FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

U. S. Department of Energy

Idaho Operations Office

Fiscal Year 2019 Consolidated Innovative Nuclear Research

Funding Opportunity Announcement:
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(Video links and presentations are available at www.neup.gov)

Issue Date: September 10, 2018

Letter of Intent (Mandatory only for NSUF Applications)
Due Date: September 24, 2018 at 7 p.m. ET

R&D/NSUF Pre-Applications (Mandatory except for IRPs)
Due Date: October 11, 2018 at 7:00 p.m. ET

NSUF Preliminary Statement of Work
Due Date: November 29, 2018 at 7:00 p.m. ET

NSUF Final Statement of Work
Due Date: January 24, 2019 at 7:00 p.m. ET

Full R&D Applications
Due Date: February 12, 2019 at 7:00 p.m. ET

IRP Applications
Due Date: February 12, 2019 at 7:00 p.m. ET

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

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: http://www.sam.gov/. For more information about SAM registration for applicants please refer to: https://www.sam.gov/sam/transcript/Quick_Guide_for_Grants_Registrations_v1.7.pdf.

3. Create an account on NEUP.gov

Questions

Questions regarding the **content of the funding opportunity announcement** must be submitted using the contact information found on page 51 of this FOA. DOE will try to respond to a question within 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
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
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 will need to 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, that has been working closely with the advanced nuclear design community to identify R&D objectives and workscopes 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. Workscopes that may be addressed in activities funded under this FOA are identified in Part IX, Appendices A-C, below. Generally speaking, proposals that offer flexibility or provision for addressing measurements, materials, and conditions relevant to private sector developers of fast-spectrum reactors (Pb-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 the world of 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.

NE reserves the right to respond to potential shifts in R&D priorities during Fiscal Year (FY) 2019 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, academe, 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 requesting R&D financial support with a joint request for NSUF access will be limited to the workscopes in NSUF-1, FC-2.5 and NEAMS-2. Workscopes 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 workscope, a broader workscope focused on NE mission priorities and also tailored to align with NSUF capabilities. NSUF-2 workscope areas are open to industry leads only.

The NSUF Fuels and Materials Library is a cataloged collection of irradiated materials and is a critical component of the NSUF. The Library was established to reduce costs and take advantage of new ideas and future analysis techniques and equipment. Researchers are encouraged to use the Library materials to develop research concepts. The catalog of available materials is available at https://nsuf.inl.gov/.

A.2.6 NSUF Fuels and Materials Library

The NSUF Fuels and Materials Library is a cataloged collection of irradiated materials and is a critical component of the NSUF. The Library was established to reduce costs and take advantage of new ideas and future analysis techniques and equipment. Researchers are encouraged to use the Library materials to develop research concepts. The catalog of available materials is available at https://nsuf.inl.gov/. In order to continue the expansion of the Library, the NSUF Program Office may recommend irradiating a larger number of samples than required for the proposed research. These samples will be added to the Library. In addition, all specimens remaining after three years of PIE will be moved into the Library. Principal Investigators (PIs) of all future awarded applications to study specimens added to the Library from previous awarded irradiation tests will be put in contact with the PI(s) of the project that produced the specimens for potential collaboration. Although collaboration with past NSUF PIs is encouraged, permission from the PIs to use previously generated materials currently in the NSUF Library is not required. DOE owns all materials in the Library.

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 workscopes, 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 workscopes contained in Part IX, Appendix A.

The Research Councils United Kingdom (RCUK) Energy Program, led by the Engineering and Physical Science Research Council (EPSRC) in the United Kingdom (UK) has announced a UK funding opportunity for certain workscopes in Appendix A. The UK funding opportunity will support UK researchers in US/UK collaborations in the following areas:

- Down-Innovative New Nickel Alloys for Molten Salt Reactor Structural Applications (RC-1)
- Liquid Metal-Cooled Fast Reactor Technology Development and Demonstration to Support Development (RC-3)
- Experimental Validation of High Temperature Gas Reactor (HTGR) (RC-5)
- Special Purpose Reactors R&D (MS-RC-1)
- Materials Recovery (FC-1.2)

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 workscopes in Part IX, Appendix B. **Industry leads can only apply to the NSUF workscopes**. NSUF-2 workscope areas are open to industry leads only. Proposed research projects in response to this area of the FOA should meet the objectives of the NEET CTD program, and within the NSUF workscopes, meet the identified objectives of the RC RD&D, FC R&D, and NEET CTD programs as described in the workscopes 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 and NEAMS-2 workscope.
- 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 workscope.
- Only industry PIs may apply for NSUF access without a joint request for R&D financial support as stated in the NSUF-2 workscope.

Eligible workscopes 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.

NOTE: 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)
- 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 Nuclear Fuels and Materials Library, 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 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 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.

Industry projects not requiring R&D financial support may apply for NSUF access only workscopes in response to this area of the FOA and the associated workscope 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, FC-2.5, NEAMS-2, or NSUF-2 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.

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 workscopes contained in Part IX, Appendix C of this FOA.

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

- Appendix A: "Workscopes 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 workscopes;
- Appendix B: "Workscopes 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 workscopes.
- Appendix C: "Workscopes for U.S. University-led Program Directed Integrated Research Projects (IRP)"

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 (FWP) and NSUF Access Awards which will be funded through a NSUF User Agreement.

B. ESTIMATED FUNDING

The estimated amounts identified for each of the FOA areas are specified below. Funding for all awards and future budget periods are 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 $45 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 $12 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 workscopes.
- MS: up to $400,000 (3-year project), except as explicitly noted in individual workscopes.

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

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 workscopes

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 50 awards under this area.

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

DOE anticipates making up to 7 awards under this area.

D.2.1 Nuclear Science User Facilities Projects

DOE anticipates making up to 10 awards under this area.

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

DOE anticipates making 1 award per IRP workscope.

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 workscope 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 workscope 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 $1,500,000
- Irradiation /PIE: $500,000 to $4,000,000
- Beamline or PIE only: $50,000 to $750,000.

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 workscopes.

F. PERIOD OF PERFORMANCE

DOE anticipates making awards for up to three years for each area with the exception of ***NSUF-1, FC-2.5, NEAMS-2 and NSUF-2 awards, which may take up to seven years if irradiation and PIE is requested.*** Assuming DOE makes awards under this FOA by September 2019, funded projects shall begin no later than October 1, 2019; additionally, each successive budget period within the project period of performance should begin on October 1st of each year during the overall project period of performance. 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, 2019, 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.

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 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. 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. **Any individuals that do not meet these criteria should not be listed as collaborators on the application.**

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.

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 Code of Federal Regulation (CFR) 910.124.

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.

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

[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.

(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.

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, 2019.
  2. The PI has three or more R&D projects that will still be active after December 31, 2019.
  3. The PI has a no-cost extension on any DOE-NE funded project (excluding Infrastructure) that will still be active beyond December 31, 2019.
- An academic PI can 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 workscope areas.
- Applications submitted in response to research requested by Appendix B are limited to three pre-applications per institution per workscope 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 still be active beyond December 31, 2019. 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.
- Applications requesting NSUF access and R&D support will be evaluated on a case-by-case basis with respect to these eligibility requirements.
- Access only requests for NSUF are not bound by these eligibility restrictions.

NOTE: 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 and FFRDCs), the provisions of the Energy Policy Act of 2005, Section 988, apply and a 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, on a budget period basis, 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 a 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: Individual Letters of Authorization may be submitted or submitted as blanket permission if all FFRDC/non-FFRDC management has been notified of all submissions and

acknowledgment of all participants are identified. 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 1 provides a summary of Parts II and III of this FOA.

Table 1. Summary of Parts II and III.

		Applicable Workscope Appendix	Estimated Available Budget	Maximum Award Size	Project Duration	Cost Share	Collaboration
University-led NEUP Projects	PS	Appendix A	$45,000,000	$800,000	Up to 3 years	Permitted but not required*	University, national laboratory, industry, and foreign collaborations are encouraged but no U.S. funding can go to entities that are not incorporated in the U.S.
	MS			$400,000			
University- or National Laboratory-led NEET CTD Projects	PS	Appendix B	$7,000,000	$1,000,000	Up to 3 years		
NSUF Projects	PS	Appendix A & Appendix B	R&D: $3,000,000 NSUF: $10,000,000	Refer to maximum award size of the project funding and NSUF funding.	Up to 7 years for Irradiation and PIE. Up to 3 years for PIE only or Irradiation only		

University-led Integrated Research Projects-NEUP	PD	Appendix C	$12,000,000	$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 can 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.

C. LETTER OF INTENT AND PRE-APPLICATION

C.1.1 LOI 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 2017 NSUF Letter of Intent" and click on "Create New Application" for the type of application you are creating.

Points of contact (POCs) for the NSUF facilities, as well as facility descriptions, are provided on the NSUF website at http://nsuf.inl.gov. 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: 2019 LOI "Insert ID #"

C.2 R&D/NSUF 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 F.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:

C.2.1 Pre-application Narrative

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

- Title of project.
- Technical Workscope Identification (e.g., FC-1.1). The PI is responsible for selecting the appropriate workscope, 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 if the R&D is for a 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, FC-2.5 and NEAMS-2 only).

4-page limit. Name File: 2019 Pre-Application Narrative “Insert ID #”

C.2.2 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 can contain brief biographies of staff and descriptions of the facilities wherein the research will be conducted.

Please indicate within this section if 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: 2019 RPA Benefit of Collaboration "Insert ID #"

C.2.3 Publications

Applications must include a list of publications that resulted from previous DOE-NE 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: 2019 RPA DOE-NE Supported Publications "Insert ID #"

C.2.4 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: 2019 RPA "Last Name of Individual" "Insert ID #.pdf"

C.2.5 Agreement Requirements

Institutions will be expected to follow quality assurance (QA) principles and requirements in conducting R&D activities. The 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 if the application is successful. 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, FC-2.5 and NEAMS-2 or NSUF-2 applications. In order to ensure compliance throughout the application review process, applicants must indicate 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.

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. 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

D. CONTENT AND FORM OF ALL FULL APPLICATIONS

Applicants must provide all information requested and can use forms and optional templates 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).

D.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), 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: 2019 CFA COI "Insert ID #.pdf"

D.2 SF-424 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: 2019 CFA SF424RR "Insert ID #.pdf"

D.3 Research and Related (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: 2019 CFA R&R Other Project Information "Insert ID #.pdf"

D.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: 2019 CFA Technical Abstract "Insert ID #.pdf"

D.5 Project Narrative

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

- Application title.
- Final Technical Workscope 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 workscope, 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 workscope. 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, FC-2.5 and NEAMS-2 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, FC-2.5 and NEAMS-2 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: 2019 CFA Technical Narrative “Insert ID #.pdf”

D.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 vita 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: 2019 CFA "Last Name of Individual" "Insert ID #.pdf"

Technical expertise and qualifications are to be provided for individual participants, whether 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 would typically not include the NSUF support staff.

D.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 if 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: 2019 CFA Benefit of Collaboration "Insert ID#.pdf"

D.8 Capabilities

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.

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: 2019 CFA Capabilities "Insert ID#.pdf"

D.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 be signed by an authorized company official.

Name File: 2019 CFA Letter of Support "Insert ID#.pdf"

D.10 Budget Documents

D.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 instructions on the form (Activate Help Mode to see instructions) and the following instructions. A separate budget for each year of support requested must be completed. The form will generate a cumulative budget for the total project period. Complete all the mandatory information on the form before the 'next period' button is activated. 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 H).

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

Name File: 2019 CFA Budget "Insert ID #xls"

D.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 $100,000 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: 2019 CFA Subaward Budget "Insert ID #xls"

D.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: 2019 CFA FWP "Insert ID #.pdf"

D.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. Any non-approved foreign travel must go through DOE-NE's foreign travel authorization process.

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):

  At the time the application is submitted it must include a letter from each third party (i.e., a party other than the organization submitting the application). The letter must state that the third party is committed to providing a specific minimum dollar amount of cost sharing. Submitting 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. This appendix will not count in the project narrative page limitation. Successful applicants must provide the signed letters of commitment within the number of days specified in Part IV. Section E, Submissions from Successful Applicants.

Name File: 2019 CFA Budget Justification "Insert ID #.pdf"

D.11 Additional Attachments

D.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: 2019 CFA Current and Pending Support "Insert ID #.pdf"

D.11.2 Coordination and Management Plan

Multiple PIs: The applicant, whether a single organization or team/partnership/consortium, must indicate if 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
- PIs' roles and administrative, technical, and scientific responsibilities for the project.

Name File: 2019 CFA CMP "Insert ID #.pdf"

D.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 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, and will not place the laboratory in direct competition with the domestic private sector."

NOTE: Individual Letters of Authorization may be submitted or submitted as a blanket permission if all FFRDC/non-FFRDC management has been notified of all submissions and all participants are identified. 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: 2019 CFA CO Authorization "Insert ID #.pdf

D.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: 2019 CFA Site Location "Insert ID#.pdf"

D.11.5 Environmental Checklist

Applicants must provide information outlined in the optional Environmental Checklist template which is available here. The checklist will not include the NSUF capabilities. Any awards that require the use of government facilities will require a NEPA review performed by the government facility granting the access before physical work can begin.

Name File: 2019 CFA ENV "Insert ID #.pdf"

D.11.6 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.

File Name: 2019 CFA Cert & Assurances "Insert ID #.pdf"

D.11.7 Foreign Government Ownership Disclosure (Required for All Leads)

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

File Name: 2019 CFA Foreign Government Ownership Disclosure "Insert ID #.pdf"

D.12 NSUF Statement of Work (NSUF Applicants Only)

NSUF applicants are required to provide a final statement of work prior to the submittal of their NSUF full application submission. 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 Final Statement of Work will be appended to the already submitted pre-application.

File Name: 2019 FinalSoW"Insert ID#".pdf

NOTE: NSUF Final Statement of Work documents will be submitted as an additional document to the already submitted NSUF pre-application.

Federal and Technical POCs for FY 2019 can be found at:
https://neup.inl.gov/SitePages/FY19_RD_Technical_Program_Contacts.aspx
https://neup.inl.gov/SitePages/FY19_IRP_Technical_Program_Contacts.aspx

Table 2 contains a summary of the required information for full application submittals.

Table 2. Summary of Full Application Required Information.

Name of Document	Format	Required From
Conflict-of-Interest	Checkbox	Affirmed by Lead Applicant for all Participants
SF424 (R&R)	Form	Lead Applicant
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 (Except NSUF-2 workscope applicants)
SF-424 (R&R) Subaward Budget (Total Fed + Non-Fed), if applicable	Form	University and Industry Collaborators (Except NSUF-2 workscope applicants)
Budget for DOE National Laboratory Contractor or FFRDC, if applicable	PDF	National Laboratory Leads and Collaborators (Except NSUF-2 workscope applicants)
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)
Project/Performance Site Location	PDF	All sites performing work
Environmental Checklist	PDF	All site performing work
SF-LLL Disclosure of Lobbying Activities	PDF	Lead Applicant
Certifications and Assurances	Form	University Leads
Foreign Government Ownership Disclosure	PDF	All Leads

E. 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
- Commitment Letter from Third Parties Contributing to Cost Sharing, if applicable

F. SUBMISSION DATES AND TIMES

F.1 NSUF Letter of Intent Due Date

(Mandatory for NSUF Projects)

LOIs for NSUF access are required by September 24, 2018, no later than 7:00 p.m. Eastern Time (ET). The LOI shall be submitted as required in Part IV, Section C.1.

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

(Mandatory except for IRPs)

Pre-applications are required by October 11, 2018, 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.

F.3 NSUF Preliminary Statement of Work Due Date

Applicants requesting NSUF access must submit a preliminary Statement of Work by November 29, 2018, 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.

F.4 NSUF Final Statement of Work Due Date

Applicants requesting NSUF access must submit a final Statement of Work by January 24, 2019, no later than 7:00 p.m. ET. The final SOW shall be submitted as required in Part IV, Section D.12. Applicants who fail to submit a final SOW will be determined non-responsive and ineligible for further consideration.

F.5 Integrated Research Projects (IRP) Due Date

IRPs must be received by February 12, 2019 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.

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

Full R&D/NSUF applications must be received by February 12, 2019, 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.

F.6 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) If it was transmitted through an electronic commerce method authorized by the FOA, it was 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) However, 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 so 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 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 by electronically to www.NEUP.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

G. INTERGOVERNMENTAL REVIEW

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

H. FUNDING RESTRICTIONS

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

H.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.

H.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 referenced in 2 CFR 200, as adopted and amended by 2 CFR 910. 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.

I. OTHER SUBMISSION AND REGISTRATION REQUIREMENTS

I.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.

I.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 valid time-frame, 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 3. 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 workscopes. Scores will be assigned according to the following program relevancy and program priority attributes:

A.1.1 Precursory 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 initial review criteria will be considered during the merit 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 workscope 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 workscope 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 workscope 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 workscope 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 workscope area.

A.1.3 Program Priority

Application relevancy scores 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 workscope 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 workscope 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 workscope 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 workscope 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 workscope 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 workscope 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 workscope 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 workscope 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 workscope 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 3 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.2.1. 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 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 3. 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 workscope 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, relevance and depth of the organization's experience and capabilities, 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 3. 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
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.

Criterion	
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 4.

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 postdocs 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 4. 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. This includes 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 which, 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.
- Readiness of the project for NSUF access

- The 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.
- The 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.

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 workscope. DOE will consider the overall evaluation results and subjective programmatic factors to select a final set of invited projects to be "invited" 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 Selection Official Considerations

The Selection Official will consider the merit review recommendations, subjective factors such as program policy considerations, and the amount of funds available to make final project selections. The Selection Official will consider the following Program Policy Factors in the selection of application(s) for negotiation of award to receive DOE funding support:

- The application's 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.
- Applications that have the potential to enhance U.S. nuclear infrastructure may be given preferential consideration.
- Foreign government ownership, if any, of the applicant, the applicant's parent companies, applicant's affiliates, or other related companies may be considered in making the award.
- The consistency and conformance of the work proposed in the application with current Office of Nuclear Energy Congressional appropriations.
- Application selection will be balanced to best optimize the selection of an appropriate mix of technologies to meet program goals.

These factors, while not indicators of the Application's merit, e.g., technical excellence, applicant's ability, etc., may be essential to the process of selecting the application that,

individually or collectively, will best achieve the program objectives. Such factors are often beyond the control of the Applicant.

B.5 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 and comment on any information about itself that a Federal awarding agency previously entered and 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, 2019.

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 H.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 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 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.

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.

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 an 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 if requested.

- **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 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;
  - If requested by the program, attending annual program review meetings and reporting project status;
  - Submitting technical reports as stated in the Federal Assistance Reporting Checklist, and incorporating DOE comments;
  - **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:
  - 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 10/31/2019 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 workscopes may be submitted to the DOE federal and technical POCs listed in Appendices A, B, and C. PIs are not allowed to contact Federal or Technical Points of Contact after the full application due date with the exception of discussion supporting NSUF feasibility assessments. Answers to questions submitted that contain 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 Q&A as early in 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. Brandon Stike E-mail: stikebm@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 workscopes. 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 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 which 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 ending in the current fiscal year should be requested by April 15. Any request beyond this date should be submitted after October 1. 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 timely submitted to NEUP@inl.gov.

K. 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: Workscopes for U.S. University-led Program and/or Mission Supporting R&D Projects

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

Appendix C: Workscopes 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: Workscopes for U.S. University-led Program and/or Mission Supporting R&D Projects

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INNOVATIVE NEW NICKEL ALLOYS FOR MOLTEN SALT REACTOR STRUCTURAL APPLICATIONS (RC-1)
(FEDERAL POC – SUE LESICA & TECHNICAL POC – SAM SHAM)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

The Molten Salt Reactor Experiment (MSRE) was operated at Oak Ridge National Laboratory during the 1960s for about five years. It deployed a uranium fuel dissolved in a fluoride-salt medium, with graphite as a moderator. A nickel alloy with about 6%Cr and molybdenum as a solid solution strengthening agent was developed and deployed for all structural applications in the MSRE. The alloy was later commercialized as Hastelloy N. During these experiments and in post-decommissioning characterization of material behavior, it was determined that the most significant challenges for structural materials are embrittlement, from helium introduced by transmutation of Ni, and corrosion and grain boundary embrittlement from the fission product tellurium. The MSRE had an outlet temperature of approximately 650°C. The mechanical properties of Hastelloy N are not sufficient to support long-term operation of an MSR above this temperature.

An NEUP award on developing the next generation MSR structural materials based on the high entropy alloy concept was made in FY18. The objective of the FY19 project is to identify existing or develop new nickel alloy(s) that can be used for welded construction of structural components for solid and liquid fueled MSRs. Characteristics of the new nickel alloy(s) to be considered include, but not limited to, high temperature strength, fuel salt compatibility, irradiation damage resistance (including helium generation from n,α reactions with thermal neutrons), fission products embrittlement, and weldability, all for the desired life times of the components. For structural applications with long service lives, microstructural stability of the candidate nickel alloys in the MSR environment is an important attribute. While not specifically a part of the scope 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 the long-term stability, 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 helium, and novel application of high-valued experiments with integrated computation materials engineering are highly encouraged. The outcome of the project is to demonstrate the potential of the developed nickel alloy(s) to meet the challenges under the extreme environments for solid and liquid fueled MSRs and a plan for fabrication scale up and intermediate term testing to further demonstrate the capability of the developed alloy(s) to meet these challenges. While not required, interaction with MSR developers on their system requirements is highly encouraged.

SALT BEHAVIOR IN MOLTEN SALT REACTORS (RC-2)

RC-2.1: UNDERSTANDING, PREDICTING, AND OPTIMIZING THE PHYSICAL PROPERTIES, STRUCTURE, AND DYNAMICS OF MOLTEN SALT
(FEDERAL POC – STEPHEN KUNG & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

With the ongoing development of molten salt reactors there is a significant need for understanding the thermochemical behavior of salt compositions. 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

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composition and redox condition of the salt may change with of time as a result of fission product formation and irradiation effect. Proposals 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.

RC-2.2: UNDERSTANDING THE STRUCTURE AND SPECIATION OF MOLTEN SALT AT THE ATOMIC AND MOLECULAR SCALE
(FEDERAL POC – STEPHEN KUNG & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

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 allowing for optimization of reactor performance and lifetime. Proposals 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 to underpin and support molten salt reactor design and development. 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.

RC-3: LIQUID METAL-COOLED FAST REACTOR TECHNOLOGY DEVELOPMENT AND DEMONSTRATION TO SUPPORT DEPLOYMENT
(FEDERAL POC – TOM SOWINSKI & TECHNICAL POC – BOB HILL)
(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.

This work scope seeks proposals to develop and demonstrate innovative technology options for liquid metal (sodium or lead-cooled) fast reactors for utilization in advanced reactor concepts proposed by U.S. nuclear industry. Features that offer the potential for significant benefits in reactor capital or operating cost reductions are of particular interest.

Examples of potentially beneficial cost reduction experimental and analytical work areas include:

- Development of sensors and prognostic techniques for deployment that can 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

- Development and application of uncertainty propagation analysis techniques to quantify impacts on key liquid metal-cooled fast reactor performance parameters (e.g., burnup) and/or safety performance. Consideration should be given to how such tools and techniques can be used to optimize and justify design and safety margins
- 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 (e.g., thermal striping) under prototypic or near prototypic conditions
- Detailed analytical performance studies of compact heat exchanger options (e.g., microchannel configurations) for lead or sodium-cooled fast reactors. Ideally this work would be coupled with experimental validation of key performance attributes
- Development of small-scale heavy liquid metal (lead or lead-bismuth) testing capabilities and/or test articles supporting lead-cooled fast reactor technology development and demonstration

Though proposals are not limited to the example work areas above, applicants should indicate how their proposed work will support current DOE, national laboratory, and/or U.S. nuclear industry liquid metal-cooled fast reactor deployment and commercialization R&D initiatives.

HTGR TRISO FUEL PARTICLE MATERIALS (RC-4)

RC-4.1: THERMOMECHANICAL PROPERTIES OF TRISO FUEL COATING LAYERS (FEDERAL POC – MADELINE FELTUS & TECHNICAL POC – PAUL DEMKOWICZ) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

One of the main functions of TRISO fuel performance models such as the PARticle FUel ModEl (PARFUME) is calculating the probability of coating layer failure from various causes during irradiation. This includes modeling the thermomechanical behavior of the coatings in response to high temperatures, neutron-irradiation-induced changes, interactions with fission products, stresses in the particle from accumulating fission gas inventory in the buffer layer and CO gas formation which is a specific concern in UO_2 fuel kernels. A number of particle failure mechanisms have been identified based on decades of empirical observations of irradiated TRISO fuel and associated computational modeling [1]. Fuel particles are typically operated within a defined performance envelope (e.g., burnup, fast neutron fluence, and temperature) that limits these failure mechanisms to very low, acceptable levels. Accurate TRISO particle materials property data is needed to improve performance modelling predictions. While some materials properties are easily measured on as-fabricated fuel with reasonable confidence, other property information has greater uncertainty levels. Furthermore, sensitivity studies demonstrate that some TRISO fuel properties have a much greater impact on model predictions of particle failure than others [2]. Among the most critical characteristics are irradiation-induced creep and dimensional change in pyrocarbon (PyC), and, to a lesser extent, the PyC elastic moduli [2].

Post-irradiation examination of the AGR TRISO Fuel Program's UCO TRISO fuel has demonstrated that discreet failure of the SiC layer can occur at very low fractions with the outer PyC (OPyC) layer remaining intact. Such failed SiC layer particles release cesium, but the intact OPyC layer effectively retains fission gases. The dominant mechanism of SiC-layer failure has been identified as localized fission product (primarily Pd) corrosion of the SiC layer [3]. A distinguishing feature of this SiC layer corrosion mechanism, however, is that it requires mechanical failure of the inner PyC (IPyC) layer, such that the inner SiC surface is exposed, allowing fission products to concentrate in a relatively small region. This IPyC failure mechanism is driven by a strong bond between the IPyC and the buffer layer. Densification of the buffer layer in the presence of a strong buffer-IPyC

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bond places additional stresses on the IPyC layer that causes IPyC fracture and IPyC-SiC delamination. Modeling of this buffer IPyC failure mechanism, which is not currently included in PARFUME or other TRISO fuel performance models, would require buffer strength and the interfacial buffer-IPyC bond strength information, for which no data are currently available.

Research proposals are sought that specifically focus on obtaining these specific TRISO coating layer properties: (a) Buffer: elastic modulus, tensile strength; (b) Pyrocarbon (IPyC and OPyC): elastic modulus, tensile strength, irradiation-induced creep and dimensional change; and (c) Buffer-IPyC bond strength. Other property measurements may be proposed, but the parameter must have a high importance ranking and impact on particle failure rates, as shown either in the PARFUME fuel performance sensitivity study [2] or based on empirical observations of TRISO fuel behavior under irradiation.

Data should be obtained at VHTR reactor-relevant temperatures using the most prototypical un-irradiated and irradiated samples possible. In cases where no data currently exist (specifically, buffer strength, buffer elastic modulus, and buffer-IPyC bond strength), un-irradiated TRISO properties would be useful as a starting point. In that case, development and demonstration of methods to measure buffer strength and buffer-IPyC bond strength on un-irradiated, prototypic TRISO materials is valuable. For TRISO pyrocarbon studies, it is critical that properties data be determined as a function of neutron fluence and damage (dpa). If surrogate material specimens are produced and used for this research, then the specimen microstructure should be comparable to AGR fuels and their irradiation damage (dpa) should be comparable to AGR fuel irradiation campaign doses. The AGR program has irradiated hundreds of thousands of TRISO particles to burnups ranging from about 5% to 20 % fissions per initial metals atoms (FIMA), fast neutron fluences ranging from 1.0E25 n/m^2 to 4.5E25 n/m^2 (E > 0.18 MeV), and irradiation temperatures ranging from approximately 900 to 1250°C. Any data collected should encompass a realistic range of HTGR normal operations and accident temperatures and neutron fluence levels. All experiments and post-irradiation microscopy 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.T. Maki et al., "The challenges associated with high burnup, high temperature and accelerated irradiation for TRISO-coated particle fuel," J. Nucl. Mater. 371 (2007) 270-280.

[2] William F. Skerjanc, Blaise P. Collin, Assessment of Material Properties for TRISO Fuel Particles used in PARFUME," INL/EXT-18-44631, Rev. 0, 2018.

[3] 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.

RC-4.2: EFFECT OF NEUTRON IRRADIATION ON FISSION PRODUCT TRANSPORT THROUGH TRISO PARTICLE SILICON CARBIDE COATING LAYER
(FEDERAL POC – MADELINE FELTUS & TECHNICAL POC – PAUL DEMKOWICZ)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Research on neutron irradiation damage tolerance of silicon carbide (SiC) and SiC composites, used in various nuclear applications, such as tri-structural-isotropic (TRISO) fuel and SiC cladding for Accident Tolerant Fuel for light water reactors (LWR), has not investigated the irradiation-induced polymorphism effects in SiC. Recently, the Advanced Gas Reactor TRISO Fuel microscopy researchers have discovered that intra-granular precipitation of fission products in the TRISO SiC coating layer occurs because of a dual step nucleation mechanism that involves the cubic (β) to hexagonal (α) SiC polymorphic transition, and subsequent transition of α-SiC into fission product precipitates [1]. This intra-precipitation behavior has not been explained completely by any known nucleation mechanism, but may provide unique beneficial metallurgical traits for mitigating the effects of fission product precipitate damage (i.e., palladium that attacks SiC) in TRISO fuel during normal operations and higher temperature accident conditions, up to 1600 °C.

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Research proposals are sought that focus on neutron irradiation-induced polymorphism in the TRISO SiC coating layer using experimental methods and advanced microscopy (e.g. SEM, TEM) that compare un-irradiated and irradiated TRISO particles with different damage (dpa) levels, using the most prototypic SiC materials available from US Advanced Gas Reactor program sample archives. While the emphasis is on carefully designed experiments, comparison of results with computational models of SiC polymorphic transition effects on fission product transport as a function of neutron damage behavior is beneficial. Any data collected or equations developed should permit application to a realistic range of HTGR operations and accident temperatures and neutron fluence levels. All experiments, microscopy, and modeling tasks must be performed to NQA-1 standards. Data, experiments, computer modelling information, and calculations shall be submitted to the Idaho National Laboratory's NGNP Data Management and Analysis System (NDMAS).

[1] S. Meher, I. J. van Rooyen, and T. M. Lillo: A novel dual-step nucleation pathway in crystalline solids under neutron irradiation, Scientific Reports, 8 (2018) 98. Available at: https://www.nature.com/articles/s41598-017-18548-8.

RC-5: EXPERIMENTAL VALIDATION OF HIGH TEMPERATURE GAS REACTOR (HTGR) SIMULATIONS

(FEDERAL POC – DIANA LI & TECHNICAL POC – HANS GOUGAR)
(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.

One of the scenarios of interest to core designers and safety analysts is a break in the primary coolant boundary that leads to depressurization of the primary loop. If no mitigating action is taken, any oxygen remaining in the reactor cavity and surrounding building can enter the primary through the break and damage the graphite structures via oxidation. (The flow path within the primary loop also has a strong influence on the amount of air actually reaching the graphite core structures but this is particularly design dependent and beyond the scope of this call.) A full-blown 'double-ended guillotine break' of the primary coaxial coolant duct is a beyond design basis event and is not within the scope of this call.

The amount of cavity air entering the pressure vessel is a complex function of the primary helium inventory (which displaces, and mixes, with the air in the cavity), the break location, size, and orientation, and the venting pathways in the reactor building itself as these determine the fraction of air forced from the building during the blowdown and the rate at which fresh air would be subsequently replenished in the reactor cavity over long periods of time [1] as the reactor gradually cools. An experiment sponsored by the Department of Energy and the NGNP Alliance yielded preliminary results and insights but a full parametric study has yet to be performed. Of particular interest is the spatial distribution of air and helium in each reactor building cavity during the blowdown. The overall effects of reactor building vent path options should also be considered (i.e., venting from the top or bottom of the building cavity(ies)).

Parametric studies should investigate the concentration of oxygen in the vessel to various small and medium-sized breaks in the primary system (pressure vessel, crossduct, or steam generator vessel), the orientation of those breaks, and alternate ventilation pathways. Principal Investigators are encouraged to consider the recommendations of the NGNP Alliance contained in reference [2].

The General Atomics 350 MWt MHTGR [3] should be used as the basis for scaling the experimental facility.

Principal Investigators are encouraged to consult with US-based HTGR vendors (Framatome, X-Energy, USNC)

to refine the experiment design and test matrix.

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.

[1] 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.

[2] NGNP Deliverable to DOE: Project Recommendations – Evaluation and Testing of HTGR Reactor

Building Response to Depressurization Accidents, AREVA Document 12-9273530-00, July 2017.

[3] Preliminary Safety Information Document for the Standard MHTGR. Volume 1, United States: N. p., 1986. Web. doi:10.2172/712676.

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. All work performed for this call must be performed to NQA-1 standards.

RC-6.1: USED FHR PEBBLE FUEL STORAGE AND HANDLING (FEDERAL POC – DIANA LI & TECHNICAL POC – DAVID HOLCOMB) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Used FHR fuel pebbles will require cooling after removal from the core prior to being able to rely on natural circulation air cooling in dry casks. Also, the pebbles will need to be transferred from the outlet of the fuel handling system to the cooling/storage system, which may be in a separate low-leakage containment environment. FHR fuel pebbles will be both smaller and have higher heat loads than those of High Temperature Gas Reactors due to their higher overall fuel loadings. This call seeks evaluation of technologies that support safe and effective used fuel pebble handling and storage prior to dry storage. For example, light water reactors transfer used fuel assemblies to a spent fuel pool for storage until they are cool enough for dry cask storage.

For the FHR, development and validation of models and simulations of passively-safe, used FHR pebble storage and handling technology is requested. The simulations should include fissile materials accountancy including developing performance uncertainty estimates (see INL/EXT-12-26561 –"Safeguards-by-Design: Guidance for High Temperature Gas Reactors (HTGRs) With Pebble Fuel"). Provide enough detail to determine necessary storage times to meet requirements for dry storage, storage configuration of pebbles, and ensure there is sufficient capacity to store pebbles for the entire lifetime of the FHR. Evaluations should also identify any necessary modifications to existing used fuel storage/transport casks for storage of FHR pebble bed fuel. Additionally, this call seeks techniques for handling and safely storing cracked/broken pebbles.

RC-6.2: EXPERIMENTAL VALIDATION OF PASSIVE DECAY HEAT REMOVAL TECHNOLOGY (FEDERAL POC – DIANA LI & TECHNICAL POC – DAVID HOLCOMB) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

A key element of FHR passive safety is the ability to reject decay heat to the environment indefinitely following a station blackout event. While both Direct Reactor Auxiliary Cooling System (DRACS) AND Reactor Vessel Auxiliary Cooling System (RVACS) type decay heat removal mechanisms are possible for FHRs, FHR RVACS systems would be similar to those of other high-temperature reactors, which have been recently modeled at

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ANL's natural convection shutdown heat removal test facility - https://www.ne.anl.gov/capabilities/rsta/nstf/index.shtml.

Molten salt DRACS systems, however, have not previously been experimentally demonstrated. Demonstration of a reduced capacity, DRACS-type natural circulation decay heat rejection system employing prototypic materials and temperatures is requested. The system should include the ability to simulate cold start-up, normal reactor operations, transition to accident conditions, and extended duration operation and confirm the system will sufficiently remove heat without salt freezing. The system should also include tritium release mitigation mechanisms. System design, fabrication, and operation should be adequately documented to provide information that could be used in a 10CFR50 Appendix B program.

RC-7: MOLTEN SALT REACTOR TECHNOLOGIES

RC-7.1: FUEL SALT SAMPLING TECHNOLOGY DEVELOPMENT (FEDERAL POC – BRIAN ROBINSON & TECHNICAL POC – DAVID HOLCOMB) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

A key technology for MSR operations is the ability to sample the hot, highly-radioactive fuel salt and to introduce additional (e.g. fuel or redox control) materials. Key parameters such as the progress of corrosion, fissile material consumption and isotope distribution, fuel salt redox condition, and in-leakage of coolant salt can be assessed by measuring fuel salt composition. The Molten Salt Reactor Experiment (MSRE) employed a sampler-enricher to enable fuel salt access. While the MSRE's sampler-enricher was generally functional, it had less than desirable reliability. [1] Proposals are requested to develop and demonstrate, in a non-radioactive environment, a modern equivalent to MSRE's sampler-enricher with improved reliability and potential to serve as a technology model to guide deployment in future MSRs.

[1] R. B. Gallaher, Operation of the Sampler-Enricher in the Molten Salt Reactor Experiment, ORNL-TM-3524, October 1971, https://www.osti.gov/biblio/4731130

RC-7.2: EVALUATION OF 316SS LIFETIME IN MSRS (FEDERAL POC – BRIAN ROBINSON & TECHNICAL POC – DAVID HOLCOMB) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

MSR designers are considering employing mature iron-nickel-chrome alloys such as stainless steel 316 along with active salt chemistry control as their salt wetted structural material. Only limited amounts of corrosion are anticipated with 316SS given the low solubility of the alloy constituent elements (non-oxidative corrosion) provided the salt is maintained in a reducing condition. Nevertheless, the high salt temperature, neutron damage, and mechanical service requirements will cause the material properties to degrade over time. Moreover, both generalized and grain boundary corrosion are expected to weaken the surface making it more vulnerable to erosion. One of the key design properties for any molten salt heat transport system is the maximum allowable fluid velocity. Understanding material aging under service conditions will support establishing an evidence-based flow specification. Experimental projects are sought to evaluate the combined corrosion and mechanical stress impact on SS316 component service lifetimes and design limits.

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RC-7.3: RADIATION HARDENED VISION SYSTEMS
(FEDERAL POC – BRIAN ROBINSON & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

MSRs will need to perform remotely guided, highly-automated, operations and maintenance (O&M) with remote tooling. Maintenance was called out as an especially difficult problem for MSRs in the AEC's review of the MSBR in 1972. [1] Optically based systems remain the most important sensing modality for guiding remote O&M. A key element of enabling the automation system or the operator to perform tasks is to provide real-time 3D visual updates of the positioning of the tooling, components, and surround structures. Depending on the local shielding employed, the MSR containment environment may have very high radiation dose rates. Radiation hardened remote tooling and operations have been developed in support of O&M in multiple prior high-radiation environments. Relatively recently, the Spallation Neutron Source target handling facilities and ITER have developed radiation hardened remote O&M technology. Demonstration of a multi-camera, radiation hardened 3D vision system to continuously update the in-containment model status is requested. Demonstration of techniques to repair and/or replace vision system components within containment is also requested.

[1] U.S. Atomic Energy Commission Division of Reactor Development and Technology, An Evaluation of the Molten Salt Breeder Reactor, WASH-1222, September 1972

RC-7.4: MOLTEN SALT MECHANICAL FILTERS
(FEDERAL POC – BRIAN ROBINSON & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Fission products will be generated in fuel salt. Not all of the fission products will be soluble. Those that are not will be suspended in the salt and tend to plate out onto surfaces within the system. While plating out corrosion resistant materials onto surfaces would, to a limited extent, be considered a positive/protective effect, it is anticipated that reactor vendors will mechanically filter fission products out of the salt. Additionally, under certain conditions, fissile materials may also plate out onto filters. Sintered nickel is the leading candidate structure to serve as a mechanical filter. Filtering out radionuclides, however, has a number of complex interrelated issues such as monitoring filter condition and performance, introducing and removing the highly-radioactive filter (if not a lifetime component), cooling and shielding the filter once removed, and surveying the filter for fissile material control and accountability. Experimental projects are sought that demonstrate fuel salt mechanical filter performance and operational issues using non or low radioactivity materials.

RC-7.5: SHUT-OFF VALVE TECHNOLOGY DEVELOPMENT
(FEDERAL POC – BRIAN ROBINSON & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

MSRs rely on multiple barrier layers to provide defense-in-depth against radionuclide release. The primary coolant salt will be operated at a somewhat higher pressure than the fuel salt to cause in-leakage in the event of heat exchanger tube failure. Nevertheless, the primary coolant salt lines penetrate radionuclide containment layers providing a potential barrier bypass route. The ability to provide high reliability closure to the primary coolant salt lines on-demand, thus, decreases the risk of radionuclide release. These valves may be a safety-related item as they could be relied upon to mitigate the impact of postulated accidents. Consequently, it would be desirable for them to remain operable even under beyond design basis event conditions. High-reliability, molten salt, safety-related shutoff valves with local activation energy storage have not previously been developed or demonstrated. It is requested to design and demonstrate (on a molten salt flow loop) MSR coolant salt shutoff valves whose component technologies would be suitable for qualification under a 10CFR50 Appendix B quality assurance program.

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RC-8: PLANT MODERNIZATION R&D PATHWAY

RC-8.1: DIGITAL INSTRUMENTATION AND CONTROL QUALIFICATION (FEDERAL POC – ALISON HAHN & TECHNICAL POC – CRAIG PRIMER) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Digital I&C qualification continues to be a major impediment to addressing the reliability and obsolescence issues in legacy analog I&C systems for the operating LWR fleet. In particular, the issue of digital common cause failure (CCF) has been difficult to address and has been the reason some nuclear plant operators have deferred upgrades of these critical plant systems, opting rather to maintain them with costly engineering and maintenance efforts.

To enable the LWR fleet a path forward with digital upgrades, a qualification method to address CCF needs to be available. There are two proposed qualification methods that require further investigation. They are 1) Testability and 2) Elimination of CCF triggers. The focus of this research is to evaluate the Elimination of CCF triggers. This analysis should focus on determination of an approach that will ensure latent digital defects are not concurrently triggered in multiple digital functions that are assumed to be independent. The outcomes of research would be to develop qualification methods and processes that would potentially address the technical and regulatory aspects of digital qualification, with regard to digital CCF.

RC-8.2: ANALYTICS TO SUPPORT EQUIPMENT CONDITION MONITORING (FEDERAL POC – ALISON HAHN & TECHNICAL POC – CRAIG PRIMER) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Equipment monitoring is one of the main contributors to maintenance costs in nuclear power plants. Whether for diagnostics or prognostics, condition monitoring is mostly based on manual efforts to collect and analyze measurements using conventional sensors and methods. Decision making is driven by a combination of periodic inspections based on vendor specifications, industry standards, and human experience.

A need to automate the phases of data collection and analytics-based decision making has emerged to reduce the workforce cost, optimize the maintenance activities during normal operation and outage conditions, maximize the maintenance activities value, and reduce risk and human errors.
In line with the vision to automate the condition monitoring process, research will focus on identifying novel sensors, automation technologies, and data analysis methodologies for optimized condition monitoring in nuclear power plants. The results of this research will help the LWR fleet drive down the costs of maintenance by providing a scalable and adaptive data infrastructure solution needed to enable implementation of a risk informed maintenance program.

RC-9: RISK-INFORMED SYSTEMS ANALYSIS R&D PATHWAY

RC-9.1: USE OF INTEGRATED PRA AND MECHANISTIC TOOLS TO ACCELERATE DEPLOYMENT OF ADVANCED TECHNOLOGIES TO LWRS (FEDERAL POC – ALISON HAHN & TECHNICAL POC – RONALDO SZILARD) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Transformative nuclear technologies are at various stages of development aiming at improving the economic performance, while maintaining and enhancing the superior safety performance, of the existing fleet of nuclear

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power plants. These new nuclear technologies include, but are not limited to: accident tolerant fuel, increased enrichment and fuel discharge burnup, fuel cycle length extension, flexible operations, passive cooling, digital instrumentation and control upgrades, and for applications other than electricity generation. Advanced modeling and simulation tools can play an important role to accelerate the deployment of these technologies. The technological and economic risks associated with the deployment of these technologies need to be thoroughly evaluated in design to ensure they meet the safety goals of plants and achieve economic benefits needed before they are deployed. Risk assessments of nuclear power plants are typically performed by combining probabilistic risk assessment (PRA) methods with mechanistic analysis methods. PRA methods not only estimate risk metrics such as core damage frequency (CDF) or large early release frequency (LERF) but also determine what the most probable accident sequences are and the components that contribute the most to the overall plant risk. Mechanistic methods employ multi-physics simulation tools in order to assure that plant safety systems can prevent core damage condition for a given set of accident conditions.

The research of this call will be to develop and apply an integrated PRA and mechanistic simulation framework to reduce the time, cost and uncertainty associated with developing, demonstrating, and deploying new nuclear technologies including increased enrichment and fuel discharge burnup, flexible operations and extending the operations of existing nuclear power plants in non-electricity applications and markets. The resulting integrated evaluation framework should enable plant system configuration variations to be studied with speed and precision, including detailed risk and benefit assessments of introducing these advanced nuclear technologies into current LWR plants to achieve both safety and operational performance enhancements. Proposals that combine the analysis methodology development and experimentation into a unified approach to address key technical and economic challenges are strongly encouraged.

RC-9.2: RISK-INFORMED ASSET LIFE CYCLE MANAGEMENT AND MAINTENANCE OPTIMIZATION (FEDERAL POC – ALISON HAHN & TECHNICAL POC – RONALDO SZILARD) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Plant asset management consists of methods designed to reduce costs and manage plant financial risk. Such methods include a large variety of models and data including:

- System Structure and Components (SSCs) aging
- Test and maintenance data
- Long term capital asset management

The call is seeking research proposals designed to reduce nuclear power plant operational costs by identifying plant asset management data that is needed to develop tools for risk-informed insights that can improve plant asset management. Methods and tools will be developed to allow risk-informed integrated business case assessments for SSCs that can more effectively and efficiently address equipment performance. This may include the use of improved data analytics with a focus on their use and management of data that are currently available.

Proposals should address the development of advanced predictive and data analysis models. This research should integrate with the RAVEN statistical framework. Proposals should address the integration of results in a coherent plant asset management framework.

The proposals may also consider how to use the results to assist in ranking major capital refurbishment and replacement of SSCs for the lifetime of a plant, to risk-inform the capital improvements that includes assessment of expected useful life. The methods and tools will be used to develop an optimized schedule for capital replacement or refurbishment of major equipment for extended plant operations.

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RC-10: MATERIALS RESEARCH PATHWAY

RC-10.1: RAPID, MULTI-MODAL CHARACTERIZATION OF CONCRETE'S DEGRADATION TOLERANCE IN SUPPORT OF SECOND LICENSE RENEWALS OF NUCLEAR POWER PLANTS (FEDERAL POC – ALISON HAHN & TECHNICAL POC – KEITH LEONARD) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

Structural concrete components in nuclear power plants may face significant structural integrity challenges due to exposure to neutron and gamma irradiation, super-ambient temperatures, and moisture ingress. The concrete's tolerance to degradation in such environments is often dictated by the physical- and chemical-degradation of its aggregate constituents; i.e., as a function of their mineralogy, cement chemistry, etc. Existing protocols for degradation assessment, e.g., based on ASTM standards, are unsuited for assessing concrete's tolerance to degradation in such extreme environments.

Therefore, it is proposed to develop new science-based, rapid characterization methods that exploit multi-modal imaging, compositional analysis, and related methods to assess the tolerance of structural concrete and its constituents to degradation, i.e., especially in the context of second license renewal applications. Degradation modes of relevance include, but are not limited to irradiation damage resistance and chemical inertness at super-ambient temperatures in the presence of moisture. The systematic integration of pioneering experimental analyses with the integrated computational materials engineering software MOSAIC (Microstructure-Oriented Scientific Analysis of Irradiated Concrete) currently under development by the DOE Light Water Reactor Sustainability Program, for characterization method development and material analysis is highly encouraged.

RC-10.2: MODELING OF HELIUM BUBBLE DEVELOPMENT DURING WELDING OF IRRADIATED METAL ALLOYS

(FEDERAL POC – ALISON HAHN & TECHNICAL POC – KEITH LEONARD)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Welding is commonly used during repair and upgrades of nuclear components. However, as the service lives of nuclear reactors are extended, the amount of transmuted helium in reactor structural materials increases, eventually reaching levels at which conventional welding technologies cannot be used reliably. Helium induced cracking in the heat affected zone has been observed at helium concentration levels below 10 atomic parts per million, a level that can be reached after approximately 40 - 60 years of operation depending on material and location. While friction stir welding and an advanced variation on laser welding are being evaluated for the repair of irradiated materials in the DOE Light Water Reactor Sustainability Program, a fundamental understanding of the effect of weld heat input on the diffusion and coalescence of helium on grain boundaries in the heat affected zone for a given material and weld conditions are not well known. Proposals are sought for a comprehensive model of helium bubble growth on grain boundaries for a given material condition (type, microstructure, reactor aging condition) and heat input (welding technique), that accounts for transient high temperature stresses generated during welding and grain boundary cohesivity, to provide industry with a clear evaluation of what weld techniques and parameters should be considered in the repair of reactor components. Validation of model under combined temperature and stress conditions are essential in the research effort. Materials of interest include type 304L and 316L stainless steel as well as alloy 182 weld metal.

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RC-11: SPECIAL PURPOSE REACTORS R&D
(FEDERAL POC – REBECCA ONUSCHAK & TECHNICAL POC – SHANNON BRAGG-SITTON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $400,000)

The Advanced Reactor Technologies Program supports technology development efforts for MW-class, very small modular reactors (e.g., <20 MWt). These "special purpose reactors" are of interest for potential national security and deployable (terrestrial) power applications for defense, commercial, or industrial use.

Applications are sought for technologies that support portable compact reactors that would be used in a microgrid configuration. Topics of interest only include technologies with features specific to special purpose reactors. Some specific areas of interest include use of advanced manufacturing to support factory manufacture of reactor and system components, reducing the time and cost associated with fabrication and assembly of the energy system; advanced instrumentation and control approaches that support semi-autonomous or autonomous control; and novel power conversion systems, static or dynamic, that improve on the current state of the art, as well as the associated heat exchanger designs. Specific technology proposals could be relevant to conversion of heat from a fission heat source to electrical power and/or direct use of heat for other applications (e.g. district heating, water purification, hydrogen generation, synfuels production, etc.).

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MATERIAL RECOVERY AND WASTE FORM DEVELOPMENT (FC-1)

This program element develops innovative methods to separate reusable fractions of used nuclear fuel (UNF) and manage the resulting wastes. These technologies, when combined with advanced fuels and reactors, form the basis of advanced fuel cycles for sustainable and potentially growing nuclear power in the U.S.

FC-1.1: ELECTROCHEMICAL SEPARATIONS
(FEDERAL POC – STEPHEN KUNG & TECHNICAL POC – MARK WILLIAMSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

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. We are seeking proposals 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-1.2: MATERIALS RECOVERY
(FEDERAL POC – DAN VEGA & TECHNICAL POC – TERRY TODD)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Solvent Extraction Chemistry and Radiation Chemistry
Aqueous recycling of used nuclear fuel using the PUREX process is being used industrially for several decades. However fundamental knowledge and understanding of the chemical speciation and partitioning of multivalent cations (e.g. Np, Tc, Zr) in advanced PUREX based extraction process using n-Tri-Butyl-Phosphate (TBP) as solvent under high gamma irradiation fields is required to improve processes being currently studied such as CoDCon (ConDeContamination process). Gamma radiation is known to produce radicals that can affect the oxidation states of multivalent cations in solution. This research effort will provide insight into the speciation of multivalent cations under gamma irradiation dose as well as the effects of the speciation on partitioning in a tri-butyl phosphate separations process (e.g. PUREX, COEX, CoDCon, etc).

FC-1.3: WASTE FORMS DEVELOPMENT AND OFF-GAS CAPTURE
(FEDERAL POC – KIMBERLY GRAY & TECHNICAL POC – JOHN VIENNA)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

FC-1.3a: ADVANCED WASTE FORM DESIGN, PROCESSING, AND TESTING - High-level waste (HLW) from separated commercial nuclear fuels will need to be processed into durable waste forms with predictable long-term performance. The international reference treatment technology is vitrification into borosilicate glass that is known to have many advantages including ease of processing and tolerance to variation in waste compositions. Modern nuclear fuel recycling processes generate HLW with narrow variation in composition compared to past U.S. practices with defense reprocessing. As a result, ceramic waste forms can be an effective means of immobilizing newly generated HLW. In addition, modern materials fabrication techniques may enable low cost processes to fabricate HLW forms applicable to high radiation environments (e.g., low handling, easy containment, minimal access to fine particles).

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The focus of this research is to develop a robust waste form for commercial fuel recycling HLW stream and demonstrate low-cost processing methods that are applicable to high radiation environments. The successful waste form would allow for higher waste loadings than typical HLW glass compositions and be processable in plants with lower construction (e.g., size) and operating (e.g., manpower) costs.

FC-1.3B: IODINE CAPTURE FROM HIGHLY OXIDIZING OFF-GAS STREAMS – US regulations could require the removal of both iodine and tritium from the off-gas stream of a used nuclear fuel (UNF) reprocessing facility. Advanced tritium pretreatment is a pretreatment step that uses high concentrations of NO_2 (60% to 80%) in a gas stream to volatilize tritium and iodine from the oxidized UNF prior to traditional dissolution. The gaseous effluent from this process would then require treatment to remove tritium and iodine, but high levels of NO_2 could have a detrimental effect on the ability of various solid sorbents to remove the volatile radionuclides. For iodine, the sorbents considered have been reduced silver mordenite (Ag^0Z), silver-functionalized silica-aerogel (AgAerogel), and silver-nitrate-impregnated alumina (AgA). Prior research has demonstrated that exposure to high concentrations of NO_2 can reduce the iodine loading capacity of Ag^0Z by > 90% when exposed for 1 week. Research in Japan has demonstrated that AgA is more robust to NO_2 exposure than AgZ, however, iodine capture tests in a recirculating high NO_2 system indicated only limited recovery with the iodine depositing elsewhere in the system. The focus of this research effort is the development of a robust iodine sorbent for use in this highly oxidizing environment. Characteristics of a suitable sorbent material include rapid adsorption kinetics, high iodine loading (> 5-10% by weight), low cost, very high iodine retention once loaded, high radiation stability, and producible in a mechanically-robust, engineered form. The proposed iodine loaded sorbent material must also have a direct pathway to a suitable waste form for ultimate disposal in a deep geologic repository.

ADVANCED FUELS (FC-2)

FC-2.1: POST IRRADIATION EXAMINATION (PIE)/NON-DESTRUCTIVE EXAMINATION (NDE) TECHNIQUES FOR CORROSION THICKNESS MEASUREMENTS ON ATF CLADDINGS (COATED-ZR, FECRAL, SIC)

(FEDERAL POC – FRANK GOLDNER & TECHNICAL POC – JASON HARP)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Proposals are solicited for techniques or a suite of techniques that can be applied to evaluate the surface oxide, surface layer adhesion and sub-surface features, such as micro-cracks and delamination, for a wide variety of accident tolerant cladding concepts. Techniques developed should be demonstrated to work in a remote, high radiation environment. Signals from the demonstrated techniques should travel greater than 30 feet from sensor to data collection equipment and must pass through a hermetically sealed feedthrough.

Coating adhesion and oxide layer thickness are both important parameters that need to be evaluated for new candidate cladding materials for light water reactors. Coated zirconium cladding is a leading candidate for near term deployment in light water reactors. The coating layer provides coping time benefits in the event of a severe accident. The in-pile corrosion and adhesion properties of coated Zr are not currently known. After irradiation the extent of corrosion and adhesion can be evaluated destructively with optical microscopy, but the sampling frequency of this technique is quite small. Another near-term cladding concept is FeCrAl alloys. This material generates different oxide layers depending on the chemistry of the oxidizing conditions. Composites of SiC are also being investigated and these composites generate very thin oxide layers in pressurized water conditions. The SiC-based cladding concepts also can contain various sub-surface interfaces and the integrity and damage accumulation at those interfaces will be a performance aspect that must be examined and quantified.

The oxide layer on zirconium alloys has typically been evaluated with Eddy Current. However, this technique typically requires a new set of sensors for every new substrate, and the response of eddy current sensors to ferritic

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substrates is quite different from non-ferritic substrates. This technique is also only applicable to conductive substrates. Presently, eddy current also cannot distinguish between voids and oxide growth.

New or next-generation non-destructive techniques to evaluate both the thickness of oxide formed on the surface and the internal structure for all of these cladding concepts during steady state reactor operations are sought. Additionally, techniques for the evaluation of the adhesion of these coatings and/or oxides and/or sub-surface damage in the event of accident operations are also solicited.

FC-2.2: Studies on Accident Tolerant Control Rods and Core Components (FEDERAL POC – FRANK GOLDNER & TECHNICAL POC –MIKE TODOSOW) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

In response to the accident at the Fukushima Daichi nuclear power plant, a significant effort was initiated by the Department of Energy, Office of Nuclear Energy (DOE-NE) in the Advanced Fuels Campaign (AFC) to develop fuels with enhanced accident tolerance, aka "Accident Tolerant Fuels (ATFs)," defined as:

> *Fuels with enhanced accident tolerance are those that, in comparison with the standard UO_2 – Zr system, can tolerate loss of active cooling in the core for a considerably longer time period (depending on the LWR system and accident scenario) while maintaining or improving the fuel performance during normal operations.*

Much of the focus to-date has been on fuels and cladding to address these objectives. However, it is recognized that retention of "functionality" of other core components, including control rods and components that affect the structural integrity/geometry of the core are also critical to successfully surviving/limiting the consequences of Beyond Design Basis Accidents (BDBAs), as well as normal operation, Anticipated Operational Occurrences (AOOs) and Design Basis Accidents (DBAs)

Proposals are sought for the neutronic, and thermo-mechanical impacts of potential future advanced materials for BWR and PWR control rods that retain/enhance the poisoning effects/requirements (worth – individual and bank, etc.) while maintaining structural integrity/functionality (e.g, ability to insert/ withdraw) during normal operation and accident conditions (temperatures, cooling, etc.). Also, materials and associated studies sought are those that address retention of the structural integrity/geometry of the core which depends on the ability of components such as grid spacers, core support plate, etc. to retain "functionality" during normal operation and accident conditions. Consultation with existing DOE-NE ATF related programs in this area is encouraged/desirable.

FC-2.3: INVESTIGATIONS INTO NON-TRADITIONAL SOLID FUELS FOR ADVANCED NON-LIGHT WATER 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 for advanced non-Light Water reactors are presently under investigation for numerous applications. Uranium-zirconium (U-Zr) metallic fuels and mixed oxides (MOX) have been the reference fuels for the majority of historic advanced reactor concepts. Both U-Zr and MOX fuel forms have myriad benefits, but in addition both possess limitations as nuclear fuels. Alternate advanced 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. Examples of alternative advanced reactor fuels include U-Mo alloys, uranium monocarbide (UC), and uranium mononitride (UN). In addition, encapsulated fuel including TRISO particles has been proposed for various novel reactor designs, fast gas-cooled reactors and non-traditional applications. Each of these alternative

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advanced reactor fuel forms have seen limited assessment and evaluation. The limited attention paid to these and other advanced reactor fuels have resulted in slowed deployment of modern experimental and simulation tools to better understand their capabilities, uncertainties, and limitations in service.

The present call intends to stimulate broad responses that address aspects of lesser known and novel fuels for advanced reactors through leveraging of modern experimental methods and capabilities as well as modeling and simulation tools. Focus should be restricted to fuel for the following previously-defined advanced non-Light Water Reactor Concepts: High Temperature (or Very High Temperature) Gas-cooled Reactors, Lead-cooled Fast Reactors, Gas-cooled Fast Reactors, Sodium-cooled Fast Reactors and Fluoride Salt-cooled High Temperature Reactors. TRISO-like and/or encapsulated fuel particle research beyond traditional thermal high temperature helium gas-cooled TRISO-fueled reactor applications will be considered and could include: (a) alternative fuel kernels (UN, UC, MOX, TRU), (b) different coating and matrix materials besides SiC and graphitic materials, (c) novel TRISO fuel and its chemical/corrosion compatibility for use in non-water, non-helium coolant reactors, and (d) fast gas-cooled reactor applications. Traditional TRISO fuel (UO2, UCO) for thermal spectrum high temperature helium gas-cooled high-temperature reactors will not be considered.

Research objectives need to be clearly defined and appropriate for the technical readiness level of the fuel and overall technical challenges to its advancement. It is anticipated, but not required, that both experiments as well as the use of modern modeling and simulation tools will play important roles in a successful proposal. Focus may be placed on addressing either a major challenge of a single component of the fuel or extended to include the fuel/cladding/coolant system. Irradiation testing and/or post irradiation examination of fuel concepts are advantageous (if applicable to the area of study) but not required, and new methods of analyzing archival post irradiation data may constitute a component of proposed work. While the potential topic areas for the present call are broad, it will be critical that the proposed work clearly articulates the key unknowns or challenges that limit further advancement of the chosen concept and how the proposed work will surmount these challenges if successful. Any proposed research on thorium-based fuel concepts will not be considered.

FC-2.4: ADVANCED CREEP TESTING OF FERRITIC STEELS FOR REACTOR CLADDING APPLICATIONS
(FEDERAL POC – JANELLE EDDINS & TECHNICAL POC – STUART MALOY)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Long term use of fuels for advanced reactors can lead to thermal and irradiation creep of fuel cladding and other stressed structures. In addition, creep can be a contributor to dimensional changes under accident conditions in a light water reactor. Typical out of pile (thermal) creep testing requires long times (many years) and large sized specimens. Although significant testing has been performed to measure the creep of HT-9 and some oxide dispersion strengthened ferritic alloys (e.g. MA-957) for cladding applications, little data is available on newly developed ferritic alloys (ODS, FeCrAl, and tempered martensitic variants) partly because of the long time required to perform this testing.

Thus, proposals are requested to measure the thermal creep of advanced fuel cladding relevant ferritic steels using methods requiring shorter evaluation times and possibly smaller scale specimens. Proposed work should apply these improved methods to measuring thermal creep of new alloys for cladding applications such as FeCrAl alloys, ferritic ODS alloys or tempered martensitic alloys. This data is not only important experimental data but also critical to the development of multiscale models. Priority will be given to proposals that show how the data will be incorporated into relevant multiscale models. It will be advantageous (but not required) if the proposed method(s) used to measure thermal creep can also be applied to measuring irradiation creep in situ.

PROGRAM SUPPORTING: FUEL CYCLE TECHNOLOGIES

FC-2.5: SEPARATE EFFECTS TESTING IN TREAT USING STANDARD TEST CAPSULES (FEDERAL POC: KEN KELLAR & TECHNICAL POC: DAN WACHS) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $500,000) (NSUF LETTER OF INTENT REQUIRED)

The response of materials (especially those containing fissile isotopes) often exhibit complex behavior while under irradiation. The presence of this complexity in multiple component fuel systems can make prediction of integral response of fuel designs very difficult to achieve, especially when the fuel is subjected to new environmental conditions or when the components are placed in new configurations. The unreliability of predictive calculation, and the concomitant requirement for comprehensive empirical validation testing, has been a significant barrier to technical innovation in nuclear fuel designs for decades. To break this barrier, 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.

Reactivation of the Transient Reactor Test (TREAT) facility creates a unique opportunity to implement this new approach. 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.

Proposals are sought 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).
This call is designated for university led investigations only. Proposals studying materials associated with high-program-interest technologies will be given the highest priority.

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, NEAMS-2, 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.

PROGRAM SUPPORTING: FUEL CYCLE TECHNOLOGIES

ADVANCED DATA INTEGRATION FOR DOMESTIC NUCLEAR SAFEGUARDS (FC-3)
(FEDERAL POC – MIKE REIM & TECHNICAL POC – MIKE BROWNE)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Molten Salt Reactor (MSR) research has continued to increase over the past 10 years. The potential safety benefits and cost savings of a comparatively simple design with respect to current commercial power reactors shows promise. However, significant research is required to establish and assess nuclear material accountancy (NMA) for liquid fueled MSRs. Specifically, online processing to remove fission products poses potential NMA challenges in a homogenous fuel/coolant system to confirm that uranium and plutonium are not diverted in the processing. Modeling efforts to quantify whether such diversions can be detected by investigating reactor response to the change of isotopic composition would benefit NMA assessments. Research proposals are sought to develop initial NMA models for simple homogenous liquid fuel MSR design with online fission product removal. University contributions are sought to:

- Utilize models to quantify observable reactor performance to isotopic composition
- Work with U.S. National Laboratory collaborators to identify potential NMA challenges

USED NUCLEAR FUEL DISPOSITION (FC-4)

FC-4.1: USED NUCLEAR FUEL 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 proposals 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 nuclear waste repository). DOE will also consider proposals 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 understanding of barrier system performance and the optimization of repository performance.

Research proposals 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

PROGRAM SUPPORTING: FUEL CYCLE TECHNOLOGIES

improved models (including uncertainties) to represent the waste container/package long term performance.

- Improved understanding of large-scale hydrologic and radionuclide transport processes in the geosphere of relevant disposal repository environments, leading to the development of improved methodologies and models (including uncertainties) to represent these processes.

- 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 new techniques for in-situ field characterization of hydrologic, mechanical, and chemical properties of host media and groundwater in a disposal system.
- 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.

- Development of new and cost-effective concepts (in different geologic media -- clay/shale, salt, crystalline rock, and tuff) for sealing repository openings (e.g., shafts, tunnels, wells) to facilitate repository closure and provide required long-term waste isolation and performance.

- Identification and assessment of innovative and novel buffer materials, new methods and tools for multi-scale integration of flow and transport data, new approaches for characterization of low permeability materials, state-of-the-art tools and methods for passive characterization and monitoring of engineered/natural system component properties and failure modes and their capability to isolate and contain waste.

FC-4.2: USED NUCLEAR FUEL 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 as a potential safety concern. The welding procedure introduces high tensile residual stress and sensitization in the heat-affected zone (HAZ), which may drive the initiation of pitting and transition to SCC growth when exposed to an aggressive chemical environment. Analysis of samples surface deposited on in-service DSCs at three near-marine ISFSIs sites have demonstrated the presence of chloride-rich salts on the outer canister surfaces (Enos et al. 2013, Bryan and Enos, 2014, EPRI, 2014, Bryan and Enos, 2015). As portions of the canister surfaces cool sufficiently, the marine atmospheric salts may deliquesce and generate an aqueous brine layer on the surface of the canisters at various locations. This aggressive environment may lead to pitting, SCC, and potentially a through-wall failure in the weldments of the canisters.

One strategy to reduce the potential for a through-wall crack is to develop repair and mitigation technologies for the identified pitting and cracks. The main incentive for development of repair and mitigation technology is to avoid the enormous cost of canister replacement, and significant safety related issues during the replacement process. The development of cost-effective repair and mitigation technologies would ensure the continuation of long-term performance of dry storage casks at ISFSIs. Development of crack repair techniques using advanced welding repair technologies in combination with advanced mitigation technologies to prevent or minimize future pitting or SCC would be essential to maintain and/or restore the mechanical integrity of the canisters under extended service conditions. Both the repair and mitigation techniques must be capable of in-service repair on loaded

PROGRAM SUPPORTING: FUEL CYCLE TECHNOLOGIES

systems, which requires low heat input, no spark source, and acceptable external forces to avoid significant reduction in mechanical strength, ignition of potential hydrogen gas inside the canister, and deformation of the canister during the repair process.

Research proposals are sought to support the understanding of the phenomena of the pitting and cracking and the efficacy of the repair and mitigation technologies for the identified pits and cracks. Key university research contributions could include one or more of the following:

- Develop numerical models and simulations for pit incubation and growth, and/or crack initiation and growth in the range of the stress, microstructure, and environmental conditions anticipated in the HAZ.
- Develop numerical models and simulations for possible repair and mitigation tehnologies in the range of the stress, microstructure, and environmental conditions anticipated. Develop empirical validation techniques for the numerical models and simulations.

FC-5: FABRICATION PROCESS ASSESSMENTS FOR COST ALGORITHM (FEDERAL POC – BP SINGH & TECHNICAL POC – FRANCESCO GANDA) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

The Systems Analysis and Integration Campaign is developing algorithms for estimating the cost of nuclear energy facilities and sub-systems in a bottom-up evaluation approach. Proposals are sought for methods for assessing the complexity and cost of fabrication of large mechanical components with an "N-stamp" as opposed to standard construction, including the complexity and costs of all the steps involved in the fabrication and delivery to customers: i.e., forging, welding, machining, inspections and transportation to site, and all the necessary paperwork. The developed capability should be of direct use to the Campaign's tool-set and so there is expected to be a close interaction with national laboratory technical personnel during the project to ensure adequate integration.

FC-6: INTERFACE TOOLS FOR TRANSMUTATION DATA LIBRARY (FEDERAL POC – BP SINGH & TECHNICAL POC – MICHAEL TODOSOW) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $800,000)

In FY18 the Systems Analysis and Integration Campaign implemented an initial version of a MySQL database of fuel cycle reactor stage information. A *stage* is a complete nuclear power production subsystem, and a complete *fuel cycle system* can have more than one stage, e.g., multiple reactor types. The database consists of legacy data, including reactor stage descriptions, isotopic information, and potentially cross sections, developed by the Campaign and its predecessors, as well as data from the Nuclear Fuel Cycle Evaluation and Screening (E&S). Additionally, the database integrates other fuel cycle reactor stage transmutation information from recent analyses, such as those performed to provide information about the possible transition to a new nuclear fuel cycle.

Proposals are sought to develop portable linkage interfaces between the database and cross section generation tools, e.g. SCALE or MC2-3, and/or depletion tools, e.g. REBUS or ORIGEN, develop automated tools for verification of the data and validation of the reactor stage models, implement novel ways to utilize and/or visualize the data, generate linkages to fuel cycle simulator tools, or other novel developments. These efforts must include and follow a software quality assurance plan and must be made available to the Campaign. There is expected to be a close interaction with national laboratory technical personnel during the project to ensure adequate integration. This interaction will include providing access to the existing MySQL database to the project team.

MISSION SUPPORTING: FUEL CYCLE TECHNOLOGIES

MS-FC-1: MAINTAINING AND BUILDING UPON THE HALDEN LEGACY (IN SITU DIAGNOSTICS) (FEDERAL POC – KEN KELLAR & TECHNICAL POC – COLBY JENSEN) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $400,000)

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 include, but are 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.

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

SEPARATE EFFECTS IRRADIATION TESTING FOR VALIDATION OF MICROSTRUCTURAL MODELS IN MARMOT (NEAMS-2)

(FEDERAL POC: DAVE HENDERSON & TECHNICAL POC: RICH WILLIAMSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(NSUF LETTER OF INTENT REQUIRED)
(UP TO 3 YEARS AND $500,000)

Requests are sought for innovative, separate effects irradiation tests of nuclear fuels and/or materials that would provide data important to informing and validating mechanistic, microstructure-based models of fuel behavior under development using MARMOT, the NEAMS tool for simulating microstructure evolution under irradiation. MARMOT models under active development are summarized under NEAMS 1.1 and in the MARMOT Assessment Report. Fuel systems of interest for which separate effects experiments are desired are the LWR fuel system (*i.e.*, both the historic UO2 fuel and Zirconium-based cladding, as well as emerging Accident Tolerant Fuel concepts) and the SFR fuel system (*i.e.*, U-Zr and U-Pu-Zr metallic fuel and steel-based cladding).

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, NEAMS-2, 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.

PROGRAM SUPPORTING: NUCLEAR ENERGY

NUCLEAR ENERGY-CYBERSECURITY RESEARCH TOPICS AND METRICS ANALYSES (NE-1)
(FEDERAL POC: TREVOR COOK & 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.

Proposals 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.

Proposals are also sought for exploring secure architectures for use in nuclear facility's digital instrumentation and control systems. Important attributes of these "secure" architectures are: eliminate or minimize common cause failure including common access attacks (access to one component of a system enables corruption of another component of the system or systems), eliminate various classes of cyber attacks (including cyber attacks that are enabled through supply chain attacks), architectures that could be resilient to a cyber attack if infiltrated, development of intrusion detection capabilities for these architectures, architectures that will allow for upgrading various components of the overall system without degrading performance or safety, architectures that are easily modeled with sufficient fidelity to support regulatory acceptance criteria, and architectures that can be manufactured in a cost effective manner.

HYBRID ENERGY SYSTEMS DESIGN AND MODELING (NE-2)

- Advanced nuclear-renewable hybrid energy systems (NHES) composed of nuclear and renewable energy sources, industrial energy users, and energy storage systems are being evaluated for their economic benefit and technical feasibility.

NE-2.1 STUDIES OF COMPONENT/SYSTEM DEGRADATION
(FEDERAL POC – MARTHA SHIELDS & TECHNICAL POC – SHANNON BRAGG-SITTON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Characterization of dynamic energy system behavior via modeling and hardware-in-the-loop (HIL) testing to capture real-time dynamic response behavior and to determine the impact of thermal cycling on components and subsystems as it relates to component and system robustness, resiliency, response rates, etc.

NE-2.2 CYBER-INFORMED SYSTEM DESIGN
(FEDERAL POC – MARTHA SHIELDS & TECHNICAL POC – SHANNON BRAGG-SITTON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Development of enhanced communications protocols that link grid operations by regional transmission

organizations / independent system operators (RTO/ISO) to tightly coupled integrated systems operations to ensure that data transmission is sufficient to support optimal energy dispatch. Work should include development of front-end-controllers and associated control theory to support optimal dispatch of nuclear plant generated thermal energy to either electricity production for the grid or to support coupled non-grid processes (via thermal or behind-the-grid electrical connection). Cyber-informed engineering should be incorporated into the respective levels of data transmission and management, human monitoring and control performance, control signal processing, and device level control actions. Studies should include control hardware in-the-loop (CHIP).

NE-2.3 SYSTEMS CONTROL
(FEDERAL POC – MARTHA SHIELDS & TECHNICAL POC – SHANNON BRAGG-SITTON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Develop predictive load and supply forecasting (e.g. using predictive agent-based models) to optimize energy dispatch in real time for integrated energy systems. Note that this work should involve development of system control technology/approaches.

MISSION SUPPORTING: NUCLEAR ENERGY

INTEGRAL BENCHMARK EVALUATIONS (MS-NE-1)
(FEDERAL POC: DAVE HENDERSON & TECHNICAL POC: JOHN BESS)
(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 qualityassured (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 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. To avoid duplication, please take into account ongoing work in these recent projects:

- An Integrated Research Project awarded under IRP-NE-1 in FY15 to prepare one or more TREAT transient testing benchmarks;
- Integral Benchmark Evaluation Projects awarded under MS-NE-1 in FY16 for a Molten Salt Reactor Experiment Benchmark Evaluation; and,
- Integral Benchmark Evaluation Projects awarded under MS-NE-1in FY17 for Reactor Physics Benchmark Evaluations for Power Burst Facility Experiments.
- Integral Benchmark Evaluation Projects awarded under MS-NE-1in for evaluation of TRIGA fuel characterization measurements for inclusion in the IRPhEP handbook.

NUCLEAR DATA NEEDS FOR NUCLEAR ENERGY APPLICATIONS (MS-NE-2)
(FEDERAL POC: DAVE HENDERSON & TECHNICAL POC: BRAD REARDEN)
(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.

Proposals 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.

Proposals 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. Partnerships with national laboratories and especially industry to clearly articulate the need for the data and to demonstrate the use of improved data in production applications are strongly encouraged.

To avoid duplication, please take into account ongoing work in these recent projects:

- Generation of thermal scattering law data for graphite and molten salts
- Generation a data format and sensitivity analysis methods for uncertainties in thermal scattering law data (see https://neup.inl.gov/SitePages/FY18_RandD_Awards.aspx)

MISSION SUPPORTING GRAND CHALLENGE (MS-NE-3)
(FEDERAL POC – TBD & TECHNICAL POC – TBD) (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 proposal'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: Workscopes for U.S. University-, National Laboratory-, or Industry-led* Program Supporting R&D Projects

*Industry may only lead in NSUF workscopes

PROGRAM SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

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

The Advanced Methods for Manufacturing program seeks proposals for research and technology development to improve the methods by which nuclear equipment, components, and plants are manufactured, fabricated, and assembled. Proposals 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 such as advanced (high speed, high quality) welding technologies; and modular 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 engagement with consensus standard organizations.

The most up-to-date information on active AMM projects can be found in the 2018 NEET Advanced Methods for Manufacturing Awards Summaries on the NE website under NEET documents.

ADVANCED DIGITAL MONITORING AND CONTROL TECHNOLOGY (NEET-2)

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 proposal should indicate whether and how the proposed technology is or may be applicable to multiple reactors or fuel cycle applications, i.e. crosscutting. Proposals 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.

PROGRAM SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

NEET-2.1: STATE OF THE ART I&C TECHNOLOGIES
(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 research, develop, and design state of the art I&C technologies for advanced control rooms and plant control and protection systems for advanced reactors in order to:

- Reduce I&C testing, validation and verification efforts associated with licensing requirements for common cause failure, design basis accidents, and cybersecurity, through methods that would support advance reactor safety features, such as passive safety.
- Rad-Harden electronics for digital based components. (e.g. PLC and FPGAs)
- Automate and enhance plant operation, such as remote operations or single control room workstation.

NEET-2.2: ADVANCED ONLINE MONITORING AND DIAGNOSTICS TECHNOLOGIES
(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 online monitoring for nuclear plant operation and maintenance to be integrated into new nuclear reactor designs. Applicants should:

- Demonstrate an optimal balance between cost and plant performance through a cost-benefit analysis for achieving reliability, availability, maintainability, and security.
- Integrate predictive analytics and risk informed condition monitoring, with business process applications, which would enable a transformational approach to supply chain and asset management.

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 develop and demonstrate new sensors and instrumentation for advanced plant control, data analytics, and nuclear applications for advanced reactors. Applicants should:

- Develop advanced instrumentation and communication of data located in higher temperature, higher radiation reactor core environments found in advanced reactors.
- Develop smart multimodal measurement devices to measure unique and complementary parameters simultaneously.
- Develop new or unique application of materials for sensor development that support monitoring, controls, and communications within harsh nuclear reactor environments.
- Develop new radiation resistant sensors not currently under development for measurement of:
    - Local radiation and temperature (e.g. solid-state detectors, diamond thermistors)
    - Dimensional changes (specifically diameter and volume) and crack propagation,
    - Material properties, such as thermal conductivity, mechanical properties, thermal expansion, etc.)
    - Fission gas release (pressure and composition).
    - Other in-core parameters important to reactor safety and/or fuel performance.

PROGRAM SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

DIGITAL/ELECTRONIC NUCLEAR FIELD SUPPORT TECHNOLOGY (NEET-3)
(FEDERAL POC – SUIBEL SCHUPPNER & TECHNICAL POC – CRAIG PRIMER)
(ELIGIBLE TO LEAD: UNIVERSITY OR NATIONAL LABORATORY)
(UP TO 3 YEARS AND $500,000)

The Advanced Sensors and Instrumentation program seeks conceptual design applications for innovative technology for digital/electronic field support systems for nuclear facilities. These technologies should be

integrated and seamless able to enhance current state of the art technology used at nuclear facilities for real time measurements such as:

- Visual inspections and accountability
- Area radiation monitoring via remote monitoring or as part of personnel dosimetry
- Access and location monitoring – personnel access and security tracking
- Field worker "Head Up Display" to provide design/engineering information

The proposal should indicate how the proposed technology is or may be applicable to a nuclear facility. It should provide a plan for technology development and demonstration after the completion of this project.
Proposals 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.

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

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

NOTE: FC-2.5 and **NEAMS-2** require NSUF access but can only be led by universities. Those workscopes can be found on page 77 and 81.

This workscope 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 workscope 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 workscopes. Applications submitted under this workscope 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 proposals 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 OR ADVANCED SENSORS FOR NUCLEAR APPLICATIONS
(FEDERAL POC: SUIBEL SCHUPPNER & TECHNICAL POC: BRENDEN HEIDRICH)
(ELIGIBLE TO LEAD: UNIVERSITY, NATIONAL LABORATORY, OR INDUSTRY)
(UP TO 3 YEARS AND $500,000)

Proposals 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: BRUCE LANDREY)
(ELIGIBLE TO LEAD: UNIVERSITY, NATIONAL LABORATORY, OR INDUSTRY)
(UP TO 3 YEARS AND $500,000)

Products from advanced and innovative manufacturing and welding 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.

NUCLEAR SCIENCE USER FACILITIES (NSUF-2)

NUCLEAR SCIENCE USER FACILITIES ACCESS ONLY (NSUF-2)
(FEDERAL POC: TANSEL SELEKLER & TECHNICAL POC: RORY KENNEDY)
(ELIGIBLE TO LEAD: INDUSTRY ONLY)

Applicants interested in utilizing Nuclear Science User Facilities (NSUF) capabilities only should submit "access only" applications under this workscope. 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 at Idaho National Laboratory. More information on computational resources available through NSUF can be found at https://nsuf.inl.gov/. NE is seeking proposals 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 workscopes 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. Proposals 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. Proposals 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. Proposals 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.

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, NEAMS-2, 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: Workscopes for U.S. University-led Integrated Research Project (IRP) R&D

PROGRAM DIRECTED: NUCLEAR ENERGY

INTERNATIONAL CHALLENGE PROBLEM FOR NUCLEAR ENERGY (IRP-NE-1)
(FEDERAL POC –JANELLE EDDINS & TECHNICAL POC – BOB HILL)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $3,000,000 TOTAL U.S. PROJECT COST)

Background: The United States and Japan participate in a bilateral collaboration for R&D, the Civil Nuclear Energy R&D Working Group (CNWG). Both countries would like to explore measures to strengthen the U.S. Japan collaboration through an initiative to facilitate the use of a nuclear facility sharing. The initiative would be to support university researchers in the nuclear field to pursue bilateral research activities and in the process would allow greater access to use of research facilities in each country. This IRP request solicits proposals that would address nuclear research needs and also include participation of Japanese researchers (primarily from universities) on the IRP team.

IRP Goal and Objectives:

The Goal of this IRP request for proposals is to solve a significant problem which presents a challenge to expanded use of nuclear energy worldwide. The main objective of the IRP is to support education, development and training in multiple technical disciplines associated with the use of nuclear energy. The IRP requires participation by both U.S. and Japanese researchers.

IRP Scope:

Applicants must address the numbered elements listed below to be considered responsive to this IRP request for proposals.

1) Define a problem which presents a challenge to expanded use of nuclear energy worldwide. Examples of such problems are provided below:

    - Materials in GEN-IV reactors share a common environment extreme of irradiation but experience a dramatically different coolant environment (liquid metal, molten salt, etc.). While there is a relatively good understanding of material behavior in a separate irradiation or corrosion condition in some coolants, there is limited knowledge of material performance in coupled extremes of irradiation and corrosion, which dictates the safety of nuclear power plants and the development of future nuclear reactors. A fundamental understanding of the synergistic irradiation and electrochemical processes on material degradation mechanisms in various reactor environments using advanced experimental and computational tools is needed to predict the continuously evolving material properties over the reactor lifetime and to develop material design strategies to enhance their performance in advanced reactors.

    - Fuel-related safety criteria will be affected by changes to the fuel design as Accident Tolerant Fuel (ATF) concepts are developed. A key criterion that will be affected is the LWR fuel burn-up limit relating to fuel/cladding system response to reactivity initiated accidents (RIAs) and to loss-of-coolant accidents (LOCAs). One aspect that governs burnup limits is the ballooning and tearing of cladding under a RIA. In order to prepare for and assess impacts of ATF fuel changes on such safety criteria, improved understanding is needed of phenomena governing LWR fuel burnup limits. Techniques to facilitate 'accelerated or simulated aging' as an efficient assessment path for new metallic cladding, e.g. coated zircaloy and FeCrAl, concepts will also need to developed and validated.

PROGRAM DIRECTED: NUCLEAR ENERGY

- Improved accident tolerance for light water reactors or advanced reactors. Accident tolerance is intended to mean, elimination of the need for operator intervention and/or off-site emergency response for at least 72 hours without significant core damage. This work could include fuel cladding improvements, fuel design or modifications of the reactor internals.

- Construction and operating costs of a sodium-cooled fast reactor system could be reduced while maintaining or enhancing the safety of the power plant, e.g., by dramatically simplifying the design, improving performance, or by using advanced materials, such that the reactor system is at least cost competitive with currently available light water reactors, although it would be desirable to be even less expensive, on a per kW-hr basis. Significant experimental work to justify approaches such as less costly material selections and reduced margins in certain areas is needed to support development of these more cost competitive options. Considerable cost analysis work would be needed to show expected cost savings of a SFR design.

- Addressing important fuel cycle challenges including materials degradation, processing, safeguarding of nuclear facilities, and radioactive waste reduction will advance options for treatment of radioactive nuclear waste and reduction of waste activity and volume. Specific needs include the following:

  (1) Evaluation of radiation effect/degradation of the materials to be used in the fuel cycle facilities. The separation solvents such as ligands and molten salts are examples.

  (2) Development of remote monitoring system for nuclear materials and FPs in high temperature and high radiation field for enhancing the safeguard of nuclear facilities such as future fuel cycle facilities.

  (3) Development of innovative process to reduce radioactive waste by separation/removal of radionuclides such as actinides/fission products from spent fuel and waste materials.

The applicant can choose any or more than one of the above problems or define one on their own – however, the Applicant must elaborate on their understanding of the problem and how it meets the goal and objective of this request for proposals.

2) This IRP imposes International Collaboration Requirements with Japan which are in addition to those specified elsewhere in the Consolidated Innovative Nuclear Research Funding Opportunity Announcement (FOA).

   a. The project team must include at least two Japanese educational/research institutions. The team must include a lead Principal Investigator from a United States educational institution and personnel form a U.S. national laboratory. The scope of work for each collaborating institution must be clearly defined. The project team shall include a Co-Principal Investigator from Japan.
   b. All U.S. funds provided under this award must be used to support the efforts of the educational institutions and their non-university partners in the United States.
   c. Participation by Japanese researchers will be funded by the Government of Japan. Such funding should include at least one of the programs designated for funding by the Government of Japan. The point of contact for information regarding designated funding programs for Japanese researchers, Japanese facilities that could be used for potential projects, and Japanese University points of contact is Shoji Kasuga (kokusai-genshiryoku@mext.go.jp).

PROGRAM DIRECTED: NUCLEAR ENERGY
3) Facility Sharing: Nuclear Science User Facilities (NSUF) under the DOE Office of Nuclear Energy offers a wide range of material irradiation (reactors and ion beams) and material characterization facilities, and nuclear materials and fuels library. These facilities and resources would be of great interest to Japanese researchers. In return, Japan can make available their material research facilities to US researchers and share expertise and resources, beneficial to both parties. Facility use may include R&D/material irradiation for development of next generation nuclear reactors designs, nuclear fuel and/or materials. 4) The Applicant must describe how any intellectual property generated under the project will be handled. 5) Proposals are required to include collaboration with a Japanese University. 6) Project Deliverables: The list of proposed project deliverables must include: a. A detailed project schedule. b. If a software is developed as part of the project, a verification and validation plan for each software. c. A final project report which includes (i) A statement of the problem and a description of the solution (ii) The extent to which the problem was solved and remaining or follow-on work needed (iii) A description of the extent to which the project was successful in supporting education, development and training in multiple technical disciplines associated with the use of nuclear energy and (iv) Lessons learned and suggestions that can be used by DOE-NE and Japan in future work.

PROGRAM DIRECTED: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION

EXTEND NEAMS TOOLS TO SUPPORT THE DEVELOPMENT OF THE VERSATILE TEST REACTOR (VTR) EXPERIMENTAL PROGRAM (IRP-NEAMS-1)
(FEDERAL POC – DAVE HENDERSON & TECHNICAL POC – CHRIS STANEK)
(UP TO 3 YEARS AND $4,000,000)

Advanced (non-LWR) reactors aim for significant advances in sustainability, safety, reliability, economics and non-proliferation. DOE supports the development of reactor concepts with improved economics for both electricity production and industrial applications. Many of the advanced reactor concepts being considered have wide-ranging coolant choices such as liquid metals (sodium, lead, lead-bismuth eutectic), helium, and molten salts are based on operation under fast spectrum. To address this priority, the DOE's Versatile Test Reactor (VTR) project is investigating a fast-flux irradiation facility that supports the experimentation and testing of a wide variety of fuel forms, materials, and advanced sensors for advanced nuclear energy systems. The initial concept for the VTR is a 300 MWth pool-type, sodium-cooled, metal fuel fast reactor system containing several static testing locations, closed loops (for experiments with different coolants), and rabbit systems. The VTR instrumentation suites and analytic capabilities will potentially result in petabytes of data over the next few decades. This presents a rare opportunity for modeling and simulation to both support the design of experiments as well as perform high fidelity analysis of experiments by correlating experiment response with the environmental conditions. Establishing and executing a modern strategy to simulate experiments and analyze measurement data is central to maximizing the impact of the entire VTR experimental program.

The goal of this Integrated Research Project (IRP) is to develop a tightly coupled research platform that enables comprehensive understanding of the multi-scale and multi-physics performance of the VTR reactor experiments through intelligent feedback between simulations and experiments. The primary focus of this effort is to extend the applicability and utility of the NEAMS tools to provide support in the development of the VTR Experimental Program through a tightly coupled collaboration between the selected IRP team, NEAMS, and the VTR Experimental group. The confluence of advanced modeling and simulation methods, data science and analytics, machine learning, and the exponential growth of computation capabilities have proven a powerful platform for modern scientific research and engineering. The VTR project presents a unique opportunity to integrate a modern data technology platform into the base design of a new advanced nuclear testing system.

The large IRP team effort should support both of the following two specific tasks:

1) **1) Accelerate extension of NEAMS computational tools to simulation of metallic fuel behavior and performance relevant to VTR and similar advanced reactor concepts, to include both high-fidelity and fast-running capabilities as needed.** Fast reactor fuels are typically designed to reach higher burnup than LWR fuels to take advantage of higher initial fissile loading and the breed-and-burn characteristics. Furthermore, swelling of materials is generally considerably greater in a fast neutron spectrum. Therefore, during the operation of an advanced reactor concept, the fuel assembly and rods may be subject to fast neutron irradiation induced swelling, thermal and irradiation creep, mechanical stresses from internal fission gas pressure, fuel handling and loading, thermal stresses from temperature gradients, flow-induced vibration and fretting, and fuel-cladding chemical and mechanical interactions. The fuel models must account for the impact of these factors on the integrity of the fuel assemblies and rods to assure that fuel system dimensions remain within operational tolerances and functional capabilities are maintained.

   Another important consideration is the analysis of fuel performance during anticipated operational occurrences and the postulated accidents that introduce an imbalance between the heat production and removal. The fuel design should provide assurance that the fuel is not damaged during the anticipated operational occurrences, and potential fuel damage during postulated accidents is not so severe that the core coolability is maintained and fuel damage does not propagate.

   The limiting performance concern for the metallic fuel rods during accidents is creep rupture of the cladding, accelerated due to fuel-cladding chemical interaction (FCCI). The mechanisms that influence

PROGRAM DIRECTED: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION

FCCI in metallic fuels are fuel constituent migration, cladding attack by lanthanide fission products, and inter-diffusion between the fuel alloy and cladding, all eventually contributing to the formation of a low-melting point interaction product at the fuel-cladding interface. Since these processes are temperature and burnup dependent, fuel models should be able to predict fuel failure probability or margin to fuel failure as a function of burnup, fission-gas-plenum pressure, fuel-cladding interface temperature, and duration of a reactor transient during which the fuel is exposed to temperatures above the normal range.

Another critical need for advanced fuel modeling and simulation is validation, as a much as possible using existing relevant data, such as metallic fuel irradiation experiments performed in EBR-II and FFTF, and transient fuel testing at TREAT. DOE's ART Fast Reactor Methods, Modeling and Validation R&D Program has been supporting development of EBR-II and FFTF metal fuel irradiation and physics analysis databases to collect and collate data needed to aid qualification of metallic fuel for future advanced reactor applications and validation of state-of-the-art codes and advanced methods for design and analysis of fast reactors. The selected experiments cover the range of fuel performance information, including prototype fuel behavior and failure mode during operational scenarios, fabrication parameters, lead tests, high temperature swelling behavior, and fuel-cladding mechanical interaction to demonstrate the viability of advanced metallic fuel forms for the U.S. vendors considering or designing advanced reactors using metallic fuels. The TREAT Test Database also covers the key metallic fuel experiments for margin to failure assessments.

Therefore, this task must include the following two important focus areas.

- Mechanistic model and transient simulation developments that incorporate or enhance capabilities for key phenomena, including
  - Fuel and cladding temperature distribution (as calculated by the NEAMS neutronics and thermal-hydraulics analysis tools),
  - Fuel-to-cladding and cladding-to-coolant heat transfer,
  - Axial burnup distribution in the fuel,
  - Thermal conductivity of the fuel and cladding for fresh and as-irradiated fuel,
  - Thermal expansion of the fuel and cladding,
  - Fission gas production, transport, and release,
  - Production and transport of lanthanide fission products,
  - Solid and gaseous fission product swelling,
  - Fuel constituent redistribution,
  - Cladding strain due to internal fission gas pressure and fuel-cladding mechanical interactions, and
  - Thinning of the cladding due to fuel-cladding chemical interactions.
- Validation of new models by leveraging the available EBR-II, FFTF, and transient fuel testing data that are relevant to both the VTR project as well as industry end-users.

2) **Accelerate coupled Neutronics and Thermal-Hydraulic Analysis capabilities to support the VTR experimental program and related advanced reactor commercialization.** Various uncertainties are involved in the predictions of reactor design parameters, which include theoretical and experimental analysis uncertainties, instrumentation uncertainties, manufacturing tolerances, correlation uncertainties, and method and simulation uncertainties. In order to assure integrity of fuel elements and reactor structures, and ultimately to protect the health and safety of the public and environment, the fuel, cladding, and coolant temperatures should not exceed the design limits with sufficient margins.

To that end, it is difficult to pin-point the exact eutectic formation temperature of a metallic fuel in an SFR because fuel-cladding eutectic formation is a complex phenomenon affected by fuel compositions, temperature, and irradiation histories. Thus, to account for theoretical and experimental uncertainties, the design limit of the eutectic formation temperature is lower than the value determined

PROGRAM DIRECTED: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION

theoretically or by empirical corrections. On the other hand, the peak cladding temperature increases from the nominal calculation to account for the stochastic errors of cladding thickness and compositions from manufacturing tolerances and uncertainties from modeling and simulations. After considering all uncertainties, the difference between the design limit and the peak cladding inner-wall temperature is defined as the minimum margin.

The gap from the nominal peak cladding inner-wall temperature to the eutectic formation temperature minus the minimum margin to limit denotes the uncertainties that are involved in the calculation of the design parameter, and in order to count the uncertainties in the reactor design, so-called hot channel factor methods have been developed and utilized since the early days of civil nuclear plant development. The hot-channel factor for a particular design parameter is defined by the ratio of the maximum value of that parameter to the nominal value. It is noted that the difference between the maximum value and nominal value is due to the uncertainties that are involved in calculating that parameter. If a factor is greater than unity for a particular parameter, the decimal part (i.e., HCF minus one) represents direct or stochastic uncertainties in the parameter.

In the United States, sets of hot-pin/channel factors have been developed for the Fast Flux Test Facility (FFTF), Clinch River Breeder Reactor (CRBR), and Experiment Breeder Reactor II (EBR-II), but additional attempts have not been made since these early SFR development programs were canceled in the mid-1990s. Development these factors with limited computing power and approximations in modeling and simulation methods resulted in the prediction of neutronics and thermal-hydraulic parameters with relatively large uncertainties, where some uncertainties could only be quantified by expensive experiments. The high-fidelity and multi-physics capabilities of the NEAMS program, accompanied by remarkable progress in the computing technologies during the last few decades, now make it possible to calculate most design parameters without support of mockups or experiments and reduce uncertainties significantly compared to the uncertainties involved in the earlier designs. Reduction of the uncertainties allows an increase in nominal parameters and safety margin, which in turn improves the economic competitiveness of the new designs.

Therefore, a key focus area will be application of NEAMS multiphysics analysis capabilities to the calculation of hot-pin and hot-channel factors, where the overall mature capability is expected to subsequently support the VTR experimental effort and help meet certain advanced reactor concept commercialization needs.

NEAMS codes, particularly those for fuels, neutronics, and thermal-hydraulics analyses, will be used in Tasks 1 and 2, as needed for the focus areas described in this scope. Should analyses be included in a proposal addressing aspects adjunct to the focus areas outlined in Tasks 1 and 2 (e.g., systems analysis), use of NEAMS codes would also be required. NEAMS code information may obtained from the Technical POC for this scope, as well as from the NEAMS website, https://neams.inl.gov/SitePages/Home.aspx. Proposals should include coordination by the IRP team with the NEAMS team and VTR project experimental groups.

PROGRAM DIRECTED: FUEL CYCLE

IRP-FC-1: USED NUCLEAR FUEL DISPOSITION: STORAGE & TRANSPORTATION (FEDERAL POC – JOHN ORCHARD & TECHNICAL POC – PETER SWIFT) (ELIGIBLE TO LEAD: UNIVERSITIES ONLY) (UP TO 3 YEARS AND $5,000,000)

Introduction

Dry storage of commercial spent nuclear fuel (SNF) is regulated by the U.S. Nuclear Regulatory Commission under Title 10 of the *Code of Federal Regulations* (10 CFR), Part 72 "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste." Some of the requirements under 10CFR72 are to prevent gross degradation of the cladding, maintain confinement of the radioactive material, and to maintain subcritical conditions, in part by maintaining the configuration of the spent fuel dry cask storage system (DCSS) internals (e.g., cladding, assembly hardware, and basket). An inert environment is desired to meet these requirements. This inert environment is obtained by removing the water from the cask and drying the SNF using either a vacuum drying or forced gas dehydration process (see for example ASTM C1553-16 "Standard Guide for Drying Behavior of Spent Nuclear fuel"). It is important to understand and quantify how much residual water may remain in a DCSS following drying.

Background

NUREG–1536, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility," states that an accepted method for vacuum drying of canisters is to evacuate to a pressure less than or equal to 4×10^{-4} MPa [3 torr], with demonstration that the canister will maintain a constant pressure for 30 minutes after being isolated from the pumping system. Often, industry will evacuate to pressures much less than 4×10^{-4} MPa [3 torr] and consider the drying process complete if the pressure remains below 4×10^{-4} MPa [3 torr] when isolated from the pumping system for 30 minutes. However, the pressure may be increasing due to both temperature increase and off-gassing or vaporization of remaining water. Many factors such as materials of construction (e.g., porous neutron poison materials), local and total decay heat load, temperature variations in the system, rate of evacuation including hold points (important to prevent icing), assembly design (grid spacers, dashpots, instrument tubes, water tubes, etc.) and the presence of damaged fuel rods may affect the effectiveness of the drying process.

Objective

This IRP is meant to build upon and expand on, not duplicate, the work performed by a recently completed IRP at the University of South Carolina. The objective of this IRP is to quantify the amount of unbound liquid water and the amount of water vapor that remains in a canister following drying performed according to typical industry practices, both vacuum drying and forced gas dehydration. In particular, the sensitivities of the effectiveness of drying on the various factors listed above, with a major emphasis on the role of large thermal gradients in the system, is to be determined.

Considering these challenges, the research needs of this IRP shall include all the following:

- **Fuel Assembly Mockup**

  To undertake these tests, a vacuum drying system and a forced-gas dehydration system similar to those used in the industry should be acquired or built, then employed on specialized canister and fuel assembly mockups. The fuel assembly mockups shall physically represent locations where water could be difficult to remove from prototypic assembly designs (e.g., pressurized water reactor 17x17 and boiling water reactor 10x10 assemblies). These should include breached rod(s) with the size and location of the holes based on operational experience for damaged fuel. Other locations shall include the dashpot region of the guide thimble tubes for pressurized water reactor assemblies, water rods for boiling water reactor assemblies, and creviced regions associated with assembly hardware such as grid spacers, nozzles, and tie plates. The guide thimble tube shall also include a mock-up rod (representing a burnable poison rod, control rod or poison rod)

PROGRAM DIRECTED: FUEL CYCLE

inserted in the guide tube to partially block the guide tube.

As needed, multiple mockups may be employed to represent different assembly designs or the range of features from different designs may be incorporated in a single mockup. The mockup shall be kept at full-length and shall have the ability to be heated to represent the decay heat load of SNF. The total decay heat shall be capable of being varied to represent both aged (long-cooled) and young (two years cooled) SNF. The thermal profile of the mockup shall be variable to simulate those found in actual SNF DCSSs.

- **Canister Mockups**

Full-sized canister mockups are not required for the test program, but they shall be able to accommodate full-length mockup assemblies. Canister mockups could be fabricated from pipe segments or other cylindrical structures fitted with bolt-on lids to allow for insertion and removal of the mockup assembly. Except for any modifications that are needed for making measurements, the ports for connection between the canister and drying system, as well as the configuration of the vacuum siphon tube, should be similar to those in industry systems. Heaters, internal or external, or insulation may be used to develop both axial and radial temperature gradients similar to those found in SNF DCSSs. Accurate measurements of the temperature profiles in the system are required. Similarly, the canister system pressure must be recorded from the start of the drying process, through the pressure rebound test, after He backfill, and until a thermal equilibrium is achieved.

- **System Testing**

The tests will involve the performance of drying operations in a manner consistent with industry practice, after which the quantity of water, both as liquid and as vapor, remaining in the canister will be determined. In a series of drying runs, specific variations of certain parameters should be made to quantify how these affect the quantity of residual water. Methods for quantifying the remaining water shall be validated and multiple methods are preferred to determine the sensitivity and accuracy of each method.

Vacuum drying is typically performed in a stepwise approach to progress down in pressure, thereby reducing the likelihood of ice formation by limiting the pumping speed and providing time for the system to equilibrate. Within the industry procedures, however, there are differences in specifications such as the number of hold points and the end pressure. Therefore, the drying runs must include variations in these parameters to envelop the range of industry standard practices. Forced-gas dehydration tests should include a range of inert gases (He, N, etc.) consistent with those used in practice. Variability in gas temperature and pressure shall be included in the testing matrix for the forced-gas dehydration tests.

While individual, separate effects tests may be run, drying sensitivity studies shall be performed on a system that has been fully flooded for at least 48 hours prior to performing the drying operation.

TASKS TO BE PERFORMED

- **Task 1:** Development of Test Plan
- **Task 2:** Development of Analytical Models for Drying Simulation
- **Task 3:** Setup and Verification of Test System
- **Task 4:** Performance of Drying Tests
- **Task 5:** Complete Project Report

DELIVERABLES

Specific deliverables shall include:

- **Approval of Test Plan by an Independent, External Review Committee that contains DOE and industry representatives**
- **Quarterly Progress Reports**
- **External Review Committee Review every 6 months**
- **Final Project Report**

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. The 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 is more complex than requesting R&D funding through this FOA. Figure E-1 depicts the process for requesting NSUF access. Note that NSUF rapid turn-around experiments are not part of this FOA.

Unlike the other workscopes 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) and 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 after the pre-application. A Final SOW will be submitted prior to the full application. As 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
- 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
- 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 D 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 facilities performing the work defined the in SOW and experiment execution plan.

NSUF Quality Assurance Requirements

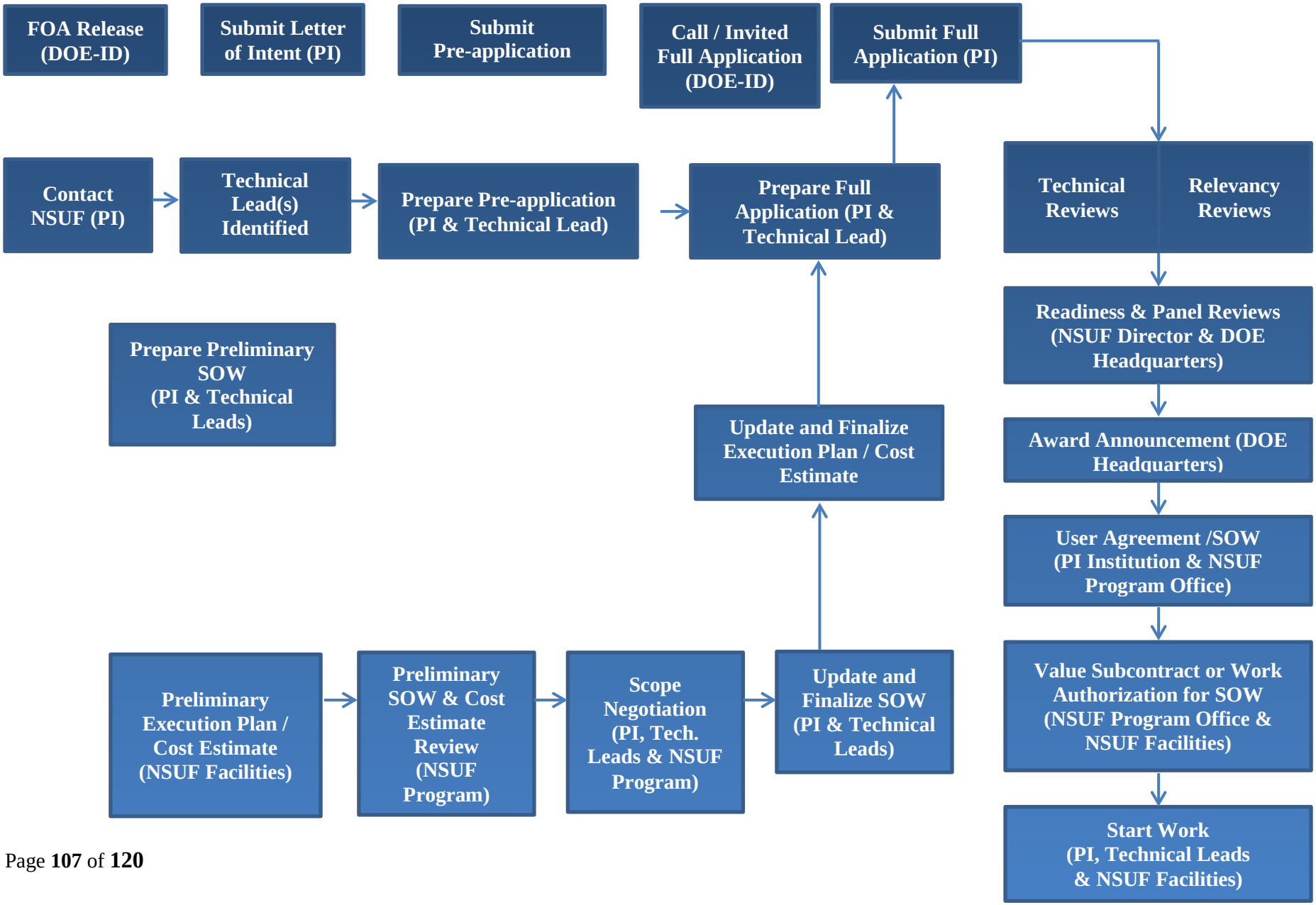
Irradiation of materials in test reactors requires additional rigor and quality assurance requirements beyond those described in other sections of this FOA. Specific requirements will depend on the reactor license, the irradiation vehicle design and specimen constituents. NSUF Technical leads will assist 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, FC-2.5 and NEAMS-2 workscopes in this FOA or via another fund source for NSUF-2 workscopes:

- 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
- Materials and supplies support at the PI's work location

Figure E-1. Process for NSUF applications.



Appendix E: Draft Nuclear Science User Facilities User Agreement

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 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.**