordination and management plan, or budget documents should be listed directly on the application form. **Any individuals that do not meet these criteria should not be listed as collaborators on the application.** The PI must certify that all collaborators are listed on the application form and have agreed to participate on the project.

NOTE: NSUF Technical Leads and instrument scientists are not considered collaborators. NSUF support staff, including Technical Leads, should not be listed in this section, unless they are receiving funding in support of a specific role in the R&D portion of the work.

Part IV, Section H outlines funding restrictions for this FOA.

1. Domestic Entities

For-profit entities, educational institutions, and nonprofits[1] that are incorporated (or otherwise formed) under the laws of a particular state or territory of the United States are eligible to apply for funding as a prime or subrecipient (only educational institutions may apply as a prime recipient for U.S. university-led PS, MS, and/or PD MS projects).

State, local, and tribal government entities are eligible to apply for funding as a subrecipient (for U.S. university-, national laboratory-, or industry-led PS and/or MS projects only).

DOE/National Nuclear Security Administration (NNSA) Federally Funded Research and Development Centers (FFRDCs) and DOE Government-Owned Government-Operated laboratories are eligible to apply for funding as a prime recipient (for PS or MS projects under NEET CTD), team member, or subrecipient. If an FFRDC is proposed as a team member or subrecipient, the requirements contained in Part III, Section C, apply.

Non-DOE/NNSA FFRDCs and non-DOE Government-Operated Government-Owned laboratories are eligible to apply for funding as a subrecipient but are not eligible to apply as a prime recipient.

Federal agencies and instrumentalities (other than DOE) are eligible to apply for funding as a subrecipient but are not eligible to apply as a prime recipient.

2. U.S. Incorporated Foreign Entities

U.S. incorporated Foreign entities, whether for-profit or otherwise, are eligible to apply for funding under this FOA as either a prime recipient or subrecipient subject the requirements in 2 CFR 910.124.

[1] Nonprofit organizations described in section 501(c)(4) of the Internal Revenue Code of 1986 that engaged in lobbying activities after December 31, 2005, are not eligible to apply for funding.

3. Incorporated Consortia

Incorporated consortia, which may include domestic and/or foreign entities, are eligible to apply for funding as a prime recipient (U.S. university- or national laboratory-led PS and/or MS projects only) or subrecipient. For consortia incorporated (or otherwise formed) under the laws of a State or territory of the U.S., please refer to "Domestic Entities" above. For consortia incorporated in foreign countries, please refer to the requirements in "U.S. Incorporated Foreign Entities" above.

4. Unincorporated Consortia

Unincorporated consortia, which may include domestic and foreign entities, must designate one member of the consortium to serve as the prime recipient/consortium representative (U.S. university- or national laboratory-led PS and/or MS projects only). The prime recipient/consortium representative must be incorporated (or otherwise formed) under the laws of a State or territory of the U.S. The eligibility of the consortium will be determined by the eligibility of the prime recipient/consortium representative.

5. Application Restrictions

The following application restrictions apply to lead PIs:

- Applicants are ineligible to apply to any area of this FOA as a lead PI under any of the following circumstances:
    1. The PI has a currently funded IRP that will be active after December 31, 2020.
    2. The PI has three or more R&D projects that will still be active after December 31, 2020.
    3. The PI has a no-cost extension on any DOE-NE funded project (excluding Infrastructure) that will still be active beyond December 31, 2020.
- An academic PI may submit up to six pre-applications (three of those applications may be as lead PI).
- A PI may have no more than one IRP or three R&D projects funded at any time, and may not submit more full applications than would be allowed by these restrictions.
- PIs cannot submit the same application to multiple work scope areas.
- Applications submitted in response to research requested by Appendix B are limited to three pre-applications per institution per work scope area.
- For IRPs, an applicant is ineligible to submit an application as the PI if (s)he is designated as PI for more than one currently funded DOE-NE project that will be active beyond December 31, 2020. Eligibility Flowchart
- If a PI chooses to submit an IRP to this FOA, that PI is not allowed to submit R&D applications as the lead PI.
- Applications requesting NSUF access and R&D support (NSUF-1 and FC-2.5) will be evaluated on a case-by-case basis with respect to these eligibility requirements.
- Access only requests for NSUF (NSUF-2) are not bound by these eligibility restrictions.

NOTE: Procurement regulations require that applications submitted to this FOA will be awarded to the applicant entity listed and will not be transferred pre-award to another institution if a lead PI changes institutions. Following the date set in this FOA for receipt of applications, PIs that are moving from one institution to another during the CINR review time period are subject to the DOE-ID Changing Principal Investigator and Related Changes/Revisions Policy which is explained at www.NEUP.gov. Post award revision must adhere to the requirements of 2 CFR 200.308.

B. COST SHARING

For applications led by universities, cost sharing is not required, but may be proposed. If cost sharing is provided, see 2 CFR 200 for the applicable cost sharing guidance and Part VIII, Section H, below. Cost sharing is **NOT** a scored review criteria.

For applications led by all other entities (i.e., other than universities, nonprofit institutions/organizations, and FFRDCs), the provisions of the Energy Policy Act of 2005, Section 988, apply. Cost share of at least 20% of the total allowable costs of the project (i.e., the sum of the government share, including FFRDC contractor costs if applicable, and the recipient share of allowable costs equals the total allowable costs of the project) and must come from non-Federal sources, unless otherwise allowed by law. (See 2 CFR 200.29 for more information on the cost sharing requirements.)

Although the DOE/NNSA FFRDC contractor cost is not included in the total approved budget for the award, DOE/NNSA will pay the DOE/NNSA FFRDC contractor portion of the effort under an existing DOE/NNSA contract. Recipient is not responsible for reporting on that portion of the total estimated cost that is paid directly to the DOE/NNSA FFRDC contractor.

By accepting federal funds under this award, you agree that you are liable for your percentage share of allowable project costs, even if the project is terminated early or is not funded to its completion. After award, failure to provide the cost sharing required may result in the subsequent recovery by DOE of some or all the funds provided under the award.

Cost sharing requirements do not apply to the value of the NSUF access.

C. OTHER ELIGIBILITY REQUIREMENTS

C.1 FFRDC Contractors

FFRDC contractors may be proposed as a lead institution (except as otherwise prohibited by this FOA) or team member on another entity's application subject to the following guidelines:

- **Authorization for non-DOE/NNSA FFRDCs**. The Federal agency sponsoring the FFRDC contractor must authorize in writing the use of the FFRDC contractor on the proposed project and this authorization must be submitted with the application. The use of an FFRDC contractor must be consistent with the contractor's authority under its award.
- **Authorization for DOE/NNSA FFRDCs**. The cognizant contracting officer for the FFRDC must authorize in writing the use of a DOE/NNSA FFRDC contractor on the proposed project and this authorization must be submitted with the application. The following wording is acceptable for this authorization:

> "Authorization is granted for the Fill-in 1: [Name] Laboratory to participate in the proposed project. The work proposed for the laboratory is consistent with or complimentary to the missions of the laboratory, will not adversely impact execution of the DOE/NNSA assigned programs at the laboratory."

NOTE: If all FFRDC/non-FFRDC management has been notified of all submissions and acknowledgment of all participants are identified, individual Letters of Authorization may be submitted or submitted as blanket permission Identification of participants by name is to be included in the body or as a separate list.

NOTE: Letter of authorization is not required for NSUF Technical Leads, unless the Technical Lead is requesting R&D funding support under this FOA.

- **Value/Funding**: The value of, and funding for, the FFRDC contractor portion of the work will not normally be included in the award to a successful applicant. Usually, DOE will fund a DOE FFRDC contractor through the DOE FWP system and other FFRDC contractors through an interagency agreement with the sponsoring agency.
- **Cost Share**: The applicant's cost share requirement will be based on the total cost of the project (excluding NSUF access value). FFRDC costs are included as part of the government cost share.
- **FFRDC Contractor Effort** (except for project(s) in support of NEET CTD and NSUF):
  - The scope of work to be performed by the FFRDC contractor may not be more significant than the scope of work to be performed by the prime applicant.
  - The FFRDC contractor effort, in aggregate, shall not exceed 20% of the total estimated costs of the projects.
- **Responsibility**: The applicant, if successful, will be the responsible authority regarding the settlement and satisfaction of all contractual and administrative issues, including, but not limited to, disputes and claims arising out of any agreement between the applicant and the FFRDC contractor.

Table 2 provides a summary of Parts II and III of this FOA.

Table 2. Summary of Parts II and III.

		Applicable Work scope Appendix	Estimated Available Budget	Maximum Award Size	Project Duration	Cost Share	Collaboration
University-led NEUP Projects	PS	Appendix A	$40,000,000	$800,000	Up to 3 years	Permitted but not required*	University, national laboratory, industry, and foreign
	MS			$400,000			

		Applicable Work scope Appendix	Estimated Available Budget	Maximum Award Size	Project Duration	Cost Share	Collaboration
University- or National Laboratory-led NEET CTD Projects	PS	Appendix B	$7,000,000	$1,000,000	Up to 3 years		collaborations are encouraged, but no U.S. funding can go to entities that are not incorporated in the U.S.
University-, National Laboratory, or Industry-led NSUF Projects	PS	Appendix A & Appendix B	R&D: $2,000,000 NSUF: $10,000,000	Refer to maximum award size of the project funding and NSUF funding.	Refer to Part II, E.2.1		
University-led Integrated Research Projects-NEUP	PD	Appendix C	$11,000,000	$5,000,000	Up to 3 years, unless otherwise noted		

***NSUF Projects that are led by industry are required to cost share based on guidance in Part VIII, Section H**

PART IV – APPLICATION AND SUBMISSION INFORMATION

NOTE: The following requirements apply to all three areas defined in Part I, Section B. of this FOA unless specific requirements are identified.

A. ADDRESS TO REQUEST APPLICATION PACKAGE

Electronic applications and instructions are available at the NEUP website. To access these materials, (1) go to www.NEUP.gov, (2) select "Sign In" from the top right hand corner of the screen, (3) enter your user credentials, (4) select "Applications" from the menu, and (5) click on "Create New Application" for the type of application you are creating. Apply at www.NEUP.gov.

Paper copies of the application package may be requested at:

INR Integration Office
Attn: Drew Thomas
PO Box 1625 MS 3730
Idaho Falls, Idaho. 83415

Telephone: 208-526-1602
Fax: 208-526-1844

B. DOCUMENT FORMAT REQUIREMENTS

All non-budget documentation (use templates where provided) is to be prepared using standard 8.5" × 11" paper with 1-inch margins (top, bottom, left, right), using a font size no smaller than Times New Roman 11 point. The preferred file format is Adobe Portable Document Format (PDF) for all documents except for spreadsheets. All spreadsheets are to be uploaded in Excel file format to the online application. Do **NOT** lock any cells in the spreadsheet. Applicants must comply with all pertinent page limitations. Signature blocks must be signed by the designated official.

Documents should be saved using the document naming suggestion at the bottom of each document description. The tracking ID will automatically be generated by the application system and can be found at the top of the application form under "Tracking ID".

C. NSUF Application Submittal Instructions

C.1 Letter of Intent

Letters of Intent are a requirement for projects needing NSUF access (NSUF-1, NSUF-2, and FC-2.5 work scopes). Letters of Intent must be submitted by the date and time specified in Part IV, Section G.1.

C.1.1 Letter of Intent Submittal Instructions

Application forms and instructions are available at the NEUP website. To access these materials, (1) go to http://www.NEUP.gov, (2) select "Login" from the top right hand corner of the screen,

(3) enter your user credentials, (4) select "Applications" from the menu, and (5) Find "FY 2020 NSUF Letter of Intent" and click on "Create New Application" for the type of application you are creating.

Letters of Intent are to include the following:

- Title of project;
- Identification of NSUF Technical Lead(s);
- Identification of NSUF facilities;
- Proposing and associated institution;
- Co-PIs and associated institutions;
- Type of project (full irradiation/PIE, irradiation-only, PIE-only or beamline);
- Applicable work scope:
  - FC-2.5 and NSUF-1 (have R&D funds available);
  - NSUF-2 for NSUF access only (no R&D funds available); and,
- A brief (<300 words) project description.

Points of contact (POCs) for the NSUF facilities, as well as facility descriptions, are provided on the NSUF website at http://nsuf.inl.gov. NSUF Partner Institution contacts are also the Technical Leads. Idaho National Laboratory Technical Leads are assigned by the NSUF Program Office. For assistance in identifying a NSUF Technical Lead or facility POC, please contact NSUF staff members listed on the website.

2-page limit. Name File: 2020 LOI "Insert ID #"

C.1.2 Agreement Requirements

Access to NSUF capabilities will require agreement and final signature to the User Agreement (copy provided in Appendix E). **The terms and conditions of the User Agreement are non-negotiable and failure to accept the terms and conditions of the User Agreement will terminate processing and review of NSUF-1, NSUF-2, and FC-2.5 applications.** In order to ensure compliance throughout the application review process, applicants must indicate in the LOI that the User Agreement has been read, understood, and the terms and conditions are accepted. Further, submission of a pre-application and a full application indicates the applicant will comply and agree to the terms and conditions of the User Agreement. Upon award of an NSUF supported project, the User Agreement must be signed before activities will begin on the project. An applicant cannot submit an LOI without checking the "I Agree" checkbox.

C.2 Pre-Application

Refer to Part IV, Section D for pre-application requirements.

When completing the Pre-Application form via NEUP.gov, it is important that you link the Letter of Intent to the Pre-Application. To link the LOI and pre-application, you must select your application from the pre-application drop-down list. Doing this assigns the same tracking identification number to the Pre-Application that is used for the LOI. The pre-application must

be submitted from the same user account that the LOI was submitted under. **Do not start a new pre-application.**

NOTE: A summary of readiness is required in the pre-applications in accordance with Part I, Section B.2.2.

C.3 NSUF Preliminary Statement of Work

NSUF applicants are required to provide a preliminary statement of work in support of their NSUF pre-application. The statement of Work must be submitted at NEUP.gov using the provided Statement of Work Template

The preliminary statement of work is necessary to inform the NSUF feasibility review and determine a preliminary value (cost) for NSUF access. The Preliminary Statement of Work will be appended to the already submitted pre-application. To append the Statement of Work, 1) Find the submitted pre-application in the "My Applications" section of the submission website; 2) Open the submitted pre-application by using the 'pencil' icon; 3) Scroll to the bottom of the application form; 4) Click "Attach File" on the "Post Submission Attachment" section and attach the preliminary Statement of Work.

Any submissions uploaded, or altered, after the deadline outlined in the FOA, will be disregarded. Do not make changes to the Statement of Work after the submission deadline, as the upload time stamps will be used to confirm timely submission

Name File: 2020 Prelim SOW "Insert ID #"

NOTE: Doe not resubmit the pre-application. A timestamp will appear in the "File Upload Date" area, which is confirmation that the Statement of Work was appended correctly.

C.4 NSUF Final Statement of Work

If an NSUF applicant is invited to submit a full application, a final statement of work is required prior to the submittal of their full application. Statement of work documents are submitted at NEUP.gov using the provided Statement of Work Template.

The final statement of work is necessary to complete the NSUF feasibility review and determine a value (cost) for NSUF access. The Statement of Work is not included in the technical peer review. Technical details that will inform a peer reviewer must be included in the 15-page technical narrative.

Final Statement of Work documents are submitted as an additional document to the already submitted NSUF pre-application. To append the Statement of Work, 1) find the submitted pre-application in the "My Applications" section of the submission website; 2) Open the submitted pre-application by using the 'pencil' icon; 3) Scroll to the bottom of the application form; 4) Click "Attach File" on the "Post Submission Attachment" section and attach the final Statement of Work.

NOTE: Do not resubmit the pre-application. A timestamp will appear in the "File Upload Date" area, which is confirmation that the Statement of Work was appended correctly.

Name File: 2020 FinalSOW "Insert ID #"

NOTE: Preliminary and final cost estimates for NSUF access are prepared and submitted by the NSUF Technical Lead(s) supporting the application.

C.5 Full Application

Refer to Part IV, Section E for full application requirements.

NOTE: A detailed summary of readiness is required in the full application in accordance with Part I, Section B.2.2.

D. CONTENT AND FORM OF ALL PRE-APPLICATIONS

(Mandatory, except for IRPs)

Pre-applications are a mandatory requirement for PS and/or MS and/or NSUF Projects (in Appendix B) for U.S. university-, national laboratory-, or industry-led projects. Pre-applications are not required for PD IRPs. Pre-applications must be submitted by the date and time specified in Part IV, Section G.2.

The PI and named collaborators identified in the pre-application may not be changed in the full application without adequate justification and consent of the Contracting Officer.

The following information shall be provided for all pre-applications:

D.1.1 Pre-application Narrative

Applicant shall provide a narrative that addresses the specific information below:

- Title of project.
- Technical Work Scope Identification (e.g., FC-1.1). The PI is responsible for selecting the appropriate work Scope, and this area may not be changed between the pre-application and full application.
- Name of Project Director/PI(s) and associated organization(s).
- A summary of the proposed project, including a description of the project and a clear explanation of its importance and relevance to the objectives.
- Major deliverables and outcomes the R&D will produce.
- Estimated cost of project (not including value of NSUF access).
- Timeframe for execution of proposed project (specify the time period for R&D, one-, two-, or three-year period or up to seven years for NSUF).
- Specific facilities and equipment access requirements (NSUF only).

- Source, scope, and duration of R&D funding (i.e., support for the PI) associated with request for NSUF Access Only (NSUF-2 only).
- A clear and concise summary of the readiness of the project for NSUF access (as described in Part I, Section B.2.1).
- Proprietary data, such as chemical composition or physical properties of a material, that the applicant wishes to protect during the irradiation or PIE phase of the project. This may negatively impact the feasibility of the project (NSUF-1, NSUF-2, and FC-2.5 only).

3-page limit. Name File: 2020 Pre-Application Narrative "Insert ID #"

D.1.2 Benefit of Collaboration

Applicant shall provide a narrative that includes an explanation of the contribution that will be made by the collaborating organizations and/or facilities to be utilized. It may contain brief biographies of staff and descriptions of the facilities wherein the research will be conducted. Please indicate within this section whether the application has benefit or influence on other ongoing or proposed NE R&D projects (e.g., modeling and simulation in one application and effect validation in a separate application).

4-page limit. Name File: 2020 RPA Benefit of Collaboration "Insert ID #"

D.1.3 Publications

Applications must include a list of publications that resulted from previous DOE-NE (NEUP, NEET, NSUF) funded projects. A reference to the project that supported each publication should be included. If the PI has not led a DOE-NE (NEUP, NEET, NSUF) project, this document is not required.

No page limit. Name File: 2020 RPA DOE-NE Supported Publications "Insert ID #"

D.1.4 Principal Investigator Vitae

The lead PI shall provide a brief vitae that lists the following:

- Contact information.
- **Education and Training**: Provide institution, major/area, degree, and year for undergraduate, graduate, and postdoctoral training.
- **Research and Professional Experience**: Beginning with the current position list, in chronological order (newest to oldest), professional/academic positions with a brief description.
- **Publications**: Provide a list of up to 10 publications most closely related to the proposed project. For each publication, identify the names of all authors (in the same sequence in which they appear in the publication), the article title, book or journal title, volume number, page numbers, year of publication, and website address if available electronically.

- Patents, copyrights, and software systems developed may be provided in addition to or substituted for publications.
- **Synergistic Activities**: List no more than five professional and scholarly activities related to the effort proposed.

2-page limit. Name File: 2020 RPA "Last Name of Individual" "Insert ID #"

D.1.5 Collaborators

A collaborator is an individual that makes a defined, material contribution that is critical to the success of the project and/or contributing to joint publications. Any individual appearing in the project summary, technical narrative, benefit of collaboration, coordination and management plan, or budget documents should be listed directly on the application form. **Any individuals that do not meet these criteria should not be listed as collaborators on the application.** The PI must certify that all collaborators are listed on the application form and have agreed to participate on the project.

NOTE: NSUF Technical Leads and instrument scientists are not considered collaborators. NSUF support staff, including Technical Leads, should not be listed in this section, unless they are receiving funding in support of a specific role in the R&D portion of the work.

D.1.6 Agreement Requirements

Institutions will be expected to follow quality assurance (QA) principles and requirements in conducting R&D activities. If the application is successful, integrity of R&D products and their usability by NE is predicated on meeting QA requirements as they apply to a specific scope of work and associated deliverables. Further, each institution serving as a team member to the proposed project shall be identified in the pre-application, with their commitment made to collaborate in the FOA process.

If applicable, access to NSUF capabilities will require agreement and final signature to the User Agreement (copy provided in Part IX, Appendix E. **The terms and conditions of the User Agreement are non-negotiable and failure to accept the terms and conditions of the User Agreement will terminate processing and review of NSUF-1, NSUF-2 and FC-2.5 applications.** In order to ensure compliance throughout the application review process, applicants must state, during the NSUF pre-application and full application submission, that the User Agreement has been read, understood, and the terms and conditions are accepted. Further, submission of a NSUF pre-application and a full application indicates the applicant will comply and agree to the terms and conditions of the User Agreement. Upon award of an NSUF supported project, the User Agreement must be signed before activities will begin on the project.

E. CONTENT AND FORM OF ALL FULL APPLICATIONS

Applicants must provide all information requested. Forms and optional templates may be used to provide the information, in accordance with the instructions below. Files that are attached must be in PDF format, unless otherwise specified in this announcement. Optional document templates can be found on the NEUP website by clicking the 'Documents' button at the bottom of the front page (https://neup.inl.gov/SitePages/Related_Documents.aspx).

You must save the full application before a tracking ID number will be generated.

E.1 Conflict-of-Interest (COI) Acknowledgement (Checkbox)

COI may exist due to previous efforts performed by the applicant or assistance provided in program direction and other mission related activities. Check the appropriate box on the application signifying whether a potential COI exists. If a COI has been identified (for the lead PI or a collaborator, including national laboratories), a file that explains the conflict must be attached, which includes a statement on how the potential conflict will be avoided, neutralized, or mitigated. This document must be attached even if the conflict appears to be insignificant. If no COI exists, check the box and proceed.

Name File: 2020 CFA COI "Insert ID #"

E.2 SF-424 Research and Related (R&R)

Applicants shall complete the SF-424, R&R form, available at www.NEUP.gov and upload a completed PDF copy of the form with the application.

Name File: 2020 CFA SF424RR "Insert ID #"

E.3 R&R Other Project Information

Applicants shall complete items 1–6 on the R&R Other Project Information form available at www.NEUP.gov and upload a completed PDF copy of the form. Items 7-12 will be completed in the application form and do not need to be completed here.

Name File: 2020 CFA R&R Other Project Information "Insert ID #"

E.4 Project Summary/Abstract

(Use Provided Template on Application Site)

The project summary/abstract must contain a summary of the proposed activity suitable for dissemination to the public. It should be a self-contained document that identifies the name of the applicant; the project director/PI(s); the project title; a list of major deliverables; the scope and objectives of the project; a description of the project, including major tasks (phases, planned approach, etc.) and methods to be employed; the potential impact of the project (i.e., benefits, outcomes); and major participants (for collaborative projects). This document must not include any proprietary or sensitive business information as DOE-NE may make it available to the public after awards are made.

- 2-page limit for IRPs. (Appendix C Template)
- 1-page limit for R&D. (Appendix A Template) (Appendix B Template)

Name File: 2020 CFA Technical Abstract "Insert ID #"

E.5 Project Narrative

Applicant shall provide a written narrative addressing the strategy to execute R&D that supports the specified Technical Work Scope. The documentation provided shall include the items specified below:

- Application title.
- Final Technical Work Scope Identification (FC-1.1, RC-1, etc.).
- Project Objectives: Provide a clear, concise statement of specific objectives/aims of the proposed project.
- Proposed scope description.
- Logical path to accomplishing scope, including descriptions of tasks. This section will provide a clear, concise statement of the specific objectives/aims of the proposed project. This section should be formatted to address each of the merit review criterion and sub-criterion listed in Part V, Section A. Provide sufficient information so that reviewers will be able to evaluate the application in accordance with these merit review criteria. **DOE has the right to evaluate and consider only those applications that separately address each of the merit review criteria**.
- Relevance and Outcomes/Impacts: This section will explain the program relevance/priority of the effort to the objectives in the program announcement and the expected outcomes and/or impacts.
- Schedule: Define timelines for executing the specified work scope, including all important activities or phases of the project. Successful applicants must use this schedule when reporting project progress.
- Milestones and deliverables.
- Type/Description of facilities that will be used to execute the scope (if applicable).
- The roles and responsibilities of each partnering organization in the execution of the work scope. Describe the role and work to be performed by each participant/investigator, the business arrangements between the applicant and participants, and how the various efforts will be integrated and managed.
- Unique challenges to accomplishing the work and planned mitigations.
- Information, data, plans, or drawings necessary to explain the details of the application.
- Source, scope, and duration of R&D funding (i.e. support for the PI) associated with request for NSUF Access Only (NSUF-2 only).
- A stand-alone detailed description of the readiness of the project for NSUF access (as described in Part I, Section B.2.1) (NSUF-1, NSUF-2, and FC-2.5 only)
- Proprietary data, such as chemical composition or physical properties of a material, that the applicant wishes to protect during the irradiation or PIE phase of the project. This may negatively impact the feasibility of the project (NSUF-1, NSUF-2, and FC-2.5 only).

Page limits include cover page, table of contents, charts, graphs, maps, photographs, tables, and other pictorial presentations while complying with the document format instructions in Part IV, Section B. **Evaluators will not review pages above the specified limit.**

- All R&D Projects: 10-pages
- All NSUF Projects: 15-pages
- All IRP Projects: 50-pages

Do not include any internet addresses (URLs) that provide information necessary to review the application; information contained in these sites will not be reviewed.

Name File: 2020 CFA Technical Narrative "Insert ID #"

E.6 Vitae (Technical Expertise and Qualifications)

Applicant shall name all teaming partners by name and organization, as well as their proposed roles and responsibilities. For collaborators (including senior key person) who will contribute in a substantial, measurable way to the project (including for subrecipients and consultants), the applicant shall provide a brief vitae that lists the following:

- Contact information.
- Education and Training: Provide institution, major/area, degree, and year for undergraduate, graduate, and postdoctoral training.
- Research and Professional Experience: Beginning with the current position list, in chronological order (newest to oldest), professional/academic positions with a brief description.
- Publications: Provide a list of up to 10 publications most closely related to the proposed project. For each publication, identify the names of all authors (in the same sequence in which they appear in the publication), the article title, book or journal title, volume number, page numbers, year of publication, and website address if available electronically.
- Patents, copyrights, and software systems developed may be provided in addition to or substituted for publications.
- Synergistic Activities: List no more than five professional and scholarly activities related to the effort proposed.

2-page limit, Name File: 2020 CFA "Last Name of Individual" "Insert ID #"

Technical expertise and qualifications are to be provided for individual participants, whether or not the participant is receiving funding or not (including consultants or national laboratory personnel). All participants making a defined, material contribution that is critical to the success of the project must be listed on the online application.

NOTE: This does not include NSUF support staff.

E.7 Benefit of Collaboration

The applicant shall provide a narrative that includes an explanation of the contribution that will be made by the collaborating organizations and/or facilities to be utilized. Please indicate within this section whether the application has benefit or influence on other ongoing or proposed NE R&D projects (e.g., modeling and simulation in one application and effect validation in a separate application).

4-page limit, Name File: 2020 CFA Benefit of Collaboration "Insert ID#"

E.8 Capabilities

Provide information on the following, as applicable:

a. Infrastructure Requirements: The applicant shall identify the infrastructure (e.g., facilities, equipment, instrumentation, and other resources) required to execute the proposed scope of work, including their location, availability, capabilities, and how they will be used in the project. Describe the non-labor (e.g., facilities, equipment, and instrumentation) resources that are available and accessible to the applicant and are required to execute the scope of work. Describe any unique equipment and facilities that are needed, are accessible, and will be used to execute the scope of work. Discuss the adequacy of these resources and identify any gaps and how these will be addressed.

b. Adequate financial resources (if cost sharing).

c. Ability to comply with the required or proposed performance schedule, taking into consideration all existing commercial and governmental business commitments.

d. A satisfactory record of performance, integrity, and business ethics.

e. Necessary organization, experience, accounting and operational controls, or the ability to obtain them (including, as appropriate, such elements as property control systems, quality assurance measures, and safety programs).

See the electronic application submission instructions for document guidance. This FOA allows the applicant to propose the purchase of any needed equipment to conduct the proposed work. If equipment purchases are proposed, describe comparable equipment, if any, already at the institution and explain why it cannot be used.

2-page limit, Name File: 2020 CFA Capabilities "Insert ID #"

E.9 Letters of Support (IRPs only)

A letter of support from non-federal, non-academic partners (industry/utility, international) is required to describe the level and type of support (e.g., financial or in-kind contributions) contemplated for the project. Letters of support must be on company stationery and signed by an authorized company official.

Name File: 2020 CFA Letter of Support "Insert ID #"

E.10 Budget Documents

E.10.1 R&R Lead Budget Form

(TOTAL FED & NON-FED) (Required for all lead institutions, not required for NSUF-2 applications)

Complete the Research and Related Budget (Total Fed & Non-Fed) form in accordance with the following instructions. A separate budget must be completed for each year of requested support. The form will generate a cumulative budget for the total project period. Complete all the mandatory information on the form. Funds may be requested under any of the categories listed as long as the item and amount are necessary to perform the proposed work, meet all the criteria for allowability under the applicable Federal cost principles, and are not prohibited by the funding restrictions in this announcement (see Part IV, Section I).

NOTE: Successful applicants may be requested to participate in an annual program review meeting and should budget travel accordingly.

NOTE: Do **NOT** lock the cells when saving this document. Applications containing budget forms with **locked cells** may not be evaluated further.

Name File: 2020 CFA Budget "Insert ID #".xls

E.10.2 R&R Subaward Budget Form

(TOTAL FED & NON-FED) (Required for University and Industry collaborators, not required for NSUF-2 applications)

Budgets for subrecipients, other than DOE FFRDC Contractors. Applicant must provide a separate cumulative SF-424 budget for each subrecipient that is expected to perform work estimated to be more than $250,000 or 50% of the total work effort (whichever is less). Use up to 10 letters of the subrecipient institution's name as the file name.

NOTE: Do **NOT** lock the cells when saving this document. Applications containing budget forms with LOCKED CELLS may not be evaluated further.

Name File: 2020 CFA Subaward Budget "Insert ID #".xls

E.10.3 Budget for DOE/NNSA Federally Funded Research and Development Center (FFRDC) Contractor

(Required for National Laboratory participants, not required for NSUF-2 applications)

If a DOE/NNSA FFRDC contractor is applying, it must provide a DOE Field Work Proposal in accordance with the requirements in DOE Order 412.1A, Administrative (Admin) Change 1, Work Authorization System dated 05/21/2014. FWPs can be obtained from respective laboratory financial administrators.

FFRDCs are permitted to propose costs in accordance with their established DOE contracts (e.g., overhead, fees, etc.).

Name File: 2020 CFA FWP "Insert ID #"

E.10.4 Budget Justification

(Required for all university and industry participants, not required for NSUF-2 applications)

The Budget Justification Supporting Documentation is available at NEUP.gov. Provide the required supporting information for all costs required to accomplish the project, including the following costs: labor; equipment; domestic and foreign travel; participant/trainees; material and supplies; publication; consultant services; automated data processing/computer services; subaward/consortium/contractual; equipment or facility rental/user fees; alterations and renovations; and indirect cost type. Provide any other information you wish to submit to justify the budget request.

Foreign travel must be included in the budget justification request. Any foreign travel not added to the budget justification will not be approved upon issuance of the cooperative agreement.

If cost sharing is required or voluntarily proposed, provide an explanation of the source, nature, amount, and availability of any proposed cost sharing.

- Third Parties Contributing to Cost Sharing Information (if applicable):

  A letter from each third party (i.e., a party other than the organization submitting the application) contributing to the cost share, at the time the application is submitted. The letter must state that the third party is committed to providing a specific minimum dollar amount of cost sharing. Submitting the letters with the application provides assurance that the letters of commitment have been signed. In an appendix to the Budget Justification, the following information for each third party contributing to cost sharing must be identified: (1) the name of the organization; (2) the proposed dollar amount to be provided; (3) the amount as a percentage of the total project cost; and (4) the proposed cost sharing - cash, services, or property. Successful applicants must provide the signed letters of commitment outlined in Part IV. Section F, Submissions from Successful Applicants.

  This appendix will not count in the project narrative page limit.

Name File: 2020 CFA Budget Justification "Insert ID #"

E.11 Additional Attachments

E.11.1 Current and Pending Support

(Required for all University and Industry Applicants)

As requested by the submission form, PI(s), subrecipients, and other senior/key persons for ongoing and pending applications shall identify all federal funding sources by agency source, project name, monetary amount (total award amounts for entire project period, including indirect costs), and length of term, person-months per year to be devoted to the project by the senior/key persons that are pending or currently in place for the university PI or collaborators within the past five years.

Name File: 2020 CFA Current and Pending Support "Insert ID #"

E.11.2 Coordination and Management Plan

Multiple PIs (multiple individuals i.e. Lead PI, Co-PI, etc.): The applicant, whether a single organization or team/partnership/consortium, must state whether the project will include multiple PIs. This decision is solely the responsibility of the applicant. If multiple PIs will be designated, the application must identify the Contact PI/Project Coordinator and provide a "Coordination and Management Plan" that describes the organization structure of the project as it pertains to the designation of multiple PIs. This plan should, at a minimum, include:

- Process for making decisions on scientific/technical direction;
- Publications;
- Intellectual property issues;
- Communication plans;
- Procedures for resolving conflicts; and,
- PIs' roles and administrative, technical, and scientific responsibilities for the project.

Name File: 2020 CFA CMP "Insert ID #"

E.11.3 Letter of Authorization for DOE/NNSA FFRDCs

(Required for all national laboratory participants listed on the application regardless of funding level or tier)

The cognizant contracting officer for the FFRDC must authorize in writing the use of DOE/NNSA FFRDC and non-DOE/NNSA FFRDC contractors on the proposed project, and this authorization must be submitted with the application. The following wording is acceptable for this authorization.

> "Authorization is granted for the Fill-in 1: [Name] Laboratory to participate in the proposed project. The work proposed for the laboratory is consistent with or complimentary to the missions of the laboratory, will not adversely impact execution of the DOE/NNSA assigned programs at the laboratory, and will not place the laboratory in direct competition with the domestic private sector."

NOTE: Individual Letters of Authorization may be submitted, if all FFRDC/non-FFRDC management has been notified of all submissions, and all participants are identified, may be submitted as a blanket permission. Identification of participants by name is to be included in the body or as a separate list.

NOTE: Letter of Authorization is not required for NSUF Technical Leads unless the Technical Lead is requesting R&D funding support under this FOA.

Name File: 2020 CFA CO Authorization "Insert ID #"

E.11.4 Project/Performance Site Location(s)

Indicate lead and collaborating site(s) where R&D work will be performed. Note the Project/Performance Site Congressional District is entered in the format of the 2-digit state code, following by the 3-digit Congressional district code (e.g., AA-001).

Name File: 2020 CFA Site Location "Insert ID #"

E.11.5 Environmental Checklist

An environmental checklist will be required at the time of award negotiations.

E.11.6 Disclosure of Lobbying Activities

If applicable, complete SF-LLL. Applicability: If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the grant/cooperative agreement, you must complete and submit Standard Form - LLL, "Disclosure Form to Report Lobbying" which is available at the application site document library

Name File: 2020 CFA SF-LLL "Insert ID #"

E.11.7 Certifications and Assurances

(Required for All University Leads) (Not required for NSUF-2 applications)

Applicants must complete and attach the Certifications and Assurances form found on the DOE Financial Assistance Forms Page at: http://energy.gov/management/downloads/certifications-and-assurances-use-sf-424.

Name File: 2020 CFA Cert & Assurances "Insert ID #"

E.11.8 Foreign Government Ownership Disclosure (Required for All Leads)

Applicants must complete and attach the Foreign Government Ownership Disclosure template.

Name File: 2020 CFA Foreign Government Ownership Disclosure "Insert ID #"

Federal and Technical POCs for FY 2020 can be found at:
https://neup.inl.gov/SitePages/FY20_RD_Technical_Program_Contacts.aspx
https://neup.inl.gov/SitePages/FY20_IRP_Technical_Program_Contacts.aspx

Table 3 contains a summary of the required information for full application submittals.

Table 3. Summary of Full Application Required Information.

Name of Document	Format	Required From	Signature Required
Conflict-of-Interest	Checkbox	Affirmed by Lead Applicant for all	

Name of Document	Format	Required From	Signature Required
		Participants	
SF-424 (R&R)	Form	Lead Applicant	Yes
Research and Related Other Project Information	Form	Lead Applicant	
Project Summary/Abstract	PDF	Lead Applicant	
Project Narrative	PDF	Lead Applicant	
Other Attachments			
Vitae - Technical Expertise and Qualifications (2 pages each)	PDF	All Leads and Collaborators	
Benefits of Collaborations (4 pages)	PDF	Lead Applicant	
Capabilities (2 pages)	PDF	Lead Applicant	
Letters of Support (PD IRPs only)	PDF	IRP Industry/Utility and International Collaborators	
SF-424 (R&R) Lead Budget Form (Total Fed + Non-Fed)	Form	All Lead Applicants*	
SF-424 (R&R) Subaward Budget (Total Fed + Non-Fed), if applicable	Form	University and Industry Collaborators*	
Budget for DOE National Laboratory Contractor or FFRDC, if applicable	PDF	National Laboratory Leads and Collaborators*	Yes
Budget Justification	PDF	University Leads and Collaborators*	
Current and Pending Support	PDF	All University and Industry Applicants	
Coordination and Management Plan	PDF	Lead Applicant	
Authorization for DOE/NNSA FFRDCs	PDF	National Laboratory Applicants (including non-funded collaborators)	Yes
Project/Performance Site Location	PDF	All sites performing work	
SF-LLL Disclosure of Lobbying Activities	PDF	Lead Applicant	Yes
Certifications and Assurances	Form	University Leads*	Yes
Foreign Government Ownership Disclosure	PDF	All Leads	

***Not required for NSUF-2 Access Only applications. The applicant will need to upload a document that states "Not required for NSUF-2 application" in these upload fields.**

F. SUBMISSION FROM SUCCESSFUL APPLICANTS

If selected for award, DOE reserves the right to request additional or clarifying information for any reason deemed necessary including, but not limited to, the following:

- Indirect cost information
- Other budget information
- Name and phone number of the Designated Responsible Employee for compliance with national policies prohibiting discrimination (*See* 10 CFR Part 1040.5);
- Representation of Limited Rights Data and Restricted Software, if applicable; and
- Commitment Letter from Third Parties Contributing to Cost Sharing, if applicable.

G. SUBMISSION DATES AND TIMES

G.1 NSUF Letter of Intent Due Date

(Mandatory for NSUF Projects)

LOIs for NSUF access are required by September 4, 2019, no later than 7:00 p.m. Eastern Time (ET). The LOI shall be submitted as required in Part IV, Section C.1.

G.2 R&D/NSUF Pre-Application Due Date

(Mandatory except for IRPs)

Pre-applications are required by September 24, 2019, no later than 7:00 p.m. ET. The pre-application shall be submitted as required in Part IV, Section C.2 . Applicants who fail to submit a pre-application will be determined non-responsive and ineligible for a comprehensive merit review.

G.3 NSUF Preliminary Statement of Work Due Date

Applicants requesting NSUF access must submit a preliminary Statement of Work by November 21, 2019, no later than 7:00 p.m. ET. The preliminary SOW shall be submitted as required in Part IV, Section C.3. Applicants who fail to submit a preliminary SOW will be determined non-responsive and ineligible for further consideration.

G.4 NSUF Final Statement of Work Due Date

Applicants requesting NSUF access must submit a final Statement of Work by January 23, 2020, no later than 7:00 p.m. ET. The final SOW shall be submitted as required in Part IV, Section C.4. Applicants who fail to submit a final SOW will be determined non-responsive and ineligible for further consideration.

G.5 Integrated Research Projects (IRP) Due Date

IRPs must be received by February 11, 2020 no later than 7:00 p.m. ET. Applicants are encouraged to transmit their applications well before the deadline. Applications received after the deadline will not be reviewed or considered for award.

G.6 Full R&D/NSUF Application Due Date

Full R&D/NSUF applications must be received by February 11, 2020, no later than 7:00 p.m. ET. Applicants are encouraged to transmit their applications well before the deadline. Applications received after the deadline will not be reviewed or considered for award.

G.7 Late Submissions, Modifications, and Withdrawals of Pre-Applications, Applications, and NSUF Statement of Work

a) Applicants are responsible for submitting any/all required submissions specified in this FOA, including letters of intent, applications, statements of work and any modifications or withdrawals thereto, so as to reach the Government office designated in the FOA by the date/time specified in the FOA.

(b)

(1) Any required FOA submittal, modification, or withdrawal received at the Government office designated in the FOA after the exact time specified for receipt of that submittal is "late" and will not be considered, unless it is received before award is made, the Contracting Officer determines that accepting the late submittal would not unduly delay the FOA award process; and—

(i) It was transmitted through an electronic commerce method authorized by the FOA, and received at the initial point of entry to the Government infrastructure not later than 5:00 p.m. one working day prior to the date specified for receipt of the submittal; or

(ii) There is acceptable evidence to establish that it was received at the Government installation designated for receipt of the submittal and was under the Government's control prior to the time set for receipt of the required submittal.

(2) A late modification of an otherwise successful submittal or application that makes its terms more favorable to the Government, will be considered at any time it is received and may be accepted.

(c) Acceptable evidence to establish the time of receipt at the Government installation includes the time/date stamp of that installation on the required electronic submission, other documentary evidence of receipt maintained by the installation, or oral testimony or statements of Government personnel.

(d) If an emergency or unanticipated event interrupts normal Government processes such that the required submittal cannot be received at the Government office designated for receipt of the

submittal by the exact time specified in the FOA, and urgent Government requirements preclude amendment of the FOA, the time specified for receipt of the required submittal will be deemed to be extended to the same time of day, as specified in the FOA, on the first work day on which normal Government processes resume.

(e) Applications and other submittals may be withdrawn by written notice (sent electronically to NEUP@inl.gov) received at any time before the exact time set for receipt of that submittal. A required submittal may be withdrawn in person by an applicant or its authorized representative, if, before the exact time set for receipt of that submittal, the identity of the person requesting withdrawal is established and the person signs a receipt for the submittal.

If electronic applications cannot be submitted, applicants can contact:

INR Integration Office
Attn: Drew Thomas
PO Box 1625 MS 3730
Idaho Falls, Idaho. 83415

Telephone: 208-526-1602
Fax: 208-526-1844

H. INTERGOVERNMENTAL REVIEW

This program is not subject to Executive Order 12372, "Intergovernmental Review of Federal Programs."

I. FUNDING RESTRICTIONS

Funding for all awards is contingent upon the availability of funds appropriated by Congress for the purpose of this program in current and future fiscal years.

I.1 Cost Principles

Costs must be allowable, allocable, and reasonable in accordance with the applicable Federal cost principles referenced in 2 CFR 200, as adopted and amended by 2 CFR 910. The cost principles for for-profit organizations are in FAR Part 31.

I.2 Pre-Award Costs

Recipients may charge to an award resulting from this announcement pre-award costs that were incurred within the ninety (90) calendar day period immediately preceding the effective date of the award if the costs are allowable in accordance with the applicable Federal cost principles. Recipients must obtain the prior approval of the contracting officer for any pre-award costs that are for periods greater than this 90-day calendar period.

Pre-award costs are incurred at the applicant's risk. DOE is under no obligation to reimburse such costs if for any reason the applicant does not receive an award or if the award is made for a lesser amount than the applicant expected.

J. OTHER SUBMISSION AND REGISTRATION REQUIREMENTS

J.1 Where to Submit

NOTE: Submit applications through www.NEUP.gov to be considered for award.

Submit electronic applications through the "Applications" function at www.NEUP.gov. For problems with completing the registration process or submitting your application, call 208-526-1602 or 208-526-8178 or send an email to NEUP@inl.gov.

J.2 Application Validity Timeframe

By submitting an application in response to this FOA applicants agree that their applications are valid for at least one year from the date set forth for receipt of applications to this FOA. DOE reserves the right (with concurrence of the applicant) to use the submitted application(s) to make additional awards for up to a one year, even after DOE's initial selection announcement has occurred.

PART V – APPLICATION REVIEW INFORMATION

NOTE: The following requirements apply to all FOA areas unless specific requirements are identified.

A. CRITERIA

A.1 Pre-application Review (PS, MS, and NSUF)

Selection of applying institutions invited to provide full applications shall be based on how well the pre-applications meet or exceed the technical and program relevancy and program priority evaluation criteria provided below, and as weighted as described in Table 4. All applications submitted under this FOA will be reviewed and scored as described below.

First, programmatic experts will assess each pre-application's program relevancy and program priority to R&D work scopes. Scores will be assigned according to the following program relevancy and program priority attributes:

A.1.1 Pre-Application Initial Review Criteria of Pre-Applications

Prior to a comprehensive merit evaluation, DOE will perform an initial review to determine that (1) the applicant is eligible for an award; (2) the information required by the announcement has been submitted; and (3) all mandatory requirements are satisfied. Only applications meeting these pre-application initial review criteria will be considered during the pre-application technical review process.

A.1.2 Relevancy Attributes

- **High Relevance:** The project is fully supportive of, and has significant, easily recognized and demonstrable ties to mission and relevant work scope area. The project builds on synergies with ongoing direct- or competitively-funded projects or meets a critical mission need. The project focuses on critical knowledge gaps where limited work is currently being performed.
- **Moderate Relevance:** The project is supportive of, and has significant, recognized and demonstrable ties to mission and relevant work scope area. The project recognizes synergies with ongoing direct- or competitively-funded projects and identifies areas for improvement to current, or recently completed, work. The project has ties to knowledge gaps where limited work is currently being performed.
- **Some Relevance:** The project is somewhat supportive of, and has some ties to mission and relevant work scope area. The project recognizes ongoing direct- or competitively-funded projects and identifies limited improvements to current work. The project addresses some knowledge gaps, although there is a moderate amount of work currently being performed in the area.
- **Low Relevance:** The project is minimally supportive of, and has limited ties to mission and relevant work scope area. The project does not recognize ongoing work and does not identify areas for improvement to current, or recently completed work. Substantial work is currently being performed in the area to address knowledge gaps.
- **No Relevance:** The project is not supportive of mission or the relevant work scope area.

A.1.3 Program Priority

Application relevancy scores from the technical evaluation will be weighted in consideration of program priority, which is established and influenced by factors such as balance of portfolio, funding constraints, and anticipated program needs. The categories for program priority are listed below:

- **High Program Priority:** The project is critical to program objectives and/or the work scope area, and will provide unique results that can be effectively integrated with other currently funded work (direct and/or competitively funded).
- **Moderate Program Priority:** The project is important to program objectives and/or the work scope area, and will provide complementary results to currently funded work (direct and/or competitively funded).
- **Low Program Priority:** The project is somewhat important to program objectives and/or the work scope area, but results may be duplicative of currently funded work (direct and/or competitively funded) or unnecessary for current program objectives.
- **No Program Priority:** The project is not important to program objectives and/or the work scope area. The project may also be duplicative of ongoing R&D efforts.

Note that the program relevancy score may be increased by up to 5 points based on evaluators' determination of the degree to which an application effectively partners with MSIs, international or industrial partners, and/or underrepresented groups.

Second, a separate technical expert/peer will assess each application on its technical merit. Reviewers will review the technical basis of the application, assigning it a merit category. Applications will then be judged as meeting all, most, or some expectations for that merit category.

After considering the overall evaluation scores, available funding, and the other selection factors (see Part V, Section A.7) as needed, DOE will make a final determination of applicants who will be invited to provide full applications.

A.1.4 Merit Categories

- **High Merit:** The project unquestionably advances the technical state of knowledge and understanding of the mission or relevant work scope area, and is creative and based largely on original concepts. The scope can be executed fully in the facilities available.
- **Moderate Merit:** The project advances the technical state of knowledge and understanding of the mission or relevant work scope area, and is based on some established concepts, although several creative and original concepts are presented. The scope may be executed fully in the facilities available.
- **Some Merit:** The project incrementally advances the technical state of knowledge and understanding of the mission or relevant work scope area, and is based predominately on established concepts, with some creative, original concepts. The scope may be difficult to execute fully in the facilities available.

- **Low Merit:** The project recognizes the technical state of knowledge and understanding of the mission or relevant work scope area, and is only marginally creative and contains few original concepts. The scope will require resources not named in the project, or will require additional facilities or resources to execute.
- **No Merit:** The project does not advance or recognize the technical state of knowledge and understanding of the mission or relevant work scope area, and is not creative or original. The scope cannot be executed fully in the facilities available.

The individual scores determined by evaluating each application against the above criteria, will then be weighted as defined in Table 4 to determine an overall evaluation score for each application.

Applicants who are not specifically invited to submit full applications may still do so at their own risk. There is no guarantee uninvited full applications will receive a full review; however, all full applications will be re-reviewed for program relevancy/priority. Only those uninvited full applications scored as "High Relevance" and at least "Moderate Program Priority" will be forwarded for technical peer review during the evaluation phase for full applications described below.

NSUF pre-applications that do not receive an invitation to submit are not permitted to submit a full application.

A.2 Feasibility Review (NSUF Projects Only)

The feasibility review is a very important part of the NSUF pre-application review process. Many factors will be taken into account as part of the feasibility review including type of project, duration of project, experimental degree of complexity, types of samples, number of samples, needed shipping and containment, potential needed capability or facility enhancement or upgrade, project schedule, and cost. In order to ensure that a pre-application and eventual application is submitted with the highest possible degree of feasibility, it is imperative that potential proposers establish contact with an NSUF Technical Lead at the earliest possible time. The NSUF Technical Lead will have knowledge of and direct access to the facility or facilities where the work will be performed. It is intended that the Technical Lead should be an integral collaborator on the project and contribute strongly to the application preparation. The Technical Lead will provide guidance in establishing the scope of the project in negotiation with the facility to produce a cost estimate. Should the project be awarded, the Technical Lead will be the primary POC to best ensure the project is performed on schedule and within budget.

Applications deemed not feasible by the NSUF Program Office will not be considered.

A.3 Readiness Review (NSUF Projects Only)

Prior to final selection, pre-applications and full applications for NSUF access will be reviewed by the NSUF Program Office to verify the project is ready for NSUF access, as discussed in Part 1, Section B.2.2. Pre-applications and full applications deemed not ready for NSUF access will not be considered.

A.4 Initial Review Criteria of Full Applications

Prior to a comprehensive merit evaluation, DOE will perform an initial review to determine that (1) the applicant is eligible for an award; (2) the named applicant, PI(s) and collaborators have not changed from the pre-application to the full application or, if they have, DOE's Contracting Officer has provided signed approval; (3) the information required by the announcement has been submitted; and (4) all mandatory requirements are satisfied. Only applications meeting these initial review criteria will be considered during the merit review and award selection decision.

A.5 PS/MS/NSUF R&D Merit Review Criteria: Full Applications

Selection will be made in accordance with the review criteria identified for each area and the program policy factors (other selection factors) listed in Part V, Section A.7 of this FOA. The criteria for the respective FOA areas are identified below along with the relative importance of each criterion or sub-criterion, if applicable. All applications will be point scored and ranked. Applications must be fully responsive to each of the following criteria.

Review of full applications shall be based on how well the applications meet or exceed the technical and program relevancy/priority evaluation criteria provided below and as weighted as described in Table 4. All invited full applications submitted under this FOA will be reviewed and scored as described in this FOA. A panel of programmatic experts will assess each full application's program relevancy/priority to NE's R&D mission and work scope area, and multiple technical peer reviewers will evaluate the project for technical merit. Effective partnerships will be incorporated into the program relevancy/priority evaluation, as described below.

A.5.1 Program Relevancy/Priority Attributes

Same criteria used for PS/MS/NSUF pre-application evaluation phase applies to full applications. See Part V, Section A.1.1.

A.5.2 Technical Merit Attributes

Applications will be subjected to formal merit review and will be evaluated against the following criteria.

- **Criterion 1 – Advances the State of Scientific Knowledge and Understanding and Addresses Gaps in Nuclear Science and Engineering Research**: The technical merit of the proposed R&D project will be evaluated, including the extent to which the project advances the state of scientific knowledge and understanding and addresses gaps in nuclear science and engineering research. Evaluation will consider how important the proposed project is to advancing knowledge and understanding within the area selected and how well the proposed project advances, discovers, or explores creative, original, or potentially transformative concepts.
- **Criterion 2 – Technical Quality of the Proposed R&D Project**: DOE will evaluate the overall quality/acceptability of the proposed R&D project. In evaluating this criterion, DOE may consider the (1) merit, feasibility, and realism of the proposed methodology and approach to the project; (2) schedule, including sequence of project tasks, principle

milestones, and times for each task; (3) planned assignment of responsibilities; (4) proposed project efficiencies; and (5) technical expertise available to the applicant in carrying out the project.

- **Criterion 3 – Applicant Team Capabilities, Risks, and Experience**: The extent to which the applicant team provides objective evidence that it has the resources and abilities to successfully complete the R&D project in a technically defensible manner will be evaluated. Current activities, working with industry, relevance and depth of the organization's experience and capabilities, past performance, together with that of the PI, and the adequacy of the requested resources and their supporting justification will all be evaluated as they relate to the likely successful completion of the R&D objectives.

  In evaluating this criterion, DOE will consider the extent to which the application demonstrates the following:

  - That the capabilities and qualifications of engineering and scientific personnel, PI, and other key contributors are such that they can successfully accomplish the technical scope of the proposed project;
  - That the applicant or respective team members have demonstrated successful experience/past performance, knowledge, and understanding of the business and regulatory requirements for projects of similar size, scope, and complexity in achieving project technical success on time with no significant, unresolved safety and quality issues;
  - The applicant team's identification of, and work with industry, to gain industry perspective and technical knowledge important to project decisions, and how the applicant will work with industry to best achieve the objectives of this FOA and the project.

Table 4. PS/MS R&D and NSUF Access Only Pre-applications and Full Applications - Weighting of Evaluation Scores.

Criterion	
Technical Application – Peer Review	Percentage of Peer Review Score
Pre-Applications	
Technical Merit Category	100%
Full Applications	
Criterion 1: Advances the State of Scientific Knowledge and Understanding and Addresses Gaps in Nuclear Science and Engineering Research	35%
Criterion 2: Technical Quality of the Proposed R&D Project	35%
Criterion 3: Applicant Team Capabilities, Risks, and Experience	30%
Peer Review Score	Sum of ratings x weights

Criterion	
Program Relevance/Priority[1] (Separate Review Process, Used for Pre-Applications, Letters of Intent and Full Applications)	Percentage of Program Relevancy/Priority Review Score
Relevancy	100%
Program Priority	Multiplier based on program priority rating
Diverse Partnerships	Up to 5 points, not to exceed the maximum relevancy points available.
Program Relevancy/Priority Score	Sum of ratings[2] x program priority multiplier
Weighting	Weighted Score Ratio (Technical : Relevancy) Program Supporting: 65:35 Mission Supporting: 80:20 NSUF Access Only: 65:35
[1] Supports Program Relevance: This element will be scored by the Program Offices, not by peer review. [2] Total program relevancy/priority points cannot exceed 100% of points available from the program relevancy/priority criteria.	

A.6 Program Directed (IRP) Merit Review for Full Application

Selection for the PD IRP for U.S. university-led projects will be based on the following criteria and sub-criteria. The criteria are equally important. Review of full applications shall be based on how well the applications meet or exceed the technical and program relevancy/priority evaluation criteria provided below, and as weighted as described in Table 5.

A.6.1 Relevancy Attributes

- **Program Factors:** Relation of the proposed project to the core research activities within the DOE programs
- **Resource Factors:** The degree to which award of the project optimizes use of the proposed resources to achieve project goals
- **Collaboration Factors:** Potential for developing synergies between the proposed IRP and other DOE research activities
- **Diverse Partnerships:** The degree to which MSIs, international and/or industry partners, and/or underrepresented groups, if any, contribute to the project's ability to support the relevant program element or overall mission

NOTE: Diverse partnerships are not required for projects to be evaluated as unquestionably relevant, but diverse partnerships will increase the relevance score by 1 to 5 points, not to exceed the maximum available relevancy points, based on meeting one of the following criteria: the project has (1) a substantive contribution by an industrial, international, underrepresented group, or MSI as lead or collaborator; (2) a demonstrable contribution by an industrial, international,

underrepresented group, or MSI as lead or collaborator; or (3) some relevant partnership with an industrial, international, underrepresented group, or MSI as lead or collaborator.

A.6.2 Technical Merit Attributes

- **Criterion 1 – Scientific and/or Technical Merit of the Project**: The scientific and technical merit of the proposed IRP will be evaluated, including the extent to which the project advances the state of scientific knowledge and understanding relative to the IRP and addresses key scientific challenges and shifts in research directions towards promising developments. Evaluations will consider how important the proposed project presents a balanced and comprehensive program of research that, as needed, supports experimental, theoretical, and computational efforts and develops new approaches in these areas.
- **Criterion 2 – Appropriateness of the Proposed Method or Approach**: The appropriateness of the proposed IRP method or approach will be evaluated, including risk posed by the approach, as well as the extent to which the strategy and plan for the development and operation of the proposed IRP identifies an acceptable approach involving senior/key personnel, the means for achieving integration on the IRP, and plans for leadership and guidance for the scientific and technical direction. DOE shall consider whether the applicant presents a comprehensive management plan for a world-class program that encourages research—including high-risk, high-reward—as well as synergisms among investigators. The organization structure should delineate the roles and responsibilities of senior/key personnel and describes the means of providing external oversight and guidance for scientific and technical direction and approval of the research program. Additionally, DOE will also consider the following:
  - The applicant's plans (if any) for education, outreach, and training in the proposed IRP are appropriate and, if needed, described as part of the scope.
  - Appropriateness and reasonableness of applicant's plans (if any) for external collaborations and partnerships.
  - The roles and intellectual contributions of the IRP lead PI, other investigator(s), and each senior/key person.
  - Maximizing the use of other available facilities and existing equipment.
  - Relation to existing and planned research programs at the host or collaborator institution.

- **Criterion 3 – Applicant Team Capabilities, Risks, and Experience**: DOE will evaluate the extent to which the applicant team provides objective evidence that it has, or can obtain the professional resources and abilities to successfully complete the IRP project in a technically defensible manner. Current activities, relevance, and depth of the organization's experience and capabilities, together with that of the PI, will be evaluated as it relates to the likely successful completion of the IRP. Risk posed by the applicant team will be evaluated. In evaluating this criterion, DOE will consider the extent to which the application demonstrates the following:
  - The applicant's senior/key personnel have a proven record of research in the disciplines needed for success in the project;

- The proposed access to existing research space, instrumentation, and facilities at the host institutions and its partners are likely to meet the needs of the proposed IRP;
- There is adequate access to experimental and computational capabilities as needed to ensure successful completion of the proposed research;
- The lead institution and the senior/key personnel for the IRP have proven records of success in project, program, and personnel management for projects of comparable magnitude;
- The plan for recruiting any additional scientific and technical personnel including new senior staff, students, and post-docs is reasonable and appropriate;
- The IRP leadership has the capability to communicate effectively with scientists of all required disciplines;
- The IRP lead PI and senior/key personnel will be adequately involved in the proposed IRP, particularly taking into account their potential involvement in other major projects.

Table 5. PD IRP Full Applications - Weighting of Evaluation Scores.

Criterion	
Technical Application – Peer Review	Percentage of Peer Review Score
Criterion 1: Scientific and/or Technical Merit of the Project	35%
Criterion 2: Appropriateness of the Proposed Method or Approach	35%
Criterion 3: Applicant Team Capabilities, Risk, and Experience	30%
Peer Review Score	Sum of ratings x weights
Relevance[1] (Separate Review Process)	Percentage of Relevancy Review Score
Program Factors	40%
Resource Factors	40%
Collaboration Factors	20%
Diverse Partnerships	Up to 5 points, not to exceed the maximum relevancy points available.
Relevancy Score	Sum of ratings[2] x weights
Weighting	Weighted Score Ratio (Peer : Relevancy) PD 50:50

[1] Supports Program Relevance: This element will be scored by the Federal Program and Technical Integration Offices, not by peer review.

[2] Total relevancy points cannot exceed 100% of points available from the relevancy criteria.

A.7 Other Selection Factors

Program Policy Factors. The Selection Official may consider the following program policy factors in the selection process:

- Degree to which proposed project optimizes/balances/maximizes use of available DOE funding to achieve DOE program goals and objectives, including how those R&D and IRP projects support DOE research. It may also include research portfolio diversity, geographic distribution and/or how the projects support other complementary efforts that, when taken together, will best achieve program research goals and objectives;
- Application selection may optimize appropriate mix of projects to best achieve DOE research goals objectives;
- Cost/Budget considerations, including availability of funding;
- Extent that the applicant has awards in progress, or not completed, from DOE, from a previous year's FOA, or has existing no cost extensions;
- Demonstrated ability of the applicant to successfully complete projects (including relevant prior projects) and do so within budget and within the specified timeframe of the award;
- Applicability across multiple reactor technologies, including future design types. Proposed cost share that exceeds minimum required amounts on the part of the applicant may be given preferential consideration;
- Potential to enhance U.S. nuclear infrastructure may be given preferential consideration;
- Consistent and conformant work proposed in the application with current Office of Nuclear Energy Congressional appropriations.
- Foreign government ownership, if any, of the applicant, the applicant's parent companies, or any entity owned or controlled by a foreign government, may be considered in making the award;
- Applications that have national security concerns;

Any of the above factors may be independently considered by the Selection Official in determining the optimum mix of applications that will be selected for support. These factors, while not indicators of the application's merit, may be essential to the process of selecting the application(s) that, individually or collectively, will best achieve the program objectives. Such factors are often beyond the control of the applicant. **Applicants should recognize that some very good applications might not receive an award because of program priorities and available funding.** Therefore, the above factors may be used by the Selection Official to assist in determining which applications shall receive DOE funding support.

For applications requesting R&D support with NSUF access, DOE reserves the right to decouple the R&D element from the NSUF access element and consider either portion for a provisional award, dependent on confirmation from the applicant that the portion selected for award can be executed independently.

B. SUMMARY OF THE REVIEW AND SELECTION PROCESS

B.1 PS/MS/NSUF Pre-applications

Pre-application projects will be evaluated against the technical and program relevancy/priority criteria described in this FOA. This technical and program evaluation process will produce a list of recommended projects for each work scope. DOE will consider the overall evaluation results and subjective programmatic factors to select a final set of invited projects to provide a full application.

NOTE: Applicants not requesting NSUF access who do not receive a formal invitation from DOE to submit full applications in response to the pre-application review process may still do so at their own risk. There is no guarantee uninvited full applications will receive a full review; however, all full applications received will be re-reviewed for program relevancy/priority. Only uninvited full applications scored as "High Relevance" and at least "Moderate Program Priority" will receive a technical peer review during the evaluation phase for full applications.

NOTE: Applicants requesting NSUF access who are not specifically invited by DOE to submit full applications will NOT be allowed to submit full applications. Due to resource limitations within the NSUF, the feasibility review, a critical element of NSUF access, will continue only for applications that are specifically invited. An uninvited NSUF application without a complete NSUF feasibility review is incomplete, and cannot be re-reviewed for program relevancy/priority.

B.2 PS/MS/NSUF Full Applications

Multiple peer reviewers will independently evaluate the applications in accordance with the technical review evaluation criteria described in this FOA. Also, DOE will complete a program relevancy/priority review process in accordance with the criteria described above. These results will be weighted in accordance with the ratio described above. DOE will consider the overall evaluation results and subjective programmatic factors to ultimately recommend a final set of applications for approval by the Selection Official.

B.3 IRP Full Applications

Multiple technical experts independently evaluate the applications in accordance with the review criteria and weighted as described above. Also, DOE will complete a program/relevancy review process in accordance with the criteria described above. Following individual review, reviewers meet as a panel for final recommendation to DOE. DOE will consider the overall evaluation results and subjective programmatic factors to ultimately recommend applications for approval by the Selection Official.

Due to the expected complexity of these projects, DOE may require clarification on the contents of application(s) and an opportunity to ask questions regarding the proposed project. As part of the evaluation and selection process for any review cycle, DOE may elect to do pre-selection clarifications. These pre-selection clarifications, if done, will be used for the purposes of clarifying the applications, not supplementing the applications. Use of such pre-selection

clarifications neither obligates DOE to make an award nor to use a clarification process for successive review cycles.

B.4 Reporting of Matters Related to Recipient Integrity and Performance

DOE, prior to making a Federal award with a total amount of Federal share greater than the simplified acquisition threshold, is required to review and consider any information about the applicant that is in the designated integrity and performance system accessible through SAM (currently FAPIIS) (see 41 U.S.C. 2313).

The applicant, at its option, may review information in the designated integrity and performance systems accessible through SAM. The applicant may comment on any information about itself that a Federal awarding agency previously entered that is currently in the designated integrity and performance system accessible through SAM.

DOE will consider any written comments by the applicant, in addition to the other information in the designated integrity and performance system, in making a judgment about the applicant's integrity, business ethics, and record of performance under Federal awards when completing the review of risk posed by applicants as described in 2 CFR 200.205 - Federal awarding agency review of risk posed by applicants.

C. ANTICIPATED NOTICE OF SELECTION

DOE anticipates making selection announcements no later than July 31, 2020.

PART VI – AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

A.1 Notice of Selection

DOE will notify applicants selected for award. This notice of selection is not an authorization to begin performance. (See Part IV, Section I.2 with respect to the allowability of pre-award costs.) Organizations whose applications have not been selected will be advised as promptly as possible. This notice will explain why the application was not selected.

A notice of Federal award, signed by the DOE Contracting Officer, is the authorizing award document for any cooperative agreements awarded as a result of this FOA. A post-selection/pre-award process will occur prior to issuing the actual award. This process includes such activities as a responsibility review/review of risk posed by the selected applicant, a technical and budget review of the selected applicant's proposed budget, etc. Once approved, the actual award notice will be provided by DOE to the recipient by electronic means.

A.2 Nondisclosure and Confidentiality Agreements Representations

In submitting an application in response to this FOA the Applicant represents that:

(1) It does not and will not require its employees or contractors to sign internal nondisclosure or confidentiality agreements or statements prohibiting or otherwise restricting its employees or contactors from lawfully reporting waste, fraud, or abuse to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive such information.

(2) It does not and will not use any Federal funds to implement or enforce any nondisclosure and/or confidentiality policy, form, or agreement it uses unless it contains the following provisions:

a. ''These provisions are consistent with and do not supersede, conflict with, or otherwise alter the employee obligations, rights, or liabilities created by existing statute or Executive order relating to (1) classified information, (2) communications to Congress, (3) the reporting to an Inspector General of a violation of any law, rule, or regulation, or mismanagement, a gross waste of funds, an abuse of authority, or a substantial and specific danger to public health or safety, or (4) any other whistleblower protection. The definitions, requirements, obligations, rights, sanctions, and liabilities created by controlling Executive Orders and statutory provisions are incorporated into this agreement and are controlling.''

b. The limitation above shall not contravene requirements applicable to Standard Form 312, Form 4414, or any other form issued by a Federal department or agency governing the nondisclosure of classified information.

Notwithstanding the provision listed in paragraph (a), a nondisclosure or confidentiality policy form or agreement that is to be executed by a person connected with the conduct of an intelligence or intelligence-related activity, other than an employee or officer of the United States Government, may contain provisions appropriate to the particular activity for which such

document is to be used. Such form or agreement shall, at a minimum, require that the person will not disclose any classified information received in the course of such activity, unless specifically authorized to do so by the United States Government. Such nondisclosure or confidentiality forms shall also make it clear that they do not bar disclosures to Congress, or to an authorized official of an executive agency or the Department of Justice, that are essential to reporting a substantial violation of law.

A.3 Notice of Award

An assistance agreement issued by the Contracting Officer is the authorizing award document (excludes NSUF access only awards). It normally includes, either as an attachment or by reference, the following: (1) special terms and conditions; (2) applicable program regulations, if any; (3) application as approved by DOE; (4) DOE assistance regulations at 2 CFR part 200, as amended by 2 CFR 910; (5) National Policy Assurances To Be Incorporated As Award Terms; (6) Budget Summary; and (7) Federal Assistance Reporting Checklist, which identifies the reporting requirements.

If award is made to a DOE national laboratory, it will be made against their existing prime contract with the DOE through the work authorization system as outlined in DOE O 412.1A, Admin Change 1. DOE O 481.1C., Work for Others, is not applicable. DOE national laboratories remain bound by the terms and conditions of their contract with DOE.

B. ADMINISTRATIVE AND NATIONAL POLICY REQUIREMENTS

B.1 Administrative Requirements

The administrative requirements for DOE grants and cooperative agreements are contained in 2 CFR 200, as amended by 2 CFR 910 (See: http://ecfr.gov). Grants and cooperative agreements made to universities, non-profits, and other entities subject to Title 2 CFR are subject to the Research Terms and Conditions located on the National Science Foundation website at http://www.nsf.gov/bfa/dias/policy/rtc/index.jsp.

B.1.1 DUNS and SAM Requirements

Additional administrative requirements for DOE grants and cooperative agreements are contained in 2 CFR, Part 25 (see http://www.ecfr.gov/cgi-bin/ECFR?page=browse). Prime awardees must be registered in the System for Award Management (SAM) before submitting an application, and must continue to maintain a SAM registration with current information at all times during which it has an active Federal award or an application or plan under consideration by DOE under this FOA. Primes and subawardees at all tiers must obtain Data Universal Numbering System (DUNS) numbers and provide the DUNS to the prime awardee before the subaward can be issued. The prime will provide this valid unique entity identifier in its application. DOE may not make a Federal award to an applicant until the applicant has complied with all applicable unique entity identifier and SAM requirements and, if an applicant has not fully complied with the requirements by the time DOE is ready to make the award, DOE may determine that the applicant is not qualified to receive an award and use that determination as a basis for making an award to another applicant.

B.1.2 Subaward and Executive Reporting

Additional administrative requirements necessary for DOE grants and cooperative agreements to comply with the Federal Funding and Transparency Act of 2006 (FFATA) are contained in 2 CFR, Part 170 (see http://www.ecfr.gov/cgi-bin/ECFR?page=browse). Prime awardees must register with the new FFATA Subaward Reporting System (FSRS) database and report the required data on their first tier subawardees. Prime awardees must report the executive compensation for their own executives as part of their registration profile in the SAM.

B.2 Special Terms and Conditions and National Policy Requirements

The DOE special terms and conditions for use in most grants and cooperative agreements are located at http://energy.gov/management/office-management/operational-management/financial-assistance/financial-assistance-forms under Award Terms.

If the Federal share of any Federal award may include more than $500,000 over the period of performance, post award reporting requirements reflected in 2 CFR 200, Appendix XII—*Award Term and Condition for Recipient Integrity and Performance Matters*, may also apply to any resultant award made under this FOA.

The National Policy assurances to be incorporated as award terms are located at http://www.nsf.gov/bfa/dias/policy/rtc/appc.pdf and at http://energy.gov/management/office-management/operational-management/financial-assistance/financial-assistance-forms under Award Terms.

Quality Assurance to be incorporated as award terms (applicable to educational institutions only).

While DOE will normally rely on the institution's quality assurance (QA) system, below are general guidelines that those systems should adhere to, as applicable, for the type of work being done. No separate deliverable is required by this provision, unless the institution's existing QA systems are not compliant with these guidelines, or in the case that the institution identifies that the work to be performed has any special or unique QA requirements. The DOE has the right of access to the university facilities and records for surveillance or inspection. Any surveillance or inspections will be coordinated with the PI.

- **Test Planning, Implementation, and Documentation (Research Planning)**
  - Test methods and characteristics shall be planned and documented, and the approaches and procedures recorded and evaluated. Characteristics to be tested and test methods shall be specified. The test results shall be documented and their conformance to acceptance criteria evaluated.
  - Documentation shall be developed to ensure replication of the work. The researcher/developer shall document work methods and results in a complete and accurate manner. The level of documentation shall be sufficient to withstand a successful peer review. Protocols on generation and safeguarding of data and process development from research shall be developed for consistency of R&D work.

- Laboratory notebooks shall be controlled by a university documented procedure/process. Also, the process for development of intellectual property documentation shall be controlled under university document control procedures/processes.
- If the university identifies any special or unique QA requirements for Test Planning, Implementation, and Documentation, the university shall submit a Test Plan/Research Plan to the funding organization for review and concurrence prior to use.

- **Equipment Calibration and Documentation**

  The researcher shall specify the requirements of accuracy, precision, and repeatability of measuring and test equipment (M&TE). Depending upon the need for accuracy, precision, and repeatability of M&TE used in research, standard university documented procedures shall be implemented. During the process development stage, and for all R&D support activities, M&TE shall be controlled. The degree of control shall be dependent on the application of the measurement. The university shall have available calibration records documenting instrument calibration to a national standard.

- **Procurement Document Control**

  University documented procurement document control procedures/processes shall be implemented, if results of initial research work are expected in the next stage of work, and if the pedigree of materials being used could influence the usefulness of the research work results. Procurement document specifications shall be controlled. For development and support activities, the level of procurement document control shall be applied to support a design basis, i.e., engineering design system criteria. If procurement document control requirements apply, the university shall have a documented procedure/process for control of suspect/counterfeit items (S/CI), and have available for submission for DOE review material pedigree records.

- **Training and Personnel Qualification**

  Personnel performing research activities shall be trained per university documented requirements to ensure work is being conducted properly to prevent rework or the production of unacceptable data. The university shall have available—for submission for DOE review—personnel training records.

- **Records**

  In many cases, the notebook or journal of the researcher is the QA record. These documents shall be controlled in accordance with university documented procedure/process, e.g., maintain notebook as a controlled document, maintain copies of critical pages or access-controlled filing when not in use to preserve process repeatability and the QA record. Electronic media may be used to record data and shall be subject to documented administrative controls for handling and storage of data. Work activity records shall be maintained by the university and available for DOE review, upon request, within sixty (60) days of completion of the work scope.

- **Data Acquisition/Collection and Analysis**

  When gathering data, the researcher shall ensure that the systems and subsystems of the experiment are operating properly. Software systems used to collect data and operate the

experiment requires verification that it meets functional requirements prior to collection of actual data. Data anomalies require investigation. When performing data analysis, define (1) assumptions and the methods used; (2) the results obtained so that independent qualified experts can evaluate how data was interpreted;(3) methods used to identify and minimize measurement uncertainty; (4) the analytical models used; and (5) whether the R&D results have been documented adequately and can be validated.

- **Peer Review**

  Peer reviews shall be performed in accordance with peer review best practices as described in Part V. The peer reviews shall be documented and maintained by the university. Peer review documentation and results shall be provided to DOE.

B.3 Intellectual Property Provisions

The standard DOE financial assistance intellectual property provisions applicable to the various types of recipients are located at http://energy.gov/gc/standard-intellectual-property-ip-provisions-financial-assistance-awards.

B.4 Lobby Restrictions

By accepting funds under this award, the applicant agree that none of the funds obligated on the award shall be expended, directly or indirectly, to influence congressional action on any legislation or appropriation matters pending before Congress, other than to communicate to Members of Congress as described in 18 U.S.C. 1913. This restriction is in addition to those prescribed elsewhere in statute and regulation.

B.5 Corporate Felony Conviction and Federal Tax Liability Representations

In submitting an application in response to this FOA the applicant represents that:

- It is not a corporation that has been convicted (or had an officer or agent of such corporation acting on behalf of the corporation convicted) of a felony criminal violation under any Federal law within the preceding 24 months.
- It is not a corporation that has any unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or have lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

  For purposes of these representations the following definitions apply:

  A corporation includes any entity that has filed articles of incorporation in any of the 50 states, the District of Columbia, or the various territories of the United States (but not foreign corporations). It includes both for-profit and non-profit organizations.

B.6 Statement of Substantial Involvement

DOE anticipates having substantial involvement during the project period, through technical assistance, advice, intervention, integration with other awardees performing related activities, and technical transfer activities. The recipient's responsibilities are listed in the first bulleted section and DOE's responsibilities are listed in the second bulleted section:

- Recipient's responsibilities. The recipient is responsible for:
  - Complying with all award requirements, including performing the activities supported by this award, including providing the required personnel, facilities, equipment, supplies and services;
  - Defining approaches and plans as may be required by this award, submitting the plans to DOE for review, and incorporating DOE's comments;
  - Managing and conducting the project activities, including coordinating with DOE management and operating (M&O) contractor(s) as required and as proposed in the recipient's project plan on activities performed under the M&O contract(s) that are related to the project;
  - Attending annual program review meetings and reporting project status, if requested by the program;
  - Submitting technical reports as stated in the Federal Assistance Reporting Checklist, and incorporating DOE comments
  - Completing reporting requirements as outlined in the instructions provided in the awards Attachment B "Federal Assistance Reporting Checklist and Instructions" including:
    - **DOE-NE Program Information Collection System (PICS:NE):** NE CINR R&D award PIs are required to complete reporting requirements as outlined in the instructions provided in the awards Attachment B "Federal Assistance Reporting Checklist and Instructions". Information provided in required award reporting will be utilized to populate PICS:NE (PICS:NE data entry will be done by DOE using information provided by the PI). PIs may be asked by the DOE PICS:NE representative for additional information during the initial work package setup process to accurately document the project plan, as well as through the award's project period to populate information in PICS:NE. PIs may be requested to provide additional assistance for clarification purposes in assuring accuracy of the information being entered into PICS:NE;
    - **DOE-NE Program Accrual Information:** DOE policy requires the monthly tracking of uncosted obligations on financial assistance awards in the DOE accounting system to assist DOE in accomplishing more accurate project management and to more accurately recognize Department liabilities to the recipient. DOE personnel do this internally by subtracting paid costs and any costs accrued (yet to be paid incurred costs of the recipient) from the amounts obligated on the financial assistance award. In accomplishing this, DOE may request the recipient provide additional cost accrual information to accurately estimate/document the accrual in the DOE accounting system. If such information is needed, it will typically be done on awards over $1M and DOE will normally do this using an e-mail to the recipient requesting the recipient identify the dollar value of work it has performed each month but not yet invoiced (or done a Treasury system draw on) as of month end. Recipients will cooperate with DOE in providing the needed cost accrual information.

- DOE responsibilities. DOE is responsible for the following items, which may be revised depending on the project:
  - Reviewing in a timely manner project plans, including technology transfer plans, and redirecting the work effort if the plans do not address critical programmatic issues;
  - Conducting annual program review meetings to ensure adequate progress and that the work accomplishes the program and project activities. Redirecting work or shifting work emphasis, if needed;
  - Promoting and facilitating technology transfer activities, including disseminating program results through presentations and publications; and
  - Serving as scientific/technical liaison between awardees and other program or industry staff.

NOTE: There are limitations on recipient and DOE responsibilities and authorities in the performance of the project activities. Performance of the project activities must be within the scope of the Statement of Objectives, the terms and conditions of the Cooperative Agreement, and the funding and schedule constraints.

C. REPORTING

Reporting requirements are identified on the Federal Assistance Reporting Checklist, DOE F 4600.2, attached to the award agreement. A sample checklist is available at http://energy.gov/management/office-management/operational-management/financial-assistance/financial-assistance-forms under Award Forms.

NOTE: The DOE F 4600.2 identifies in box 4.E "Other Reporting", a checkbox titled "Other (see special instructions)". For NEUP and NEET/NSUF awards, the other box is checked and the following is requested.

Work Package Template (one time submission) – Completed and submitted by the PI to assist DOE with populating general award information in the PICS:NE system. The template is due no later than 10/31/2020 for awardees in the above listed areas.

Quad Chart (quarterly submission) – The chart is completed and submitted by the PI to provide DOE-NE program managers and technical leads with a quick "snap-shot" look at R&D progress.

Research Performance Progress Report Template (quarterly submission) – The DOE F 4600.2 identifies in box 4.A "Management Reporting", a checkbox titled "Research Performance Progress Report (RPPR)(RD&D Projects)". The PI will complete and submit this template, which asks for information that satisfies the RPPR.

PART VII – QUESTIONS/AGENCY CONTACTS

A. QUESTIONS

Questions regarding the content of this CINR FOA must be submitted to the Agency Contact listed in Part VII, Section B. Questions regarding work scopes may be submitted to the DOE federal and technical POCs listed in Appendices A, B, and C. Applicants can communicate directly with the Federal and Technical Point of Contact until full applications are submitted regarding work scopes and technical questions. Questions pertaining to items such as application processes, eligibility, or application document requirements should be directed to NEUP@inl.gov. PIs are not allowed to contact Federal or Technical Points of Contact after the full application due date, except for discussions supporting NSUF feasibility assessments. Answers to submitted questions submitted containing information about the FOA or the FOA process, that would be necessary for the preparation of applications, will be posted to www.NEUP.gov as soon as practical. Information provided to a potential applicant in response to its request will not be disclosed if doing so would reveal the potential applicant's confidential business strategy and/or is otherwise protected. DOE will try to respond to a question within three (3) business days, unless a similar question and answer have already been posted on the website.

Interested parties are encouraged to ask questions as early in the FOA process as possible. Questions and comments concerning this FOA shall be submitted not later than five (5) business days prior to the application due date. Questions submitted after that date may not allow the Government sufficient time to respond.

Questions relating to the registration process, system requirements, how an application form works, or the submittal process, must be directed to NEUP@inl.gov.

B. AGENCY CONTACT

Name: Mr. Andrew Ford
E-mail: fordaj@id.doe.gov

C. INFORMATIONAL WEBINAR

DOE holds a webinar each year to discuss the structure and execution of this FOA, including major updates from previous years, including work scopes. Applicants can watch and participate in the live webinars and submit questions, through the GoToWebinar interface, to be answered in real time. Registration information and webinar presentations are available on www.NEUP.gov for review by applicants.

PART VIII – OTHER INFORMATION

A. MODIFICATIONS

Notices of any modifications to this announcement will be posted on www.FedConnect.net and www.Grants.gov and will also be posted as a courtesy on www.NEUP.gov. It is recommended that the website is checked frequently at www.NEUP.gov to ensure you receive timely notice of any modifications or other announcements.

B. GOVERNMENT RIGHT TO REJECT OR NEGOTIATE

DOE reserves the right, without qualification, to reject any or all applications received in response to this announcement and to select any application, in whole or in part, as a basis for negotiation and/or award.

C. COMMITMENT OF PUBLIC FUNDS

The Contracting Officer is the only individual who can make awards or commit the Government to the expenditure of public funds. A commitment by anyone other than the Contracting Officer, either explicit or implied, is invalid.

Funding for all awards is contingent upon the availability of funds appropriated by Congress for the purpose of this program.

D. PROPRIETARY APPLICATION INFORMATION

Patentable ideas, trade secrets, proprietary or confidential commercial or financial information, disclosure of which may harm the applicant, should be included in an application only when such information is necessary to convey an understanding of the proposed project. The use and disclosure of such data may be restricted, provided the applicant includes the following legend on the first page of the project narrative and specifies the pages of the application which are to be restricted:

> "The data contained in pages [Insert pages] of this application have been submitted in confidence and contain trade secrets or proprietary information, and such data shall be used or disclosed only for evaluation purposes, provided that if this applicant receives an award as a result of or in connection with the submission of this application, DOE shall have the right to use or disclose the data herein to the extent provided in the award. This restriction does not limit the government's right to use or disclose data obtained without restriction from any source, including the applicant."

To protect such data, each line or paragraph on the pages containing such data must be specifically identified and marked with a legend similar to the following:

> "The following contains proprietary information that (name of applicant) requests not be released to persons outside the Government, except for purposes of review and evaluation."

E. EVALUATION AND ADMINISTRATION BY NON-FEDERAL PERSONNEL

In conducting the merit review evaluation, the Government may seek the advice of qualified non-Federal personnel as reviewers. The Government may also use non-Federal personnel to conduct routine, nondiscretionary administrative activities. The applicant, by submitting an application, consents to the use of non-Federal reviewers/administrators. Non-Federal reviewers must sign COI and non-disclosure agreements prior to reviewing an application. Non-Federal personnel conducting administrative activities must sign a non-disclosure agreement.

F. INTELLECTUAL PROPERTY DEVELOPED UNDER THIS PROGRAM

Patent Rights. The Government will have certain statutory rights in an invention that is conceived or first actually reduced to practice under a DOE award. 42 U.S.C. 5908 provides that title to such inventions vests in the United States, except where 35 U.S.C. 202 provides otherwise for nonprofit organizations or small business firms. However, the Secretary of Energy may waive all or any part of the rights of the United States subject to certain conditions. (See "Notice of Right to Request Patent Waiver" in Section G below.)

Rights in Technical Data. Normally, the Government has unlimited rights in technical data created under a DOE agreement. Delivery or third-party licensing of proprietary software or data developed solely at private expense will not normally be required except as specifically negotiated in a particular agreement to satisfy DOE's own needs or to insure the commercialization of technology developed under a DOE agreement.

Special Protected Data Statutes. This program is covered by a special protected data statute. These special protected data statutes apply to only those applicants who cost share. The provisions of the statute provide for the protection from public disclosure, for a period of up to five (5) years from the development of the information, of data that would be a trade secret, or commercial or financial information that is privileged or confidential, if the information had been obtained from a non-Federal party. Generally, the provision entitled, Rights in Data - Programs Covered Under Special Protected Data Statutes (Item 4 under 2 CFR 910, Appendix A to Subpart D), would apply to an award made under this announcement. This provision will identify data or categories of data first produced in the performance of the award that will be made available to the public, notwithstanding the statutory authority to withhold data from public dissemination, and will also identify data that will be recognized by the parties as protected data.

G. NOTICE OF RIGHT TO REQUEST PATENT WAIVER

Applicants may request a waiver of all or any part of the rights of the United States in inventions conceived or first actually reduced to practice in performance of an agreement as a result of this announcement, in advance of or within thirty (30) days after the effective date of the award. Even if an advance waiver is not requested or the request is denied, the recipient will have a continuing right under the award to request a waiver of the rights of the United States in identified inventions, i.e., individual inventions conceived or first actually reduced to practice in performance of the award. Any patent waiver that may be granted is subject to certain terms and conditions in 10 CFR 784 at http://energy.gov/gc/services/technology-transfer-and-procurement/office-assistant-general-counsel-technology-transf-1 under the Patent Waivers.

Domestic small businesses and domestic nonprofit organizations will receive the patent rights clause at 37 CFR 401.14, i.e., the implementation of the Bayh-Dole Act. This clause permits domestic small business and domestic non-profit organizations to retain title to subject inventions. Therefore, small businesses and non-profit organizations do not need to request a waiver.

H. UNDERSTANDING COST SHARING REQUIREMENTS (Cost sharing is not required for Universities and FFRDCs)

Department-wide cost sharing requirements are established by Section 988 of the Energy Policy Act of 2005. The DOE Financial Assistance Rules at 2 CFR 200 and 2 CFR 910 implement cost sharing requirements (see 2 CFR 200.306 and 2 CFR 910.130). The FOA requires a minimum of 20% cost sharing by awardees, except for applications led by U.S. non-profit educational institutions/universities. The applicant's cost share requirement will be based on the total cost of the project. FFRDC costs are included as part of government cost share.

In accordance with section 988 (d), Calculation of Amount, when calculating the amount of the non-Federal contribution, the Government:

1. May include the following costs as allowable in accordance with the applicable cost principles:
   a. Cash.
   b. Personnel costs.
   c. The value of a service, other resource, or third party in-kind contribution determined in accordance with the applicable circular of the Office of Management and Budget [**Note**: In-kind contributions, like any other cost, need to be incurred during the award project period, e.g., cannot give credit for costs incurred prior to the award, including prior development costs, unless otherwise authorized by the applicable cost principles].
   d. Indirect costs or facilities and administrative costs.
   e. Any funds received under the power program of the Tennessee Valley Authority (except to the extent that such funds are made available under an annual appropriation act).

Shall not include:

   a. Revenues or royalties from the prospective operation of an activity beyond the time considered in the award.
   b. Proceeds from the prospective sale of an asset of an activity.
   c. Other appropriated Federal funds.

The terms and conditions of the cooperative agreement will include appropriate provisions on allowable costs.

The Federal share shall not be required to be repaid as a condition of award. Royalties should not be used to repay or recover the Federal share, but may be used as a reward for technology transfer activities.

Cost share is often confused with some form of cost matching. The key to understanding how cost share works is to understand the base from which the cost share percentage is calculated. Cost share percentage is a percentage of the total allowable costs of the project. Note that it is NOT a percentage of the DOE funds, but rather the entire project, including all awardee funds, DOE funds, and all FFRDC requirements.

When determining the cost share requirement in dollars, it is first necessary to determine the entire project cost. Initially, no consideration would be given as to where the funds would come from. An applicant would determine that a certain cost (e.g., hours, travel, supplies, etc.) would be needed to complete the project as proposed in the application. Once the project cost is determined, an applicant can then calculate the cost share requirement by multiplying the cost share percentage by the project cost. The resulting dollar figure would be the dollar requirement that the applicant must provide as cost share.

Below are several examples of how the cost share amount would be calculated:

Example 1

The applicant determines that the following budget requirements are needed to carry out the work described in its application to DOE:

Direct Labor	$100,000
Travel	$3,000
Equipment	$17,000
Supplies	$10,000
Subcontract	$20,000
Total Project Cost	**$150,000**

A cost share requirement of 20% was specified in the funding announcement.
Cost Share = (cost share percentage) × (***total project cost***)
Cost Share = (20%) × ($150,000)
Cost Share = $30,000

The applicant must now identify $30,000 of $150,000 as Cost Share.
The applicant would then request DOE funding in the amount of $120,000.

DOE Share = $120,000 **Awardee Share = $30,000**

Example 2

The applicant determines that the following budget requirements are needed to carry out the work described in its application to DOE:

Direct	$200,000
Labor	$10,000
Travel	$20,000
Equipment	$10,000
Supplies	$60,000
Total Project	**$300,000**

A cost share requirement of 20% was specified in the funding announcement.

Cost Share = (cost share percentage) × (total project cost)
Cost Share = (20%) × ($300,000)
Cost Share = $60,000

The applicant must now identify $60,000 of $300,000 as Cost Share. DOE would pay $60,000 directly to the FFRDC. The applicant would then request DOE funding in the amount of $180,000.

DOE Share = $180,000 (funds to Awardee) + $60,000 (FFRDC) = $240,000

Awardee Share = $60,000

NOTE: FFRDC funds are paid directly to the FFRDC by DOE. The work provided by the FFRDC is still considered part of the total project cost; therefore, it is included in the base from which the awardee cost share is calculated.

In all cases, the applicant must specify the individual costs that make up each part of the total project cost and indicate whether DOE or non-DOE funds will be used to cover the cost.

The budget from **Example 1** might look something like the following:

		DOE	**Non-DOE**
Direct Labor	$100,000	$70,000	$30,000
Travel	$3,000	$3,000	$0
Equipment	$17,000	$17,000	$0
Supplies	$10,000	$10,000	$0
Subcontract	$20,000	$20,000	$0
Total Project Cost	**$150,000**	**$120,000**	**$30,000**

The application forms in this FOA will facilitate the identification of funding sources.

I. NOTICE REGARDING ELIGIBLE/INELIGIBLE ACTIVITIES

Eligible activities under this program include those which describe and promote the understanding of scientific and technical aspects of specific energy technologies, but not those that encourage or support political activities such as the collection and dissemination of information related to potential, planned, or pending legislation.

J. NO-COST TIME EXTENSIONS

Unilateral no-cost time extensions will NOT be permitted to awards made under this FOA. All no-cost time extensions must provide adequate justification and receive approval from the Contracting Officer. No-cost time extensions should be requested as soon as the need is identified and normally no later than three months before the original project end date.

No-cost time extensions on existing DOE-NE funded projects must be requested between October 1-April 15. Any request outside of this period will not be considered. One no-cost time extension request may be granted for up to 12 months pending review and approval. No more than one no cost time extension will be allowed. No-cost time extensions must be submitted prior to the deadline to NEUP@inl.gov.

K. REBUDGET REQUEST

Any rebudget request where the cumulative amount of such change is expected to exceed 10 percent of the total budget as last approved by the Federal awarding agency must be requested in writing (see 2 CFR 200.308). The request must include a detailed budget justification, and an updated budget in the same format for which was included in the original application. Any request for the purchase of equipment exceeding $5k must be requested in writing to include a valid quote, and justification for purchase.

Budget forms can be found at: https://www.energy.gov/management/downloads/sf-424-research-and-related-budget-rr

L. CONFERENCE SPENDING

The recipient shall not expend any funds on a conference not directly and programmatically related to the purpose for which the grant or cooperative agreement was awarded that would defray the cost to the United States government of a conference held by any executive branch department, agency, board, commission, or office for which the cost to the United States government would otherwise exceed $20,000, thereby circumventing the required notification by the head of any such executive branch department, agency, board, commission, or office to the inspector general (or senior ethics official for any entity without an inspector general), of the date, location, and number of employees attending such conference.

PART IX – APPENDICES/REFERENCE MATERIAL

Appendix A: Work Scopes for U.S. University-led Program and/or Mission Supporting R&D Projects

Appendix B: Work Scopes for U.S. University-, National Laboratory-, or Industry-led Program and/or Mission Supporting R&D Projects

Appendix C: Work Scopes for U.S. University-led Integrated Research Project (IRP) R&D

Appendix D: Accessing Nuclear Science User Facilities

Appendix E: Draft Nuclear Science User Facilities User Agreement

Appendix A: Work Scopes for U.S. University-led Program and/or Mission Supporting R&D Projects

PROGRAM SUPPORTING: NUCLEAR REACTOR TECHNOLOGIES

RC-1: INNOVATIVE NEW STRUCTURAL MATERIALS FOR MOLTEN CHLORIDE SALT FAST REACTOR APPLICATIONS

(FEDERAL POC – SUE LESICA & TECHNICAL POC – SAM SHAM)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Metallic structural components of Molten Salt Reactors (MSRs) have significant structural integrity challenges due to the extreme environments of high temperatures, corrosive coolants and neutron irradiation (including fission and transmutation products). The selection of metallic alloys for structural applications is further complicated by the variety of MSR systems that are being considered, e.g., fast versus thermal spectrum reactor core, solid versus liquid fuel, and fluoride versus chloride salts. Existing ASME code qualified metallic alloys do not meet the challenges imposed by these extreme environments.

NEUP awards on developing the next generation MSR structural materials for applications in fluoride-based MSRs were made in FY18 and 19. The objective of this call is to develop high performance new metallic alloys that can be used for welded construction of structural components of molten chloride salt fast reactors using liquid fuel. Non-metallic materials are not within the scope of this call.

Characteristics of the new metallic alloy(s) to be considered include, but are not limited to, high temperature strength up to 900 to 950C, long-term thermal stability, chloride-based fuel salt compatibility, irradiation damage resistance, resistance to possible fission or transmutation product embrittlement, adequate tensile and creep ductility and weldability, all for the desired life times of the components. While not specifically a part of this call, the long-term goal of alloys developed under this effort would be their qualification for nuclear service under ASME Section III, Division 5, hence fabricability and potential capability for commercialization of any alloys developed are important. Innovative concepts, such as exploiting nano-scale interfaces within the alloy to trap defects and possible transmutation products, to address the material challenges are highly encouraged, as are novel applications of high-value experiments with integrated computation materials engineering for the development and testing of new metallic alloy(s).

While not required, interaction with molten chloride salt fast reactor developers on their system requirements is highly encouraged.

RC-2: MICRO-REACTOR TECHNOLOGY DEVELOPMENT AND SUPPORT FOR DEPLOYMENT

The DOE's Micro-reactor Research, Development, and Demonstration (RD&D) Program supports technology development efforts for MW-class reactors with flexible deployment options. The program is seeking applications that support the deployment case for micro-reactors, mature advanced technologies to reduce development time and cost, and/or validate modeling and simulation tools to enable their readiness for use in deployment design and licensing activities. These three areas are discussed in more detail below:

RC-2.1: MICRO-REACTOR DEPLOYMENT MARKETS

(FEDERAL POC – TOM SOWINSKI & TECHNICAL POC – JESS GEHIN)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

This work scope seeks applications to analyze potential markets and applications that take advantage of unique micro-reactor characteristics. Micro-reactors are being designed to enable flexible siting that can support applications for remote areas (e.g., remote communities and mining operations) and for integration into microgrids in populated areas to provide resilient power as well as use for emergency operations related to natural disasters. Applications are sought to perform techno-economic analyses on micro-reactor application topics such as the following:

- Requirements and ability to site micro-reactors in both remote and populated areas

PROGRAM SUPPORTING: NUCLEAR REACTOR TECHNOLOGIES

- Assessment of micro-reactor needs for remote industries including mining, high value local data processing centers, and other applications unique to micro-reactors
- Evaluation of micro-reactors use for increased resilience of the existing electrical grid and for microgrids

Studies should incorporate current micro-reactor designs and concepts, avoid duplication of recent micro-reactor market studies, recommend micro-reactor design requirements and potential improvements relevant to specific applications, and provide a data-driven market assessment for a range of micro-reactor sizes.

RC-2.2: VALIDATION OF MICRO-REACTOR MODELING AND SIMULATION TOOLS (FEDERAL POC – TOM SOWINSKI & TECHNICAL POC – JESS GEHIN) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

The Micro-reactor RD&D program is seeking to enable the use of modeling and simulation capabilities being developed by the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program for use in micro-reactor design and licensing activities by supporting the validation of the tools. This includes performing validation of the tools with existing experimental data and performing new experiments that target validation needs. Specific areas for validation include:

- Neutronics validation specifically considering unique micro-reactor materials, such as high-temperature moderators
- Thermal/heat transfer for gas-cooled and heat-pipe-cooled micro-reactors including in-reactor heat transfer and coupling to heat exchangers
- Mechanics of structural systems such as solid-core block
- Integrated system performance validation

This work scope is specifically focused on validating NEAMS tools and maturing them for micro-reactor deployment applications (i.e., not on development of new modeling and simulation capabilities). Experimental work to develop validation data for current design concepts is encouraged. Applications should connect the proposed experiments with a clear validation need.

RC-2.3: MICRO-REACTOR TECHNOLOGY DEVELOPMENT AND MATURATION (FEDERAL POC – TOM SOWINSKI & TECHNICAL POC – JESS GEHIN) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Many micro-reactor concepts employ technologies developed and demonstrated in previous and existing DOE advanced reactor R&D programs. This work scope seeks the development of approaches to deploy innovative technologies and solutions specific to micro-reactors. These technologies and solutions should build upon and enhance (though not duplicate) previous/existing DOE advanced reactor technology RD&D efforts in the following areas:

- Reducing the amount of high-assay low-enriched uranium (HALEU) required for micro-reactor concepts
- Accelerating manufacturing and fabrication approaches for unique micro-reactor components
- Flexible siting options that reduce on-site preparation needs and supports site-independent designs
- Transportation of fueled micro-reactors to site and return of the used micro-reactor
- Micro-reactor operational and maintenance regimes that minimize staffing requirements
- Integration of micro-reactor components such as innovative heat exchangers (heat pipe, gas, and/or liquid coolants) to power conversion systems and/or process heat systems

PROGRAM SUPPORTING: NUCLEAR REACTOR TECHNOLOGIES

Technologies and RD&D approaches should be described in detail and include a description of the expected improvements over the current state of the art and improvements in development schedule and cost. The technology readiness and development time line should also be described in detail.

RC-3: LIQUID METAL-COOLED FAST REACTOR TECHNOLOGY DEVELOPMENT AND DEMONSTRATION TO SUPPORT DEPLOYMENT (FEDERAL POC – TOM SOWINSKI & TECHNICAL POC – CHRIS GRANDY) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

The Department of Energy, National Laboratories, and U.S. nuclear industry are aggressively working to revive, revitalize, and expand U.S. nuclear energy capacity. Advanced non-light water reactors such as liquid metal-cooled fast reactor concepts offer the potential for significant improvements to safety, economics, and environmental performance to help sustain and expand the availability of nuclear power as a clean, reliable, and secure power source for our nation.

The Mechanisms Engineering Test Loop (METL) located at Argonne National Laboratory (ANL) is a sodium test facility designed to test small to intermediate-scale components and systems in order to develop advanced liquid metal technologies. Testing different components in METL is essential for the future of advanced liquid metal-cooled fast reactors as it provides invaluable performance data and reduces the risk of failures during plant operation. METL also provides developmental opportunities for the next generation of scientists, engineers, and designers who will ultimately lead the advancement of U.S. liquid metal technologies. The hands-on experience gained with METL will ultimately lead to better liquid metal technology programs that can support the commercialization of advanced liquid metal-cooled fast reactors.

This work scope seeks applications to develop experiments, instrumentation, control strategies, and performance enhancing technologies for the METL facility that have the potential to subsequently be deployed and used by liquid metal (sodium or lead-cooled) fast reactor concepts proposed by U.S. nuclear industry. Experiments that offer the potential for significant overall benefits to reactor capital or operating cost reductions are of particular interest.

Examples of potentially beneficial METL experimental work and technology development areas include:

- *Development of test articles for testing in the Mechanisms Engineering Test Laboratory (METL) sodium loop facility* – The test articles should consider demonstration of innovative fast reactor sub-components (sensors, seals, mechanisms, etc.) or validation of key fast reactor behaviors under prototypic or near prototypic conditions.
- *Advanced sensors and instrumentation* – Advanced liquid metal-cooled fast reactors will contain sensors and instrumentation that may be required to operate while immersed in the primary liquid metal coolant. These include sensors for the rapid detection of hydrogen presence in sodium (which is indicative of a leak), the detection of impurities in the coolant (i.e., improvement of plugging meters or oxygen sensors), alternative methods of leak detection, improved sensors for level measurement, and other advanced sensors or instrumentation that improve the overall performance of the liquid metal-cooled fast reactor systems.
- *Thermal hydraulic testing in prototypic sodium environment* – A thermal hydraulic test loop could be used to acquire distributed temperature data in the cold and hot pools of a small scale sodium-cooled fast reactor during simulated nominal and protected/unprotected loss of flow accidents. This testing could allow for the articulation of the heated region in the core for use in a parametric study of intermediate heat exchanger (IHX)/core outlet height difference and its effect on thermal stratification of sodium in the hot pool. Ultimately, this data would be used for validating CFD and systems level code.
- *Mechanisms for self-actuated control and shutdown systems* – Components have been conceived by various designers to provide added defense-in-depth for reducing the consequences of beyond-design-

basis accidents. These self-actuated control and shutdown mechanisms include devices such as curie-point magnets and fusible linkages. Performance of such mechanisms in a liquid metal environment may further enhance the safety case of liquid metal-cooled reactors.

- *In-service repair technologies* – These systems include visualization sensors for immersed coolant applications and technologies for the welding and repair of structures in contact with the primary coolant.
- *Performance improvement technologies for METL* – Technologies for improving the performance of liquid metal test loops including rugged high temperature resistance heating systems, improved insulation technology, improved sodium leak detection and identification technologies, vessel support technologies that reduce heat losses, improved clamp on flow meters, thermal monitoring, etc.
- *Health Monitoring of METL systems and components* – Development of deployable sensors and prognostic techniques for demonstration in METL that can be used to monitor and quantify materials degradation in liquid metal-cooled fast reactor primary systems. Of interest are technologies that are able to detect degradation early, can survive in typical liquid metal-cooled fast reactor environments over extended periods of time, and can be embedded in/on structural materials to enable structural health monitoring (e.g., nondestructive examination techniques, remote or automated inspection techniques including visualization in optically opaque coolants). Consideration should be given to deployment issues that may arise, such as powering the sensor and data exfiltration needs.

Though applications are not limited to the example work areas above, applicants should indicate how their proposed work will support testing articles in the METL facility to develop and deploy technologies for use in U.S. liquid metal-cooled fast reactor concepts and/or to increase the performance of the METL facility to support current DOE, national laboratory, and U.S. nuclear industry liquid metal-cooled fast reactor deployment and commercialization R&D initiatives.

The following web site contains more information on METL:

https://www.anl.gov/nse/mechanisms-engineering-test-loop-facility

RC-4: HTGR TRISO FUEL PARTICLE MATERIALS

RC-4.1: TRISO FUEL BUFFER LAYER BEHAVIOR DURING NEUTRON IRRADIATION (FEDERAL POC – DIANA LI & TECHNICAL POC – PAUL DEMKOWICZ) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

The AGR TRISO program has demonstrated very low coating failure fractions for tristructural-isotropic (TRISO) coated particle fuel under irradiation and post-irradiation safety testing at 1600–1800°C. A common failure mechanism observed in the few AGR particles that exhibited elevated release of fission products through degraded SiC layers was associated with how the buffer layer behaved during irradiation. In these particles, dimensional changes in the buffer led to cracks in the inner pyrolytic carbon (IPyC) that exposed the SiC to higher concentrations of reactive fission products (primarily palladium in UCO-TRISO and CO in UO2-TRISO) [1,2]. The buffer is a heterogenous, carbonaceous material with significant porosity (~50% dense). Radiation-induced densification of the buffer results in significant dimensional change not observed in the denser pyrocarbon layers. Post-irradiation examination has shown that over certain temperature and fluence ranges, shrinkage of the buffer layer is usually accompanied by fragmenting or tearing of the buffer material.

Observations of irradiated AGR TRISO particles [3,4] suggest that the preferred buffer evolution is when stress from radiation-induced densification of the buffer results in circumferential tearing in the buffer close to the buffer/inner pyrolytic carbon (IPyC) interface, such that the majority of the buffer layer is decoupled from the IPyC. This allows the thick inner portion of the buffer to freely shrink down around the kernel, and stress on the IPyC layer is reduced because only a thin outer portion of the buffer remains attached. In contrast, IPyC fracture

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has been observed to be associated with locations where the buffer and IPyC layers were connected and a developing buffer fracture intersected the buffer/IPyC interface [1]. Circumferential bands of varying density/porosity are observed in the as-fabricated buffer as a result of variability during coating as particles cycle through the fluidized bed and the rate of surface area-normalized buffer material deposition changes with increase of particle diameter. This banding may impact how and where buffer tearing occurs and may offer strategies for encouraging desired behavior under irradiation.

Research applications are sought that specifically focus on modeling the time-dependent evolution of the buffer and IPyC dimensional and stress states as a function of particle dimension, initial buffer microstructure, irradiation temperature, neutron flux, and neutron fluence. Of particular interest are the radiation induced shrinkage of the buffer and associated stress state leading to internal buffer tearing, and the analysis should be focused on length scales associated with the internal buffer tearing phenomena, which is on the order of tens of microns. It would also be advantageous for computational models to consider the stresses induced on the IPyC layer due to these buffer behaviors, as these can contribute (along with other factors such as irradiation-induced strain in the IPyC) to IPyC fracture and separation from the SiC layer. The impact of kernel swelling should also be included as another source of stress in the buffer that can lead to dimensional changes and buffer fracture. In many cases, material properties are not known (e.g., buffer strength, buffer elastic modulus, and buffer-IPyC bond strength). Parametric studies over a range of material properties may be used to compare modeling results to available data from observation of TRISO fuel irradiated by the AGR program.

All project tasks must be performed to NQA-1 standards. Data, experiments, fuel performance computational modelling information, and any calculations shall be submitted to the Idaho National Laboratory's NGNP Data Management and Analysis System (NDMAS).

[1] J.D. Hunn et al., "Detection and analysis of particles with failed SiC in AGR-1 fuel compacts," Nucl. Eng. Des. 306 (2016) 36–46.

[2] R.N. Morris et al., "Initial results from safety testing of US AGR-2 irradiation test fuel," Nucl. Eng. Des. 329 (2018) 124–133.

[3] F.J. Rice et al., "Ceramography of irradiated TRISO fuel from the AGR-2 experiment, " INL/EXT-16-39462, Rev. 0, 2016.

[4] J.D. Hunn et al., "Initial examination of fuel compacts and TRISO particles from the US AGR-2 irradiation test," Nucl. Eng. Des. 329 (2018) 89–101.

RC-4.2: ROBUST INDIVIDUAL TRISO-FUELED PEBBLE IDENTIFICATION METHOD FOR EX-CORE EVALUATION
(FEDERAL POC – DIANA LI & TECHNICAL POC – PAUL DEMKOWICZ)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Several advanced gas-cooled and salt-cooled reactor designs currently under consideration utilize spherical fuel pebbles containing thousands of TRISO fuel particles. These pebbles are not static, but move through the reactor core and are periodically removed in order to measure the burnup nondestructively [1]. Pebbles that are below a specified target burnup value are returned to the core, while pebbles that exceed this target are sent to spent fuel storage. New pebbles are added to the core to replace those that were removed to spent fuel storage. In pebble-bed reactors that have been operated to date, the identity of the individual pebbles in the core (typically many thousands of pebbles, depending on design) have not been tracked during operation. However, there are advantages to maintaining pebble identity, including determination of pebble transit time to validate computational models [2]. This can help determine if any pebbles are retained for unexpectedly long times in the core which could result in excessive burnup accumulation. Therefore it may be useful to tag individual pebbles in order to track the identities as they cycle ***out*** of the reactor core ***following irradiation*** for analysis and potential core reentry. However, pebble identification poses several inherent challenges including: (a) potential abrasion

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or degradation of the pebble surface, (b) the high-temperature neutron irradiation environment, and (c) the large number of pebbles that need to be tracked and catalogued during reactor operations, which requires a relatively rapid ex-core burnup assessment [1] period following in-core irradiation. The development of a novel method which overcomes these challenges and provides rapid, reliable, and robust pebble identification would be of great interest and use for several pebble-based advanced reactor designs.

The proposed "tagging and tracking" identification method needs to be very robust and radiation resistant, and should encompass a realistic range of HTGR normal operation and accident temperatures and neutron fluence levels: (1) burnup to 20% fissions per initial metal atom (FIMA), (2) fast neutron fluences up to 4.5E25 n/m^2 (E > 0.18 MeV), and (3) normal operational irradiation temperatures ranging from approximately 900 to 1250°C. The proposed identification technique may use existing gamma spectroscopy and passive neutron counting of spontaneous fission neutrons used in proposed pebble burnup measurement systems [1] and/or additional detection methods to read the individual pebble tag identification. Applications for developing burnup monitoring systems are not solicited in this call.

All work (e.g., experiments and calculations) must be performed to NQA-1 standards. Data, experiments, and any calculations shall be submitted to the Idaho National Laboratory's NGNP Data Management and Analysis System (NDMAS).

1. Su, Bingjing, "Design and Construction of a Prototype Advanced On-Line Fuel Burn-up Monitoring System for the Modular Pebble Bed Reactor," University of Cincinnati, NERI Project 00-100, Final Report, DE-FG07-00SF22172, March 30, 2004, available at: https://www.osti.gov/servlets/purl/822595.

2. Chen, Hao, et al., "Quantitative analysis of uncertainty from pebble flow in HTR," Nucl. Eng. Des. 295 (2015) 338-345.

RC-5: EXPERIMENTAL VALIDATION OF HIGH TEMPERATURE GAS REACTOR (HTGR) SIMULATIONS
(FEDERAL POC – DIANA LI & TECHNICAL POC – GERHARD STRYDOM)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Experimental validation of High Temperature Gas Reactor (HTGR) simulations is focused on providing data of high temperature gas-cooled reactor (prismatic or pebble bed) phenomena for the validation of system and computational fluid dynamics models. These phenomena are relevant to core safety and performance. Two scenarios of interest to core designers and safety analysts involve disruptions of the nominal helium flow rate and transition to either the Pressurized or Depressurized Conduction Cooldown (PCC/DCC) events [1], [2], [3]. The PCC is initiated by a helium circulator or turbine trip, while the DCC is the result of a slow depressurization after a leak or break in the primary pressure boundary. Most HTGR reactor systems incorporate water-or air-cooled Reactor Cavity Cooling System (RCCS) [2] as a final heat sink and for protection of the vessel and concrete confinement structures.

This work scope entails the evaluation of two elements - degraded or asymmetric RCCS performance and a plenum-to-plenum natural circulation characterization. Applications utilizing existing integral and/or separate effects test facilities (with modifications) are encouraged, in addition to applications suggesting development of new facilities.

In previous studies (e.g. reference [2]), the RCCS performance during PCC/DCC events were mostly characterized in separate effects or integral facilities assuming as-designed operation. In reality, various failure modes of the RCCS can result in either degraded (i.e. at a lower total heat removal rate) or asymmetric (i.e. an azimuthal section of the RCCS is non-operational) performance. The impact of these conditions on localized vessel and concrete temperatures should be characterized. In addition to the PCC event (i.e. terminating forced cooling and remaining at a pressurized condition), it is also desired that three classes of break events be included

in the "compromised" RCCS test matrix: slow (depressurization over 12 hours), medium (1-6 hours) and fast (< 10 minutes) to assess the effects of blowdown periods on the figures of merit. If the test facility geometry allows different break locations (e.g. top and bottom breaks and inlet/outlet plena), this would enable various natural convection regimes to establish over different time-scales.

Finally, principal investigators are also invited to propose an experimental characterization of low-velocity (natural circulation) plenum-to-plenum gas flow at prototypical conditions. A flow reversal condition can for example occur during a PCC, i.e. hot gas flows upwards from the outlet plenum to the inlet plenum via the control rod and other bypass flow channels This facility could be part of a larger (new or existing) experimental setup, or a dedicated facility that would allow assessment of the natural circulation flow between two large void regions.

Principal investigators are encouraged to consult with US-based HTGR vendors (Framatome, X-Energy, etc.) to refine the experiment design and test matrix. A literature review of previous experimental work performed (e.g. [2]) and the HTGR community V&V needs [4], specifically for CFD codes, would be expected to leverage previous recommendations and lessons-learned.

All experiments must be performed to NQA-1 standards. Data, experiments, and calculations shall be submitted to the Idaho National Laboratory's NGNP Data Management and Analysis System (NDMAS). Assistance shall be provided by Idaho National Laboratory for NDMAS use and ensuring NQA-1 standards are properly established.

References:

[1] Sterbentz, J.W., et al,. (2016). High-Temperature Gas-Cooled Test Reactor Point Design. INL/EXT-16-38296, Idaho National Laboratory.

[2] Yang, Se Ro & Kappes, Ethan & Nguyen, Thien & Vaghetto, Rodolfo & Hassan, Y. (2018). Experimental study on 1/28 scaled NGNP HTGR reactor building test facility response to depressurization event. Annals of Nuclear Energy. 114. 154-164. 10.1016/j.anucene.2017.12.023.

[3] NGNP Deliverable to DOE: Project Recommendations – Evaluation and Testing of HTGR Reactor Building Response to Depressurization Accidents, AREVA Document 12-9273530-00, July 2017.

[4] Schultz, R.R., et al., (2017). Identification and Characterization of Thermal Fluid Phenomena Associated with Selected Operating/Accident Scenarios in Modular High Temperature Gas-cooled Reactors. INL/EXT-17-34218, Idaho National Laboratory.

RC-6: FLUORIDE SALT-COOLED HIGH TEMPERATURE REACTOR (FHR)

The Fluoride Salt-cooled High Temperature Reactor (FHR) focus area is seeking to address either one of the two areas discussed below.

RC-6.1: OPTIMIZED FLUORIDE SALT PIPE JOINTS FOR FLUORIDE SALT COOLED HIGH TEMPERATURE REACTORS
(FEDERAL POC – DIANA LI & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Flanges that require repeated sealing along with thermal cycling for service conditions above 500 °C with low internal pressures remain a substantial engineering challenge. Bolts creep and relax, threads gall, and the torque used to seal at room temperature is inappropriate at operating temperature. Differential thermal expansion of multi material systems frequently result in leaks. Resilient metal seals require precise surfaces to achieve/maintain seal. Other designs rely upon internal pressure to force a compressible seal into a mated

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backing. The historic MSR program relied upon frozen salt gaskets which were not testable prior to filling along with high-temperature bolting. All of the available designs are difficult to make-up and remove using remote/automated tooling. Optimized fluoride salt pipe joints are sought that are suitable for both large and small pipes, can be repeatedly joined and disconnected, can be tested prior to filling with salt, function when subjected to repeated thermal cycling, do not require internal pressure for sealing, and are tolerant of common engineering tolerances (roughness and alignment) of mating surfaces.

Due to the relatively early stage of maturity of FHR facilities and significant resources required, establishing an NQA-1 program may not be feasible, however priority will be given to experiments that are performed to NQA-1 standards.

RC-6.2: PUMP SCALING TECHNOLOGY FOR FLUORIDE SALT COOLED HIGH TEMPERATURE REACTORS
(FEDERAL POC – DIANA LI & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

The pump shaft seals and oil lubricated shaft bearings were among the most problematic technologies at the MSRE with hydrocarbon lubricant leaking into the fuel salt with a wide range of undesirable impacts. Also, as FHR technology progresses from laboratory to industrial scale, its component technologies need to scale. Long-shafted, cantilever pumps are the currently leading candidate for larger-scale FHR primary pumps. Gas-foil seals (to avoid hydrocarbon lubricants), however, require precise, well aligned shaft and seal surfaces, which, are more challenging at scale and, in practice, require bearings within the salt. Fluoride salt compatible bearings remain largely unproven. Larger gas gaps leave larger paths for gaseous radionuclide releases. Development and demonstration of scalable fluoride salt pump component technologies (seals and bearings) are requested.

Due to the relatively early stage of maturity of FHR facilities and significant resources required, establishing an NQA-1 program may not be feasible, however priority will be given to experiments that are performed to NQA-1 standards.

RC-7: PLANT MODERNIZATION R&D PATHWAY

RC-7.1: DIGITAL INSTRUMENTATION AND CONTROL
(FEDERAL POC – ALISON HAHN & TECHNICAL POC – CRAIG PRIMER)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

One of the current challenges of digital modernization for operating Light Water Reactors is digital conversion, enabling elimination of analog field circuits in the plant I&C systems, including the field logic devices (relays, timers, etc.) and associated cables. Developing the digital system software equivalent of an analog circuit is labor-intensive and susceptible to error. An automated or semi-automated means of converting analog circuit design information (derived from electronic design drawings) to equivalent digital system function block logic (or other types digital logic) would be a significant enabler of full digital modernization for nuclear plants. Such a capability should generate code that can be automatically tested either in the target digital platform or a simulation for correct operation.

Proposed research will address:

- Develop an automated or semi-automated means of converting analog circuit design information (derived from electronic design drawings) to equivalent digital system function block logic (or other types of digital

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logic). This capability will further enable the function block logic (or other digital logic) to be automatically tested for correct operation either on the target digital platform or an equivalent simulator.

RC-7.2: VIRTUALIZED DISTRIBUTED CONTROL SYSTEMS FOR NUCLEAR POWER PLANTS (FEDERAL POC – ALISON HAHN & TECHNICAL POC – CRAIG PRIMER) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Harvesting and reuse of process control application software and use of IT-based hardware at basic control level (Purdue Model Level 1) within a distributed control system (DCS) has the potential to dramatically reduce technology refresh costs and provide a long term, sustainable lifecycle support strategy to address digital obsolescence. Up to this point, efforts by industrial control system suppliers have been largely constrained to Level 2 and higher within the Purdue Model. Virtualized software (and its imbedded intellectual property) can be migrated to new IT based hardware when needed, reducing the cost of performing technology refreshes at Level 2 and above. Research is needed to determine the viability of virtualizing the function of DCS process controllers at Level 1. This would largely decouple core DCS control application software from the custom built and closely intertwined hardware and software of current DCS industry product. Controller application software could then be migrated to a new IT based hardware.

Proposed research will address:

- Develop methods and techniques to allow virtualization of Distributed Control System (DCS) Purdue Model Level 1 hardware & software while maintaining key properties of current DCSs such as control segmentation, low latency, determinism, redundancy, fault tolerance, and graceful degradation.
    - Identify logical and physical architecture attributes/properties that enable virtualization of DCS Purdue Model Level 1 above the input/output interface to physical processes being monitored and controlled.
    - Demonstrate the proposed architecture ensuring current attributes (e.g. control segmentation, determinism, redundancy, fault tolerance, graceful degradation) of current DCSs at Purdue Model Level 1 are maintained.

RC-7.3: REDUCING HUMAN FACTOR UNCERTAINTY USING ARTIFICIAL INTELLIGENCE IN OPERATION AND MAINTENANCE OF NUCLEAR POWER PLANTS (FEDERAL POC – ALISON HAHN & TECHNICAL POC – CRAIG PRIMER) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

The labor-centric business model of the existing domestic fleet of nuclear power plants is presenting an economical sustainability challenge. Today, operation and maintenance (O&M) involve several activities such as testing, inspection, data collection, interpretation, and decisions-making, that are performed by large number of skilled field workers. This introduces potential for human factors errors and variability between activities that are at times difficult to correlate due to missing record or sparseness.

Proposed research will:

- Leverage advancement in technologies to automate possible O&M activities along with explainable artificial intelligence and machine learning research to analyze all the data sources. Innovative and scientifically strong applications in the area of artificial intelligence and machine learning techniques to reduce human error, variability, and uncertainty in data interpretation and decision-making. The outcomes of the research are expected to provide consistent interpretation of data, diagnosis of any potential problem, estimate future state, make acceptable recommendation, and quantify the uncertainty in decision-making. The demonstration

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of the developed concept in a representative environment is preferred to enable implementation of the developed concept in a nuclear power plant.

RC-8: RISK-INFORMED SYSTEMS ANALYSIS R&D PATHWAY

RC-8: EVALUATION OF PHYSICAL PHENOMENA DATA IMPACT AND IMPROVEMENTS (FEDERAL POC – ALISON HAHN & TECHNICAL POC – CURTIS SMITH) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Modeling the effects of physical events (fire, flood, high winds, etc.) in a nuclear power plant's risk assessment involves using data and a standard of practice guidance. This data and guidance typically use a conservative evaluation based on historical data, expert judgement, and experiments of the physical phenomena. Further, some of the historical experiments used in analysis today were performed before the availability of advanced measurement tools and controlled environments. These unknowns in input parameters and lack of resolution in results causes uncertainties and conservative decisions in order to cover knowledge gaps.

Some small changes in results or reduction in uncertainty can have a large effect in results of a PRA model, such as the heat release rate curve in a fire model. However, recreating all these experiments may be cost prohibitive and often unnecessary. We request a project to research and evaluate the data used for hazard guidance in phenomena-driven areas and develop a method to determine significant contributors to uncertainty and determining what rerun or new experiments would be of most value (i.e., change in data/guidance leading to a difference in risk compared to the cost of new experiments). Possible work could include experiment determined to be of significant value for a specific phenomenon.

RC-9: MATERIALS RESEARCH PATHWAY

RC-9: ELUCIDATING HOW WATER CHEMISTRY AFFECTS THE CORROSION SENSITIVITY OF PRISTINE STAINLESS STEEL IN NUCLEAR POWER PLANTS (FEDERAL POC – ALISON HAHN & TECHNICAL POC – XIANG (FRANK) CHEN) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Reductions in the operating costs of nuclear power plants (NPPs) are mandatory to pass the benefits of cost-effective electric power generation to the end-consumer. One possibility of operating cost reduction involves switching the alkalinization agent from LiOH to KOH. While a cost-effective possibility, the impacts of such a change and the consequent water chemistry alterations on the corrosion processes and NPP core-internal component service-life remain poorly understood; more so in the case of irradiated materials (e.g., stainless steels).

Therefore, applications are sought to develop a robust new understanding of the mechanisms and processes by which ions interact with alloy surfaces bearing diverse microstructures, in aqueous solution, and affect the near-surface local electrochemical environment thereby resulting in the onset of corrosion processes - in pristine stainless steels, and those subjected to irradiation. It is critical to understand how water chemistry changes (e.g., from LiOH to KOH) may affect the degradation and durability of NPP core-internals; exploring simultaneously how contributions of mechanical stress factors affect corrosion sensitivity will be considered a key advantage. The systematic integration of pioneering experimental analyses with integrated computational materials engineering (ICME) for developing new fundamental insights is highly encouraged.

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RC-10: ADVANCED SMALL MODULAR REACTOR R&D (FEDERAL POC – TIM BEVILLE & TECHNICAL POC – TBD)

The DOE's Advanced SMR Research and Development (R&D) Program supports technology development efforts for domestic SMR designs that can provide safe, affordable and resilient power generation options to meet the nation's economic, energy security and environmental goals. SMRs are nuclear power plants that are smaller in size (approximately 50 to 300 megawatts electric) than current generation base load plants (many are 1,000 megawatts electric or higher). These smaller, compact designs consist of major components and modules that can be factory-fabricated and transported to a nuclear power site by truck, rail, or barge. The Department is currently working with industry, the national laboratories and academia to advance the certification, licensing, and siting of domestic SMR designs, and to reduce economic, technical, and regulatory barriers to their deployment. DOE's work is focused on domestic deployment of SMRs, but many of our international partners are also interested in SMR technology and its maturation. This effort under the NEUP is seeking applications that can develop technologies to support the accelerated development and deployment of SMR designs, and to conduct economic and market analysis that can provide insights into the potential for reducing the costs as well as the domestic and international market penetration of SMRs. These areas are discussed in more detail below:

RC-10.1: TECHNOLOGIES TO SUPPORT SMR DEVELOPMENT AND COMMERCIALIZATION (FEDERAL POC – TIM BEVILLE & TECHNICAL POC – TBD) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

This work scope seeks applications that would develop technologies, capabilities and methodologies specific to SMR characteristics and environments that would help to improve the deployment potential of SMRs. Applications should support a broad range of SMR technologies (i.e., light water, gas, liquid metal and molten salt cooled designs), and offer specific safety, safeguards, operational, and economic efficiency improvements for this class of reactor designs. Applicants should focus on areas that address the niche characteristics of SMRs, such as the simplified designs, operational flexibility, multi-unit deployment, potential for fleet-level deployment, potential for below grade siting, and other key aspects. Examples of technology development areas where applications are sought include, but are not limited to, the following:

- Remote or autonomous operation capabilities;
- Control room improvements;
- Compact, high efficiency heat exchanger and steam generator designs;
- Improved penetration technologies for primary system components;
- On-line power monitoring capabilities for anticipated advanced SMR cores;
- Methodologies or use of robotics for remote or automated maintenance in confined environments and high radiation fields; and,
- Ability to conduct material accountability for advanced fuel designs in fleet-level deployment.

RC-10.2: SMR MARKET ANALYSES (FEDERAL POC – TIM BEVILLE & TECHNICAL POC – TBD) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

This work scope seeks applications to analyze potential markets and applications that take advantage of SMR characteristics. SMRs are being designed to enable siting at areas that are not feasible for the current generation of large light water reactors but require more power than can be provided by micro-reactor systems. This includes applications to replace retiring fossil plants where deployment of a large LWR is not economically feasible, for powering remote areas (e.g., remote communities, mission-critical installations, and mining operations), and to potentially provide a generation source for microgrids in populated areas to provide resilient

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power. Applications are sought to perform analyses on topics such as, but not limited to, the following:

- Feasibility of siting SMRs in both remote and populated areas;
- Examination of markets that are specifically trying to retire coal plants that are in the same output range as known SMR designs, and could be "sweet spots" for SMR deployment;
- Assessment of SMR capabilities to support remote industries such as mining operations, remote population centers, to provide resilient power to permanent, mission-critical facilities, and other potential applications;
- Evaluation of SMR capabilities to provide increased resilience of the existing electrical grid and for possible microgrid applications;
- Specific evaluation of the uses of non-electric SMR output to support residential, commercial, or industrial applications in both remote and populated areas.

Studies should incorporate information consistent with the capabilities of current domestic SMR designs and concepts of any technology type, should avoid duplication of existing SMR market studies, recommend SMR design requirements and potential improvements relevant to specific applications, and provide a data-driven market assessment for a range of SMR sizes and performance parameters.

RC-10.3: SMR ECONOMIC ANALYSES
(FEDERAL POC – TIM BEVILLE & TECHNICAL POC – TBD)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

This work scope seeks applications to conduct analyses or sensitivity studies that can address economic impacts of various SMR plant design, fabrication, construction, operation, and decommissioning activities, state and national-level energy policies and initiatives, and financing structures on the levelized cost of electricity (LCOE) of SMRs. Applicants should focus on areas that address the niche economic characteristics of SMRs, such as potential for factory fabrication, ability to transport major components and modules, ability to replace fossil generation, fleet deployment aspects, and other key elements. The goal of the studies should be to bolster and improve the business case for domestic deployment of SMRs. Applications may address the impact on economics of a wide range of SMR-specific factors including, but not limited to, the following:

- Fabrication and construction improvements;
- Supply chain development and improvement activities;
- Unique transportation methodologies for major SMR components and modules that could improve construction schedules;
- Unique considerations for fleet-level fuel transportation and disposition;
- Decommissioning policies and methodologies;
- Financing structures that would support incremental deployment of multiple plant modules, or plant deployments at multiple locations; and,
- Potential federal and state policy changes, including actions such as changes in tax structures and valuation of resilience capabilities.

Studies should incorporate information consistent with the capabilities of current domestic SMR designs and concepts of any technology type, should avoid duplication of existing SMR economic studies, and recommend potential improvements relevant to areas assessed.

PROGRAM SUPPORTING: FUEL CYCLE TECHNOLOGIES

FC-1: MATERIAL RECOVERY AND WASTE FORM DEVELOPMENT

This program element develops innovative methods to separate reusable fractions of used nuclear fuel (UNF) and manage the resulting wastes. The program employs a long-term, science-based approach to foster innovative and transformational technology solutions and applies the unique nuclear fuel cycle chemistry expertise and technical capabilities to a broad range of civil nuclear energy applications. These chemical technologies, when combined with advanced reactors and their fuels, form the basis of advanced fuel cycles for sustainable and potentially growing nuclear power in the U.S.

FC-1.1: NUCLEAR FUEL CYCLE CHEMISTRY
(FEDERAL POC – STEPHEN KUNG & TECHNICAL POC – TERRY TODD)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $600,000)

Complexation Chemistry, Actinides Chemistry, Radiation Induced Degradation and Chemistry

A fundamental knowledge of the electronic structure of the complexes of actinides will expand our ability to predict their behavior quantitatively under conditions relevant to all stages in fuel recycling. To better controlling and tailoring chemical species and properties of actinides and fission products will enhanced separation and recovery efficiencies. There is also a need for an improved understanding of the fundamental processes that affect the formation of radicals and ultimately control the accumulation of radiation-induced damage to separation systems. For example, gamma radiation is known to produce radicals that can affect the oxidation states of multivalent cations in solution. Fundamental knowledge of the chemical speciation and partitioning of multivalent cations (e.g. Np, Tc, Zr) in advanced extraction process under high irradiation fields will improve processes being studied. Applications are requested to enhance fundamental understanding of fuel cycle chemistry and to develop novel new approaches for advanced reactor used fuels treatments and recycling.

FC-1.2: ELECTROCHEMICAL SEPARATIONS
(FEDERAL POC – STEPHEN KUNG & TECHNICAL POC – MARK WILLIAMSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 2 YEARS AND $400,000)

The solubility limit of fission products in molten chloride salts becomes one limit that impacts the timing for salt treatment and recycle, or disposal. Solubility data as a function of temperature and composition is available for many binary and ternary chloride systems especially those that contain alkali and alkaline earth chlorides. However, similar data is lacking for complex multicomponent chloride salt systems especially those involving the lanthanide and actinide elements. Applications are requested to establish fundamental thermochemical data in chloride salt systems with an emphasis on multicomponent solubility of the fission product chlorides. Experimental work may be supplemented by thermodynamic data simulation to yield a more complete understanding and predictive models of the solid-liquid equilibria in the complex chloride systems.

FC-1.3A: WASTE FORMS DEVELOPMENT AND OFF-GAS CAPTURE
(FEDERAL POC – KIMBERLY GRAY & TECHNICAL POC – BOB JUBIN)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 2 YEARS AND $400,000)

IODINE IMMOBILIZATION FROM CAUSTIC SCRUBBER SOLUTION - The size and cost of using silver-based solid sorbent material alone to remove I-129 are relatively large. Recent studies have demonstrated that the combination of a caustic scrubber followed by a silver-based solid sorbent polishing bed may reduce the sorbent usage by ~90%. The recovered iodine, associated tramp halogens, and co-absorbed carbon (C-12 plus C-14) in

PROGRAM SUPPORTING: FUEL CYCLE TECHNOLOGIES

the caustic scrubber solution must be converted to a highly stable and corrosion resistant waste form. Applications are requested to develop conversion process(es) for the spent scrubber bottoms solution into highly durable waste form. The proposed waste forms/processes that avoid the use of silver or other hazardous metals are preferred. The conversion process should also consider, and experimentally verify, the fraction of the halogens and carbon that would be released during the conversion process and that would require recapture. The proposed effort should include the production of multiple, 20 gram monolithic waste form test samples that would be provided to the DOE National Laboratories for testing beginning no later than 15 months into the effort and continuing to the conclusion of the proposed effort. Samples of the proposed waste forms would be evaluated using the facilities and methods developed within the DOE National Laboratory complex.

FC-1.3B: WASTE FORMS DEVELOPMENT AND OFF-GAS CAPTURE
(FEDERAL POC – KIMBERLY GRAY & TECHNICAL POC – JOHN VIENNA)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 2 YEARS AND $400,000)

SALT WASTE RECYCLE AND IMMOBILIZATION– Some advanced reactors and fuel cycles generate alkali- and alkaline-earth halide-based salt waste streams. These streams contain fission products and some actinides and must be treated to immobilize the radioactive components. The national laboratories are developing a method to dehalogenate the salt waste using phosphate compounds. This process generates a phosphate liquid containing fission products and actinides. Durable phosphate-based waste glasses may be used to immobilize the resulting molten phosphate-based streams. Applications are requested to develop a highly durable and easily processable phosphate-based waste glass. The waste form should be developed to be processed efficiently in existing waste glass melter technologies and result in acceptable glass when slow cooled in full scale waste glass canisters. The proposed effort should include the production of multiple, 20 gram monolithic waste form test samples that would be provided to the DOE National Laboratories for testing beginning no later than 15 months into the effort and continuing to the conclusion of the proposed effort. Samples of the proposed waste forms would be evaluated using the facilities and methods developed within the DOE National Laboratory complex.

FC-2: ADVANCED FUELS

FC-2.1: NDE TECHNIQUES FOR ASSESSING INTEGRITY OF COATED CLADDING TUBES
(FEDERAL POC – FRANK GOLDNER & TECHNICAL POC – TARIK SALEH)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Near-term Accident Tolerant Fuel (ATF) technologies currently under development include coated cladding concepts, including coatings on zirconium alloys and SiC-SiC composites. Coating thicknesses under development by commercial fuel vendors are typically between 2-20 µm in thickness. In order to enable and support cost effective manufacturing, non-destructive quality assurance techniques are needed to: (1) verify the thickness and uniformity of the coating layers, (2) identify areas of missing coating layers, and (3) confirm coating-substrate bond quality.

The present call seeks to stimulate applications to develop and demonstrate innovative, non-destructive, and potentially high-throughput inspection techniques for coated zirconium alloy and/or coated SiC-SiC cladding tubes that address one or more of these characterization needs. It is expected that applicants will need to work in collaboration with one or more of the DOE-sponsored ATF vendors (i.e., Westinghouse, General Electric, and Framatome) in order to obtain coated cladding specimens for testing. Applicants should clearly identify the coating-cladding combination to be investigated and which fuel vender will supply the applicant with specimens for testing. The applicant and the fuel vendor are responsible for establishing the intellectual property protection plan for their collaboration and should provide a written confirmation of this established framework in the final application. No portion of the funds in this award area may be used to develop new coating technologies; the focus must be on development of inspection techniques in support of commercial concepts.

PROGRAM SUPPORTING: FUEL CYCLE TECHNOLOGIES

FC-2.2: INVESTIGATIONS OF CARBIDE AND NITRIDE FUEL SYSTEMS FOR ADVANCED FAST REACTORS

(FEDERAL POC – JANELLE EDDINS & TECHNICAL POC – ANDY NELSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

A wide range of solid fuel advanced fast reactors are presently under investigation for numerous applications ranging beyond historic transmutation missions to include once-through fuel cycle concepts. Uranium-zirconium (U-Zr) metallic fuels and mixed oxides (MOX) have been the reference fuels for the majority of historic fast reactor concepts beyond commercial power generation. Both U-Zr and MOX fuel forms have myriad benefits, but both possess well known limitations as nuclear fuels for certain applications. Alternate fast reactor fuels have been proposed and assessed to varying degrees over previous decades, but none have been advanced to the degree of either U-Zr or MOX. There is renewed interest among commercial advanced reactor designers for high density ceramic fuels such as uranium monocarbide (UC) and uranium mononitride (UN) as candidates for gas-cooled or lead-cooled fast reactors. In comparison to metallic and oxide fuels, these fuel forms have seen much less assessment and evaluation. The more limited attention given to carbides and nitrides as fast reactor fuels has limited the use of modern experimental and simulation tools to better understand the capabilities, uncertainties, and limitations in service of these fuels.

The present call intends to stimulate applications that address aspects of carbide and nitride fuels for advanced reactors through leveraging of modern experimental methods and capabilities as well as modeling and simulation tools. Focus should be restricted to previously-defined solid fuel fast reactor concepts. The goal is to contribute to advancing the technological readiness levels of UC and UN fuel forms as applied to gas fast reactor and lead fast reactor systems, respectively, in anticipation of future commercial use. It is anticipated, but not required, that both experimental and modern modeling and simulation tools will play important roles in a successful application. Focus may be placed on either a major challenge of a single component of the fuel or extended to include the fuel/cladding/coolant system. Specifically, applications that address high priority items related to these fuel types such as chemical compatibility between UN and Pb coolant, or compatibility of ferritic-martensitic steels or Al-forming steels with Pb coolant are encouraged, as well as fuel property measurements to fill gaps in existing databases. Design, irradiation (both neutron and ion beam), or postirradiation examination of fuel concepts is beyond the scope of the call, but new methods of analyzing archival postirradiation data may constitute a component of proposed work. While the potential topic areas for the present call are broad, it will be critical that proposed work clearly articulate the key unknowns or challenges that limit further advancement of the chosen concept and how the proposed work will surmount those challenges if successful.

FC-2.3: HIGH-THROUGHPUT AND/OR MICRO-SCALE POST-IRRADIATION EXAMINATION TECHNIQUES TO SUPPORT ACCELERATED FUEL TESTING

(FEDERAL POC – KEN KELLAR & TECHNICAL POC – LUCA CAPRIOTTI)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

There are current activities in the Advanced Fuels Campaign to perform irradiation testing on a sizable number (i.e., dozens) of miniature, significantly reduced-diameter fuel rodlets (e.g., metallic or oxide fuels with steel cladding diameters as low as 0.1-in. and cladding lengths on order of 2.0-in.) as part of an approach to significantly accelerate the burnup accumulation rate in the Advanced Test Reactor and simultaneously explore a diverse set of fuel design parameters. This approach will create the need to perform postirradiation examinations (PIE) on large numbers of miniature fuel rodlets, which will challenge traditional PIE methods relative to both timely throughput of large sample numbers and reduced dimensional scales. The present call intends to stimulate applications to develop and demonstrate (on unirradiated, surrogate specimens) innovative techniques that can be applied in a hot cell environment to efficiently perform PIE on miniaturized integral fuel rods. Both non-destructive and destructive methods are of interest, including (but not limited to) measurements of cladding deformation, fuel swelling, fission gas release, and microstructural characterization of fuel or cladding.

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FC-2.4: MAINTAINING AND BUILDING UPON THE HALDEN LEGACY OF *IN-SITU* DIAGNOSTICS

(FEDERAL POC – KEN KELLAR & TECHNICAL POC – COLBY JENSEN)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

With the loss of access to the Halden reactor, the nuclear research community is at risk of losing the extensive *in situ* diagnostic capabilities practiced at Halden. The global nuclear community is involved in using and expanding upon Halden's diagnostic achievements. The Department of Energy, Office of Nuclear Energy is interested in research and development efforts that utilize and improve upon Halden in situ diagnostics. This call is open to all viable diagnostic approaches and is not limited to the methods used at the Halden facility. Halden also demonstrated excellence in test specimen manufacture. Their work included conversion of large irradiation specimens to smaller instrumented specimens while preserving important features of the test specimen, e.g., the cracked state of irradiated fuel pellets. Another notable attribute of Halden experiments was the ability to combine multiple diagnostics on one test specimen.

Real-time in-core diagnostic instrumentation of interest includes, but is not limited to: creep, crack propagation, swelling, corrosion/crud build up, temperature, pressure, flux, two-flow phase, and fission product transport. Research that enables in-core application and associated logistics is also encouraged such as focuses on miniaturization, non-contact/non-intrusive as well as innovative data transmission techniques, such as wireless methods is also encouraged.

Emphasis in awarding R&D grants will be placed on diagnostics that can most directly benefit ongoing modelling and computer simulation development and future U.S. irradiation experiments, and that measure phenomena that is difficult to assess during irradiation or post-irradiation examinations, e.g., crack propagation rates and non-linear phenomena.

FC-2.5: NSUF SEPARATE EFFECTS TESTING IN TREAT USING STANDARD TEST CAPSULES

(FEDERAL POC – KEN KELLAR & TECHNICAL POC – DAN WACHS)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(REFER TO NSUF WORK SCOPE TIME PERIODS (PART II, SECTION E.2.1), UP TO $500,000)
(NSUF LETTER OF INTENT REQUIRED)

Modern nuclear fuel technology development strategies are being developed that rely on integration of micro-scale material science and thermal-mechanical engineering through advanced modeling and simulation techniques that are envisioned to accelerate the development and deployment of advanced fuel technologies. Realization of this vision requires implementing current and new nuclear science research tools in new ways to build the experimental databases that will be used to develop and qualify these tools. This includes developing the physical models input into the codes as well as the integral system data to be used in validating the result of the simulations.

TREAT is designed to deliver a time dependent neutron flux to test specimens. The specific shape of the transient (ranging through steady-state 'flat-tops', power ramps, pulses, or combinations of each) can be selected to achieve the experimenter's desired energy deposition in the test sample. The test can be immersed in a variety of sample environments provided by specialized irradiation devices. Multi-purpose, modular test devices allow experimenters the flexibility to quickly design experiment-specific test capsules that can provide a wide array of thermal, mechanical, and/or chemical environmental boundary conditions. The response of the test sample to the nuclear stimulus while immersed in this carefully controlled environment can be readily monitored using existing qualified or user supplied instruments.

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Applications are encouraged that will leverage TREAT's Minimal Activation Reusable Capsule Holder (MARCH) irradiation testing system and modern modeling and simulation tools to conduct novel separate effects tests of this type. Examples may include in-situ evaluation of physical properties of fissile material while under irradiation, thermal-mechanical response of fuel system components to nuclear heating, or short-term microstructural evolution of fissile materials under irradiation. Test samples can be supplied by the experimenter or allocated from the NSUF or DOE program's library of historic materials (fresh or pre-irradiated). Applicant should review the 2019 TREAT/NSUF awarded work to ensure new applications are unique and/or complementary to the ongoing work.

NOTE: Access to NSUF capabilities will require agreement and final signature to the User Agreement (copy provided in Appendix D and at https://atrnsuf.inl.gov/documents/ATRNSUFStandardNon-PropUserAgreement.pdf). **The terms and conditions of the User Agreement are non-negotiable and failure to accept the terms and conditions of the User Agreement will terminate processing and review of the FC-2.5, NSUF-1, or NSUF-2 applications.** In order to ensure compliance throughout the application review process, applicants must indicate during the pre-application and full application submission that the User Agreement has been read, understood, and the terms and conditions are accepted. Further, submission of a pre-application and a full application indicates the applicant will comply and agree to the terms and conditions of the User Agreement. Upon award of an NSUF supported project, the User Agreement must be signed before activities will begin on the project.

FC-3: MATERIALS PROTECTION, ACCOUNTING AND CONTROL TECHNOLOGY
(FEDERAL POC – MIKE REIM & TECHNICAL POC – MIKE BROWNE)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 2 YEARS AND $400,000)

The Materials Protection, Accounting and Control Technology program seeks to develop innovative technologies, analysis tools, and advanced integration methods to enable U.S. domestic nuclear materials control and accounting for advanced fuel cycles and reactors. This program also includes assessing vulnerabilities in current nuclear systems while minimizing proliferation and terrorism risks. Applications are requested to develop innovative materials control and accounting technologies and tools for molten salt related nuclear energy applications. Technologies and tools should be able to increase the accuracy, reliability, and efficiency of nuclear materials quantification and/or tracking capability.

FC-4: SPENT FUEL AND WASTE DISPOSITION

FC-4.1: SPENT FUEL AND WASTE DISPOSITION: DISPOSAL
(FEDERAL POC – JOHN ORCHARD & TECHNICAL POC – PETER SWIFT)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Assessments of nuclear waste disposal options start with waste package failure and waste form degradation and consequent mobilization of radionuclides, reactive transport through the near field environment (waste package and engineered barriers), and transport into and through the geosphere. Science, engineering, and technology improvements may advance our understanding of waste isolation in generic deep geologic environments and will facilitate the characterization of the natural system and the design of an effective engineered barrier system for a demonstrable safe total system performance of a disposal system. DOE is required to provide reasonable assurance that the disposal system isolates the waste over long timescales, such that engineered and natural systems work together to prevent or delay migration of waste components to the accessible environment.

Mined geologic repository projects and ongoing generic disposal system investigations generate business and R&D opportunities that focus on current technologies. DOE invites applications involving novel material development, testing methods, and modeling concept and capability enhancements that support the program efforts to design, develop, and characterize the barrier systems and performance (i.e., to assess the safety of a

PROGRAM SUPPORTING: FUEL CYCLE TECHNOLOGIES

nuclear waste repository). DOE will also consider applications addressing applications of state-of-the-art uncertainty quantification and sensitivity analysis approaches to coupled-process modeling and performance assessment which contribute to a better assurance of barrier system performance and the optimization of repository performance.

Research applications are sought to support the development of materials, modeling tools, and data relevant to permanent disposal of spent nuclear fuel and high-level radioactive waste for a variety of generic mined disposal concepts in clay/shale, salt, crystalline rock, and tuff. Key university research contributions for the disposal portion of this activity may include one or more of the following:

- Improved understanding of waste package failure modes and material degradation processes (i.e. corrosion) for heat generating waste containers/packages considering direct interactions with canister and buffer materials in a repository environment leading to the development of improved models (including uncertainties) to represent the waste container/package long term performance.

- New concepts or approaches for alleviating potential post-closure criticality concerns related to the disposal of high capacity waste packages. Development of models and experimental approaches for including burn-up credit in the assessment of the potential for criticality assessment for spent nuclear fuel permanently disposed in dual- purpose canisters that are designed and licensed for storage and transportation only.

- Development of pertinent data and relevant understanding of aqueous speciation, multiphase barrier interactions, and surface sorption at elevated temperatures and geochemical conditions (e.g., high ionic strength) relevant to deep geologic disposal environments.

- Identification and assessment of innovative and novel buffer materials, new methods and tools for multi-scale integration of relevant repository characterization data (including hydrological, thermal, transport, mechanical, and chemical properties), new approaches for imaging and characterization of low permeability materials, state-of-the-art tools and methods for passive and active characterization and monitoring of engineered/natural system component properties and failure modes and their capability to isolate and contain waste.

FC-4.2: SPENT FUEL AND WASTE DISPOSITION: STORAGE & TRANSPORTATION (FEDERAL POC – JOHN ORCHARD & TECHNICAL POC – PETER SWIFT) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

The possibility of stress corrosion cracking (SCC) in welded stainless steel dry storage canisters (DSC) for spent nuclear fuel (SNF) has been identified and studied as a potential safety concern. The welding procedure introduces high tensile residual stress and microstructure sensitization in the heat-affected zone (HAZ) of the fabrication welds in the DSC, which might promote the initiation of pitting and transition to SCC growth when exposed to an aggressive chemical environment. Further, if storing the canister in a marine environment, the atmospheric salts might deliquesce and generate an aqueous brine layer on the surface of the canisters at various locations, creating an aggressive chemical environment that could lead to pitting and subsequent SCC. Studies and research conducted so far indicate that the possibility of SCC in these canisters is low and that implementing technologies to mitigate SCC might further reduce the risks for long-term storage of these DSCs.

Research applications are sought to develop mitigation technologies for enhancing the reliability of long-term storage and maintenance of DSCs. Possible technologies include sprays, coatings, weld depositions, and other techniques where long-term performance can be demonstrated.

MISSION SUPPORTING: FUEL CYCLE TECHNOLOGIES

MS-FC-1: UNDERSTANDING, PREDICTING, AND OPTIMIZING THE PHYSICAL PROPERTIES, STRUCTURE, AND DYNAMICS OF MOLTEN SALT
(FEDERAL POC – STEPHEN KUNG & TECHNICAL POC – MARK WILLIAMSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 2 YEARS AND $400,000)

Molten salts find applications in advanced nuclear technologies as electrolytes for pyro-processing and fuel solvents and coolants for advanced reactors. Thermodynamic models are needed to predict critical salt characteristics such as melting points, heat capacity, free energies for potential corrosion reactions, and solubilities for fission and corrosion products as function of temperature and composition. The atomic composition and redox condition of the salt may change with of time as a result of fission product formation and irradiation effect. Applications are requested to better understand, predict, and optimize the physical properties and thermochemical behavior of molten salts. The goal is to develop and use first-principles molecular dynamics simulations and computational electronic structure method to extend the limited experimental data sets in covering a broader range of chemical evolution and environments. Innovative approaches to (1) apply molecular dynamics simulations to predict thermophysical and transport properties; (2) build multi-component models for prediction of phase diagrams; and (3) develop advanced models to guide the experimental efforts to manipulate the molten salt thermophysical properties are especially encouraged.

MS-FC-2: UNDERSTANDING THE STRUCTURE AND SPECIATION OF MOLTEN SALT AT THE ATOMIC AND MOLECULAR SCALE
(FEDERAL POC – STEPHEN KUNG & TECHNICAL POC – MARK WILLIAMSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $600,000)

To understand the effects of structure and dynamics of molten salts on their physical and chemical properties—such as viscosity, solubility, volatility, and thermal conductivity—it is necessary to determine the speciation of salt components as well as the local and intermediate structure at operationally relevant temperatures. Real-time spectroscopic and electrochemical methods can help monitoring key chemical species in solution. Applications are requested to take advantage of recent breakthroughs in advanced characterization tools and instrumentation methods to provide information at the atomic and molecular scale. The goals are to determine the local structure and bonding of chemical species in salt solution and to develop innovative real-time analytical methods for microscopic and macroscopic property measurements. Innovative approaches to: (1) determine salt molecular structure using scattering and spectroscopic methods; (2) develop novel electrochemistry and spectroscopy methods for in-situ monitoring and predictive modeling; and (3) develop molten salts optical basicity scale to determine corrosivity and solubility of actinides are especially encouraged.

PROGRAM SUPPORTING: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION (NEAMS)

NEAMS-1: DEVELOPMENT OF GENERALIZED MULTIGROUP CROSS SECTIONS FOR ARBITRARY REACTOR GEOMETRIES

(FEDERAL POC – DAVE HENDERSON & TECHNICAL POC – DAVID KROPACZEK)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $600,000)

The generation of multigroup cross sections for light water reactor (LWR) geometry is a fairly well understood problem. The solution generally relies on well-known geometry factors for circular fuel rods arranged in square lattices. However, many advanced reactor designs being proposed no longer use circular fuel rods in square lattices. New reactor designs include: TRISO double heterogeneous fuel, Light Bridge fuel with "clover" designs, TCR fuel with square fuel segments with round flow channels, and molten salt reactors with homogeneous fuel. In addition to the geometry issues, many advanced designs have energy spectrums in epi-thermal and fast ranges. The main difficulty in calculating accurate multigroup cross sections is calculating appropriate energy spectrums of resonances in the arbitrary geometry. The current approach of handling arbitrary geometry configurations and different energy spectrums is to use Monte Carlo (MC) methods with continuous energy cross sections. While this approach is general in nature, MC methods are not efficient for design work involving either large reactors and/or 1000's of different design calculations. The inefficiency of MC methods is amplified by multi-physics feedback, where the temperatures and material densities are additional parameters to solve for.

Applications are sought that investigate and develop efficient methods of generating multigroup cross sections for reactors with arbitrary geometries and energy spectrums. The primary focus should be the generation of cross sections in the resolved resonance ranges. The proposed methods must also be able to support multi-physics feedback. The methods developed should support calculation of transport corrections. The ability to calculate multigroup cross sections for arbitrary geometries and energies will greatly enhance the ability to perform efficient core design calculations. Applications are not sought that rely on simply generating a large set of MC snapshot cases.

The application should include the development of multiple benchmark problems covering both existing LWR geometries and proposed advanced reactor configurations. The final results should include side-by-side benchmark results, for a realistic test problem, run with MC methods, current methods (where applicable), and the new method(s). Results should focus on both accuracy and computer run-times

NEAMS-2: NEAR-WALL GAS-FLOW CORRELATIONS IN PEBBLE BED REACTORS

(FEDERAL POC – DAVE HENDERSON & TECHNICAL POC – RICHARD MARTINEAU)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $600,000)

The pebble bed reactor (PBR) is a type of gas-cooled reactor that combines a variety of desirable features such as inherent meltdown safety, small excess reactivity, and online refueling. Design and licensing of pebble bed reactors almost exclusively relies on the porous medium flow approximation. The accuracy of porous media calculations hinges on the accuracy of the correlations for pressure drop, effective conductivity of the pebble bed, and heat transfer coefficients from the pebbles to the coolant.

One of the phenomena of interest is flow near the wall of the pebble bed and its interaction with core bypass flow through gaps between reflector blocks. Currently existing correlations are insufficient for an accurate prediction of these flow conditions because measured data is extracted from integral pressure drop experiments, for isothermal flow conditions, and/or neglecting the effect of flow into/out of reflector gaps. Despite an "high importance" ranking in the phenomena identification and ranking tables, near-wall flow and its interaction with bypass flow remains poorly understood.

Improving the understanding the important effects for flow near the wall of a porous medium and its interaction with core bypass flow is of great importance for PBRs. The desired primary outcome from these investigations is

PROGRAM SUPPORTING: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION (NEAMS)

the generation of new and useful correlations for pressure drop and heat transfer coefficients between pebbles, wall, and fluid. Correlations must be useable in porous media codes such as Pronghorn.

We seek an experimental investigation of flow near the pebble wall interface based on high-resolution, spatio-temporal resolved measurements techniques such as time-resolved particle image velocimetry (TR-PIV), laser induced fluorescence (LIF), and matched refractive index (MRI). Experimental techniques should be paired with advanced data analysis techniques such as proper orthogonal decomposition, image recognition, or other suitable methods that allow extraction of pertinent information from the flow field. It is desired to provide for non-uniform pebble heating and adjustable core bypass flow in the experimental apparatus and test matrix. In support of the experimental work, high fidelity calculation with advanced LES and URANS CFD software such as Nek5000 is recommended for supporting conclusions, computing non-measurable quantities, and extrapolating the obtained data.

Experimenters must be able to reduce data into second-order or higher closure correlations. Applications must include efforts to obtain closure data for turbulent heat flux and viscous and form drag; must obtain data for non-isothermal helium temperature distribution with a maximum solid phase temperature of 1000C; must specify and use pebble and near-wall surrogates that are manufactured to match characteristics of graphite; and must include a large enough pebble field to account for radial variation in volume fraction (porosity).

NEAMS-3: MOLTEN SALT CHEMISTRY MODELING
(FEDERAL POC – DAVE HENDERSON & TECHNICAL POC – DAVID ANDERSSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $600,000)

Design and deployment of molten salt reactors require understanding of salt chemistry and corrosion of structural materials used in reactor components, where corrosion is interpreted broadly to include both loss of material from the structural component and deposition of chemical species in the salt. The salt chemistry combined with the choice of alloy for structural materials determines the corrosion potential, which, together with kinetic coefficients, governs the rate of material loss or gain. In addition to the chemistry of a freshly fueled pure salt, it is also critical to determine the impact of impurities, additives and fission products, since they often have an outsized influence on the corrosion potential and thus the real-life material performance. The chemical state of each species in the salt is also important to assess the consequences of a potential release of fuel or fission products in an accident scenario. Modeling these behaviors requires thermodynamic databases of fuel salts with dissolved impurities, additives and fission products as well as for the relevant structural alloys. The biggest capability gaps exist for the salt chemistry. Some of the information needed to expand the salt databases can be found in the literature and new data is being acquired or is planned to be acquired through experiments and atomic scale simulations based on either density functional theory or empirical potentials.

In order to enable predictions of molten salt chemistry and corrosion, work is solicited to synthesize new thermodynamic and corrosion data into high-quality validated databases that can be used for complex multi-component salts and that include uncertainty quantification. Support for filling identified data gaps and reducing uncertainties with targeted experiments and/or modeling in coordination with national laboratories and other researchers funded separately through existing DOE NE projects may also be considered. Work on interfacing the thermodynamic databases with corrosion models specifically incorporating the micro-structure of alloys used in structural components is also encouraged. Applications must clearly identify the specific salt to be used, neutron spectrum, facilities to be used, schedule and the portion of the above scope to be conducted.

Applications are not sought that only emphasize data generation by either experiments or modeling using, for example, ab initio molecular dynamics, empirical potential development or similar techniques.

MISSION SUPPORTING: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION

MS-NEAMS-1: SAM BASELINE DEVELOPMENT
(FEDERAL POC – DAVE HENDERSON & TECHNICAL POC – TANJU SOFU)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 2 YEARS AND $400,000)

The System Analysis Module (SAM) is a modern system analysis tool being developed under the support of the NEAMS program. It aims to provide fast-running, whole plant transient analyses capability with improved-fidelity for advanced non-LWR safety analysis. SAM utilizes an object-oriented application framework (MOOSE) and its underlying libraries to leverage the modern advanced software environments and numerical methods. Although significant capabilities have been developed and implemented in SAM, specialized expertise in universities are sought to address unresolved challenging issues in multi-scale thermal fluid simulations and to support the development of materials modeling capabilities for safety assessment and source term evaluation before fuel failure.

1. Multi-scale thermal fluid simulation

Multi-scale thermal fluid simulations are crucial for a wide range of transient simulations of nuclear systems. Although the proof-of-concept study on the coupling between SAM and Nek5000 codes at fluid-to-fluid interfaces was successful, further studies are needed for the verification and validation of the coupled code simulations. Also, the coupling of 2D solid structure and 3D fluid flow would enable wider range of coupled code simulations. New algorithm or schemes for coupling at 1D-3D fluid-to-fluid or 2D-3D structure-to-fluid interfaces are sought. New experimentation (in existing facilities) designed explicitly for validations of multi-scale thermal fluid simulation, analysis of existing benchmark datasets or development of new benchmark datasets, as well as performing direct comparison of datasets with NEAMS code simulations are also of interests.

2. Integrate the material transport model into SAM

Material performance under high temperature irradiative and corrosive environments remains a key challenge for advanced reactor applications. It is important to integrate computationally efficient yet accurate lumped parameter material models into system-level analysis code SAM for transient safety evaluations of advanced reactors such as liquid-metal- or salt-cooled reactors, as well as source term evaluation before fuel failure. A general species transport modeling capability is available in SAM. Developing advanced reduced-order material models (such as production, transport, the phase changes, source term, precipitation and corrosion) and integrating those into SAM are of interests.

PROGRAM SUPPORTING: NUCLEAR ENERGY

NE-1: NUCLEAR ENERGY-CYBER SECURITY RESEARCH TOPICS AND METRICS ANALYSES (FEDERAL POC – SUIBEL SCHUPPNER & TECHNICAL POC – STEVEN HARTENSTEIN) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Cost-effectively preventing, detecting, and mitigating cyber threats to nuclear energy systems is the subject of this research. Understanding the risks associated with each design decision is fundamental to cyber protection. With the increasing application of digital instrumentation, control, and communication systems and the constant evolution of cyber security threats and technologies, there is a need for comprehensive analytical capability to model and simulate control systems and their vulnerabilities. Applications are sought for modeling and simulation capabilities that can inform researchers, designers and operators when assessing cyber security risks. Research of most interest will addresses characteristics and behaviors of components within embedded instrumentation and control (I&C) systems that are used within the nuclear enterprise.

Another area of interest includes Integration of cyber research enabling platforms that would couple high fidelity nuclear plant simulators with emulation, hardware-in-the-loop, or human-in-the-loop instances of control and communication. Models shall capture the behavior of an I&C system to 1) simulate characteristics of an I&C system under cyber-attack; 2) study the cyber risk impacts of upgrades and maintenance on such systems; 3) enable future nuclear energy cyber security research, and 4) facilitate nuclear facility operation education and training.

NE-2: INTEGRATED ENERGY SYSTEMS DESIGN AND MODELING (FEDERAL POC – MELISSA BATES & TECHNICAL POC – SHANNON BRAGG-SITTON) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Advanced nuclear-renewable integrated energy systems (IES) are comprised of one or more nuclear and renewable energy sources, industrial energy users, and energy storage systems. Various IES configurations are being evaluated for their economic benefit and technical feasibility within various geographic regions; systems may be "tightly coupled" within a single "energy park" type of configuration, or may be loosely coupled within a grid balancing area.

Work scopes of interest for FY20 applications focus on the use of IES to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water. The Water Security Grand Challenge is of particular interest for application of IES (see https://www.energy.gov/eere/water-security-grand-challenge). The Water Security Grand Challenge is a White House initiated, U.S. Department of Energy led framework to advance transformational technology and innovation to meet the global need for safe, secure, and affordable water. Key goals within the challenge include the following:

- "Launch desalination technologies that deliver cost-competitive clean water,"
- "Transform the energy sector's produced water from a waste to a resource,"
- "Achieve near-zero water impact for new thermoelectric power plants, and significantly lower freshwater use intensity within the existing fleet," and
- "Develop small, modular energy-water systems for urban, rural, tribal, national security, and disaster response settings."

For example, the petroleum extraction produces a large volume of waste water. Processes for the purification of this waste water, and the coupling of such processes to nuclear thermal energy sources (current fleet, light-water

small modular reactors, or other advanced reactor designs) are of interest. Researchers should not propose a novel reactor design, but should instead focus on novel coupling technologies, system control, and optimized operational dispatch to support both water processing and electricity production demands. Likewise, proposed projects should only involve domestic reactor designs. Cyber-informed engineering should be considered in system design, dispatch optimization, and system control. Computational models should be capable of integrating with the Modelica and RAVEN-based ecosystem for modeling and analysis that is used by the lab team for IES. Systems of interest could be applicable to fixed installations or could be modular and transportable in their design to address the range of applications called out within the Water Security Challenge. Principle investigators are encouraged to investigate the potential markets and market competitiveness of proposed solutions within large-scale centralized grid or islanded microgrids that may be applicable to SMR or microreactor technologies.

NE-3: TRANSFORMATIONAL CHALLENGE REACTOR R&D
(FEDERAL POC – TANSEL SELEKLER & TECHNICAL POC – SHERRI BUCHANAN)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 2 YEARS AND $800,000)

The Transformational Challenge Reactor (TCR), a new initiative in FY 2019, provides a revolutionary platform to demonstrate the ability to reduce the deployment costs and timelines for nuclear energy systems. The TCR program enhances the development of breakthrough technologies that provide the ability to manufacture small/micro advanced reactor components using additive manufacturing techniques. A central goal of the TCR program is to demonstrate the ability to exploit advanced manufacturing techniques and digital predictive analysis capabilities to deliver a new approach to nuclear design and qualification for advanced reactor technologies. It will combine advanced manufacturing with materials and computational sciences to predict optimal performance of components to enable faster innovation and certification.

This work scope seeks applications to provide validation of the approaches taken by the TCR program on key areas, including application of quality assurance to artificial intelligence, automation of reactor control systems, and the expected performance of the novel reactor core design. Significant advancements are expected in these areas with the approaches taken including first-of-a-kind methodologies.

The digital platform will heavily rely on artificial intelligence. Artificial intelligence development and deployment are unlike traditional software development, and the approach to quality assurance must also be different. For example, quality assurance testing must occur during the software development phase when the software is being trained to make decisions, in addition to prior to putting the software into production. Testing must address completeness and complexity in the training model, not just data quality, and ensure that informational or human-induced bias has not inadvertently been introduced. To ensure a high-performing digital platform, independent review of the quality assurance process is important for successful deployment. Applications should outline a multi-stage review process to assess the quality assurance methodologies for the digital platform.

Advanced feedback controls and autonomous controls are observed in many engineering disciplines—from deep space missions, unmanned aerial vehicles to self-driving cars. Nuclear power generation is lagging other industries in adopting the advances that have emerged in the last two decades. As a step toward establishing the framework and functional architecture for autonomous operations in a nuclear power plant, the TCR program will develop information and processes to integrate sensors and control systems meeting nuclear standards and test them for operation within an automatic control system. Applications are sought to evaluate the functionality and safety of the TCR control system designs. Additional information on the TCR control system approach can be found at the following link. https://info.ornl.gov/sites/publications/Files/Pub126479.pdf

The design being developed under the TCR program is a helium-cooled gas reactor that exploits advanced manufacturing to enable design approaches not achievable with conventional manufacturing technologies. The TCR program is seeking university participation in application of advanced methods to develop optimized neutronic and thermal hydraulic core designs that are free of conventional manufacturing requirements. Applications in support of modeling complex flow geometries through the core and highlighting benefits of these

designs compared to conventional designs are encouraged.

MISSION SUPPORTING: NUCLEAR ENERGY

MS-NE-1: INTEGRAL BENCHMARK EVALUATIONS (FEDERAL POC – DAVE HENDERSON & TECHNICAL POC – JOHN BESS) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $400,000)

The International Reactor Physics Experiment Evaluation Project (IRPhEP) and International Criticality Safety Benchmark Evaluation Project (ICSBEP) are recognized world-class programs that have provided quality assured (peer-reviewed) integral benchmark specifications for thousands of experiments. The Project produces two annually updated Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) Handbooks that are among the most frequently quoted references in the nuclear industry. Applications are sought, within the scope of these two projects, to provide complete benchmark evaluations of existing experimental data that would be included in IRPhEP and ICSBEP handbooks, and would support current and future R&D activities.

The IRPhEP and ICSBEP Handbooks are the collaborative efforts of nearly 500 scientists from 24 countries to compile new and legacy experimental data generated worldwide. Without careful data evaluation, peer review, and formal documentation, legacy data are in jeopardy of being lost and reproducing those experiments would incur an enormous and unnecessary cost. The handbooks are used worldwide by specialists in reactor safety and design, criticality safety, nuclear data, and analytical methods development to perform necessary validations of computational models. Proposed benchmark evaluations should be of existing experimental data. Measurements of interest include critical, subcritical, buckling, spectral characteristics, reactivity effects, reactivity coefficients, kinetics, reaction-rate and power distributions, and other miscellaneous types of neutron and gamma transport measurements. A growing area of interest includes evaluation of transient and/or multiphysics benchmark experiment data for light water reactor systems, such as PWRs and BWRs.

All evaluations must be completed according to the requirements, including peer review, in the IRPhEP and the ICSBEP. DOE currently invests tens of millions of dollars each year to develop the next generation of nuclear engineering modeling & simulation tools. These tools need ad-hoc evaluated and quality-assured experimental data for validation purposes and, consequently, benchmark evaluations in support of DOE programs such as, but not limited to, TREAT, LWRS, FCT, ART, and NE's Advanced Modeling and Simulation Program (which combines application of computational capabilities from the NEAMS ToolKit and the VERA suite developed by the Energy Innovation Hub for Reactor M&S) are of particular interest to this call. Applications must clearly identify and demonstrate the importance of the proposed work to deployment or operation of a reactor (e.g. letter of support or impact from industry). Applications should demonstrate knowledge of existing benchmark handbook validation content similar to their proposed work and clearly identify gaps in existing data that the proposed work will address.

Note: Letters of Support for this workscope are not required until full application submission. Letters of Support should be uploaded with the Benefits of Collaboration document. A Letter of Support **will not** count against the 4-page limit for the Benefits of Collaboration document.

MS-NE-2: NUCLEAR DATA NEEDS FOR NUCLEAR ENERGY APPLICATIONS (FEDERAL POC – DAVE HENDERSON & TECHNICAL POC – BRAD REARDEN) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $400,000)

The Evaluated Nuclear Data File (ENDF) maintained by the National Nuclear Data Program (NNDC) at Brookhaven National Laboratory (BNL) provides the most reliable and commonly used nuclear data for nuclear energy applications. However, a close and critical examination of the existing nuclear data often finds that it is

inadequate for current and emerging applications.

Applications are sought that address nuclear data needs in NE mission areas, provided that these needs are clearly demonstrated to be a limiting factor in nuclear fuel and reactor design, analysis, safety, and licensing calculations. Use of sensitivity and uncertainty analysis methods in proposed efforts is encouraged to demonstrate these needs.

Many nuclear data needs for NE may be found in the NEA Nuclear Data High Priority Request List (HPRL) (https://www.oecd-nea.org/dbdata/hprl/, which includes a broad spectrum of needs encompassing light water reactors (LWRs) as well as sodium fast reactors. Other emerging needs not yet listed on the HPRL include continued investigations of thermal scattering data in high-temperature graphite, thermal scattering data for fluorine-based molten salt reactors, and chlorine reactions for fast spectrum molten salt reactors. Additional nuclear data needs that meet documented needs for industry and DOE-NE missions are also encouraged especially as aligned with the Gateway for Accelerated Innovation in Nuclear (GAIN), Nuclear Energy Advanced Modeling and Simulation (NEAMS), Consortium for Advanced Simulation of LWRs (CASL), Advanced Reactor Technologies (ART), Fuel Cycle Research and Development (FCR&D), Transient Test Reactor (TREAT), Light Water Reactor Sustainability (LWRS) and others.

Applications are sought that provide relevant improvements in nuclear data that address one or more stated needs by developing and demonstrating the enhancements through the entire nuclear data pipeline, from 1) new nuclear data measurements; 2) evaluation in the appropriate format (e.g. ENDF); 3) inclusion of nuclear data covariances; 4) processing into usable forms for application codes; 5) confirmation of improved predictions and uncertainties through application studies and validation; and 6) deployment through the National Nuclear Data Center at BNL for inclusion by external users in quality-assured design, analysis, safety, and licensing calculations. Application must clearly identify and demonstrate the importance of the proposed work to deployment or operation of a reactor (e.g. letter of support or impact from industry) and collaborations with industry are specifically encouraged for this reason.

Note: Letters of Support for this workscope are not required until full application submission. Letters of Support should be uploaded with the Benefits of Collaboration document. A Letter of Support **will not** count against the 4-page limit for the Benefits of Collaboration document.

MS-NE-3: MISSION SUPPORTING GRAND CHALLENGE
(FEDERAL POC – BRAD WILLIAMS & TECHNICAL POC – JON CARMACK)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $400,000)

The Office of Nuclear Energy mission supports enhancing the long-term viability of the presently operating light water reactors, stimulating the development and commercialization of advanced reactor concepts, and extending nuclear energy beyond conventional electrical generation applications. Many specific challenges have been identified elsewhere in this FOA, yet many challenges remain. Applications are sought that address other issues that hinder continued operation of the existing fleet, improve the deployment potential of advanced reactor concepts or expand nuclear energy's role in meeting the nation's energy, environmental, and national security needs. Applicants must clearly outline the challenge to be addressed, the proposed solution, and the methodology that will be used to achieve the solution, including specific resources (costs and schedules) and milestones associated with the application's activities, as well as estimates of longer-term resources (costs and schedules) and milestones associated with implementation of the proposed solution. Proposed solutions can be at the system or component level. High-risk, high-reward ideas are encouraged.

Appendix B: Work Scopes for U.S. University-, National Laboratory-, or Industry-led* Program Supporting R&D Projects

*Industry may only lead in NSUF work scopes

PROGRAM SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

NEET-1: ADVANCED METHODS FOR MANUFACTURING
(FEDERAL POC – TANSEL SELEKLER & TECHNICAL POC – TBD)
(ELIGIBLE TO LEAD: UNIVERSITY OR NATIONAL LABORATORY)
(UP TO 3 YEARS AND $1,000,000)

The Advanced Methods for Manufacturing program seeks applications for research and technology development to improve the methods by which nuclear equipment, components, and plants are manufactured, fabricated, and assembled. Applications should support the Department of Energy's (DOE) Office of Nuclear Energy's (NE) mission to advance U.S. nuclear power in order to meet the nation's energy needs by: 1) enhancing the long-term viability and competitiveness of the existing U.S. reactor fleet; 2) developing an advanced reactor pipeline, and, 3) implementing and maintaining the national strategic fuel cycle and supply chain infrastructure.

The goal of the program is to accelerate innovations that reduce the cost and schedule of constructing new nuclear plants and make fabrication of nuclear power plant components faster, cheaper, and more reliable. The program seeks to encourage innovation that supports the "factory fabrication" and expeditious deployment of reactor technologies. Potential areas for exploration include:

1.1 FACTORY AND FIELD FABRICATION TECHNIQUES

Applications are sought for innovative technologies specific to improvements in surface modification and cladding techniques, and advanced modular factory and field fabrication and installation techniques.

1.2 QUALITY CONTROL TECHNIQUES AND QUALIFICATION METHODOLOGIES

Applications are sought to develop quality control techniques and qualification methodologies for advanced manufacturing processes. This should include active engagement with consensus standard organizations with a pathway to code/regulatory acceptance.

The most up-to-date information on active AMM projects can be found in the 2019 NEET Advanced Methods for Manufacturing Awards Summaries on the NE website under NEET documents.

NEET-2: ADVANCED SENSORS AND INSTRUMENTATION

The Advanced Sensors and Instrumentation program seeks applications for innovative technology for controls, analytics, and instrumentation of advanced reactors systems. Technology should demonstrate greater accuracy, reliability, resilience, higher resolution, and ease of replacement/upgrade capability for applications in the nuclear environment, minimizes operations and maintenance costs, and address regulatory concerns.

The application should indicate whether and how the proposed technology is or may be applicable to multiple reactors or fuel cycle applications, i.e. crosscutting. Applications should support the Department of Energy's (DOE) Office of Nuclear Energy's (NE) mission to advance U.S. nuclear power in order to meet the nation's energy needs by (1) enhancing the long-term viability and competitiveness of the existing U.S. reactor fleet; (2) developing an advanced reactor pipeline, and, (3) implementing and maintaining the national strategic fuel cycle and supply chain infrastructure.

NEET-2.1: ADVANCED CONTROL SYSTEMS
(FEDERAL POC – SUIBEL SCHUPPNER & TECHNICAL POC – CRAIG PRIMER)
(ELIGIBLE TO LEAD: UNIVERSITY OR NATIONAL LABORATORY)
(UP TO 3 YEARS AND $1,000,000)

Applications are sought for research projects that will design, develop, and demonstrate advanced control for semi-autonomous and remote operation of advanced reactor designs. Outcomes should:

PROGRAM SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

- Streamline and simplify the advanced control system design process to automate and enhance plant operation. Design should result in reduced long term Operations and Maintenance costs and include a cost benefit analysis.
- Reduce I&C testing, validation and verification efforts associated with licensing requirements through developing verifiable architectures (hardware and software) using novel test methodologies that would enable use of smart digital devices in both safety related and non-safety related applications for nuclear power plants.

NEET-2.2: BIG DATA, MACHINE LEARNING, AND ARTIFICIAL INTELLIGENCE (FEDERAL POC – SUIBEL SCHUPPNER & TECHNICAL POC – CRAIG PRIMER) (ELIGIBLE TO LEAD: UNIVERSITY OR NATIONAL LABORATORY) (UP TO 3 YEARS AND $1,000,000)

Applications are sought to develop and demonstrate advanced analytics for nuclear plant operation and maintenance systems that support semi-autonomous and remote monitoring of advanced reactor designs. Cost-benefit analysis should be conducted as part of the project to demonstrate technology or product viability. Research should:

- Demonstrate an optimal balance between cost and plant performance to achieve reliability, availability, maintainability, and security.

Develop and demonstrate a transformational approach to monitor and analyze semi-autonomous operation of advanced reactors through real time integration of predictive analytics and risk informed condition monitoring.

NEET-2.3: ADVANCED SENSORS AND COMMUNICATION (FEDERAL POC – SUIBEL SCHUPPNER & TECHNICAL POC – CRAIG PRIMER) (ELIGIBLE TO LEAD: UNIVERSITY OR NATIONAL LABORATORY) (UP TO 3 YEARS AND $1,000,000)

Applications are sought to enable deployment of sensors, instrumentation, and supporting electronics for semi-autonomous and remote operation of advanced reactor concepts. Applicants should:

- Develop radiation hardened electronic systems to support wired and wireless communication of data from sensors and instrumentation located in-vessel and near-vessel in high temperature and high radiation environments found in advanced reactors.
- Develop sensor performance models for the initial calibration, routine operation, radiation degradation, in-situ re-calibration, and predictive failure mechanisms to understand sensor performance for the lifetime of operation in advanced reactors.

PROGRAM SUPPORTING: NUCLEAR SCIENCE USER FACILITIES (NSUF-1)

NSUF-1: NUCLEAR ENERGY-RELATED R&D SUPPORTED BY NUCLEAR SCIENCE USER FACILITIES CAPABILITIES

NOTE: FC-2.5 require NSUF access but can only be led by universities. Those work scopes can be found in Appendix A under the "Fuel Cycle" header.

This work scope solicits applications for nuclear energy-related research projects focused on the topical areas described below. It is intended that these focused topical areas will change with each future CINR FOA. The focused topical areas are selected by NE's R&D programs (e.g. Nuclear Reactor Technologies, Fuel Cycle Technologies, and Nuclear Energy Enabling Technologies) with the explicit purpose to leverage the limited R&D funding available with access to NSUF capabilities. All applications submitted under this work scope will be projects coupling R&D funding with NSUF access. Projects requiring "NSUF access only" (see NSUF-2 below) or "R&D funding only" must be submitted under other appropriate work scopes. Applications submitted under this work scope must support the Department of Energy Office of Nuclear Energy mission. Capabilities available through the NSUF can be found on the website at nsuf.inl.gov.

The Office of Nuclear Energy (NE) supports the Department of Energy's HPC4 Materials (High Performance Computing for Materials) initiative to accelerate "…industry discovery, design, and development of materials for severe environments by enabling access to computational capabilities and expertise in the DOE laboratories." NE's high-performance computing capabilities include Falcon at the Idaho National Laboratory. More information on computational resources can be found at NSUF.inl.gov. NE is seeking applications for the development of innovative materials or material concepts for the extreme operating and accident environments expected in advanced reactor and fuel cycle technologies using the high-performance computing capabilities at the INL.

NSUF-1.1: TESTING OF ADVANCED MATERIALS FOR SENSORS AND ADVANCED SENSORS FOR NUCLEAR APPLICATIONS
(FEDERAL POC – SUIBEL SCHUPPNER & TECHNICAL POC – BRENDEN HEIDRICH)
(ELIGIBLE TO LEAD: UNIVERSITY, NATIONAL LABORATORY, OR INDUSTRY)
(REFER TO NSUF WORK SCOPE TIME PERIODS (PART II, SECTION E.2.1), UP TO $500,000)

Applications are sought for irradiation testing and post-irradiation examinations that support the development of advanced materials for sensors, and development of advanced sensors themselves to support NE's mission to enhance the long term viability and competitiveness of the existing fleet, to develop an advanced reactor pipeline, and to implement and maintain national strategic fuel cycle and supply chain infrastructure. **This funding does not support research and development activities to develop materials or sensors, but rather the irradiation of sensors and materials as described below.**

1) Advanced Materials for Sensors: Successful irradiation testing and post irradiation examination of candidate materials proposed for advanced sensors applications will include: a description of the materials; irradiation and post irradiation examination needs; the role of the materials in new sensors, controls, communications or associated applications.

2) Advanced Sensors: Successful irradiation and post irradiation examination of sensors and associated instrumentation will include: a description of the sensor and associated instrumentation and materials requiring irradiation and post irradiation examination; irradiation and post irradiation examination needs; and the purpose and application of the developed sensor in nuclear energy systems.

PROGRAM SUPPORTING: NUCLEAR SCIENCE USER FACILITIES (NSUF-1)

NSUF-1.2: IRRADIATION TESTING OF MATERIALS PRODUCED BY INNOVATIVE MANUFACTURING TECHNIQUES
(FEDERAL POC – TANSEL SELEKLER & TECHNICAL POC – TBD)
(ELIGIBLE TO LEAD: UNIVERSITY, NATIONAL LABORATORY, OR INDUSTRY)
(REFER TO NSUF WORK SCOPE TIME PERIODS (PART II, SECTION E.2.1), UP TO $500,000)

Products from advanced and innovative manufacturing, welding / joining, and surface modification and cladding techniques can be proposed for evaluation of irradiation effects on material performance in support of NE's mission to enhance the long term viability and competitiveness of the existing fleet, to develop an advanced reactor pipeline, and to implement and maintain national strategic fuel cycle and supply chain infrastructure.

This funding does not support research and development activities to develop manufacturing and construction techniques, but rather evaluate the irradiation effects on material performance.

NSUF-1.3: NUCLEAR MATERIALS DISCOVERY AND QUALIFICATION INITIATIVE
(FEDERAL POC – TANSEL SELEKLER & TECHNICAL POC – RORY KENNEDY)
(ELIGIBLE TO LEAD: UNIVERSITY, NATIONAL LABORATORY, OR INDUSTRY)
(REFER TO NSUF WORK SCOPE TIME PERIODS (PART II, SECTION E.2.1), UP TO $500,000)

The NSUF has been tasked to lead the Nuclear Materials Discovery and Qualification Initiative (NMDQi) whose goal is to accelerate both the discovery of new materials that can be applied to the needs of the nuclear industry and the ultimate qualification of those materials. In order to facilitate this acceleration, the NSUF intends to follow the materials design concept and apply the combinatorial and high-throughput methodology (CHT) to the unique challenges of the nuclear materials field. The CHT methodology integrates combinatorial materials fabrication methods, high-throughput characterization techniques, material modeling, and data analytics with the potential of incorporating machine learning and artificial intelligence schemes. As a reference, potential proposers are directed to the Materials Genome Initiative and its successful use of the CHT methodology to introduce new materials into the market faster and at lower cost. Applications are sought in any of the areas of the CHT methodology as applied to nuclear materials from fabrication to irradiation and PIE. In addition, Applications focused on the development of techniques for CHT, particularly in the area of high-throughput mechanical property testing and the high-throughput testing of radioactive materials will also be accepted. To this, CHT fabrication and testing techniques for bulk material properties as well as studies to correlate bulk properties to those obtained from CHT techniques on micro- or nano-scale samples are encouraged. Areas of interest include materials for core, cladding, and structural applications, metallic and ceramic advanced fuels, sensor materials, multi-layer structures (e.g. coatings), interface interactions (fcci, fcmi), and corrosion. All applications must be directly associated with one or more of the CHT methodology components (combinatorial materials fabrication methods, high-throughput characterization techniques, material modeling, and data analytics).
In addition to the access to NSUF capabilities (including high performance computing), the NSUF will support the R&D activities of awardees for this work scope only.

NUCLEAR SCIENCE USER FACILITIES (NSUF-2)

NSUF-2: NUCLEAR SCIENCE USER FACILITIES ACCESS ONLY (FEDERAL POC – TANSEL SELEKLER & TECHNICAL POC – RORY KENNEDY) (ELIGIBLE TO LEAD: UNIVERSITY, NATIONAL LABORATORY, AND INDUSTRY) (REFER TO NSUF WORK SCOPE TIME PERIODS (PART II, SECTION E.2.1))

Applicants interested in utilizing Nuclear Science User Facilities (NSUF) capabilities only should submit "access only" applications under this work scope. Applications must support the Department of Energy Office of Nuclear Energy's mission. Capabilities available through the NSUF can be found on the website at nsuf.inl.gov.

The Office of Nuclear Energy (NE) supports the Department of Energy's HPC4 Materials (High Performance Computing for Materials) initiative to accelerate "…industry discovery, design, and development of materials for severe environments by enabling access to computational capabilities and expertise in the DOE laboratories." NE's high-performance computing capabilities include Falcon and Lemhi at Idaho National Laboratory. More information on computational resources available through NSUF can be found at https://nsuf.inl.gov/. NE is seeking applications for the development of innovative materials or material concepts for the extreme operating environments expected in advanced reactor and fuel cycle technologies using the high-performance computing capabilities at the INL.

Experiments with synchrotron radiation may be proposed in applicable work scopes below. NSUF has access to the 6% of the available beam time at the X-ray Powder Diffraction beamline at NSLS-II.

NSUF-2.1: CORE AND STRUCTURAL MATERIALS

This element is primarily focused on fundamental understanding of irradiation effects in core and structural materials such as material aging and degradation mechanisms (e.g. fatigue, embrittlement, void swelling, fracture toughness, IASCC processes and mitigation), as well as developing alternate and/or radiation resistant materials for application in current and future fission reactors, and materials from alternate or advanced manufacturing techniques (including welding and joining). Proposed projects may involve R&D in the areas of material irradiation performance and combined effects of irradiation and environment on materials. Projects whose relevancy is based solely or primarily on fusion energy needs will not be considered. Applications coupling experimental methods with modeling and simulation are highly encouraged.

NSUF-2.2: NUCLEAR FUEL BEHAVIOR AND ADVANCED NUCLEAR FUEL DEVELOPMENT

This program element is primarily focused on increasing our fundamental understanding of the behavior of nuclear fuels (including cladding) in reactor and research and development activities for advanced nuclear fuels and improving the performance of current fuels. Areas of interest include physics and chemistry of nuclear fuels, irradiation and thermal effects on microstructure development and the effects on, for example, thermophysical and thermomechanical properties as well as chemical interactions. Advanced fuels applicability extends to fast spectrum transmutation systems, coated particle fuels for high-temperature reactor systems, and robust fuels for light water reactors including accident tolerant fuels. Activities should be aimed at irradiation experiments and post irradiation examination that investigate fundamental aspects of fuel performance such as radiation damage, amorphization, fuel restructuring, species diffusion and migration, and fission product behavior. Separate effects testing focused on specific V&V issues are encouraged. Applications coupling experimental methods with modeling and simulation are highly encouraged.

NSUF-2.3: ADVANCED IN-REACTOR INSTRUMENTATION

This program element includes irradiation to support qualification of advanced in-reactor instrumentation for characterization of materials under irradiation in test reactors and for on-line core monitoring in power

reactors. Applications should address the deployment and qualification strategy of radiation resistant sensors.

Development of techniques that are non-intrusive with respect to irradiation specimens, and nontraditional methods such as optical fibers and ultrasonic techniques as well as other incorporated wireless transmission techniques are encouraged. Applications that also support the GAIN initiative, such as those involving development of advanced instrumentation, sensors, and measurement techniques for use in advanced reactors including molten salt reactors, sodium cooled fast reactors, lead cooled fast reactors, or high temperature gas reactors are encouraged. For MSR with dissolved fuel, an important and challenging problem is the ability to measure local chemical composition in real time at critical locations.

NSUF-2.4: HIGH PERFORMANCE COMPUTING AT IDAHO NATIONAL LABORATORY (LIMITED TO 3 YEARS)

Nuclear Science User Facility (NSUF) High-Performance Computing (HPC) resources offered through **Idaho National Laboratory** provide scientific computing capabilities to support efforts in advanced modeling and simulation. Applications in this area may address a wide range of research activities, including performance of materials in harsh environments (including the effects of irradiation and high temperatures), performance of existing light water and advanced nuclear reactors, and multiscale multiphysics analysis of nuclear fuel performance.

Current HPC resources include:

- Falcon: a SGI ICE-X distributed memory system with 34,992 cores, 121 TB of memory and a LINPACK rating of 1 Petaflop/s. Falcon's network is a seven-dimensional enhanced hypercube utilizing FDR InfiniBand. Individual compute nodes contain dual Xeon E5-2695 v4 processors with 18 cores each and 128GB of memory. Falcon came online in Fall 2014 and ranked #97 on the November 2014 TOP500 list.
- Lehmi: a Dell 6420-based system with 20,160 cores, 94 TB of memory and a LINPACK rating of 1 Petaflop/s. Lemhi's network is an omnipath fat tree. Individual compute nodes contain dual Xeon Gold 6148 processors with 20 cores each and 192GB of memory. Lemhi came online in Fall 2018 and ranked #427 on the November 2018 TOP500 list.

HPC support includes: access to INL HPC systems, assistance with system login and running code, basic HPC training, and software support and expertise as requested. Software includes an assortment of tools in the areas of: Compter Aided Engineering, Chemistry, Code Development, Data Manipulation, Math, MOOSE, MPI, Neutronics and Transport, Numerical Libraries, Programming, and Visualization. Access to HPC resources through this FOA does not provide licenses to software. Use of DOE-developed software from the NEAMS and CASL programs is encouraged.

NOTE: Access to NSUF capabilities will require agreement and final signature to the User Agreement (copy provided in Appendix D. The terms and conditions of the User Agreement are non-negotiable and failure to accept the terms and conditions of the User Agreement will terminate processing and review of the FC-2.5, NSUF-1, or NSUF-2 applications. In order to ensure compliance throughout the application review process, applicants must indicate during the pre-application and full application submission that the User Agreement has been read, understood, and the terms and conditions are accepted. Further, submission of an pre-application and a full application indicates the applicant will comply and agree to the terms and conditions of the User Agreement. Upon award of an NSUF supported project, the User Agreement must be signed before activities will begin on the project.

Appendix C: Work Scopes for U.S. University-led Integrated Research Project (IRP) R&D

PROGRAM DIRECTED: REACTOR CONCEPTS

IRP-RC-1: INFRASTRUCTURE TO SUPPORT MSR RESEARCH AND DEVELOPMENT (FEDERAL POC – BRIAN ROBINSON & TECHNICAL POC – LOU QUALLS) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $5,000,000)

The Department of Energy is interested in working with universities to increase the amount of domestic research infrastructure available for the study of Molten Salt Reactors (MSR). Specifically, the objective is to develop and enhance domestic university capabilities to generate high-quality data, in coordination with the DOE MSR Campaign and MSR developers, which could be useful in the development and licensing of MSRs.

MSRs differ from current commercial plants in their fundamental design features, which leads to new technological challenges but also allows designers to take advantage of additional passive safety features and inherent protections. MSR component development and analysis as well as innovative engineering techniques for operations and reliability are sought to increase levels of safety and robustness, present new functionalities, and improve system performance.

Teams of universities, industry, and national laboratories are expected to provide a broad range of expertise and experience to the application. However, the emphasis on proposed efforts should include the establishment of new or enhanced research infrastructure at universities to broaden the base capability, to provide high-quality data for model validation or material property performance and prepare students to enter the emerging advanced reactor technical field. The development and/or expansion of university, industry and national laboratories irradiation facilities is strongly encouraged. Infrastructure support could include but are not limited to salt production, characterization and property measurement, and isotope production and isolation.

To ensure proposed infrastructure efforts complement existing research, specific examples are provided below. In addition to these examples, other applications enhancing the domestic MSR research infrastructure are welcome.

EXPERIMENTAL VALIDATION OF THERMAL HYDRAULIC SIMULATIONS

Experimental Validation of Molten Salt Reactor Simulations should be focused on providing high quality data for the validation of system and computational fluid dynamics models of MSR (liquid fueled or pebble bed) phenomena. Multiple phenomena have been identified as relevant to core safety and performance but for which insufficient data exist for validating models and codes. Applications should include: core heat transfer, plenum-to-plenum heat transfer by natural circulation, heated two-component stratified flow in the outlet plenum, bypass flow between fuel or reflector blocks, and performance of reactor cavity cooling systems in cooling the reactor guard vessel (ex-vessel heat transfer).

Validation of codes that capture these phenomena requires the coordinated completion of a number of fundamental, separate effects tests (SET), mixed effects tests (MET), such as combined mass flow and heat transfer, and integral tests, all properly scaled to reproduce the thermal fluid conditions bounding MSRs under nominal and accident scenarios.

Applications are sought that will fill the gaps in the data needed MSR code validation with appropriately scaled fundamental, SET, or MET experiments that complement those that have been, or can be, conducted at suitable, existing integral facilities. Investigators who wish to propose new experiments using one or more of DOE's existing facilities are strongly urged to coordinate with the Principal Investigators at those facilities before submitting the final application to obtain guidance on costs, schedule, and quality assurance.

ADVANCED HEAT EXCHANGERS

Molten salt reactor systems may benefit from advanced heat exchangers for improved cost and efficiency. Molten

PROGRAM DIRECTED: REACTOR CONCEPTS

Salt Reactors (MSRs), which have a reactor output temperature (≈700°C) are good candidates for inclusion of advanced heat exchanger technology. Secondary heat exchangers would require accommodating the large differences in pressure between the low-pressure secondary salt coolant and the high-pressure working fluid in the power conversion system.

High efficiency heat exchangers have complex passageways that are a complicating factor for performing the rigorous stress analysis required to assess elevated temperature cyclic life under combined pressure and thermal gradient induced stresses. Other complicating factors are the number of structural features to be represented and stress concentrations at the corners of the flow channels. Because of this complexity, it is difficult to apply the normal stress classification process of the ASME Code. However, there are recently developed methodologies based on analysis approaches using an elastic-perfectly plastic (EPP) model to limit various stress measures and strain accumulation.

EXPERIMENTAL DATA FOR FISSION PRODUCT RETENTION, DIFFUSION AND TRANSPORT PROPERTIES

The objective is to study the release and transport behavior of radionuclides (gaseous, mists, foams) in liquid-fueled molten salt reactors under representative irradiation conditions. Separate effects testing on transport mechanisms, thermomechanical or thermophysical property influence, and primary structural system interaction that are related or coupled to modeling efforts are encouraged. However, the emphasis of this effort should be to develop data necessary to model radionuclide release from fuel salt surfaces and subsequent transport during both normal and accident conditions, including the effects of direct fission in the salt. Applications are sought to provide separate effects fission product data for temperature and temporal dependent performance modelling. The use of university reactors to execute irradiations is strongly encouraged.

TARGETED IRRADIATIONS OF CORE INTERNAL AND BOUNDARY MATERIALS

The objective is to understand radiation damage effects (swelling, embrittlement, segregation, etc.) on advanced structural materials for representative molten salt reactors and also for candidate non-metal reactor core structural material, such as graphite or silicon carbide. Applications are sought for irradiation and post-irradiation examination of MSR candidate core boundary and internal materials to provide data for validation data for structural performance, fabricability, and/or surface degradation. The use of university reactors to execute irradiations is strongly encouraged.

PROGRAM DIRECTED: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION

IRP-NEAMS-1: NEAMS THERMAL HYDRAULICS AND FUELS (FEDERAL POC – DAVE HENDERSON & TECHNICAL POC – CHRIS STANEK)

Given the urgency to accelerate development and deployment of DOE-NE mod-sim capabilities to meet industry and NRC needs, a specific goal of this particular call is to recruit a team of university researchers to participate within the program, working closely with national laboratory colleagues in support the overall programmatic effort. The applied R&D performed by the program requires highly specialized expertise that is resident within universities and when combined with existing national laboratory efforts can importantly increase momentum of the development of DOE-NE modeling and simulation tools, which are those to be exclusively developed and utilized. In addition to technical contributions, it is further expected that university partners will assist with the definition of programmatic priorities and deliverables as well as potentially serving in program leadership positions. When appropriate, university partners are also expected to serve as representatives of the program representatives, much like their national laboratory counterparts, presenting technical progress at meetings, conferences, etc. Applications should identify a university team, preferably a consortium of two or more universities, to maximize areas and depth of expertise, as well as mechanisms to solicit input from, prioritize research in concert with, and share results with the nuclear industry and the NEAMS program.

The above IRP description pertains to applications sought in two topical areas: (1) university component of the existing Center of Excellence for Thermal-Fluids Applications in Nuclear Energy, and (2) university component in the NEAMS Fuel Performance Area.

IRP-NEAMS-1.1: THERMAL-FLUIDS APPLICATIONS IN NUCLEAR ENERGY (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $3,000,000)

In 2018, the Nuclear Energy Advanced Modeling and Simulation program initiated a Center of Excellence for Thermal-Fluids Applications in Nuclear Energy (https://neams.inl.gov/centerofexcellence). A primary goal of the Center of Excellence concept was to create a clear "front-door" to stakeholders (primarily industry and NRC) for access to DOE-NE thermal hydraulics capabilities and in particular modeling and simulation in order to perform research on novel solution strategies for historically challenging flow issues that still plague the current fleet of deployed Light Water Reactor (LWR) nuclear reactors as well as predicting various fluid flow and fluid related issues with advanced reactor technologies.

The Center of Excellence strives to advance a thermal-fluids research and development approach that synergistically combines three natural, though overlapping, length and time scales in a hierarchal multi-scale approach to avoid the temptation and pitfalls of attempting to develop a single "solve all" algorithm for physical fluid flow problems that will span 9 orders of magnitude in spatial and temporal scales. Key components of the early stage of the Center of Excellence included (1) improving the coherence of the hierarchal multi-scale thermal hydraulics modeling and simulation approach, and (2) communicating modeling and simulation capabilities through workshops and establishing pathways to collaboration with stakeholders. Now, given the early success of the Center of Excellence for Thermal-Fluids Applications in Nuclear Energy we are interested in expanding upon it by supporting university R&D.

We seek applications to establish a university complement to the lab-led Center of Excellence that will leverage recent advancements to develop a CFD framework for the simulation of single-phase flow with the primary goal of facilitating the design and assessment of advanced reactors. It must be coupled with the fuel performance code BISON to deliver coupled CFD-fuel performance simulations, which are likely to play an increasingly larger role for future advanced fuel forms. Finally, the applications must identify plans to integrate the results obtained with these advanced models in the overall multiscale approach of the center of excellence, supporting the creation of reduced order models or novel closures for use in systems codes (e.g., SAM, RELAP-7).

PROGRAM DIRECTED: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION

IRP-NEAMS-1.2: MULTISCALE NUCLEAR FUEL PERFORMANCE (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $3,000,000)

Given the importance of nuclear fuel performance in many of the non-LWR designs, we seek applications for a university consortium that contributes to the advancement of the BISON nuclear fuel performance code for non-LWR advanced reactors. In particular, in order to accelerate the development of BISON for the simulation of particle fuel, applications are sought that focus on the thermomechanical behavior of particle fuel under anticipated Operational Occurrences (AOOs) and accident scenarios, including development of materials and behavioral models (including UCO and UC fuel kernels), tracking fission gas and other radioisotopes, and where appropriate coupling to thermal hydraulics and neutronics. Applications should account for research already under way, such as that under existing CINR/NEUP awards as well as the Scientific Discovery through Advanced Computation – SciDAC (https://collab.cels.anl.gov/display/FissionGasSciDAC2). The university team work will work with the NEAMS program, in concert with national laboratory researchers to establish priorities and perform technical research, as well as to engage the NRC and vendors to ensure NEAMS work is relevant to fuel qualification efforts and complementary to previous experiments.

Additional information on the NEAMS Fuel Performance activities can be found at the following website: https://neams.inl.gov/SitePages/Fuels%20Product%20Line.aspx

Appendix D: Accessing Nuclear Science User Facilities

As previously described in this document, the NSUF provides access, at no cost to the user, to DOE, University, and Industry facilities. Access to these facilities includes the support of the technical staff at each facility to ensure that the applicant is able to successfully complete their research. Requesting NSUF access funding is more complex than requesting R&D funding through this FOA. Figure D-1 depicts the process for requesting NSUF access. Note that NSUF rapid turn-around experiments (RTEs) are not part of this FOA, for information on RTEs see NSUF.inl.gov. A list of NSUF work scopes can be found on the work scope index on Table 1.

Unlike the other work scopes in this FOA, the applicant will not be able to provide cost information without the involvement of the NSUF facilities and staff. The effort to develop a firm cost estimate requires effort on the applicant's part, as well as the NSUF facilities and staff and must be started at the earliest possible date in order to have the information available for inclusion in the full application. In order to get this process started, the applicant may need to contact the NSUF Program Office to identify the NSUF technical lead(s), (points of contact for NSUF partner institutions are the Technical Leads listed on NSUF.inl.gov. INL Technical Leads are assigned by the NSUF Program Office). The applicant is required to submit a NSUF Letter of Intent and pre-application to apply for the FOA. The applicant will work with the NSUF Technical Lead(s) to prepare the LOI and pre-application. If invited to submit a full application, the applicant and NSUF Technical Lead(s) will work together to develop the application and define the scope of the application and estimate the cost.

For all applications, the NSUF Technical Lead(s) will work with the applicant to define the scope in the form of a Statement of Work (SOW). A Preliminary SOW will be submitted as a "post submission document" in the pre-application. If invited to submit a full application, a Final SOW will be submitted prior to the full application and must also be submitted as a "post submission document" in the pre-application.. At a minimum, the SOW will include the following (as applicable):

- Facilities and equipment required to conduct the experiment;
- Specific requirements for specimen acquisition (e.g., material location, material condition, and fabrication or preparation requirements);
- Specific requirements for irradiation or beam-time (e.g., neutron or beam energy spectrum, target temperature, flux and fluence [or burn-up/dpa] for each specimen, in-pile instrumentation, etc.) including a detailed test matrix; and,
- Specific requirements for post-irradiation examination (PIE) of each specimen (e.g., visual examination, dimensional examinations, tensile testing, radiography, microscopy, etc.) including a detailed test matrix.

The Preliminary and Final SOW will be utilized by the NSUF facility technical staff to develop an execution plan and cost estimate for the SOW (Statement of Work Template). The execution plan will typically address the following elements (as applicable):

- Concept for the irradiation device including fabrication and assembly plans;
- Irradiation position and duration;
- Experiment shipping;

- Disassembling and cataloging the experiment;
- Specimen preparation and shipping;
- Specimen examination details;
- Waste disposal; and,
- Resource loaded schedule.

After award announcement, several steps will be required prior to initiation of work. The successful applicant's institution will be required to sign a Non-Proprietary User Agreement with Battelle Energy Alliance. Appendix E contains the standard User Agreement. **The User Agreement is not negotiable.** The SOW will be an appendix in the User Agreement in order to bind the PI to the SOW and to define the NSUF policies applicable to the scope of work. A subcontract(s) or work authorization(s), with a total value equal to the previously developed cost estimate, will be placed with NSUF institutions performing the work defined in the SOW and experiment execution plan.

NSUF Quality Assurance Requirements

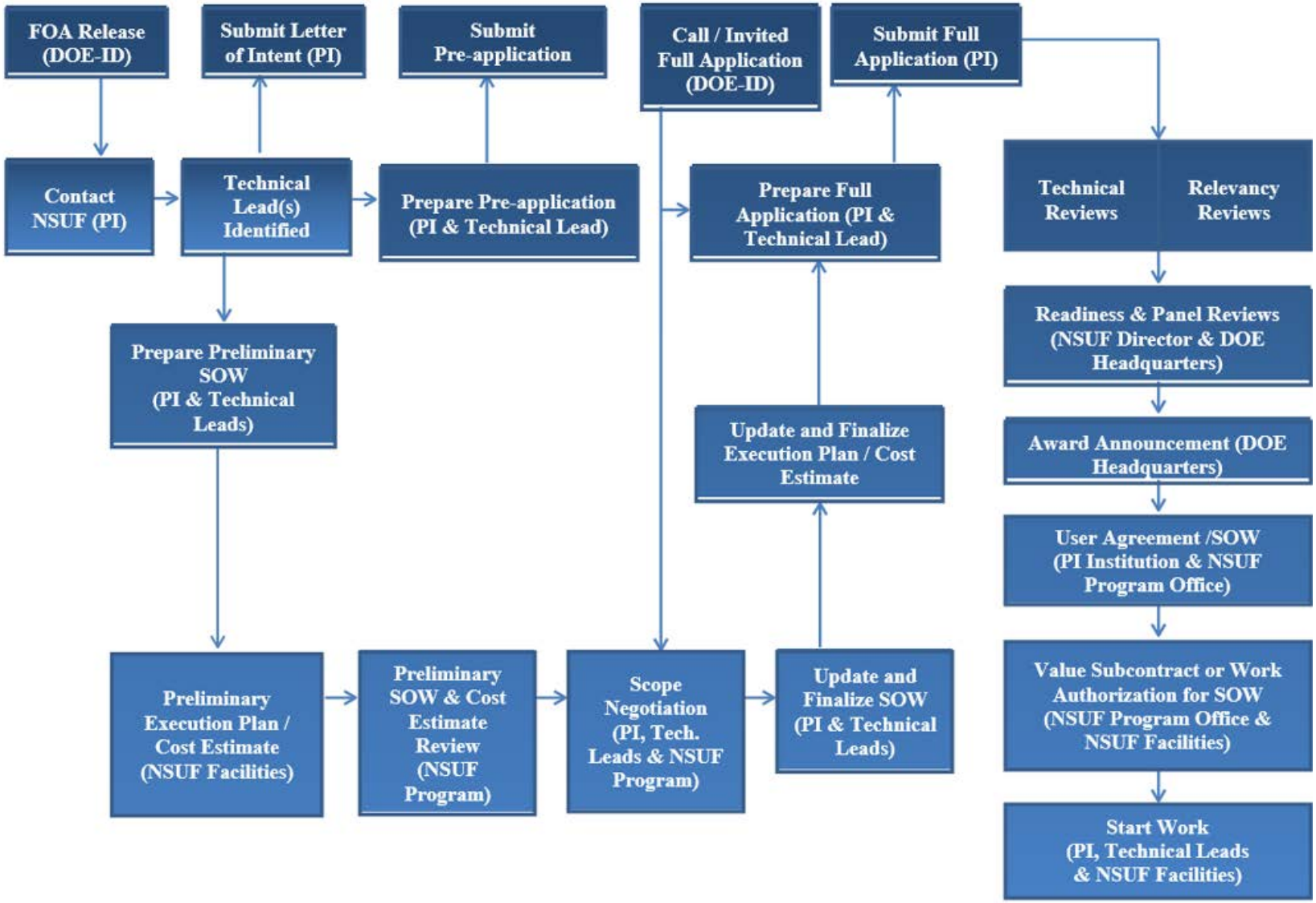
Irradiation of materials in test reactors requires additional rigor and quality assurance requirements beyond those described in other sections of this FOA. Specific requirements will depend on the reactor license, the irradiation vehicle design, and specimen constituents. NSUF Technical leads will assist the PI in understanding the specific requirements early in the process.

Budget Development for NSUF Applications

Applicants need to ensure that the following cost elements are covered within the R&D budget for NSUF-1 and FC-2.5 work scopes in this FOA or via another fund source for NSUF-2 work scopes:

- Travel costs to NSUF facilities for facility access training, technical meetings, examinations, experiment loading, etc.;
- Applicant salary support;
- Graduate student support;
- Post-doctoral or other researcher support; and,
- Materials and supplies support at the PI's work location.

Figure D-1. Process for NSUF applications.



Appendix E: Draft Nuclear Science User Facilities User Agreement

NOTE: Access to NSUF capabilities will require agreement and final signature to the User Agreement (copy provided in Part IX, Appendix D).**The terms and conditions of the User Agreement are non-negotiable, and failure to accept the terms and conditions of the User Agreement will terminate processing and review of the NSUF-1, NSUF-2, and FC-2.5 applications.** In order to ensure compliance throughout the application review process, applicants must indicate in the LOI and full application submission that the User Agreement has been read, understood, and the terms and conditions are accepted. Further, submission of a pre-application and a full application indicates the applicant will comply with and agree to the terms and conditions of the User Agreement. Upon award of an NSUF supported project, the User Agreement must be signed before activities will begin on the project.

NOTE: For Public Institutions residing in the State of Colorado, a version of the User Agreement, compliant with Colorado statute, is available. Contact the NSUF program office for more information.

Non-Proprietary User Agreement

User Facility Agreement No. xxxxx BETWEEN

BATTELLE ENERGY ALLIANCE, LLC

(" CONTRACTOR")
Operator of The Idaho National Laboratory (hereinafter "Laboratory") under U.S. Department of Energy (DOE) Contract No. DE-AC07-05ID14517

AND

XXXXXXXXXXXXXXXXXX

("USER")

(Collectively, "the Parties")

The obligations of the above-identified DOE Contractor may be transferred to and shall apply to any successor in interest to said Contractor continuing the operation of the DOE Non-Proprietary User Facility involved in this User Agreement.

ARTICLE I. <u>FACILITIES AND SCOPE OF WORK</u>

Subject to the terms and conditions of this Agreement, CONTRACTOR will make available to employees, consultants and representatives of USER (hereinafter called "Participants") certain Laboratory Non-Proprietary User facilities, which may include equipment, services, information and other material, with or without Laboratory scientist collaboration, for purposes as described in the attached Scope of Work and in accordance with the attached Funding Statement, both of which are incorporated by this reference and are made a part of this Agreement. Amendments to the attached Scope of Work and Funding Statement may be submitted by USER for identifying facilities and purposes during the term of this Agreement (see Article II). Such amendments will be considered to be part of this Agreement upon written acceptance by

CONTRACTOR. The attached Scope of Work sets forth a specific project, including deliverables, to be performed pursuant to this Agreement. The Scope of Work and abstracts thereof, shall not be considered proprietary information and shall be publicly releasable. The Parties agree that an initial abstract of the work to be performed shall be deliverable under this Agreement.

ARTICLE II. TERM OF THE AGREEMENT

This Agreement shall have a term of X years from the effective date. The term of this Agreement shall be effective as of the date on which it is signed by the last of the Parties.

ARTICLE III: COST

Each Party will bear its own costs and expenses associated with this Agreement unless otherwise agreed to by the Parties or as may otherwise be agreed to by the User and DOE.

ARTICLE IV: ADMISSION REQUIREMENTS

USERs and Participants are subject to the administrative and technical supervision and control of CONTRACTOR; and will comply with all applicable rules of CONTRACTOR and DOE with regard to admission to and use of the User facility, including safety, operating and health-physics procedures, environment protection, access to information, hours of work, and conduct. Participants shall execute any and all documents required by CONTRACTOR acknowledging and agreeing to comply with such applicable rules of CONTRACTOR. Participants will not be considered employees of CONTRACTOR for any purpose.

ARTICLE V: PROPERTY AND MATERIALS***

USER may be permitted by Contractor to furnish equipment, tooling, test apparatus, or materials necessary to assist in the performance of its experiment(s) at the USER facility. Such items shall remain the property of USER, except as otherwise provided in this Article. Unless the Parties otherwise agree, all such property furnished by USER or equipment and test apparatus provided by USER will be removed by USER within sixty (60) days of termination or expiration of this Agreement or will be disposed of as directed by USER at User’s expense. Any equipment that becomes integrated into the facility shall be the property of the Government. USER acknowledges that any material supplied by USER may be damaged, consumed or lost. USER will return facilities and equipment utilized in their original condition except for normal wear and tear.

CONTRACTOR shall have no responsibility for USER's property in CONTRACTOR's possession other than loss or damage caused by willful misconduct or gross negligence of

CONTRACTOR or its employees.

Personal property produced or acquired during the course of this Agreement shall be disposed of as directed by the owner at the owner's expense.

USER represents that it owns and has full authority to transfer ownership and title to any materials it supplies for the purpose of irradiation under this Agreement and that said materials are free of any liens, claims of ownership, or other liabilities. Transfer of materials for irradiation and/or examination under this Agreement, shall constitute a transfer of title of said materials from User to DOE upon delivery of the materials at the Nuclear Science User Facility (NSUF) unless otherwise specified.

After the material has been irradiated, transferred to an examination facility and extracted from the encapsulation and/or holders, the USER will be notified by the CONTRACTOR that the irradiated material is available for examination. The USER will have exclusive research rights to the irradiated material for a period of three (3) years from the date of notification. After the three (3) years, DOE and CONTRACTOR have full discretion to make the irradiated material available to the general research community, maintain possession, transfer possession, or dispose of the irradiated material. DOE may transfer title to the material at its discretion.

ARTICLE VI: SCHEDULING***

USER understands that CONTRACTOR will have sole responsibility and discretion for allocating and scheduling usage of the User Facilities and equipment needed for or involved under this Agreement.

ARTICLE VII: INDEMNITY AND LIABILITY***

A. Personnel Relationships - USER shall be responsible for the acts or omissions of Participants.

B. Product Liability - To the extent permitted by US and US State law, if USER utilizes the work derived from this Agreement in the making, using, or selling of a product, process or service, then USER hereby agrees to hold harmless and indemnify CONTRACTOR and the United States Government, their officers, agents and employees from any and all liability, claims, damages, costs and expenses, including attorney fees, for injury to or death of persons, or damage to or destruction of property, as a result of or arising out of such utilization of the work by or on behalf of USER, its assignees or licensees.

C. General Indemnity - To the extent permitted by US and US State law, USER hereby agrees to indemnify and hold harmless CONTRACTOR and the United States Government, their officers, agents and employees from any and all liability, claims, damages, costs and expenses, including attorney fees, for injury to or death of persons, or damage to or destruction of property, to the extent such liability, claims, or damages is

caused by or contributed to the negligence or intentional misconduct of USER or its employees or representatives during the performance of the work under this Agreement.

D. Patent and Copyright Indemnity—Limited - *To the extent permitted by US and US State law, USER shall fully indemnify the Government and CONTRACTOR and their officers, agents, and employees for infringement of any United States patent or copyright arising out of any acts required or directed or performed by USER under the Agreement to the extent such acts are not normally performed at the facility.*

E. The liability and indemnity provisions in paragraphs B, C and D above shall not apply unless USER shall have been informed as soon as practicable by CONTRACTOR or the Government of the suit or action alleging such infringement, and such indemnity shall not apply to a claimed infringement that is settled without the consent of USER unless required by a court of competent jurisdiction.

F. General Disclaimer -

THE GOVERNMENT AND CONTRACTOR MAKE NO EXPRESS OR IMPLIED WARRANTY AS TO THE CONDITIONS OF THE USER FACILITY FURNISHED HEREUNDER. IN ADDITION, THE GOVERNMENT, CONTRACTOR AND USER MAKE NO EXPRESS OR IMPLIED WARRANTY AS TO THE RESEARCH OR ANY INTELLECTUAL PROPERTY, GENERATED INFORMATION, OR PRODUCT MADE OR DEVELOPED UNDER THIS AGREEMENT, OR THE OWNERSHIP, MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE OF THE RESEARCH OR RESULTING PRODUCT; THAT THE GOODS, SERVICES, MATERIALS, PRODUCTS, PROCESSES, INFORMATION, OR DATA TO BE FURNISHED HEREUNDER WILL ACCOMPLISH INTENDED RESULTS OR ARE SAFE FOR ANY PURPOSE INCLUDING THE INTENDED PURPOSE; OR THAT ANY OF THE ABOVE WILL NOT INTERFERE WITH PRIVATELY OWNED

RIGHTS OF OTHERS. THE GOVERNMENT, CONTRACTOR AND/OR USER SHALL NOT BE LIABLE FOR SPECIAL, CONSEQUENTIAL, OR INCIDENTAL DAMAGES ATTRIBUTED TO USE OF SUCH FACILITIES, RESEARCH OR RESULTING PRODUCT, INTELLECTUAL PROPERTY, GENERATED INFORMATION, OR PRODUCT MADE OR DELIVERED UNDER THIS AGREEMENT.

ARTICLE VIII: <u>PATENT RIGHTS</u>***

A. Definitions

1. “Subject Invention” means any invention or discovery conceived or first actually reduced to practice in the course of or under this Agreement.

2. "USER Invention" means any Subject Invention of USER.

3. “CONTRACTOR Invention” means any Subject Invention of CONTRACTOR.

4. "Patent Counsel" means the DOE Counsel for Intellectual Property assisting the DOE Contracting activity.

B. Subject Inventions

CONTRACTOR and USER agree to disclose their Subject Inventions, which includes any inventions of their Participants, to each other, concurrent with reporting such Subject Inventions to DOE.

C. CONTRACTOR's Rights

Except as provided below in the case of joint inventions, CONTRACTOR Inventions will be governed by the provisions of CONTRACTOR'S Prime Contract for operation of the User facility.

D. USER's Rights

Subject to the provisions herein, USER may elect title to any USER Invention and in any resulting patent secured by USER within one year of reporting the subject invention to DOE. The USER shall file a US patent application within a reasonable period of time. Where appropriate, the filing of patent applications by USER is subject to DOE security regulations and requirements.

E. Joint Inventions

For Subject Inventions conceived or first actually reduced to practice under this Agreement that are joint Subject Inventions made by CONTRACTOR and USER, each Party shall have the option to elect and retain title to its undivided rights in such joint Subject Inventions.

F. Rights of Government

1. USER agrees to timely assign to the Government, if requested, the entire right, title, and interest in any country to each USER Invention where USER:

a. Does not elect to retain such rights; or

b. Fails to timely have a patent application filed in that country on the USER Invention or decides not to continue prosecution or not to pay the maintenance fees covering the Invention; or

c. At any time, no longer desires to retain title.

2. USER shall provide the Government a copy of any application filed by USER promptly after such application is filed, including its serial number and filing date.

3. USER hereby grants to the Government a nonexclusive, nontransferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States the USER Invention made under said project throughout the world.

4. USER acknowledges that the DOE has certain March-in Rights to any USER Inventions elected by the USER in accordance with 48 C.F.R. 27.304-1(g) and that the USER is subject to the requirements with respect to preference for U.S. industry pursuant to 35 U.S.C. § 204 to any USER Inventions elected by the USER.

5. The USER agrees to include, within the specification of any U.S. patent applications and any patent issuing thereon covering a USER Invention, the following statement: "The Government has rights in this invention pursuant to a USER Agreement (specify number) between (USER name) and (CONTRACTOR Name), which manages and operates (name of Laboratory) for the US Department of Energy."

6. USER agrees to submit on request periodic reports to DOE no more frequently than annually on the utilization of USER Inventions or on efforts to obtain such utilization that are being made by USER or its licensees or assignees.

7. Facilities License: USER agrees to and does hereby grant to the Government a nonexclusive, nontransferable, irrevocable, paid-up license in and to any inventions or discoveries, regardless of when conceived or actually reduced to practice or acquired by USER, which are incorporated in the User Facility as a result of this Agreement to such an extent that the facility is not restored to the condition existing prior to the Agreement (1) to practice or to have practiced by or for the Government at the facility, and (2) to transfer such licenses with the transfer of that facility. The acceptance or exercise by the Government of the aforesaid rights and license shall not prevent the Government at any time from contesting the enforceability, validity or scope of, or title to, any rights or patents herein licensed.

G. Invention Report and Election

USER shall furnish the Patent Counsel a written report concerning each USER Invention within six months after conception or first actual reduction to practice, whichever occurs first. If USER wishes to elect title to the Invention, a notice of election should be submitted with the report or within one year of such date of reporting.

ARTICLE IX: RIGHTS IN TECHNICAL DATA***

A. Definitions:

1. "Technical Data" means recorded information regardless of form or characteristic, of a scientific or technical nature. Technical Data as used herein does not include financial reports, costs analyses, and other information incidental to Agreement administration.
2. "Proprietary Data" means Technical Data which embody trade secrets developed at private expense, outside of this agreement, such as design procedures or techniques, chemical composition of materials, or manufacturing methods, processes, or treatments, including minor modifications thereof, provided that such data:
   - **a.** Are not generally known or available from other sources without obligation concerning their confidentiality.
   - **b.** Have not been made available by the owner to others without obligation concerning their confidentiality
   - **c.** Are not already available to the CONTRACTOR or the Government without obligation concerning their confidentiality.
   - **d.** Are marked as “Proprietary Data.”
3. "Unlimited Rights" means right to use, duplicate, or disclose Technical Data, in whole or in part, in any manner and for any purpose whatsoever, and to permit others to do so.

B. Allocation of Rights

1. The Government shall have Unlimited Rights in Technical Data first produced or specifically used in the performance of this Agreement except as otherwise provided in this Agreement.
2. USER shall have the right to use for its private purposes, subject to patent, security or other provisions of this Agreement, Technical Data it first produces in the performance of this Agreement provided the data delivery requirements of this Agreement have been met as of the date of the private use of such data; and Technical Data first produced by CONTRACTOR, if any, under this Agreement. USER agrees that to the extent it receives or is given access to Proprietary Data or other technical, business or financial data in the form of recorded information from DOE or a DOE contractor or subcontractor, USER shall treat such data in accordance with any restrictive legend contained thereon, unless use is specifically authorized by prior written approval of the Contracting Officer.

C. Deliverables

1. USER agrees to furnish to DOE or CONTRACTOR those data, if any, which

are (a) specified to be delivered in Appendices, (b) essential to the performance of work by CONTRACTOR personnel or (c) necessary for the health and safety of such personnel in the performance of the work. Any data furnished to DOE or CONTRACTOR shall be deemed to have been delivered with unlimited rights unless marked as "Proprietary Data" of USER.

2. Upon completion or termination of the project, USER agrees to deliver to DOE and CONTRACTOR a nonproprietary report describing the work performed under this Agreement.

D. Legal Notice

The following legal notice shall be affixed to each report or publication resulting from this Agreement which may be distributed by USER:

DISCLAIMER NOTICE

This document was prepared by __ as a result of the use of facilities provided through the U.S. Department of Energy (DOE) Nuclear Science User Facilities program, which is managed by Battelle Energy Alliance, LLC, acting under Contract No.DE-AC-07-05ID14517. Neither Battelle Energy Alliance, LLC, DOE, the U.S. Government, nor any government contractors, nor other persons and facilities performing work under this Agreement or acting on behalf of any of the above: (a) make any warranty or representation, express or implied, with respect to the information contained in this document; or (b) assume any liabilities with respect to the use of, or damages resulting from the use of any information contained in the document.

E. Copyrighted Material

1. USER agrees to, and does hereby grant to the Government, and to its officers, agents, servants and employees acting within the scope of their duties:

a. A royalty-free, nonexclusive, irrevocable license to reproduce, translate, publish, use, and dispose of and to authorize others so to do, all copyrightable material first produced or composed in the performance of this Agreement by USER, its employees or any individual or concern specifically employed or assigned to originate and prepare such material; and

b. A license as aforesaid under any and all copyrighted or copyrightable works not first produced or composed by USER in the performance of this Agreement but which are incorporated in the material furnished or delivered under the Agreement, provided that such license shall be only to the extent USER now has, or prior to completion or

final settlement of the Agreement may acquire, the right to grant such license without becoming liable to pay compensation to others solely because of such grant.

2. USER agrees that it will not knowingly include any copyrightable material furnished or delivered under this Agreement without a license as provided for in subparagraph 1(b) hereof, or without the consent of the copyright owner, unless it obtains specific written approval of the Contracting Officer for the inclusion of such copyrighted materials.

F. Disclosure of Proprietary Data

In the absence of a properly executed and effective non disclosure agreement between USER and CONTRACTOR, the USER shall not bring Proprietary Data into the USER facility except at USER's own risk and any such data, regardless how it is marked, shall be deemed Technical Data and shall be treated according to this article of this Agreement.

ARTICLE X: LABORATORY SITE ACCESS, SAFETY AND HEALTH***

As a precondition to using CONTRACTOR facilities, Participants must complete all CONTRACTOR Site Access documents and requirements. USER and participant shall take all reasonable precautions in activities carried out under this Agreement to protect the safety and health of others and to protect the environment. Participants must comply with all applicable safety, health, access to information, security and environmental regulations and the requirements of the Department and CONTRACTOR, including the specific requirements of the User Facility covered by this Agreement. In the event that USER or Participant fails to comply with said regulations and requirements, CONTRACTOR may, without prejudice to any other legal or contractual rights, issue and order stopping all or any part of USER's activities at the User Facility.

ARTICLE XI: PERSONNEL RELATIONSHIPS***

Participants will remain employees or representatives of the USER at all times during their participation in the work under this Agreement, and shall not be considered employees of CONTRACTOR or DOE for any purpose. Participants shall be subject to the administrative and technical supervision and control of CONTRACTOR during and in connection with the Participant's activities under this Agreement.

ARTICLE XII: EXPORT CONTROLS***

USER acknowledges that the export of goods or Technical Data may require some form of export control license from the U.S. Government and that failure to obtain such export control license may result in criminal liability under the laws of the United States.

ARTICLE XIII: PUBLICATIONS***

A. USER and CONTRACTOR will provide each other copies of articles of any publication of information generated pursuant to this Agreement for review and comment fourteen (14) days prior to publication.

B. USER will not use the name of CONTRACTOR or the United States Government or their employees in any promotional activity, such as advertisements, with reference to any product or service resulting from this Agreement, without prior written approval of the Government and CONTRACTOR.

ARTICLE XIV: DISPUTES***

The parties will attempt to jointly resolve all disputes arising under this agreement. If the parties are unable to jointly resolve a dispute within a reasonable period of time, either party may contact the laboratory's Technology Transfer Ombudsman (TTO) to provide assistance. The TTO may work directly to resolve the dispute or, upon mutual agreement of the parties, contact a third party neutral mediator to assist the parties in coming to a resolution. The costs of the mediator's services will be shared equally by the parties. In the event that an agreement is not reached with the aid of the ombudsman or mediator, the parties may agree to have the dispute addressed by neutral evaluation. The decision rendered by the neutral evaluator shall be nonbinding on the parties, and any costs incurred there from shall be divided equally between the parties. Upon mutual agreement, the parties may request a final decision by the DOE Contracting Officer. Absent resolution, either party may seek relief in a court of competent jurisdiction.

ARTICLE XV: CONFLICT OF TERMS***

This Agreement constitutes the primary document which governs the work described in the attached Appendices. In the event of any conflict between the terms of this document and any other document issued by either Party, the terms of this document shall prevail.

ARTICLE XVI: TERMINATION***

Either Party may terminate this Agreement for any reason at any time by giving not less than thirty (30) days prior written notice to the other Party. Notice will be deemed made as of the day of receipt. The obligations of any clause of this Agreement, which by their nature extend beyond its termination, shall remain in full force and effect until fulfilled.

BATTELLE ENERGY ALLIANCE, LLC (CONTRACTOR):

BY: _____
Signature

NAME: _____
Printed

TITLE: Deputy Laboratory Director, Science & Technology

DATE: _____

User's Formal Name (USER):

BY: _____
Signature

NAME: _____
Printed

TITLE: _____

DATE: _____

ADDRESS: _____

TELEPHONE: _____

User Principal Investigator Acknowledgment

I, XXXXXXXX, have read and hereby acknowledge the above terms and conditions.

BY: _____
Signature

TITLE: _____

DATE: _____

ADDRESS: _____

TELEPHONE: _____

***** Any changes to the *** or substantive changes to the non *** provisions will require formal written approval by DOE.**