FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

U. S. Department of Energy

Idaho Operations Office

Fiscal Year 2016 Consolidated Innovative Nuclear Research
Funding Opportunity Announcement:
DE-FOA-0001281

Announcement Type: Initial 8/7/2015 Draft
Amendment 00001 (8/13/2015)
Amendment 00002 (8/18/2015)

CFDA Number: 81.121

Informational Webinar: August 10–12, 2015
(Video links and presentations will be made available at www.neup.gov)

Issue Date: August 13, 2015

Letter of Intent (Mandatory only for NSUF Applications)
Due Date: August 27, 2015 at 8:00 p.m. ET

Pre-Application (Mandatory except for IRPs and MS-EM-1)
Due Date: September 17, 2015 at 8:00 p.m. ET

IRP Application
Due Date: December 3, 2015 at 8:00 p.m. ET

Full Application
Due Date: February 18, 2016 at 8:00 p.m. ET

Amendment 00001 – The purpose of this amendment is to release the final Funding Opportunity Announcement (FOA) document, included are all updated workscopes associated with this FOA.

Amendment 00002 – The purpose of this amendment is to update Appendix C, workscope IRP-FC-1, to now allow 4 year projects under this scope. Also, some minor edits were made in the header on Appendix C to be consistent with that section. The pagination at the footer was also corrected. Finally, title corrections were made to the FC-2.1 and FC-2.2 workscope areas:

- **FC-2.1: Coupling Experimental Data with Advanced Modeling and Simulation**
- **FC-2.2: Advanced Reactor Metallic Fuel**

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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
FY	Fiscal Year
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
NE	Office of Nuclear Energy
NEAMS	Nuclear Energy Advanced Modeling and Simulation
NEET	Nuclear Energy Enabling Technologies
NEUP	Nuclear Energy University Programs
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
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 (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 advanced reactors and fuel cycle concepts while maximizing the impact of DOE resources.

NE strives to promote integrated and collaborative research conducted by national laboratory, university, industry, and international partners under the direction of NE's programs. 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 Programs (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-, university- and industry-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. In addition to the consolidation of the NSUF Call for Applications (CFA) for access to capabilities, NEUP or NEET CTD projects requiring irradiation testing and/or post-irradiation examination (PIE) may include no-cost access to NSUF capabilities through a single application response to this FOA.

NE reserves the right to respond to potential shifts in R&D priorities during Fiscal Year (FY) 2016 that may be driven by events, policy developments, or Congressional/budget direction. NE will factor such considerations into decisions related to the timing and scale of award announcements associated with this FOA. Further, NE reserves the right to fund all or part of an application to this FOA with programmatic funds.

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 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 nuclear wastes have been fully implemented. Additionally, it is desired that advanced nuclear fuel and 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 burnup 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 results of the evaluation to stakeholders.

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

The mission of the RC RD&D program is to develop new and advanced reactor designs and technologies that broaden the applicability, improve the competitiveness, and ensure the lasting contribution toward meeting our Nation's energy and environmental challenges. Research activities are designed to address the technical, cost, safety, and security issues associated with various reactor concepts. The four technical areas are Light Water Reactor Sustainability (LWRS), Small Modular Reactors (SMR), Advanced (Non-Light Water) Reactor Concepts and Advanced SMRs.In addition, R&D for the development and manufacturing of radioisotope and fission power systems for national security and space exploration missions is supported through the Space and Defense Power Systems Program.

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

The mission of the NEAMS program is to develop and deploy the NEAMS ToolKit, comprised of advanced computational tools, for use by government, industry, and academia in nuclear R&D, design, and analysis. 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. The NEAMS ToolKit spans length scales from atomic to mesoscale to continuum, and time scales from picoseconds to seconds to days. NEAMS tools are currently being used to help evaluate advanced nuclear fuels and reactor concepts, design and analyze nuclear fuel experiments, and explore potential breakthroughs in the use of transient test reactors.

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, improving its competitiveness and promoting 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. The knowledge generated through these activities will allow NE to address key challenges affecting nuclear reactor and fuel cycle deployment with a focus on cross-cutting 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 cost-free access to state-of-the-art experimental irradiation testing and PIE facilities as well as technical assistance including the design and analysis of reactor experiments. NSUF and its partner facilities represent a prototype laboratory for the future. 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 no-cost access to designated capabilities at the following facilities:

- Idaho National Laboratory
- Center for Advanced Energy Studies Microscopy and Characterization Suite (MaCS)
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Illinois Institute of Technology
- Massachusetts Institute of Technology
- North Carolina State University
- Purdue University
- University of California, Berkeley
- University of Michigan
- University of Nevada, Las Vegas
- University of Wisconsin, Madison
- Westinghouse Materials Center for Excellence.

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

IMPORTANT NOTE: Applicants requesting R&D financial support with a joint request for NSUF access will be limited to the workscopes in NEET-NSUF-1. Applicants will no longer be allowed to couple NSUF access to any workscope. Workscopes in NEET-NSUF-1 have been tailored to align NSUF capabilities with focused NE program and mission priorities. Applicants

requesting NSUF Access Only will apply to the NEET-NSUF-2 workscope, a broader workscope focused on NE mission priorities and also tailored to align with NSUF capabilities.

A.2.6 NSUF Sample Library

The NSUF sample 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 sample library materials to develop research concepts. The catalog of available materials is available under the "User Resources" tab located at http://nsuf.inl.gov/default.aspx?Page=Sample%20Library&cat=1&Display=5&id=222. In order to continue the expansion of the sample 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 sample library. In addition, all specimens remaining after three years of PIE will be moved into the sample library. Principal Investigators (PIs) of all future awarded applications to study non-generic or non-standard 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 non-generic or non-standard specimens for potential collaboration.

NSUF capabilities are described in detail at http://nsuf.inl.gov.

B. FUNDING OPPORTUNITIES

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

Specifically, this FOA contains four 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 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 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 Appendix A of this FOA.

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

These funding opportunities are available to teams led by either U.S. university, national laboratory, or U.S.-incorporated industry PIs. 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 Appendix B of this FOA.

B.2.1 Note for Nuclear Science User Facilities Access Projects

NSUF access project applications will 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 in addition to the relevancy and technical reviews. Very important aspects of NSUF access applications are described in Appendix E 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 proposing researcher to support salaries, tuition, travel, and other costs typically supported via NE Program R&D funds.

All awarded NSUF access projects will be fully funded for the entire duration of the project. NSUF access project attributes:

- 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 NEET-NSUF-1 workscope
- U.S. universities, national laboratory and industry PIs may apply for only NSUF access without a joint request for R&D financial support as stated in the NEET-NSUF-2 workscope

NSUF R&D projects may have a R&D component that is complemented by the unique capabilities of NSUF. The R&D portion of the project cannot exceed $500,000. Eligible workscopes for a NSUF R&D project are found in Appendix B and applications must comply with the provisions of Appendix E. Since NSUF projects involving reactor neutron irradiation 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.

Projects not requiring R&D financial support may apply for NSUF access only projects in response to this area of the FOA and the associated workscopes contained in Appendix B of this FOA, wherein only no-cost access to capabilities are sought to perform research in nuclear science.

Additional information on the NSUF process is included in Appendix E.

B.3 U.S. University-led IRP R&D

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 Appendix C of this FOA.

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

- 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" 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 Integrated Research Project (IRP) R&D"

DOE has significant interest in leveraging multiple needs to the extent possible. Accordingly, Appendix D provides a description of key data needs for validating advanced modeling and simulation tools being developed by NE. Researchers should evaluate their applications in light of these data needs and highlight any potential for capturing key data.

NOTE: While NE continues to evaluate potential infrastructure investments, NE has committed to fund NE related access to the Intermediate Voltage Electron Microscope (IVEM) facility at ANL through at least September 30, 2016.

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.

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 $40 million in awards for this FOA area.

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

DOE currently estimates that it will fund approximately $12 million in awards for this FOA area.

B.2.1 Nuclear Science User Facilities Projects

DOE currently estimates that it will fund approximately $5.7 million in award value for this FOA area.

B.3 U.S. University-led IRP R&D

DOE currently estimates that it will fund approximately $21 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-, National Laboratory-, or Industry-led PS/MS 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.
- MS: up to $500,000 (3-year project).

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):
Full 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 R&D

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 up to approximately 40 awards under this area.

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

DOE anticipates making up to 15 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 IRP R&D

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-, National Laboratory-, or Industry-led PS/MS R&D Projects

DOE anticipates that R&D awards will be up to $1,000,000/award for PS projects and up to $500,000/award for MS projects (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 PI) will fall within the following ranges:

- Irradiation only: $500K to $1.0M
- Full Irradiation /PIE: $500K to $4.0M
- Beamline or PIE only: $50K to $750K.

E.3 U.S. University-led IRP R&D

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 3 years for each area with the exception of ***IRP-FC-1 and IRP-FC-2, which may take up to 4 years, as well as NEET-NSUF-1 and NEET-NSUF-2 awards under Appendix B, which may take up to 7 years.*** Assuming DOE makes awards under this FOA by September 2016, successful applications shall begin no later than October 1, 2016; 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, 2016, 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.

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. The following link provides the current list of MSI: http://www.ed.gov/about/offices/list/ocr/edlite-minorityinst.html.

In Appendix A and C, no more than 20% of the total funds provided by the government can go to a non-university collaborator.

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 form.**

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 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-Operated Government-Owned 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.

[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.

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

2. U.S. Incorporated Foreign Entities

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) 910.214.

3. Incorporated Consortia

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

4. Unincorporated Consortia

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

5. Application Restrictions

The following application restrictions apply:

- PIs with a currently funded IRP; who have three or more R&D projects that will still be active after December 31, 2016 or who have a no-cost extension on any DOE-NE funded project (excluding Infrastructure) which will still be active beyond December 31, 2016, are ineligible to apply to any area of this FOA as a lead PI, but are eligible to participate as a collaborator.
- An academic PI cannot be included in more than six pre-applications with no more than three applications as the primary PI.
- PIs cannot submit an application to multiple workscope areas.
- A PI may have no more than one IRP or three R&D projects funded at any time, and may therefore not submit more full applications than would be allowed by these restrictions should these applications be selected for funding.
- Applications submitted in response to PS and/or MS research requested by the NEET CTD are limited to three pre-applications per institution per workscope area. If an academic PI is designated as the lead, these submissions will count toward the above overall university researcher limitation of being associated with no more than six pre-applications total in response to all areas of this FOA, with no more than three of those associations being as the lead PI.

- 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, 2016. 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.

B. COST SHARING

For applications led by universities, cost sharing is encouraged, but not required. If cost sharing is provided, see 2 CFR 200 for the applicable cost sharing guidance and Part VIII, Section H below.

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.)

The DOE/NNSA FFRDC contractor cost is not included in the total approved budget for the award, because 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: Letter of authorization 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 field work proposal (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	$40,000,000	$800,000	Up to 3 years	Encouraged 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			$525,000			
University-, National Laboratory-, or Industry-led NEET CTD Projects	PS	Appendix B	$12,000,000	$1,000,000	Up to 3 years	Required by Industry leads	
	MS			$500,000			
NSUF Projects	MS	Appendix B	R&D: $3,000,000-$5,000,000 NSUF: $5,700,000	Refer to maximum award size of the project funding and NSUF funding.	Up to 7 years	Required for Industry seeking R&D support	
University-led IRP - NEUP	PD	Appendix C	$21,000,000	$5,000,000	Up to 3 years, unless otherwise noted	Encouraged but not required	

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

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) click on "Create New Application" for the type of application you are creating.

Apply at http://www.NEUP.gov.

B. LETTER OF INTENT AND PRE-APPLICATION

B.1 Letter of Intent (Mandatory for NSUF Projects Only)

LOIs must be submitted by the date and time specified in Part IV, Section E.1. Pre-applications for NSUF projects will not be accepted without submittal of a LOI by the due date.

All NSUF applications must be (1) initiated with a LOI and (2) generated in close collaboration with a Technical Lead from the NSUF facility to define scope and feasibility of the project. Awarded NSUF projects are to be fully funded for the entire duration of the project; thus, where applicable, a firm cost estimate must be prepared for the NSUF portion of the project in addition to the required budget for the PS or MS R&D funding. Since the cost estimate for the NSUF provided workscope to be included in the full application must be obtained from the particular NSUF facility or facilities where the work is to be performed, the application must be generated in close collaboration with a Technical Lead from the NSUF facility wherein the scope and feasibility of the project are established. The scope of work and the cost estimate are important considerations during the feasibility review (outlined in Part V, Section A.2). It is imperative that all potential applicants establish immediate contact with a Technical Lead when preparing the pre-application to produce the most accurate feasibility result. **Pre-applications will not be accepted without submission of a LOI identifying the Technical Lead and NSUF facility to be used by the date and time specified in Part IV, Section E.1.**

In addition to the NSUF Technical Lead, LOIs should include the following:

- Title of the project
- Proposing and associated institution
- Co-PIs and associated institutions
- Type of project (full irradiation/PIE, irradiation-only, PIE-only, or beamline)
- Applicable workscope: NEET-NSUF-1 for R&D support with NSUF Access (specify workscope subpart [e.g., 1.3c]) or NEET-NSUF-2 for NSUF Access Only
- A brief (<300 words) project description.

Points of contact (POCs) for the NSUF facilities, as well as facility descriptions, are provided on the NSUF website at http://nsuf.inl.gov. For assistance in identifying a NSUF Technical Lead or facility POC, please contact NSUF staff members listed on the website.

B.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 2016 NSUF Letter of Intent" and click on "Create New Application" for the type of application you are creating.

LOIs are 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.

2-page limit. Name File: 2016 LOI "Insert ID #"

B.2 Pre-applications (Mandatory except for IRPs and MS-EM-1)

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 and MS-EM-1. Pre-applications must be submitted by the date and time specified in Part IV, Section E.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.

Pre-applications are 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 following information shall be provided for all pre-applications:

B.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 associated with request for NSUF Access Only (NEET-NSUF-2 only).

3-page limit. Name File: 2016 RPA Narrative "Insert ID #"

B.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).

2-page limit. Name File: 2016 RPA Benefit of Collaboration "Insert ID #"

B.2.3 Principal Investigator Vitae

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

- Contact information.
- Education and Training: Undergraduate, graduate, and postdoctoral training. Provide institution, major/area, degree, and year.
- Research and Professional Experience: Beginning with the current position list, in chronological order, 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 5 professional and scholarly activities related to the effort proposed.

2-page limit. Name File: 2016 RPA "Last Name of Individual" "Insert ID #.pdf"

B.2.4 Agreement Requirements

Each institution serving as a team member to the proposed project must be identified in the pre-application, with their commitment made to collaborate in the FOA process.

C. CONTENT AND FORM OF APPLICATION: PS, MS, PD, AND NSUF FULL APPLICATIONS

Applicants must complete the mandatory forms and any applicable optional forms (e.g., Disclosure of Lobbying Activities [SF-LLL]) in accordance with the instructions on the forms

and the additional instructions below. Files that are attached to the forms must be in Adobe Portable Document Format (PDF) unless otherwise specified in this announcement.

NOTE: The review process for full applications (PS/MS R&D) is a semi-blind process. Please be sure to review the requirements below carefully as non-compliant applications may be excluded from review.

C.1 SF 424 (R&R)

Applicants shall complete the SF424 (R&R) form available at www.NEUP.gov and upload a completed PDF copy of the form with the application.

Name File: 2016 CFA SF424RR "Insert ID #.pdf"

C.2 Research and Related Other Project Information

Applicants shall complete items 1–6 on the Research and Related Other Project Information form available at www.NEUP.gov and upload a completed PDF copy of the form as well as complete the NEUP application form (items listed below).

Name File: 2016 CFA R&R Other Project Information "Insert ID #.pdf"

C.3 Project Summary/Abstract (Use Provided Template)

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; list of major deliverables; 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.

The project summary/abstract 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.

- 2-page limit for IRPs.
- 1-page limit for R&D.

Name File: 2016 CFA Technical Abstract "Insert ID #.pdf"

C.4 Project Narrative

Applicant shall provide a written narrative addressing its 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.
- 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.
- 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, 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 associated with request for NSUF Access Only (NEET-NSUF-2 only)

- Evaluate the application in light of the data needs for verification and validation of modeling and simulation tools identified in Appendix D and highlight any potential for capturing key data, if applicable.

NOTE: References are included in the page limits.

The R&D technical narrative (PS/MS and R&D application requesting NSUF access) shall NOT include the following information:

- Cost and pricing information.
- Identification, by individual name or name of institution, of any teaming partner or lead institution. Examples of acceptable ways of referring to partners will be posted on the NEUP website.
- Official name or title of facilities used to execute scope. Describe the facility by function and/or technical attributes such as an accelerator, a test reactor, etc.

NOTE: For applications requesting NSUF access, NSUF facilities may be named.

10-page limit for PS/MS; 15-page limit NSUF Projects; 50-page limit for PD IRPs. Page limits include cover page, table of contents, charts, graphs, maps, photographs, tables, and other pictorial presentations, when printed using standard 8.5" × 11" paper with 1-inch margins (top, bottom, left, right) (single-spaced) with font no smaller than 11 points. EVALUATORS WILL ONLY REVIEW THE NUMBER OF PAGES LIMITS SPECIFIED.

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: 2016 CFA Technical Narrative "Insert ID #.pdf"

C.5 Vitae (Technical Expertise and Qualifications)

Applicant shall name all teaming partners by name and organization, as well as their proposed roles and responsibilities. The Lead PIs vita as submitted during pre-application may be used for evaluation or may be updated if desired. 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: Undergraduate, graduate, and postdoctoral training. Provide institution, major/area, degree, and year.
- Research and Professional Experience: Beginning with the current position list, in chronological order, 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 5 professional and scholarly activities related to the effort proposed.

2-page limit for each (8.5" × 11" with 1-inch top, bottom, side margins). Name File: 2016 CFA "Last Name of Individual" "Insert ID #.pdf"

Technical expertise and qualifications are to be provided for individual participants, whether to receive 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 application form.

NOTE: This would typically not include the NSUF support staff.

C.6 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. For R&D applications only, the benefit of collaboration document may be used as submitted during pre-application or updated as desired. 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).

2-page limit for PS, MS, and NSUF projects; 4-page limit for PD IRPs.

Name File: 2016 CFA Benefit of Collaboration "Insert ID#.pdf"

C.7 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.

NOTE: While NE continues to evaluate potential infrastructure investments, NE has committed to fund NE related access to the Intermediate Voltage Electron Microscope (IVEM) facility at ANL through at least September 30, 2016.

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

2-page limit for Program Supporting, Mission Supporting, NSUF, and Program Directed IRPs. Name File: 2016 CFA Capabilities "Insert ID#.pdf"

C.8 Letters of Support (PD IRPs only)

IRPs are expected to foster and encourage robust interaction with collaborators to accomplish the scope of R&D defined by this FOA. Applicants are encouraged to provide information regarding their plans to create a research environment that promotes diverse collaboration, when appropriate, to enable organizational cognizance of international capabilities, industry/utility readiness, technology transfer, and assisting the transition of developed technologies to industrial development.

A letter of support from non-Federal partners (industry, utility, international) is required to describe the level and type of support contemplated for the project.

The applicant shall include letters of support on company stationery and be signed by an appropriate company official.

Name File: 2016 CFA Letter of Support "Insert ID#.pdf"

C.9 Budget Documents

C.9.1 Research and Related Budget (TOTAL FED & NON-FED) (Required for all Lead Institutions)

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. You must complete a separate budget for each year of support requested. The form will generate a cumulative budget for the total project period. You must complete all the mandatory information on the form before the NEXT PERIOD button is activated. You may request funds 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 G).

Do not lock your cells when saving this document.

Name File: 2016 CFA Budget "Insert ID #xls"

C.9.2 SF424 (R&R) Subaward Budget Form (TOTAL FED & NON-FED) (Required for University and Industry collaborators)

Budgets for subrecipients, other than DOE FFRDC Contractors. Applicant must provide a separate cumulative SF424 (R&R) 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.

Do not lock your cells when saving this document.

Name File: 2016 CFA Subaward Budget "Insert ID #xls"

C.9.3 Budget for DOE/NNSA Federally Funded Research and Development Center (FFRDC) Contractor (Required for National Laboratory participants)

If a DOE/NNSA FFRDC contractor is applying, they must provide a DOE Field Work Proposal in accordance with the requirements in DOE Order 412.1A, Administrative Change 1, Work Authorization System dated 05/21/2014. This Order and a sample DOE Field Work Proposal form are available at https://www.directives.doe.gov/directives-documents/400-series/0412.1-BOrder-a-admchg1

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

Name File: 2016 CFA FWP "Insert ID #.pdf"

C.9.4 Budget Justification (Required for all university and industry participants)

Provide the required supporting information for all costs required to accomplish the project, including the following costs (See SF424 [R&R] instructions): 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 your budget request. Attach a single budget justification file for the entire project period in Field K. The file automatically carries over to each budget year.

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 you submit your application, you must have 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. By submitting your application, you are providing assurance that you have signed letters of commitment. In an appendix to your Budget Justification, you must identify the following information for each third party contributing to cost sharing: (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 commitments within the number of days specified in Part IV.D, Submissions from Successful Applicants.

Name File: 2016 CFA Budget Justification "Insert ID #.pdf"

C.10 Additional Attachments

C.10.1 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: 2016 CFA Current and Pending Support "Insert ID #.pdf"

C.10.2 Conflict-of-Interest (COI) Statement (Required for all Applicants)

COI may exist due to previous efforts performed by the Laboratories or assistance provided in program direction and other mission related activities. Accordingly, each applicant must identify any potential conflicts of interest; fully explain the conflict, whether you feel it is significant or not, along with your rationale; and how you will avoid, neutralize, or mitigate the potential conflict.

Name File: 2016 CFA COI "Insert ID #.pdf"

C.10.3 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: 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: 2016 CFA CO Authorization "Insert ID #.pdf

C.10.4 Project/Performance Site Location(s) (Required for all Lead Institutions)

Indicate the primary site where R&D work will be performed. If a portion of the project will be performed at any other site(s), identify the site(s). 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., A-001).

Name File: 2016 CFA Site Location "Insert ID#.pdf"

C.10.5 Disclosure of Lobbying Activities (SF-LLL)

If applicable, complete SF-LLL.

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

Name File: 2016 CFA SF-LLL "Insert ID #.pdf"

C.10.6 Certifications and Assurances (Required for All University and Industry Leads)

Applicants must complete/attach form 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: 2016 CFA Cert & Assurances "Insert ID #.pdf"

Federal and Technical POCs for FY 2016 can be found at https://neup.inl.gov/SitePages/FY16_RD_Technical_Program_Contacts.aspx and https://neup.inl.gov/SitePages/FY16_IRP_Technical_Program_Contacts.aspx

Table 2 contains a summary of the required forms/files required for full application submittals.

Table 2. Summary of Full Application Required Forms/Files.

Name of Document	Format	Required From
SF424 (R&R)	Form	All Lead Applicants
Research and Related Other Project Information	Form	All Lead Applicants
Project Summary/Abstract	PDF	All Lead Applicants
Project Narrative	PDF	All Lead Applicants
Other Attachments		
Vitae - Technical Expertise and Qualifications (2 pages each)	PDF	All Leads and Collaborators
Capabilities (2 pages)	PDF	All Lead Applicants
Benefits of Collaborations (PS/MS/NSUF - 2 pages; PD - 4 pages)	PDF	All Lead Applicants
Letters of Support (PD IRPs only)	PDF	IRP Academic and Industry Collaborators
Current and Pending Support	PDF	All University and Industry Applicants
Project/Performance Site Location	PDF	All Lead Applicants

Name of Document	Format	Required From
Conflict-of-Interest Statement	PDF	All Applicants
Authorization for DOE/NNSA FFRDCs	PDF	National Laboratory Leads and Collaborators (including non-funded collaborators)
Research and Related Budget (Total Fed + Non-Fed)	Form	All Lead Applicants
SF424 (R&R) Subaward Budget (Total Fed + Non-Fed), if applicable	Form	University and Industry Collaborators
Budget for DOE National Laboratory Contractor or FFRDC, if applicable	PDF	National Laboratory Leads and Collaborators
Budget Justification	PDF	University and Industry Leads and Collaborators
SF-LLL Disclosure of Lobbying Activities	Form	If applicable
Certifications and Assurances	Form	University and Industry Leads

D. 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 complying 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.

E. SUBMISSION DATES AND TIMES

E.1 Letter of Intent Due Date (Mandatory for NSUF Projects)

LOIs for NSUF access are required by August 27, 2015 at 8:00 p.m. Eastern Time (ET). The LOI shall be submitted as required in Part IV, Section B.1.

E.2 Pre-Application Due Date (Mandatory except for IRPs and MS-EM-1)

Applicants must submit a pre-application by September 17, 2015 at 8:00 p.m. ET. The pre-application shall be submitted as required in Part IV, Section B.2. Applicants who fail to submit a pre-application will be determined non-responsive and ineligible for a comprehensive merit review.

E.3 Integrated Research Projects Due Date

IRPs must be received by December 3, 2015, not later than 8:00 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.

E.4 Full Application Due Date

Full applications must be received by February 18, 2016, not later than 8:00 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. INTERGOVERNMENTAL REVIEW

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

G. 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.

G.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.

G.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.

H. OTHER SUBMISSION AND REGISTRATION REQUIREMENTS

H.1 Where to Submit

NOTE: Applications must be submitted through www.NEUP.gov to be considered for award.

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

H.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, a panel of programmatic experts will assess each pre-application's program relevancy and program priority to NE's R&D PS/MS/NSUF workscopes. Scores will be assigned according to the following program relevancy and program priority attributes:

A.1.1 Relevancy Attributes

- **High Relevance:** The project is fully supportive of, and has significant, easily recognized and demonstrable ties to, the NE mission and the 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, the NE mission and the 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, the NE mission and the 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, the NE mission and the 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 the NE mission or the relevant workscope area.

A.1.2 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.6) as needed, NE will make a final determination of applicants who will be invited to provide full applications.

A.1.3 Merit Categories

- **High Merit:** The project unquestionably advances the technical state of knowledge and understanding of the NE 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 NE 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 NE 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 NE 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 NE 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.

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 Initial Review Criteria of Full Application

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 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.4 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, Item 6 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.

A.4.1 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.

A.4.2 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, Experience, and Resources**: 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 within budget and 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	
Merit Category	100%
Full Applications	
Criterion 1: Scientific and Technical Merit	35%
Criterion 2: Technical Quality of the Proposed R&D Project	35%
Criterion 3: Team Capabilities, Experience, and Resources	30%
Peer Review Score	Sum of ratings x weights
Program Relevance/Priority[1] (Separate Review Process, Used for Both Pre-Applications and Full Applications)	Percentage of Program Relevancy/Priority Review Score
Relevancy	100%
Program Priority	Multiplier based on program priority rating
Diverse Partnerships	Up to 5 points, not to exceed the maximum relevancy points available.
Program Relevancy/Priority Score	Sum of ratings[2] x program priority multiplier
Weighting	Weighted Score Ratio (Peer : Relevancy) Program Supporting: 65:35 Mission Supporting: 80:20 NSUF Access Only: 80:20

[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.5 Program Directed 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.5.1 Relevancy Attributes

- **Program Factors:** Relation of the proposed project to the core research activities within the DOE-NE 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-NE 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 NE 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.5.2 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, Experience, and Resources**: 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.
- **Criterion 4 – Reasonableness and Appropriateness of the Proposed Resources**: The application will be evaluated to determine the reasonableness and appropriateness of requested resources from a technical perspective. DOE will consider whether the (1) requested funding aligns with the project description; (2) proposed resources including proposed costs are reasonable for the planned scientific program; and (3) costs for existing and new equipment and instrumentation are realistic.

Table 4. PD IRP R&D Full Applications - Weighting of Evaluation Scores.

Criterion	
Technical Application – Peer Review	Percentage of Peer Review Score
Criterion 1: Scientific and Technical Merit	25%
Criterion 2: Appropriateness of the Proposed Method or Approach	25%
Criterion 3: Applicant Team Capabilities and Experience	25%
Criterion 4 - Reasonableness and Appropriateness of the Proposed Resources	25%
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.6 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-NE funding to achieve DOE program goals and objectives. This includes how those R&D and IRP projects support DOE-NE 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-NE research goals objectives.
- Cost/Budget considerations, including availability of funding.

The demonstrated ability of the applicant to successfully complete projects (including relevant prior NE CINR projects) and do so within budget and within the specified timeframe of the award. This includes the extent that applicant has awards in progress, or not completed, from DOE, from a previous year's FOA, or has existing no cost extensions.

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 peer and program evaluation process will produce a list of recommended projects for each workscope provided in Appendices A through C. DOE-NE will consider the overall evaluation results and subjective programmatic factors to select a final set of 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.

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 employ a semi-blind process to evaluate the applications in accordance with the technical review evaluation criteria described in this FOA. Also, a program relevancy/priority review process will be completed by DOE 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 peer and federal program reviewers will independently evaluate the applications in accordance with the review criteria and weighted as described above. DOE will consider the overall evaluation results and subjective programmatic factors to ultimately recommend applications for approval by the Selection Official.

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.

C. ANTICIPATED NOTICE OF SELECTION

DOE will strive to make selections within three to four months after receipt of applications.

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 G 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.2 Nondisclosure and Confidentiality Agreements Representations

In submitting an application in response to this FOA the applicant represents that it will not require its employees or contractors seeking to report fraud, waste, or abuse to sign internal nondisclosure or confidentiality agreements or statements prohibiting or otherwise restricting such employees or contactors from lawfully reporting such waste, fraud, or abuse to a designated investigative or law enforcement representative of a Federal department or agency authorized to receive such information.

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. 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 keep their data at System for Award Management (SAM) current. 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.

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.

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 university researcher.

- **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 journal peer review requirements. The peer reviews shall be documented and maintained by the university. Peer review documentation and results shall be provided to DOE, if requested.

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, you 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.
- No officer or agent of the corporation has been convicted of a felony criminal violation for an offense arising out of actions for or on behalf of the corporation under Federal law in the past 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 paragraph b and DOE's responsibilities are listed in paragraph c:

- 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, attend 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):** 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. 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. The checklist is available at http://energy.gov/management/office-management/operational-management/financial-assistance/financial-assistance-forms under Award Forms.

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 pre-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 at the Grants.gov/FedConnect websites with a courtesy posting 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. Shawn Tinsley
E-mail: tinslesm@id.doe.gov

C. INFORMATIONAL WEBINAR

DOE-NE 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 to be answered in real time. All webinar presentations are recorded and posted 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 FedConnect and Grants.gov and will also be posted as a courtesy on www.NEUP.gov. It is recommended that you check the www.NEUP.gov site frequently 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 F 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 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 nonprofit organizations to retain title to subject inventions. Therefore, small businesses and nonprofit organizations do not need to request a waiver.

H. UNDERSTANDING COST SHARING REQUIREMENTS (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).
2. 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 3 months before the original project end date.

No cost time extensions on existing DOE-NE funded projects must be requested by April 15, 2016. Any request beyond this date will not be considered. No cost time extensions must be 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: Data Needs for Validation

Appendix E: Accessing Nuclear Science User Facilities

Appendix F: 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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EXPERIMENTAL VALIDATION OF GAS-COOLED REACTOR SIMULATIONS (RC-1)
(FEDERAL POC – STEVE REEVES & TECHNICAL POC – HANS GOUGAR)

Experimental Validation of Gas-Cooled Reactor Simulations is focused on providing high quality data for the validation of system and computational fluid dynamics models of high temperature gas-cooled reactor (prismatic or pebble bed) phenomena. These phenomena have been identified as relevant to core safety and performance but for which insufficient data exist for validating models and codes. They include: air and water ingress, core heat transfer, plenum-to-plenum heat transfer by natural circulation, heated two-component stratified flow in the outlet plenum, bypass flow between fuel or reflector blocks, dust and fission product transport in the reactor coolant system, and performance of reactor cavity cooling systems in cooling the pressure vessel (ex-core heat transfer).

Validation of codes that capture these phenomena requires the coordinated completion of a number of fundamental, separate effects (SET), mixed effects (MET) such as combined mass flow and heat transfer, and integral tests, all properly scaled to reproduce the thermal fluid conditions bounding gas-cooled reactor under nominal and accident scenarios. Integral testing facilities are generally large, long-term investments generally beyond the scope of NEUP awards, however, a few have been built for this purpose using other sources of funding. The High Temperature Test Facility (HTTF) at Oregon State University, the Natural circulation Shutdown Test Facility (NSTF) at Argonne National Laboratory, and the Matched Index of Refraction Facility (MIR) at Idaho National Laboratory are examples of those available for integral tests that can complement the smaller and generally less expensive experiments that can be effectively conducted at universities.

Applications are sought that will fill the gaps in the data needed for high temperature reactor code validation with appropriately scaled fundamental, SET, or MET experiments that complement those that have been, or can be, conducted at HTTF, NSTF, MIR, or other suitable integral facilities not identified here. Investigators who wish to propose new experiments using one or more of these facilities are strongly urged to coordinate with the Principal Investigators at those facilities before submitting the final application to obtain guidance on costs, schedule, and quality assurance.

Experimental investigations can and should be conducted in conjunction with pre-test and post-test simulations using system, computational fluid dynamics, or other suitable codes. Nonetheless, the emphasis is on the generation of high quality experimental data that can be used for the validation of different analysis codes rather than the development of those codes. All data and simulation results are to be uploaded (preferably in real-time if possible) and archived on the NGNP Data Management and Analysis System (NDMAS) hosted at the Idaho National Laboratory. Investigators are strongly urged to coordinate with INL personnel to link to NDMAS. Contact information for the INL and Integral Facility personnel can be obtained from the Points of Contact listed above).

All validation and verification benchmark problems must be performed using NQA-1 2008, with 2009 NRC accepted paragraphs on quality assurance practices.

ADVANCED REACTOR COMPONENTS (RC-2)
(FEDERAL POC – CARL SINK & TECHNICAL POC – BOB HILL)

Advanced non-light water reactors differ from current commercial plants in their fundamental design features. This leads to new technological challenges but also allows designers to take advantage of additional passive safety features and inherent protections. Advanced reactor component development and analysis as well as innovative engineering techniques for operations and reliability are sought to increase levels of safety and robustness, present new functionalities, and improve system performance. Applications are sought that support the identified needs of the advanced reactor technology program including those applicable to advanced non-light water reactors in the following areas:. Experimental demonstration/validation is encouraged.

RC-2.1: COMPACT HEAT EXCHANGERS

Advanced nuclear reactor systems may utilize compact, high efficiency, Brayton cycle energy conversion systems

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for improved cost and efficiency. Electricity produced in this manner could play a significant role in the strategy to advance the growth of carbon-free energy as well as to provide energy production diversity. Compact heat exchangers (CHXs) are an essential feature of such a system. Sodium Fast Reactors (SFRs), which have a reactor output temperature (≈550°C) that matches well with the supercritical carbon dioxide (sCO_2) Brayton cycle, are an example of a good candidate for inclusion of CHXs. SFRs would, however, require accommodating the large differences in pressure between the low pressure primary sodium coolant and the high pressure sCO_2 in the secondary loop. High temperature gas cooled reactors may also utilize CHXs.

The leading CHX configurations for such applications are the diffusion bonded micro channel heat exchanger and the diffusion bonded or brazed plate fin type. The micro channel type comprises a series of bonded thin plates or shims with chemically etched micro channels with integral inlet and outlet flow distribution channels. The primary and secondary fluids flow in the channels in alternate shim plates. The plate fin type consists of a corrugated formed plate sandwiched between two flat plates or shims. The micro channel type's advantage is accommodation of high pressures while the plate fin type has the advantage of more efficient use of material and larger flow passages. For an SFR, one proposed sCO_2 CHX employs both configuration types in alternating layers with the high pressure sCO_2 in the etched micro channels and the liquid sodium in the plate fin channels.

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

The objective of this project is to develop a structural design methodology that provides for the assessment of the elevated temperature failure modes of a CHX under sustained and cyclic loading due to pressure and thermal gradients. Analytical considerations should be complemented with experimental data. Results from this study will be used as the technical basis for developing a Section III, Division 5 ASME Code Case for CHXs in nuclear systems, currently constructed to the requirements for Section VIII, Division 2 components. Input from industry involved in the design or manufacture of CHXs would be considered valuable. Ideally, this Code Case would be based on recently developed EPP design methodologies that specifically address elevated temperature cyclic failure modes.

RC-2.2: ELECTROMECHANICAL PUMPS

Advanced liquid metal-cooled (e.g., sodium, lead, lead-bismuth eutectic) reactors may utilize electromagnetic (EM) pumps in place of traditional mechanical pumps to circulate liquid metal coolant. EM pumps offer potential benefits such as greater reliability, fewer moving parts, less complexity, and reduced maintenance compared to mechanical pumps. Many current Sodium Fast Reactor (SFR) concepts employ electromagnetic pumps in their designs.

Expanded research and development (R&D) has taken place on several technical areas to build upon the above EM pump benefits and enhance overall EM pump performance. One important area requiring further R&D pertains to EM pump end effects. Current EM pump designs generate a magnetic field across the liquid metal coolant flow gap which distorts at both ends of the pump. This distortion can impact the EM force created by the vector product of the magnetic field and its perpendicular induced current. The EM forces impacted by these end effects may oppose the EM pump inlet force causing reduced pump efficiency.

The objective of this project is to analyze the impact of end effects on the magnetic field and pump efficiency of current SFR EM pump designs. The project will also consider coupling results obtained from EM pump performance analyses with modern CFD modeling techniques.

RC-2.3: HELIUM TRIBOLOGY FOR HTGRS

High temperature gas cooled reactors (HTGRs) and very high temperature gas cooled reactors (VHTRs) use helium

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as a reactor coolant to transfer heat from the core to either a primary-to-secondary heat exchanger or to a steam generator. Current HTGR designs incorporate reactor outlet temperatures of 700 to 800°C, with VHTRs anticipated to extend this up to 950°C. Metallic components in the primary circuit are envisioned to be constructed of high alloys, such as Alloy 800H or nickel-based alloys such as Inconel 617 and rely on thin chromium oxide layers for protection of the metal during service. Such oxide layers are normally formed within the primary helium coolant, which contains small amounts of H_2, H_20, CO, CO_2 and CH_4 that are generated during reactor operation.

The interface between metallic surfaces at high temperature with low water or oxygen partial pressures can be an issue. Friction and wear between metallic surfaces in the high temperature helium environment typical of HTGR reactor coolant is of concern. Valves, valve seats and valve shafts are of particular concern. For rubbing surfaces, accelerated friction and surface damage, both by wear and fretting, may be a problem. Unintentional bonding of surfaces in static contact for extended periods of time can also be an issue, especially in higher temperature locations. There is some existing research and operational history for this topic for 800H, but with the imminent addition of Alloy 617 to the ASME Code for high temperature construction, it would be useful to reexamine this topic, not only for 800H-800H interfaces but also for Alloy 617 interfaces with 800H and with other Alloy 617 to 617 interfaces.

The objective of this project is to develop an improved understanding of the potential for enhanced tribological damage to Alloy 800H and 617 in simulated HTGR helium at relevant reactor operating temperatures. Experimental studies to compare the friction, wear, and self-welding of the similar and dissimilar metal alloy couples in HTGR helium compared to that in air should be performed as functions of time, load, rate, environment, etc. Conditions under which significant enhancement of deteriorated behavior in helium is observed should be identified and quantified. Mitigation approaches should be developed and reported, if possible. Input from industry involved in the design or manufacture of primary circuit components subject to helium tribology issues would be considered valuable.

COMPUTATIONAL METHODOLOGIES TO SUPPORT DESIGN AND ANALYSIS OF SODIUM-COOLED FAST REACTORS (RC-3)
(FEDERAL POC – THOMAS SOWINSKI & TECHNICAL POC – TANJU SOFU)

The R&D activities on fast reactor methods under the DOE-NE's Advanced Reactor Technologies (ART) program is focused on development and validation of computational tools to study the Sodium-cooled Fast Reactor (SFR) core neutronics/thermal-hydraulics/structural performance during normal operations and postulated accidents. The objective is to raise the technical readiness of SFR concepts and support commercial deployment by a vendor. This could be accomplished by developing and gaining regulatory acceptance of reduced-order models that predict important safety behaviors.

ART program methods development focus on a range of areas from neutronics analysis of complex reactivity feedback mechanisms to thermal-hydraulics analysis of very low Prandtl-number liquid metal heat transfer to system analysis of whole-plant dynamics. Code development activities include enhanced transient and severe accident analysis capabilities tailored to important phenomena specific to SFRs. To support development of an integrated multi-physics analysis tool suite and validation of its components, contributions to development of advanced modules and/or conducting of tests to provide validation data are being sought in the following specific topic: Modeling the mixing and thermal-stratification in large volumes (e.g., upper plena) and its influence on natural circulation flow rates and decay heat removal in a pool type SFR.

Although the mixing and heat transfer in reactor inlet/outlet plena can be modeled reasonably accurately using various CFD techniques, the computational resource requirements make the use of such high fidelity approaches prohibitively expensive within the context of system analyses. With the system analysis codes, the reactor plena are typically modeled as perfectly mixed 0-D volumes, often leading to inaccurate estimate of the natural circulation flow rates for decay heat removal. Therefore, the reduced-dimension/fidelity modeling approaches need to be implemented under the system analysis codes such as the SAS4A/SASSYS-1 to support conceptual design studies and license applications. To address this need, development and assessment of thermal stratifications models or applications that provide the experimental data needed for validation of these models

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will be primarily considered.

MATERIALS AGING AND DEGRADATION (RC-4)
(FEDERAL POC – RICHARD REISTER & TECHNICAL POC – KEITH LEONARD)

Nuclear reactors present a very harsh environment for component service. Components within a reactor core must tolerate high temperature water, stress, vibration, and an intense neutron field. Degradation of materials in this environment can lead to challenges in required performance, and in some cases, sudden failure. Materials degradation phenomena within a nuclear power plant are very complex. There are many different types of materials that make up different components: over 25 different metal alloys can be found within the primary and secondary systems, not to mention the concrete containment vessel, instrumentation and control, and other support facilities. When this diverse set of materials is placed in the complex and harsh environment coupled with varying types of loading, degradation over an extended life is indeed quite complicated. Clearly, materials degradation could potentially impact the safe operation of a reactor. Routine surveillance and component replacement can mitigate these factors, although failures can still occur. While all components can, in theory be replaced, it may not be practical or economically favorable. Therefore, understanding, controlling, and mitigating materials degradation processes are key priorities for extending the reactor operating life. In a recent, joint activity with the US Nuclear Regulatory Commission, the DOE Light Water Reactor Sustainability (LWRS) program completed the Expanded Proactive Materials Degradation Assessment (EMDA), detailed in NUREG-CR7153.

The EMDA identified a number of potential knowledge gaps for second license renewal. Many of these potential knowledge gaps are being researched under the base LWRS program, although there are needs for innovative and creative research to close potential knowledge gaps in other areas not currently be addressed by ongoing LWRS-funded research. Specifically, research proposals to address degradation and/or mitigation in second-license renewal environments are sought in the following areas:

- Effect of irradiation on fracture toughness, irradiation creep, swelling, and stress corrosion cracking (SCC) for Type 308/309 Stainless Steel (SS) weldments;
- SCC susceptibility at very long lifetimes for 304, 316, and 308/309 weldments, particularly in Boiling Water Reactor (BWR) normal water chemistry (NWC) environments;
- Potential impact of poor water chemistry control in service water on crevice corrosion, pitting, and microbial-induced corrosion for 304, 317, and 308/309 SS weldments;
- Potential impact of thermal embrittlement on low-alloy steel reactor pressure vessel components and dissimilar metal weldments;
- Creep-creep cracking interaction in concrete structures due to structure modification or changes in loading; and
- Mechanistic understanding of the effects of long-term wetting on low and medium voltage cable insulation.

INFORMATION, INSTRUMENTATION AND CONTROLS (II&C) (RC-5)
(FEDERAL POC – RICHARD REISTER & TECHNICAL POC – BRUCE HALLBERT)

Research is sought to develop the capability to interrogate through active sensors or passive signals and process the associated signals from these sensors or network of sensors to detect degradation of passive components in existing nuclear power plants as a part of strategies to manage their long-term operation. In particular, proposals are desired related to the presence of alkali-silica reactions in concrete and flow-assisted corrosion in piping of secondary systems of nuclear power plants. Successful applicants will participate as part of a multi-disciplinary R&D team comprising material scientists, non-destructive examination experts, and online-monitoring experts. Regarding flow assisted corrosion: applicants would be expected to work with a test rig and sensor network under

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development by INL. Desired outcomes of research are the development of a structural modeling framework, diagnostic indicators, and prognostic parameters.

REACTOR SAFETY TECHNOLOGIES (RC-6)
(FEDERAL POC – RICHARD REISTER & TECHNICAL POC – CURTIS SMITH)

The LWRS Reactor Safety Technologies (RST) pathway seeks to improve understanding of beyond design basis events and reduce uncertainty in accident progression and in key phenomena using advanced modeling tools developed by the Risk Informed Safety Margin Characterization (RISMC) pathway as well as information gleaned from accidents. These insights may be used to aid in developing accident tolerant fuel and components or developing mitigating strategies for current Light Water Reactors (LWRs) and advanced LWR designs to provide additional time or margin for adequate core cooling.

One observation from the extended station blackout at Fukushima was that passive decay heat removal systems, like the Reactor Core Isolation Cooling system, would provide core cooling for extended time periods even without DC control power. Another observation is that advanced fuel designs, like accident tolerant fuel systems, have the potential of minimizing clad oxidation and hydrogen generation during transients or accidents for extended time periods. As more time is made available for operator actions, it provides additional opportunity for a successful transition to portable FLEX equipment to ensure long-term core cooling.

Objective: Perform a simulation study using the advanced thermal-hydraulic system model, RELAP-7, to model an extended loss of AC power accident sequence for a BWR or PWR and determine the range of time available for transition to portable FLEX equipment considering:

- Extended operation of passive heat removal systems (e.g., RCIC or AFW or innovative systems)
- Alternative fuel designs that employ accident tolerant cladding materials
- Uncertainties in thermal-hydraulic parameters that affects the time to significant fuel damage.

Fuel damage for this study can be defined as the point when the fuel loses it coolable geometry. For current LWR cladding material, this has been determined to occur when cladding material reaches 2200F and/or 17% local clad oxidation. Analysis of alternative fuels should include a comparison to loss of coolable geometry comparable to limits for conventional fuel designs.

These research efforts would be in direct program support of advanced modeling tool development (RISMC) and associated safety analyses (RST).

VALIDATION OF RELAP-7 (RC-7)
(FEDERAL POC – RICHARD REISTER & TECHNICAL POC – CURTIS SMITH)

Significant and continuing advances in computer simulation and rising costs of building test facilities and conducting tests are increasing the reliance on complex models in licensing facilities, optimizing designs, improving performance, and understanding the underlying science. At the same time, however, the complexity of these models and associated computational methods present unprecedented challenges for code verification and validation (V&V). Advanced computer models can represent physical characteristics that cannot feasibly be measured in experiments, compounding these challenges.

Basic V&V (including development of generic closure relationships) of the MOOSE (Multi-physics Object Oriented Simulation Environment)-based RELAP-7 code is needed before it can be transferred to industry for development of closure relationships specific to their reactor designs so that it can be used by industry for design and analysis. The majority of verification is done as part of the process of developing MOOSE-based applications; however, some additional verification may also be needed. Proposals are encouraged that include

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development of a V&V approach suitable to advanced computer models (see for example Stoots et. al, INL/EXT-12-27066, September 2012), and the application of this V&V approach to the RELAP-7 reactor system safety analysis simulation tool currently under development in the Light Water Reactor Sustainability (LWRS) Program. Activities that can be considered under this project include: • A survey of available data and data gaps (building on reports generated by the LWRS Program and the LWRS Program partner, EPRI) • Acquisition of new validation data from existing facilities • Synthesis of the data into a form that can be used in RELAP-7, and validation of RELAP-7 models against existing data • Acquisition of new validation data from new facilities and experiments • Identification of additional experiments needed, if any. All activities are to be conducted within the overall budget available for these projects. Note that this may limit the development of new experiments and facilities. The proposed activities should follow the RELAP-7 verification and validation plan (Smith, et. al, INL/EXT-14-33201, September 2014). The activities under this NEUP project will be closely coordinated with and guided by the LWRS Program RELAP-7 activities.

MISSION SUPPORTING: NUCLEAR REACTOR TECHNOLOGIES

REACTOR CONCEPTS RD&D (MS-RC-1)
(FEDERAL POC – THOMAS SOWINSKI & TECHNICAL POC – BOB HILL)

Development of new reactor concepts that may offer the potential for revolutionary improvements to reactor performance and/or safety is sought. Such advanced reactor concepts could include the incorporation of advanced systems or components into existing concepts (e.g., Generation-IV systems), inclusion of innovative design alternatives (e.g., new fuel type, nano-engineered coolants, etc.), or designs employing radically different technology options (e.g., advanced coolants, fuel, or operational regimes). Concepts could also include reactors with unique capabilities to address operational missions other than the delivery of base load electric power, such as desalination or mobile reactors. The scope of the proposed project should include a thorough viability assessment of the concept, a detailed technology gap analysis and a comprehensive technology development roadmap that identifies research needed on key feasibility issues.

SPACE NUCLEAR POWER SYSTEMS R&D (MS-RC-2)
(FEDERAL POC – SCOTT HARLOW & TECHNICAL POC – STEPHEN JOHNSON)

The Space and Defense Power Systems program has designed, developed, built, and delivered radioisotope power systems (RPS) for space exploration and national security applications for over fifty years. RPS systems convert the decay heat from Pu-238 into electricity and are reliable, maintenance free, and capable of producing heat and electricity for decades. The program also supports technology development efforts for space reactor power systems for use on the surface of planets, in deep space, and for propulsion. The Department of Energy is currently supporting NASA technology development efforts for space reactor power systems and for nuclear thermal propulsion activities. Support for terrestrial use of small reactors is also of interest for national security applications. Nuclear power systems for space and national security applications enable missions that require a long-term, unattended source of electrical power and/or heat in harsh and remote environments.

Applications are sought for the development of advanced neutronic and multi-physics fuel and reactor models with the capability to simulate and evaluate a 25,000-30,000 lb-thrust nuclear thermal propulsion system using NERVA (Nuclear Engine for Rocket Vehicle Application) derived composite fuels. Proposals should attempt to leverage existing NERVA fuel and reactor designs (and historical fuel and reactor performance data) to optimize proposed reactor models.

Innovative NTP designs for the reactor, the fuel, and the propulsion process are also being requested. These designs must take into consideration the restrictions placed on space applications. Ideas addressing the integration of a proposed reactor concept within proposed engine platforms or the creation of a reactor subsystem within a proposed space vehicle will also be considered.

Conceptual designs are also sought for a portable compact reactor design that can be deployed for terrestrial applications. Proposals should address how a reactor can be integrated with a reliable, low maintenance and compact system that enables rapid transport, deployment and removal. Desired power output can range from 100 kWe to 1 MWe.

Additionally, any novel power conversion systems, static or dynamic, that improve on the current state of the art are encouraged for consideration. These systems should be focused on conversion of heat from a radioisotope or fission heat source to electrical power. These systems should be operable in a space environment and have a special emphasis on low mass, durability (both reliability and robustness) and adaptability to varying system architectures. Of particular interest are conversion methods that, once developed, could be produced without the need to invest in the sustainment of a single-purpose supply chain.

PROGRAM SUPPORTING: FUEL CYCLE TECHNOLOGIES

MATERIAL RECOVERY AND WASTE FORM DEVELOPMENT (FC-1)
(SEE BELOW FOR POCS)

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)

To enhance electrochemical separation process development and facilitate predictive model development relevant to nuclear fuel recycling, proposals are solicited in the following areas:

FC-1.1a: Metal – Salt Separation: Actinides recovered during the electrorefining process contain residual molten salt adhering to the surface and within the structure of the metallic product. The residual salt must be separated from the metal before the metal can be used in fuel fabrication. Proposals are requested for innovative methods of separating the residual salt from the metal that limit actinide loss and provide highly effective separation. (Methods that use hydrogenous solvents or materials will not be considered.)

FC-1.1b: Off-gas Sequestration: Off-gas released from used fuel during electrochemical processing needs to be treated so that long-lived radionuclides can be sequestered for storage. Specifically, novel methods are sought to separate krypton and tritium from xenon and argon (i.e., inert gas from hot-cell) present in the off-gas stream produced during electrochemical processing.

FC-1.1c: Actinide / Fission Product Separations: Proposals are requested for advanced electrochemical separations technologies that improve upon the efficiency (decontamination factor, waste management, etc.) of current technologies while providing the desired product quality. The proposals should address the expected improvements resulting from the advanced technology and integration of the technology into existing flowsheets.

FC-1.2: MATERIALS RECOVERY
(Federal POC – Jim Bresee & Technical POC – Terry Todd)

FC-1.2a: Oxidation and stabilization of Am(III) to Am(V) or (VI) in nitric acid, by chemical or electrochemical means. Techniques should focus on kinetics, and mechanisms with the goal of developing a workable process for minor actinide separation applications. (Preliminary work can be performed with surrogates, but any proposal must include verification testing with americium).

FC-1.2b: Liquid kinetics of trivalent minor actinide stripping in ALSEP or other advanced extraction processes (such as diglycolomide based extractants), or in related solvent extraction systems relying on the use of an aqueous complexant for selectivity for trivalent minor actinides. (Preliminary work can be performed with surrogates, but any proposal must include verification testing with trivalent minor actinides).

FC-1.3: ADVANCED WASTE FORMS-1
(Federal POC – Kimberly Gray & Technical POC – John Vienna)

FC-1.3a: Fuel Processing Off-gas Management- Mechanistic Understanding of Silver Sorbent Aging Processes – Develop a fundamental understanding of the silver aging processes on selected sorbents aged in off-gas streams containing air, NOx, and iodine. Determine the cause for observed differences in adsorption capacity of different silver sorbents exposed to moist air and NOx. In particular, why do silver functionalized aerogels age and load differently than silver mordenite?

FC-1.3b: Waste Forms Development- High-Level Waste Salt Immobilization – Develop a waste form and process to efficiently immobilize [Li,K]Cl based waste stream containing fission products. Current immobilization

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technology for electrochemical salt waste is constrained by the solubility and control of chlorine in glass bonded sodalite waste form. Processes that can convert the chloride salts into a high-loaded waste form with good chemical durability with significantly lower cost that the baseline technology are desired. Special attention to controlling the fate of chlorine is essential to success.

ADVANCED FUELS (FC-2)
(FEDERAL POC – FRANK GOLDNER & TECHNICAL POC – JON CARMACK)

This program element develops advanced nuclear fuel technologies using a science-based approach focused on developing a microstructural understanding of nuclear fuels and materials. The science-based approach combines theory, experiments, and multi-scale modeling and simulation to develop a fundamental understanding of the fuel fabrication processes and fuel and clad performance under irradiation. The objective is to use a predictive approach to design fuels and cladding to achieve the desired performance (in contrast to more empirical observation-based approaches traditionally used in fuel development).

The advanced fuels program conducts research and development of innovative next generation LWR and transmutation fuel systems. The major areas of research include: enhancing the accident tolerance of fuels and materials, improving the fuel system's ability to achieve significantly higher fuel and plant performance, and developing innovations that provide for major increases in burn-up and performance. The advanced fuels program is interested in advanced nuclear fuels and materials technologies that are robust, have high performance capability, and are more tolerant to accident conditions than traditional fuel systems. Model development should be consistent with the placement and use in the NEAMS MOOSE-BISON-MARMOT (MBM) fuel performance code structure.

Technologies NOT of interest in this workscope include thorium-based fuels and molten salt-based technologies.

Proposers should also be familiar with the ongoing advanced fuels program and its past NEUPS to avoid duplication of activities already being supported or pursued.

FC-2.1: Coupling Experimental Data with Advanced Modeling and Simulation

A number of advanced fuel concepts are currently being investigated by the FCRD AFC for application as accident tolerant fuels for the LWR fleet and advanced recycle fuels for future reactors. Proposals for separate effect experiments linking integral experimental data with microstructural-level material properties of candidate fuel system components are desired. These experimental activities should produce data to be used in the validation of material property and fuel performance models. The model(s) supported and developed should be consistent and compatible with the NEAMS MBM fuel performance tools. Proposals focused on advancing LWR accident tolerant fuel and advanced recycle fuel concepts currently under study by the FCRD AFC will be given higher priority.

FC-2.2: Advanced Reactor Metallic Fuel

The FCRD program is investigating transmutation fuels for use in fast reactors, which have the potential to significantly increase resource utilization, maximize energy generation, minimize waste generation and decrease the burden on future repositories. A current focus of the development effort is metallic fuel alloys. Proposals for optimized metallic fuel alloys which could improve the performance of traditional fast reactor fuels are requested. Improved performance is especially desired in the area of identification of minor alloy additions capable of immobilizing the lanthanide fission products, prevent their transport to the fuel-cladding gap, and thus minimize or eliminate the traditional fuel-cladding chemical interaction issue between metallic fuels and stainless steel cladding. Proposals should identify optimized alloys and/or alloy additions to be studied and develop an experimental plan to demonstrate improvements. Of particular importance is that the data generated be integrated with the development of a metallic fuel performance modeling capability using the NEAMS tools,

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BISON and MARMOT.

ADVANCED SAFEGUARDS DATA INTEGRATION (FC-3)
(FEDERAL POC – DANIEL VEGA & TECHNICAL POC – MIKE MILLER)

Advanced Safeguards Data Integration: Methods to integrate and distill data from traditional nuclear material accountancy with other data streams to achieve a higher level of awareness of nuclear material flows are being sought. An example of particular interest to the Fuel Cycle Technologies R&D program is the case of electrochemical processing where integration of traditional nuclear material accountancy data (with assignable uncertainties) with advanced process monitoring (salt level and density, voltages, temperatures, etc.) is needed for near real time accountancy and process awareness. Such methods should keep an eye towards decreasing the Standard Error of the Inventory Difference (SEID) by innovative means of integrating data streams of relevant process data.

USED NUCLEAR FUEL DISPOSITION: DISPOSAL (FC-4)
(FEDERAL POC – JC DE LA GARZA & TECHNICAL POC – PETER SWIFT)

Assessments of nuclear waste disposal options start with the degradation of waste forms and consequent mobilization of radionuclides, reactive transport through the near field environment (waste package and engineered barriers), and transport into and through the geosphere. Research needs support the development of modeling tools or data relevant to permanent disposal of used nuclear fuel and high-level radioactive waste in a variety of generic disposal concepts, including mined repositories in clay/shale, salt, and crystalline rock, and deep boreholes in crystalline rocks. It should be noted that R&D has been undertaken in several key technical areas in the past 10 years. In proposing work, the applicants are encouraged to demonstrate a good understanding of work performed to date. Also, describe the need and importance of the research activity proposed to the demonstration of the safety case for a repository. Key university research needs for the disposal portion of this activity include:

Improved understanding of degradation processes (i.e., corrosion and leaching) for used nuclear fuel and waste forms that could be generated in advanced nuclear fuel cycles (i.e., glass, ceramic, metallic) through experimental investigations under variable conditions of saturation, temperature, and water chemistry, leading to the development of improved models to represent these processes;

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

Improved understanding of the degradation processes for engineered barrier materials (i.e., waste containers/packages, buffers, seals) and radionuclide transport processes through these materials leading to the development of improved models to represent these processes;

Improved understanding of coupled thermal-mechanical-hydrologic-chemical processes in the near-field of relevant disposal model environments, leading to the development of improved models to represent these processes;

Improved understanding of large-scale hydrologic and radionuclide transport processes in the geosphere of relevant disposal model environments, leading to the development of improved models to represent these processes;

Development of new techniques for in-situ field characterization of hydrologic, mechanical, and chemical properties of host media and groundwater in a borehole or an excavated tunnel;

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Aqueous speciation and surface sorption at elevated temperatures and geochemical conditions (e.g., high ionic strength) relevant to the disposal environments being considered;

Consideration of how specific waste forms may perform in different disposal environments using theoretical approaches, models and/or experiments, with quantitative evaluations including uncertainties of how the long-term performance of waste forms can be matched to different geologic media and disposal concepts; and

Experimental and modeling investigations for the effect of radiolysis on used fuel, high-level waste, and barrier material degradation at temperatures and geochemical conditions relevant to potential storage and disposal environments.

FUEL CYCLE OPTION ANALYSIS (FC-5)
(FEDERAL POC – BHUPINDER SINGH & TECHNICAL POC – TEMI TAIWO)

FC-5.1a: Visualization Tools

The Fuel Cycle Options campaign performs analysis and evaluates integrated fuel cycle systems with the purpose of identifying and exploring sustainable nuclear fuel cycles that are candidates for future deployment. An important consideration for any deployment of nuclear power is the overall energy generation context in which such systems would be used, which is generally the production of electricity to support the electric grid, although other uses for the energy generated by nuclear power could also be included, e.g., process heat, desalination, or hydrogen production. This program element is interested in the development of visualization tools which can perform the following tasks for communication to and enhancing understanding of public and other stakeholders about benefits and drawbacks of nuclear power and nuclear fuel cycle alternatives:

Comparative analysis of nuclear energy systems in the context of an integrated energy generation infrastructure including e.g., solar, biomass, oil, natural gas, wind, etc., and to one another in the overall energy generation context. An Evaluation and Screening of Fuel Cycle Options Study was completed for the Office of Nuclear Energy in October 2014 (available at https://www.inl.gov/nuclear-fuel-cycle-evaluation-and-screening/) identified those alternative nuclear fuel cycles that would provide the most benefit compared to today's U.S. fuel cycle.

Demonstrate and explore the potential of nuclear power in future energy systems. The target audience is a technically oriented layperson. The tool should model the strengths and weaknesses of energy options in a realistically demanding environment. At a minimum it should have a business (electricity generator) perspective and an electricity consumer perspective. Market considerations and government subsidy consideration should be included.

The software user must see and experience the challenge of providing reliable electricity service, reflecting the variable nature of some generation sources such as wind and solar in contrast to stable sources of power such as natural gas and nuclear. The product should address both short and long time scales. Short scales address daily electricity demand variability, supply variability of renewable sources (wind shifts, solar level changes,). Long time scales are important to address investment pay back, facility lifetime, outages, changes in power demand including seasonal patterns, changes in rates and costs as well as regulatory changes.

For the business perspective, end profit factors, basic revenues and expenses (fixed costs, variable cost including debt service), electricity rates, tax rates, fuel rates are all important. Subsidies and their effect should be included. Transmission details are relevant as unreliable power sources rely on grid manipulation. Transmission losses and the scale of weather patterns are also relevant.

For the consumer perspective, reliability and cost are key considerations. Environmental impacts such as pollution and the amount and type of waste can be outcomes that are calculated by the tool.

The tool should be populated with "boiler plate data" to allow easy initial use. The data could be specific to the

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United States or a state or a region. A desirable feature would be for the boiler plate to be easily updated regularly (continuously or at least annually) For example, the ability to click on "my state" and view a model with a fairly accurate energy supply and demand portfolio would enhance usefulness. At this level, only few representative technologies should be needed. For example for nuclear energy, it should be adequate to pick from a modern PWR, SMR, or a recycling fast spectrum reactor. Similarly other sources need only have one or two technology options.

The boiler plate data should be easily modifiable for more interested or advanced users. Layers of modification would be desirable. The first layers offering simple variable manipulation with possibly more details modifications in deeper layers.

When completed this tool must be publicly available, easy and intuitive to use, and should be usable on different computer platforms, including laptop and perhaps even handheld devices.

FC-5.1b: Maintaining and advancing Fuel Cycle Simulation Capability

The current nuclear fuel cycle is a well-established and well-understood system. Fuel cycle analysis is important for understanding how a transition to an alternative fuel cycle will impact that system. Cyclus (www.fuelcycle.org) is an open-source nuclear fuel cycle simulator that is designed to enable collaborative enhancements and improvements that accommodate different fuel cycle analysis questions and use cases. Projects which can maintain and advance this capability developed in part due to past NEUP support are invited. For example:

- Develop modules that support specific types of fuel cycles or fuel cycle technologies
- Develop capability for sensitivity analysis and/or optimization
- Interfacing with tools designed to model broader energy & climate futures (e.g., MARKAL, GCAM, etc.)
- Developing capability for economic and financial modeling
- Incorporation of time and geospatial considerations for the transportation of material
- Maintaining and enhancing Cycamore, the basic module library for Cyclus and providing the Cyclus community facilitator role and a resource for developers of archetype modules and analysis tools.

MISSION SUPPORTING: FUEL CYCLE TECHNOLOGIES

FUEL CYCLE R&D (MS-FC-1)
(FEDERAL POC – DAVID HENDERSON & TECHNICAL POC – KEMAL PASAMEHMETOGLU)

Sustainable fuel cycle options are those that improve uranium resource availability and utilization, minimize waste generation, and provide adequate capability and capacity to manage all wastes produced by the fuel cycle. The objective is to develop a suite of options that will enable future decision-makers to make informed choices about how best to manage the used fuel from reactors. Applications should address the technologies and options that would allow for the sustainable management of used nuclear fuel that is safe, economic, and secure and widely acceptable to American society. Examples of topics may include advanced fuel treatment or material recovery processes, innovative fuel designs, and innovative fuel cycle analysis tools. Areas of interest include "blue sky" concepts for advanced methods of managing used nuclear fuel, such as innovative recycling, transport, storage, and disposal concepts. Areas of interest for transmutation fuel include, but are not limited to, existing LWRs, other thermal, and fast or mixed spectrum reactors. Advanced fuel concepts may also include LWR fuel with improved performance benefits and fast reactor fuel with improved cladding performance (e.g., ability to withstand 400 dpa). Extended use of nuclear power may drive improvements in defining resource availability and on fuel resource exploration and mining.

PROGRAM SUPPORTING: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION

NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION (NEAMS-1)
(FEDERAL POC – DAN FUNK & TECHNICAL POC – DAVID POINTER)

The Nuclear Energy Advanced Modeling and Simulation (NEAMS) Toolkit takes advantage of scalable simulation methods on high performance computing architectures in combination with a science-based, mechanistic approach to modeling to allow scientists and engineers better understand reactor materials properties and coupled phenomena in nuclear energy systems. This toolkit covers length scales from atomic to mesoscale to continuum and time scales from picoseconds to seconds to days.

The computational tools developed for this toolkit provide predictive assessments of the performance and safety of a broad class of nuclear reactor systems. Validation of the underlying mechanistic models (materials science, thermal-hydraulics, neutronics, continuum and structural mechanics) both in separate effects and integrated simulations, is essential for ensuring the toolkit is accurate, robust, and useful. Broad validation assessments instill confidence that simulations capture the essential features and phenomena appearing in real, operating nuclear systems, which is essential if the NEAMS ToolKit is to provide a successful transition between conventional descriptive engineering models and predictive simulation-based HPC models.

The NEAMS program is seeking applications that contribute to improving the mechanistic models, computational methods, and validation basis of NEAMS ToolKit and its components. Proposals should clearly define quantitative metrics of success for the proposed work that illustrate the return on investment (e.g., the implemented model will reduce error in predictions of peak temperature in the selected benchmark problem by X%).

Model development and validation can span the entire hierarchy from single-scale and single-effects experiments designed to address individual phenomena to integrated models or experiments that address strong coupling of multiple phenomena. Applications to run simulations or conduct experiments at DOE laboratories and Nuclear Science User Facilities (http://atrnsuf.inl.gov/) in support of the NEAMS Toolkit are encouraged, though computation or experimentation at university laboratories is also acceptable. Collaboration with members of the NEAMS development team residing at DOE laboratories is strongly encouraged.

FY16 proposals should address one of the following areas:

NEAMS 1.1 – ATOMISTIC AND MESOSCALE MODELING AND SIMULATION OF NUCLEAR FUELS, CLADDING, AND REACTOR STRUCTURAL MATERIALS

The NEAMS ToolKit includes the MARMOT mesoscale nuclear materials simulation code, which computes the evolution of microstructure and the consequent change in material properties in fuel and cladding materials during reactor operation. The microstructure evolution is described using the phase field method coupled to solid mechanics and heat conduction, and solved using the finite element based Multiphysics Object Oriented Simulation Environment (MOOSE). MARMOT is dependent on free energies, diffusivities, and other data for material systems from experiments and atomistic simulations using molecular dynamics and density functional theory. MARMOT has primarily focused on LWR fuel and cladding materials and can be employed for studies of a broad range of materials. Proposals are sought which improve predictive capabilities for additional phenomena of interest in nuclear materials impacting their in-reactor performance, extend the capabilities of MARMOT to a broader range of fuel and cladding materials, and improve the validation basis of the code. Examples of additional phenomena of interest include corrosion, creep, chemical interaction, dislocation, and phase separation in multi-phase, multi-component systems in reactor materials including current and future reactors. Validation should involve closely correlated experiments and modeling using MARMOT, as well as uncertainty quantification.

Proposals on atomistic to mesoscale and physics coupling using MARMOT are also encouraged.

NEAMS 1.2 – MACROSCALE FUEL PERFORMANCE

PROGRAM SUPPORTING: NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION

The NEAMS macroscale fuel performance module BISON provides capabilities for 1-D, 2-D and 3-D predictions of changes in thermal and structural response of the fuel and cladding from beginning of life through long-term storage. BISON's material and behavior models are being improved through coupling with the MARMOT code and through coordination with MARMOT development. NEAMS encourages proposals that aid in the development of theory-based models of advanced materials' properties, , propose more robust and efficient numerical algorithms, extend capabilities of BISON to fuel forms that are currently under supported, tackle fuel failure mechanisms, and improve the validation basis of the code, particularly for 3-D problems.

Proposals that employ coupling of BISON and MARMOT simulations using sequential, concurrent, or hybrid methods are encouraged.

NEAMS 1.3 – CORE NEUTRONICS

NEAMS' investment in neutronics methods is driven by the need to provide much more detailed spatial and temporal descriptions of reaction rates and isotopic densities to the NEAMS fuels performance modules than can be achieved with more conventional methods. The NEAMS ToolKit uses the PROTEUS neutronics module, which provides tools for second order discrete ordinates transport, cross-section library generation, and kinetics. PROTEUS is integrated with ORIGEN for depletion. NEAMS also supports the development and demonstration of the MOOSE-based MAMMOTH depletion application and RattleSnake transport application for assessment of transient fuel performance in the TREAT reactor. Proposals are sought which improve predictive capabilities for complex transients, provide capabilities for multi-resolution simulations with mixed homogenized and heterogeneous regions, expand and demonstrate simulation capabilities of PROTEUS to other reactor types, extend capabilities of PROTEUS for fuel cycle analysis with a wide range of reactor core configurations, demonstrate improved accuracy for fuel performance simulations, and improve validation basis for the codes.

Proposals that consider the integration of the NEAMS macroscale fuels and neutronics capabilities are also encouraged.

NEAMS 1.4 – THERMAL HYDRAULICS

The NEAMS thermal hydraulics module Nek5000 provides capabilities for high resolution Direct Numerical Simulation (DES), Large Eddy Simulation (LES), Unsteady Reynolds Average Navier Stokes (URANS) simulation, and reduced order distributed resistance modeling. A low-mach number two-phase boiling simulation capability is also in the early phases of implementation in Nek5000. Proposals are sought which expand the turbulence modeling options available in Nek5000, demonstrate its applicability to a wider range of reactor types and conditions, and improve validation basis for the code. In particular, new sets of measured data for validation of the two-phase boiling capability, including boiling water experiments (preferably at higher pressures) and/or experiments with detailed measurements in relevant fuel assembly geometries are desired.

NEAMS 1.5 – STRUCTURAL MECHANICS

The NEAMS structural mechanics module Diablo provides capabilities for high-resolution simulation of structural temperatures, strain and stresses, and deformation in large complex structural components using a mix of 2-D and 3-D methods. Diablo also offers diverse options for addressing material-to-material contacts. Proposals are sought which add models to Diablo or expand the validation of Diablo to enhance its ability to predict the behavior of reactor structures, possibly leveraging the ToolKit's existing mesoscale and continuum material simulation capabilities such as MARMOT and BISON.

Proposals that consider integrations of the NEAMS tools for Thermal-Structural or Fluid-Structural applications are also encouraged.

PROGRAM SUPPORTING: NUCLEAR ENERGY

NUCLEAR ENERGY CYBERSECURITY IMPLICATIONS IN CONTROL ROOM OPERATIONS (NE-1)
(FEDERAL POC: TREVOR COOK & TECHNICAL POC: STEVEN HARTENSTEIN)

As the use of digital instrumentation and controls becomes common place in both research reactors and operating nuclear power plants, there is an opportunity to conduct research that will inform plant engineer and operator responses to cybersecurity threats. Proposals should focus on technologies and methodologies for diagnosing a cyber event and on developing methods, procedures, and protocols for operator responses to cyber events. Research should lead to enhancements in cybersecurity education, training, and technologies that improve the diagnosis of cyber events and the response to the event by control room operators and shift engineers.

MISSION SUPPORTING: NUCLEAR ENERGY

INTEGRAL BENCHMARK EVALUATIONS (MS-NE-1)
(FEDERAL POC: ROB VERSLUIS & TECHNICAL POC: JOHN BESS)

The International Reactor Physics Experiment Evaluation Project (IRPhEP) and International Criticality Safety Benchmark Evaluation Project (ICSBEP) are recognized world-class programs that have provided quality-assured (peer-reviewed) integral benchmark specifications for thousands of experiments. The Project produces two annually updated Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) Handbooks that are among the most frequently quoted references in the nuclear industry. Applications are sought to provide complete benchmark evaluations of existing experimental data that 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. All evaluations must be completed according to the requirements, including peer review of 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, M&S HUB, NEAMS, LWRS, FCT and ART, and DOE activities such as resumption of transient testing, are of particular interest to this call.

MISSION SUPPORTING: ENVIRONMENTAL MANAGEMENT

RADIOACTIVE WASTE MANAGEMENT (MS-EM-1)
(FEDERAL POC: HITESH NIGAM & TECHNICAL POC: JEFFREY GRIFFIN)
(UP TO $525,000 AND 3 YEARS; ANTICIPATE 1 AWARD AT $400,000)

Pre-Applications are not required for this area.

The proposed scope supports joint research conducted by United States (U.S.)-lead universities in direct collaboration with Japanese universities/research institutions on the development of environmental measure for the management of radioactive waste. In this project, each country will provide research & development (R&D) funding for its own research institutions, with the research in each country performed in collaboration/coordination with the other project partners.

The R&D focus will be on basic and fundamental joint research which contributes to environmental safety while decommissioning; and to storage, treatment and disposal of radioactive wastes produced by decommissioning. Such work is of mutual interest and benefit in that it: 1) contributes to the acceleration of decommissioning of the TEPCO Fukushima Daiichi Nuclear Power Plant (NPP), and 2) contributes to the overall DOE Office of Environmental Management (EM) cleanup mission.

The proposed topics of joint research that have joint applicability and interest for Japan and the U.S. are:

Systems studies on radioactive waste treatment and packaging facilities or operations. Processes involving the treatment operations (generally decontamination and/or packaging) of radioactive waste materials are typically complex operations with many steps. For such systems, optimization of the performance of the entire process requires careful analysis of the components and their interactions. This area of study could include proposals for assessing and optimizing the performance of specific waste treatment or packaging systems OR approaches to improving the performance of critical steps in specific systems.

Technologies for rapid analysis and assessment of key radiological contaminants (Cs-137, Sr-89, Sr-90, others as identified) in water and soil matrices. This area of study seeks the development and/or evaluation of rapid methods for analyzing certain key radioactive contaminants in water and/or soil matrices. Such technologies can greatly speed the assessment of contamination (or progress in cleanup) in environmental conditions. Easily deployable field technologies are desired.

Modeling tools and techniques for assessing contaminant risk and target cleanup levels. This area of study seeks to proposal to develop or demonstrate models and techniques that can be used to assess contaminant risk and target cleanup levels – based on such variable factors as physical conditions at the site, the extent of contamination, the chemical/physical form, current and future use of the site, etc. The results of such models provide target cleanup levels which can then be used to guide the selection of the appropriate environmental remediation approach.

Note: A*pplicants to this work scope must propose a direct collaboration with one or more Japanese universities/research institutions to be considered responsive.* An equivalent amount of funds are anticipated to be provided by the Japanese government to the Japanese collaborators. Availability of these funds will be addressed in a solicitation sponsored by the Ministry of Education, Culture, Sports, Science and Technology. Applicants must address one or more of the above problem statements to be considered responsive to this work scope. Also, as with all work scopes contained in this FOA, research consortiums may be proposed that contain diverse institutions including academia, national laboratories, non-profit research institutes, industry/utilities, and international partners.

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

PROGRAM SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

ADVANCED METHODS FOR MANUFACTURING (NEET-1)
(FEDERAL POC – ALISON HAHN & TECHNICAL POC – JACK LANCE)

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. The focus and emphasis will be placed on technologies that can be deployed in the near-term. Areas that should be considered are the improvement of plant component manufacturing using innovations like additive manufacturing, innovations in the fabrication of reactor and in-reactor components and the development of new construction modular building technologies that support the development and delivery of modular systems. Most importantly, reducing the cost of construction here in the U.S. for both ALWRs and SMRs is an important goal for any proposed research.

- Proposals must demonstrate that they meet at least one of the following specific goals
- Accelerate deployment schedule by at least 6 months compared to current new plant construction estimates
- Reduce component fabrication costs by 20% or more
- Increase installation of key subsystems without cost increase or schedule delay.

The program seeks to develop manufacturing and fabrication innovation, assembly processes and materials innovation that support the "factory fabrication" and expeditious deployment of SMR technologies. Potential areas for exploration include:

Factory and field fabrication techniques that include improvements in manufacturing technologies such as advanced (high speed, high quality) welding technologies, practical (shop floor) applications of electron beam welding for fabricating heavy sections, surface modification and metal spraying techniques that reduce erosion, corrosion and wear on component surfaces.

Assembly and material innovation to enhance modular building techniques such as innovation using concrete composite and steel form construction methods and innovative rebar pre-fab and placement systems.

Advances in manufacturing processes for reactor plant components, reactor internals, fuel cladding and fuel support assemblies. Research could include advanced manufacturing methods for individual components or fabrication of assemblies. Cladding or surface modification methods to resist corrosion and wear are relevant to this research topic.

Details of several areas for innovation can be found in the NEET 2010 Workshop report

(http://energy.gov/sites/prod/files/Neet_Workshop_07292010.pdf).

Through innovation in manufacturing, fabrication and assembly, significant advancements in nuclear technology quality, performance and economic improvements will be achieved. One of the key success criteria for the program is the development of products or components that will gain acceptance by the appropriate regulatory or standard-setting bodies and licensing for commercial nuclear plant deployment.

ADVANCED SENSORS AND INSTRUMENTATION (NEET-2)
(FEDERAL POC – SUIBEL SCHUPPNER & TECHNICAL POC – BRUCE HALLBERT)

The Advanced Sensors and Instrumentation program seeks applications for innovative robust methods for transmitting signals and data in a nuclear environment.

The selected technology should be applicable to multiple reactors or fuel cycle applications (i.e., crosscutting).

PROGRAM SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

Research objectives:

- Develop and demonstrate the ability to transmit greater amounts of data and other signals through physical boundaries in nuclear facilities
- Address new communication demands needed for advanced measurement and control technologies including protection of data
- Take into consideration the environment and the conditions under regular operation and/or accident scenario
- Test and validate prototype through demonstration in appropriate representative environment.

Proposals must address each of the above objectives to be considered responsive to this scope. If one of the objectives is considered not applicable to the proposed approach, an explanation must be provided.

REACTOR MATERIALS (NEET-3)
(FEDERAL POC – SUE LESICA & TECHNICAL POC – STUART MALOY)

The NEET Crosscutting Reactor Materials program seeks applications for advanced materials characterization techniques and tools. Successful completion of awards will provide advanced methods for sample preparation and new tools and techniques for examining and understanding material microstructures in a variety of conditions ranging from as-received to treated to irradiated.

Developing an extensive understanding of material behavior in extreme environments is vital to the development of new materials for service in advanced nuclear reactors and fuel cycles. This understanding is also needed for the extension of the operating lifetimes of the current fleet of nuclear reactors. Advanced characterization methods utilizing advanced tools and techniques, coupled with modeling and simulation and advanced sample preparation tools will further the understanding of the effects of irradiation, temperature, pressure and corrosive environments on material microstructures and mechanical behavior. Modern sample fabrication tools could also allow for more efficient use of existing irradiated materials and enable fabrication of smaller specimens from previously examined materials.

REDUCTION IN CYBERSECURITY VULNERABILITIES AND ATTACK SURFACES IN NUCLEAR POWER PLANTS (NEET-4)
(FEDERAL POC: TREVOR COOK & TECHNICAL POC: STEVEN HARTENSTEIN)

A significant source of threat to nuclear cyber systems include demonstrated and conceptualized vulnerabilities within the supply chain and insider threats. These vulnerabilities can represent realized risks and consequences from unintentional errors or malicious actions. Proposed research of interest should focus on development of deployable cybersecurity solutions that enhance the protection of nuclear energy facilities from supply chain vulnerabilities or insider threats. Research outcomes should pursue the evolution of a prototype with accompanying experimental data that demonstrates the potential improvement in security, operational performance and risk reduction for a nuclear energy facility. The research solutions of most interest will have a cost effective, credible pathway for near-term operational deployment within the current nuclear power plant fleet and have applicability to small modular reactor and advanced reactor designs.

MISSION SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

NUCLEAR ENERGY-RELATED R&D SUPPORTED BY NUCLEAR SCIENCE USER FACILITIES CAPABILITIES (NEET-NSUF-1)
(FEDERAL NSUF POC: ALISON HAHN & TECHNICAL NSUF POC: RORY KENNEDY)

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 NEET-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. Information regarding the current Nuclear Energy R&D Roadmap as well as specific research areas can be found at http://energy.gov/ne/mission.

As part of this FOA, NSUF provides no-cost access to unique nuclear energy R&D infrastructure in the areas of irradiation, post irradiation examination, and beamline experiments; thus enabling research in critical areas as described below. New to this FOA, NSUF offers access to High Performance Computing capabilities and applications coupling experimentation to computational modeling and simulation are encouraged. Successful applications will have demonstrated that the proposed research will produce High Impact results. Criteria to demonstrate High Impact research will include 1) the project's ability to validate and verify (V&V) developed or developing models (see appendix on V&V needs); 2) the project's potential to lead to or uncover new mechanisms, models, or theoretical understanding; 3) the project's ability to solve specifically identified pressing issues recognized by industry and/or NE R&D programs within the proposed workscope.

Note: All projects awarded under NEET-NSUF-1 are categorized as mission supporting and will have a R&D component that is complemented by the unique capabilities of NSUF. The R&D portion of NEET-NSUF-1 projects cannot exceed $500,000 and a 3-year duration (see Part II, Section C). However, since NSUF-supported projects involving reactor neutron irradiation may be up to 7 years in duration, flexibility in R&D funding distribution can be established to accommodate actual resource allocation requirements, i.e., a 3-year research effort may be planned across a longer period of performance to accommodate breaks in R&D activities during NSUF support periods).

NEET-NSUF 1.1 - NUCLEAR REACTOR TECHNOLOGIES
NEET-NSUF 1.1A TARGETED IRRADIATIONS OF LWR CORE INTERNAL MATERIALS
(FEDERAL POC: RICHARD REISTER & TECHNICAL POC: KEITH LEONARD)

Under irradiation, the large concentrations of radiation-induced defects will diffuse to defect sinks such as grain boundaries and free surfaces. These concentrations are in far excess of thermal-equilibrium values and can lead to coupled-diffusion with particular atoms. In engineering metals such as stainless steel, this results in radiation-induced segregation (RIS) of elements within the steel. For example, in 316 stainless steel, chromium (important for corrosion resistance) can be depleted at grain boundaries, whereas elements like nickel and silicon are enriched to levels well above the starting, homogenous composition. While RIS does not directly cause component failure, it can influence corrosion behavior in a water environment. Further, this form of degradation can accelerate the thermally driven phase transformations mentioned above and also result in phase transformations that are not favorable under thermal aging (such as G or gamma-prime phases observed in stainless steels). Additional fluence may exacerbate radiation-induced phase transformations and should be considered. Proposals are sought for irradiation and post-irradiation examination of LWR core internal materials (for example, cast austenitic stainless steel, model and commercial alloys) to provide data for validation data for phase transformation models under development in the LWRS Program.

NEET-NSUF 1.1B GAMMA IRRADIATION OF LWR CABLES
(FEDERAL POC: RICHARD REISTER & TECHNICAL POC: KEITH LEONARD)

A variety of environmental stressors in nuclear reactors can influence the aging of low- and medium-electrical-

MISSION SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

power and instrumentation and control (I&C) cables and their insulation, such as temperature, radiation, moisture/humidity, vibration, chemical spray, mechanical stress, and oxygen present in the surrounding gaseous environment (usually air). Exposure to these stressors over time can lead to degradation that, if not appropriately managed, could cause insulation failure, which could prevent associated components from performing their intended function. Proposals are sought on gamma irradiation of LWR cable insulation in the HFIR gamma irradiation facility, followed by examination of cables to support determination of remaining useful life of cable insulation in the LWRS Program.

NEET-NSUF 1.1C IRRADIATION OF LWR WELD MATERIAL
(FEDERAL POC: RICHARD REISTER & TECHNICAL POC: KEITH LEONARD)

Advanced welding technologies that can be used to repair highly irradiated reactor internals without helium-induced cracking are an important mitigation technology under investigation in the LWRS Program. Weld-repair techniques must be resistant to long-term degradation mechanisms, including exposure to the challenging nuclear environment. Advanced weld technique development in the LWRS Program is being performed collaboratively with EPRI. Research includes mechanistic understanding of helium effects in weldments, and is supported by characterization of model alloys before and after irradiation and welding. Demonstration of the performance of weldments under extended service conditions is required before weld techniques can be used by industry. In this task, irradiation and post-irradiation examination of LWR weld materials is requested. Proposals should be coordinated with the LWRS Program.

ADVANCED REACTOR TECHNOLOGIES (ART)
NEET-NSUF 1.1D EXPERIMENTAL DATA FOR FISSION PRODUCT RETENTION, DIFFUSION AND TRANSPORT PROPERTIES FOR GAS COOLED REACTORS AND SODIUM FAST REACTORS USING NUCLEAR SCIENCE USERS FACILITIES
(FEDERAL POC: MADELINE FELTUS & TECHNICAL POC: DAVID PETTI)

Experimental data for fission product behavior in Gas-Cooled and Sodium Fast Reactors is focused on providing high quality data for irradiation performance and accident computer models that simulate the retention, time-dependent diffusion and radionuclide transport conditions of key fission products from TRISO particle fuel and sodium fast reactor fuel. These fission product phenomena have been identified as relevant to fuel safety and performance but for which insufficient separate effects data exist for validating computer models and codes.

For the advanced TRISO fuel for gas-cooled reactors, experimental data is needed to develop the microstructural and physical properties of the neutron irradiated TRISO fuel materials, fuel matrix and structural graphite materials, as fission products are released during irradiation, decay and diffuse during post-irradiation evaluations and during transient safety heat up testing. Using advanced characterization techniques will be needed to enhance the ability to link the AGR TRISO fuel program integral experimental data with separate effects testing at the microstructural-level to produce data needed for the validation of structural graphite, graphitic matrix, and TRISO fuel performance models to discern time and temperature-dependent fission product transport, diffusion, sorption and retention characteristics. Similarly, fission product transport, diffusion and retention behavior data is needed for advanced sodium fast reactor fuel and sodium coolant system environments, for temperature and time-dependent conditions.

Proposals are sought that use NSUF capabilities, e.g., Idaho National Laboratory (INL) hot cells, INL Advanced Test Reactor, NSUF Partner Facilities, as well as applicant university facilities to provide sufficient separate effects fission product data needed for TRISO fuel matrix and gas-cooled reactor structural graphite conditions for temperature and temporal dependent performance modelling, and/or advanced sodium fast reactor conditions. Proposals may use non-radioactive elements of interest (e.g., Kr, I, Cs, Sr, Ru, Ag, etc.) as surrogates for the radioactive species for the separate effects experiments; however, the proposed experiments should be performed on both un-irradiated and irradiated materials, e.g., TRISO fuel or surrogate, matrix and graphite structural materials and/or sodium fast reactor fuel or surrogate, reactor coolant and structural materials, and the test must be performed at typical reactor operating conditions.

Data collection, experiments, data validation, and verification effort may require compliance with NQA-1 2008 and

MISSION SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

2009 NRC accepted paragraphs for quality assurance practices. Archive of data and simulation results in the INL Nuclear Data Management and Analysis System (NDMAS) may also be required. Investigators are strongly urged to coordinate with INL personnel working on NDMAS, as well as obtaining appropriate irradiated materials for these separate effects fission product experiments. Applicability of these requirements will depend on the proposal and will be addressed during the NSUF Feasibility Review.

NEET-NSUF 1.1E NUCLEAR THERMAL PROPULSION FUELS TESTING
(FEDERAL POC: SCOTT HARLOW & TECHNICAL POC: STEVE JOHNSON)

Based on NASA's Nuclear Thermal Propulsion (NTP) Independent Review Panel's fuels down-selection recommendations, performance data of graphite composite fuels in a relevant irradiation environment is sought. The data is needed to optimize fuel fabrication parameters and to verify computational simulations on fuel element performance. Since current fuel fabrication and computational simulation activities are based on historical test data from the Rover/NERVA program, new test data is needed to correlate current fuel element performance to historical tests.

Composite fuels need to be irradiated under prototypic operating conditions to understand their response to neutron damage in the severe operational environment. The possibility of neutron irradiation damage being a significant contributor to the "mid-band" corrosion issue observed in the NERVA program needs to be investigated and understood.

Initial irradiation tests would include small samples in low-cost non-instrumented capsules within HFIR or ATR. Specimen holder assemblies would be designed to stress the fuel samples under the elevated temperatures of irradiation. Specimens would be recovered and inspected for signs of stress corrosion cracking in their protective coating. Complementary experiments would be carried out by the DOE/NASA nuclear thermal propulsion program in non-nuclear furnaces to apply similar stress under the same conditions without irradiation. Comparison between the two cases will provide an indication of the significance of irradiation damage to coating cracking.

If irradiation damage is a significant contributor to coating cracking, then more sophisticated instrumented capsules might need to be developed. Within these capsules, representative samples approximately 1" across and up to 24" in length could potentially be irradiated at elevated temperature. These experiments would be used to verify performance of the most promising fuel and coating combinations.

If a successful low-cost testing technique can be developed, then other promising coatings would be investigated; first in the furnace tests and later in reactor tests. Currently, multilayer coatings are being investigated to see if underlying materials with variable thermal expansion properties can reduce stress within the outer protective coating layer. If these coatings can be successfully applied, then they would be tested and compared to the single-layer coated fuel samples. It is thought that multiple coatings applied with greater precision can significantly reduce coating cracking and carbon loss from the composite fuel, which would make it the ideal fuel.

NEET-NSUF 1.2 - FUEL CYCLE TECHNOLOGIES
FUEL CYCLE RESEARCH AND DEVELOPMENT
NEET-NSUF 1.2A EXPERIMENTAL DATA AND MODELS FOR ADVANCED REACTOR FUELS AND CLADDING MATERIALS USING NUCLEAR SCIENTIFIC USERS FACILITIES
(FEDERAL POC: JANELLE ZAMORE & TECHNICAL POC: JON CARMACK)

The FCRD Advanced Fuel Campaign is developing advanced fast spectrum reactor metallic fuels and advanced LWR fuel technologies to improve performance of fuels and materials in Light Water Reactors during off-normal conditions. Proposals for separate effect experiments linking integral experimental data with microstructural-level material properties of candidate fuel system components are desired. Priority will be given to proposals that focus on metallic alloy fuels for advanced reactors and for technologies currently under investigation by the Accident Tolerant Fuel program. The experimental activities should produce data to be used in the validation of material property and fuel performance models. The model(s) supported and developed should be consistent and compatible

MISSION SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

with the NEAMS MBM fuel performance tools. Proposals focused on advancing LWR accident tolerant fuel and advanced recycle fuel concepts currently under study by the FCRD AFC will be given higher priority.

Proposals are sought that use the NSUF, e.g., Idaho National Laboratory (INL) hot cells, INL Advanced Test Reactor, NSUF Partner Facilities., as well as applicant university facilities to provide sufficient separate effects data needed for development of high performance models of nuclear fuels and materials performance and behavior.

Proposals in this field that do not intend to use any NSUF capabilities should apply under the mirror call in Appendix A, see workscopes FC-2.1 and FC-2.2.

NEET-NSUF 1.3 - NUCLEAR ENERGY ENABLING TECHNOLOGIES
CROSSCUTTING TECHNOLOGY DEVELOPMENT
NEET-NSUF 1.3A SEPARATE EFFECTS IRRADIATION TESTING OF FISSION PRODUCT BEHAVIOR
(FEDERAL POC: SUE LESICA & TECHNICAL POC: RORY KENNEDY)

The objective of this workscope will be to study behavior of fission products (gaseous, insoluble solid, soluble solid) and actinide species of relevance to fuel performance. Separate effects testing on transport mechanisms, thermomechanical or thermophysical property influence, and fuel cladding interaction that are strongly related or coupled to modeling efforts are encouraged. All fuel forms specifically relevant to the mission of DOE-NE can be applied against.

NEET-NSUF 1.3B IRRADIATION ASSISTED STRESS CORROSION CRACKING (IASCC)
(FEDERAL POC: SUE LESICA & TECHNICAL POC: RORY KENNEDY)

Mechanistic studies, data for high fluence conditions, innovative experiment designs, and alternative irradiations. Correlations between irradiated microstructures with IASCC susceptibility, role of precipitates on hardening and cracking, influence of stress/loading history, void/bubbles, fluence, and neutron spectrum on IASCC.

NEET-NSUF 1.3C IRRADIATION TESTING OF MATERIALS PRODUCED BY INNOVATIVE MANUFACTURING TECHNIQUES
(FEDERAL POC: ALISON HAHN & TECHNICAL POC: RORY KENNEDY)

Products from advanced and innovative manufacturing techniques that offer lower cost and higher performance can be proposed for irradiation testing to demonstrate performance. Coupling to modeling mechanisms predicting performance enhancements is encouraged.

NEET-NSUF 1.3D EXPERIMENTS WITH SYNCHROTRON RADIATION AT THE ADVANCED PHOTON SOURCE
(FEDERAL POC: SUE LESICA & TECHNICAL POC: RORY KENNEDY)

Proposed research includes the use of facilities at the Materials Research Collaborative Access Team (MRCAT) beamline located in the Advanced Photon Source Facility at Argonne National Laboratory. Proposals requesting the use of these facilities should focus on post-irradiation examination or concurrent use with ongoing irradiations at ATR NSUF. Experiments conducted at MRCAT will be facilitated by the Illinois Institute of Technology. Experiments that can currently be carried out at the MRCAT include x-ray diffraction (XRD), x-ray absorption (XAS), x-ray fluorescence (XRF), and 5 μm spot size fluorescence microscopy.

Research Areas for Experiments with Synchrotron Radiation - The research areas listed here represent promising applications of synchrotron x-ray techniques in characterizing microstructural evolution and associated physical and mechanical properties of materials under irradiation.

- Fundamental Aspects of Radiation Damage
- Phase Stability and Phase Transformation under Irradiation
- Surfaces and Grain Boundaries in Irradiated Materials

MISSION SUPPORTING: NUCLEAR ENERGY ENABLING TECHNOLOGIES (NEET)

- Deformation and Fracture of Irradiated Materials
- Physics and Chemistry of Nuclear Fuels.

MISSION SUPPORTING ACCESS ONLY: NUCLEAR SCIENCE USER FACILITIES (NSUF)

NUCLEAR SCIENCE USER FACILITIES ACCESS ONLY (NEET-NSUF-2)
(FEDERAL POC: ALISON HAHN & TECHNICAL POC: RORY KENNEDY)

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. Information regarding the current Nuclear Energy Research and Development Roadmap as well as specific research areas can be found at http://energy.gov/ne/mission.

NSUF provides access to unique nuclear energy R&D infrastructure in the areas of irradiation, post irradiation examination and beamline experiments; thus enabling research in critical areas as described below. New to this FOA, NSUF offers access to High Performance Computing capabilities and applications coupling experimentation to computational modeling and simulation are encouraged. Successful applications will have demonstrated that the proposed research will produce High Impact results. Criteria to demonstrate High Impact research will include 1) the project's ability to validate and verify (V&V) developed or developing models (see appendix on V&V needs); 2) the project's potential to lead to or uncover new mechanisms, models, or theoretical understanding; 3) the project's ability to solve specifically identified pressing issues recognized by industry and/or NE R&D programs within the proposed workscope.

All applications submitted under this workscope must identify the R&D funding source, scope, and duration associated with the requested "NSUF access only" scope.

Core and Structural Materials

This element is primarily focused on understanding material degradation mechanisms and developing radiation resistant materials for application in current and future reactors. Proposed projects may involve R&D in the areas of material irradiation performance and combined effects of irradiation and environment on materials.

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 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 designing simple irradiation experiments and post irradiation examination that investigate fundamental aspects of fuel performance such as radiation damage, amorphization, fuel restructuring, species diffusion, and fission product yields for TRU materials.

Advanced In-reactor Instrumentation

This program element includes development of advanced in-reactor instrumentation for characterization of materials under irradiation in test reactors and for on-line condition monitoring in power reactors. Applications should address the development of radiation resistant sensors for measurement of thermal conductivity, dimensional changes (specifically diameter and volume), crack propagation in materials, and internal fission gas pressure. Development of practical techniques that are non-intrusive with respect to irradiation specimens is encouraged, as are concepts

MISSION SUPPORTING ACCESS ONLY: NUCLEAR SCIENCE USER FACILITIES (NSUF)

that examine the feasibility and practical use of nontraditional methods such as optical fibers and ultrasonic techniques as well as other incorporated wireless transmission techniques.

Experiments with Synchrotron Radiation at the Advanced Photon Source

Proposed research includes the use of facilities at the Materials Research Collaborative Access Team (MRCAT) beamline located in the Advanced Photon Source Facility at Argonne National Laboratory. Proposals requesting the use of these facilities should focus on post-irradiation examination or concurrent use with ongoing irradiations at NSUF. Experiments conducted at MRCAT will be facilitated by the Illinois Institute of Technology. Experiments that can currently be carried out at the MRCAT include x-ray diffraction (XRD), x-ray absorption (XAS), x-ray fluorescence (XRF), and 5 μm spot size fluorescence microscopy.

Research Areas for Experiments with Synchrotron Radiation - The research areas listed here represent promising applications of synchrotron x-ray techniques in characterizing microstructural evolution and associated physical and mechanical properties of materials under irradiation.

- Fundamental Aspects of Radiation Damage
- Phase Stability and Phase Transformation under Irradiation
- Surfaces and Grain Boundaries in Irradiated Materials
- Deformation and Fracture of Irradiated Materials
- Physics and Chemistry of Nuclear Fuels.

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

PROGRAM DIRECTED: FUEL CYCLE TECHNOLOGIES

BENCHMARK EXPERIMENTS TO VALIDATE MULTI-PHYSICS SIMULATIONS FOR NUCLEAR ENERGY SYSTEMS (IRP-FC-1)
(FEDERAL POC – BHUPINDER P. SINGH & TECHNICAL POC – DAVID POINTER)
(UP TO 4 YEARS AND $5,000,000)

Over the past decade, significant investment and efforts have been made by the Department of Energy's Nuclear Energy programs (e.g., NEAMS, CASL, LWRS, FCR&D) to develop capabilities for advanced modeling and simulation of nuclear energy systems. These simulation models couple multiple physical phenomena to predict normal and off-normal operation of nuclear reactors, and the important modeled phenomena include neutron transport, core/reactor thermal-hydraulics, nuclear fuels and cladding performance, and core and structural material behaviors. Traditional methods used for coupling and validating single physics and ad-hoc integral codes are not adequate for validating these complex high-fidelity strongly coupled multi-physics codes. Furthermore, some of the experimental data sets used to validate these codes may not be of sufficient quality to validate high-fidelity modeling and simulation (M&S) tools.

The Office of Nuclear Energy (NE) is sponsoring establishment of a Nuclear Energy Knowledge and Validation Center (NEKVaC) to be a resource for addressing methods in the validation of codes used for modern nuclear plant and fuel cycle analyses. The organization for this center is being established in FY 2015 and will include a Methods and Guidelines committee. This committee is responsible for identifying gaps and deficiencies in current nuclear analysis code validation, recommending new approaches, and developing and disseminating guidelines and best practices in modern code validation including those for design of validation experiments. NE is also working with the Nuclear Energy Agency of the Organisation for Economic Cooperation and Development (OECD/NEA) to support similar efforts internationally.

The goal of this Integrated Research Project (IRP) is to make progress toward establishing benchmarks for complete validation of high-fidelity multi-physics codes, for example, those which model the phenomena governing light water reactor accident tolerant fuel behavior in postulated accident conditions.

The scope of activities for this IRP includes:

1) Plan, design, and conduct an experiment that can serve as a benchmark for critically assessing the results predicted by a multi-physics simulation code for a nuclear energy system. The applicant can choose a code from the suite of codes contained in DOE-NE Software projects (MBM, SHARP, MAMMOTH, or VERA-CS) and the specific models within the code for which the experiment would serve as a benchmark over a defined range of applicability. It is not expected that the benchmark will be sufficient for complete validation of the specific code. Plan, design and conduct of the experiment are expected to follow a rigorous validation protocol. The goal is to demonstrate high-fidelity experimental methods for strongly coupled phenomena, while delineating phenomenological contributions. It is anticipated that the applicant will work with the simulation model developer right from the start of the project.

2) Document the methods for designing the experiment including those for collection of data and quantification of uncertainties. All applicable boundary conditions, experimental limitations, assumptions, and experimental techniques must be documented, and pre-experimental sensitivity analyses should be conducted to evaluate the impact of these conditions on the usefulness of the experiment as a benchmark. It is anticipated that applicant will work with the NEKVaC Methods and Guidelines Committee to establish methods for evaluating the experimental uncertainty impacts on the simulation results and will inform the Committee's efforts as well as NE activities in this subject area with the OECD/NEA .

3) Collect, store, reduce and present the data in a context which preserves all of the expert knowledge and rigor that went into the design and execution of the experiment. The QA program applicable to the

PROGRAM DIRECTED: FUEL CYCLE TECHNOLOGIES

experiment will be described and all appropriate records including the experiment procedures, qualification and training of personnel and calibration of equipment/instruments will be retained. It is important that those who wish to use the data to validate a code/model must know the pedigree of the data, why the particular measurements were taken, the uncertainties in the instrumentation, a precise geometry of the experiment, etc. The knowledge (data and the context in which it was generated) must be stored in a format that is maintainable and accessible. The Nuclear Energy – Knowledge Base for Advanced Modeling and Simulation (NE-KAMS) provides such a framework and its use is highly recommended.

Applicants must address all three of the above listed elements to be considered responsive to this IRP request for proposals.

In addition to the scope described above, the applicant may propose to exercise the specific selected code application and compare results from the code and the benchmark experiment. It is desirable that the knowledge learned be incorporated in a college course on Verification and Validation.

CASK MIS-LOADS EVALUATION TECHNIQUES (IRP-FC-2)
(FEDERAL POC – JC DE LA GARZA & TECHNICAL POC – JOHN SCAGLIONE)
(UP TO 4 YEARS AND $3,000,000)

INTRODUCTION

There are many types and designs of spent nuclear fuel casks and containers currently in storage around the country at various nuclear power plant sites. The inventory of spent fuel in these casks/canisters has multiple internal components that are designed to provide structural integrity during storage and transportation. The long-term internal stability of the internals and the spent fuel is important to maintain sub-criticality of the fissile materials in the fuel during the Normal Conditions of Transport (NCT) and Hypothetical Accident Conditions (HAC) that are specified in the NRC transportation regulations (10CFR71). Given the desired attributes for the cask/container designs, it is a challenge to assess the condition of the internals and the spent fuel non-intrusively after transportation that includes NCT, and possibly HAC. This research topic addresses the development of innovative technologies to determine the extent of any damage or degradation of internal components during transportation.

BACKGROUND

One important safety requirement in the transportation regulations (i.e., 10CFR71), is that it must be demonstrated that the spent fuel will remain subcritical. This requirement is non-mechanistic. That is, there does not need to be an initiating event that precipitates the potential for a criticality. It is assumed that there is an optimal geometry and complete moderation.

A technical gap identified in the Used Fuel Disposition (UFD) Storage and Transportation R&D program is the need to develop an analysis methodology to account for a potential mis-load(s) in currently loaded casks/canisters for which burnup credit is required for transportation. A validated methodology for boiling water reactor (BWR) Used Nuclear Fuel (UNF) burnup credit, which is only needed for degraded, flooded conditions (e.g., transportation, HAC or disposal), is needed. This project will require the development of the modeling framework to assess criticality conditions in transport HAC environments, testing to provide data to benchmark the model and code, and demonstration of the model to HAC conditions.

WORK TO BE PERFORMED

The research needs for this IRP will include the following scope of activities:

- **Innovative Methodology Development**
  Describe the underlying fundamental principles and description of the technology to be developed with an assessment of any limitations. Justification for how the technology will be successful

PROGRAM DIRECTED: FUEL CYCLE TECHNOLOGIES

should be provided based on any experimental or analytical studies that may be available.

- **Proof of Principle Evaluation**
  Develop and demonstrate the feasibility of the methodology using an integrated analysis and experimental justification. Here, the opportunity exists to establish the degree of conformance to the initial expectation of performance and provide any refocus needs.

- **Identify and Quantify Inherent Uncertainties**
  Systematically develop uncertainties associated with the methodology and its application to a basic system. All non-destructive evaluation systems have both bias and uncertainty. It is important to understand and quantify these, and incorporate the uncertainties in the data evaluation process.

- **Develop and Implement a "mock-up" Test Program**
  To the degree possible, tests should be conducted to obtain data associated with fuel behavior to assess the amount of damage and potential for release of fissile material (e.g., the release fraction) that could contribute to a criticality and that would be used as input for model verification.

- **Prepare a Detailed Final Report**
  The report will document the R&D elements of the IRP, provide bias/uncertainty in the system and discuss the lessons learned from the effort.

TASKS TO BE PERFORMED

- **Task 1:** Development of an integrated plan describing the technology development and testing – 3 to 5 months after the beginning of the performance period.
- **Task 2:** Methodology development – 9 months after the beginning of the performance period.
- **Task 3:** Proof of principle testing and uncertainty evaluation – 15 to 18 months after the beginning of the performance period.
- **Task 4:** Develop and conduct "mock-up" tests – 26 to 32 months after the beginning of the performance period.
- **Task 5:** Analysis of test results and benchmarking of model – 33 to 40 months after the beginning of the performance period.
- **Task 6:** Complete project report – 48 months after the beginning of the performance period.

DELIVERABLES

- **Technology Assessment Report**
  Twenty-four months into the project, a progress report must be submitted to the DOE that provides a technical assessment of progress made toward solving the issues discussed above.
- **Final Report**
  Forty-eight months into the project, a report will be submitted to the DOE that discusses the technologies developed and how they can be effectively implemented.

PROGRAM DIRECTED: NUCLEAR REACTOR TECHNOLOGIES

VALIDATION OF ADVANCED COMPUTER MODELS (IRP-RC-1)
(FEDERAL POC – RICHARD REISTER & TECHNICAL POC – CURTIS SMITH)
(UP TO 3 YEARS AND $4,000,000)

Background

Significant and continuing advances in computer simulation coupled with rising costs of building test facilities and conducting tests are increasing the reliance on complex models in licensing facilities, optimizing designs, improving performance, and understanding the underlying science. However, the complexity of these models and associated computational methods present unprecedented challenges for code verification and validation (V&V). Advanced computer models can model physical characteristics that cannot feasibly be measured in experiments. For example, multiple computer models may be coupled together to describe a scenario of interest, a scenario that may span long time periods and incorporate multiple types of physics models. In addition, the available data for validation purposes may span many different "scales" ranging from facility operation (large scale); integral effects test (medium scale); and separate effect tests or fundamental tests including experiments on individual components (small scale).

Extensive V&V is a prerequisite for industry use of new computer models. Proposed approaches should consider how to transfer the research and development (R&D) products to a community-of-practice in order to provide a systematic and growing knowledge base targeted at (ultimately) industry applications of these computer models. Methodologies developed and data obtained and analyzed under this IRP will also contribute to the planned knowledge and validation center under the Nuclear Energy Enabling Technologies (NEET) Program.

Proposed Work

Proposals are encouraged that include the development of a V&V methodology suitable to advanced computer models, and the application of the V&V methodology to components of the MOOSE-based RISMC Toolkit (including NEUTRINO [flooding model], MASTODON [seismic model], RPV & concrete Grizzly [component aging models], RELAP-7 [thermal-hydraulics]) currently under development in the Light Water Reactor Sustainability (LWRS) Program. A V&V'ed version of the RISMC Toolkit will be useful to several industry and DOE programs including the LWRS Program, the Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program, the M&S Hub, as well as others. The methodologies developed and data analyzed under this IRP shall be made available to the planned knowledge and validation center (proposed to start in FY-16 under the NEET Program).

While the majority of verification is done as part of the process of developing MOOSE-based models, validation (and some additional verification) is also needed before the Toolkit will be used by industry. This IRP focuses on validation of the RISMC Toolkit components, including a survey of available data and gaps (building on reports generated by the LWRS Program and the LWRS Program partner, EPRI), development of a verification and validation plan, and identification of additional experiments needed (if any). Proposals should include verification; validation against existing data; acquisition of data from existing experiments and operational information; and development of new experiment(s) as needed within the overall budget available for this IRP.

Advanced approaches to V&V are also encouraged; including (1) probabilistic methods that focus on quantifying the degree that computer model should be considered "valid" and (2) decision-theoretic based considerations that focus on how the advanced computer model will be used for decision making and its potential impact on applicable decisions.

Proposals should include a description of the planned approach to data mining, methodology development, and recommended V&V of one or more components of the RISMC Toolkit. They should also discuss transfer of the V&V insights and approaches to industry, including a discussion of what is an adequate level of V&V.

PROGRAM DIRECTED: FUEL CYCLE TECHNOLOGIES AND ENVIRONMENTAL MANAGEMENT

ENHANCED GLASS FORMS FOR NUCLEAR WASTE IMMOBILIZATION (IRP-FC-EM-1)
(FEDERAL POC- RODRIGO RIMANDO & TECHNICAL POC- DAVID PEELER
CO-FEDERAL POC- PATRICIA PAVIET)
(UP TO 3 YEARS AND $3,000,000)

The purpose of this Integrated Research Program (IRP) is to promote advancing the fundamental understanding of glass science and glass chemistry as they apply to the disposition of nuclear waste created from the reprocessing of spent nuclear fuel and defense nuclear target materials. The fundamental data stemming from this program will support development of advanced glass chemical formulations, key process treatment control models, and a more complete understanding of the basic processes of glass production and underlying chemical durability under various environmental and/or radioactive long term conditions.

The DOE Office of Environmental Management (EM) is responsible for treating and dispositioning about 92 million gallons of highly radioactive and chemically complex liquid waste. Most of this nuclear waste is a byproduct of national defense plutonium-production efforts during World War II and the Cold War era. The technology selected for the treatment and stabilization of DOE's high level waste is vitrification, which a thermal and chemical process that converts the waste to glass thereby rendering it in a stable and durable physical form for permanent disposal in a geological repository. Borosilicate glass has been chosen for the immobilization of radioactive elements largely due to ease of processing, compositional flexibility, and chemical durability. The largest operating waste vitrification plant in the world is EM's Defense Waste Processing Facility (DWPF) at DOE's Savannah River Site (SRS) in Aiken, SC. DWPF began radioactive operations in March 1996 to vitrify 37 million gallons of radioactive liquid waste stored among 51 underground tanks. At DOE's Hanford Site in eastern Washington, this vitrification technology will also be used to disposition about 56 million gallons of radioactive liquid waste that was historically stored in 177 underground storage tanks. The Waste Treatment and Immobilization Plant (WTP) is currently being built at Hanford to vitrify this waste. Once fully constructed, WTP will surpass the size of DWPF.

The DOE Office of Nuclear Energy (NE) is sponsoring research aimed at enabling advanced nuclear fuel cycles and management options for commercial used nuclear fuel (UNF). Recent fuel cycle evaluations have shown that the most promising fuel cycles all include the recycling of fissile components of UNF. If implemented, the recycling processes will generate high-level liquid waste that must be immobilized with borosilicate glass, since it is the world-wide standard for immobilizing HLW from commercial UNF recycling. The compositions and amounts of HLW produced using advanced separations technologies differ significantly from those generated from U.S. defense plutonium-production efforts.

Property-composition models are used to help optimize borosilicate glass formulations for specific waste compositions. Efforts have been and are currently being made to increase the loading of radioactive liquid wastes in glass—that is, increasing the specific concentration of a particular constituent of interest within the glass form—while maintaining adequate processability, regulatory compliance, and product quality. A fundamental tenet underlying the current research efforts is an attempt to be less conservative than previous work that is currently implemented in vitrification facility operations. The research outlined here is motivated by the potential for substantial economic benefits (e.g., significant increases in waste throughput and reductions in glass volumes) that will be realized when advancements in glass formulation continue and models supporting facility operations are implemented.

Included among the topics and areas of academic, scientific and engineering pursuit for the application of Enhanced Glass Forms for Nuclear Waste Immobilization include, a more complete understanding of the glass formation reactions, the role of glass component (e.g., network formers and network modifiers) for the benefit of stabilization of waste species, melting dynamics, batch blanket chemistries, mechanistic information of chemical durability and the reaction kinetics of dissolution of the vitreous network in aqueous environments. The end use of the scientific studies should allow DOE to implement glass formulations with improved total system efficiency for both EM and NE target applications.

Domains of scientific interest include, but are not limited to:

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1) Chemical durability and leaching phenomena in the borosilicate glasses. Addressing the fundamental understanding of the durability and ageing resistance of borosilicate glasses. To date DOE has attempted to address this matter in a largely qualitative manner.

   Research is needed to better understand the rate-limiting mechanisms for radionuclide release from a glass waste form. The existing performance assessments of this waste form are largely conservative. By updating the existing long-term glass corrosion models to better reflect the extraordinary durability of vitrified waste, a significant opportunity exists to increase public confidence in disposal. DOE recognizes this opportunity and, utilizing this IRP, will continue to advocate a collaborative approach to glass corrosion research. Although the various models utilize different mechanistic bases, they can be generally distilled into three mechanistic categories: (1) dissolution reaction (affinity) control; (2) diffusion control; and (3) ion-exchange release mechanisms. One of these mechanisms (or perhaps a combination of them) will limit the rate of radionuclide release at any given time. Research continues and is needed to determine the relative importance of these mechanisms, including events that may affect them, such as the precipitation of crystalline phases.

2) A problem facing DOE is the behavior of technetium (Tc)-bearing wastes in the waste treatment process and disposal facility. Technetium readily evaporates during melting of glass feeds and out of the molten glass, leading to low retention in the cooled glass product. DOE currently has a program that seeks to understand aspects of Tc retention by means of studying Tc partitioning between phases during glass melting (including gas) and methods to increase Tc retention in the glass. However, there are additional avenues of investigation that are warranted; for example, studies to evaluate Tc behavior in other waste processes that would either substantively change the retention in the glass or improve management of recycle processes.

   Additionally, Tc behavior is the challenge of the stability of Tc in glass in a disposal environment after it has been immobilized. The major environmental concern with Tc-99 is its high mobility in addition to a long radioactive half-life (211,000 years). The pertechnetate ion (TcO_4^-) is highly soluble in water and does not adsorb well onto the surface of minerals and so migrates nearly at the same velocity as groundwater. Long-term corrosion of glass waste forms is an area of current interest to the DOE, but attention to the release and speciation of Tc from glass has been little explored. It is expected that the release of Tc from glass should be highly dependent on the local chemical environment within the glass (e.g., structure and redox) as well as the chemistry of the surrounding environment, including groundwater pH, Eh, and composition. Though the speciation of Tc in glass has been previously reported, environmental Tc release mechanisms are not well understood.

3) The ability to formulate crystal-tolerant HLW glasses that will allow high waste loadings, and at the same time will protect the HLW glass melter from detrimental accumulation of crystals in the melter during idling. For examples, Hanford HLW glass formulation could be significantly improved if higher concentrations of spinel could be tolerated in the melter and a closed fuel cycle HLW vitrification plant could significantly benefit from tolerance to noble metals in the melt. DOE's long-term objectives are to develop a robust empirical model that can predict the crystal accumulation in the melter as a function of glass composition and temperature, and to understand the mechanism for agglomeration of particles and their effect on accumulation rate. Investigations can be performed on glasses of different compositions to investigate the effect of different components, temperature, and agglomeration on the accumulation rate.

4) The incorporation of anionic species into glass melts needs to be evaluated. Studying the process of melting itself to understand how anionic species (e.g., chloride (Cl^-), sulfate (SO_4^{2-}), and molybdate (MoO_4^{2-})) become incorporated into the melt. Work done several years ago suggested that the molybdate case was quite complicated with an initial molybdate phase initially forming on the melt surface which was then incorporated into the melt. Other aspects of this would be to further investigate what parameters actually control the solubility of these anionic species into a glass network.

PROGRAM DIRECTED: ENVIRONMENTAL MANAGEMENT

ADVANCED CAPABILITIES FOR NUCLEARIZED ROBOTICS FOR INTEGRATED MAPPING (IRP-EM-1)
(FEDERAL POC – RODRIGO RIMANDO & TECHNICAL POC – STEVEN TIBREA)
(UP TO 3 YEARS AND $3,000,000)

Technical Objective

This Integrated Research Project (IRP) seeks a functional prototype of a robotic solution that will: (1) remotely gain access to and maneuver within a high-hazard, physically challenged, confined, and unstructured space or area within a nuclear facility; (2) obtain high-resolution color video footage; (3) perform simultaneous localization and mapping (SLAM); (4) perform radiation and radioactivity measurements of alpha and beta particles as well as gamma rays as dictated by the radioisotope(s) expected to be present; (5) perform appropriate non-destructive *in situ* measurements of the materials of construction to help determine structural integrity; and (6) integrate and correlate SLAM and radiation data for analysis, scientific visualization and computer simulation.

Introduction

This IRP is intended to promote the development of robotics technologies for use in nuclear facilities and related nuclear applications. While DOE Office of Environmental Management (EM) is the lead Program Secretarial Office for this IRP, there are inter-mission commonalities, cross-cutting applications, and opportunities for knowledge and technology sharing that warrant DOE-NE/DOE-EM collaboration. DOE-NE derives direct benefit from the mission-relevant research conducted under this IRP.

DOE-EM is placing emphasis on the application of robotics for: (1) handling of high-hazard, high-consequence materials and waste, (2) performing worker/operator tasks that are dirty (contaminated, toxic, nuisance), dull (routine, labor-intensive, repetitive, mundane), and dangerous (pose significant occupational hazards); (3) easing the performance of worker/operator tasks that are physically demanding on or stressful to human body or are otherwise ergonomically challenging; (4) performing tasks that are beyond human abilities; (5) improving the ability to response to and recover from unplanned events or operational emergencies; and (6) improving the safety, quality, efficiency, and productivity of facility operations.

This IRP supports the National Robotics Initiative as part of the President's Advanced Manufacturing Partnership to accelerate the development and use of robots in the U.S. that work beside or cooperatively with people. This IRP is intended to implement, in part, broader collaboration with other federal agencies, colleges and universities, and other non-federal technology and research centers as described in the Secretary's response to the Secretary of Energy Advisory Board Task Force on Technology Development for Environmental Management.

Background

For the purpose of this IRP, "robotics" refers to the study, science and engineering of technologies associated with the theory, design, fabrication, testing, and application of mechanical devices and systems capable of performing a variety of investigative or manipulative tasks (1) as directed by human command or control or (2) according to pre-determined or programmed instructions. As such, this IRP

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seeks integrated robotic systems that will remotely gain access to and maneuver within areas and spaces of interest and then perform data and information gathering tasks and/or perform a wide variety of manipulative tasks.

"Radiation hardened systems" refers to systems that are immune or unaffected by the effects of ionizing radiation or radioactivity. "Radiation tolerant systems" refers to systems that are resistant to the effects of ionizing radiation or radioactivity to certain threshold limits.

Areas of Interest

Topics and areas of academic, scientific and engineering pursuit for the application of DOE-EM robotics technologies include, but are not limited to:

- Remote Access
  - Radiation hardened systems and radiation tolerant systems that provide remote entry into areas and spaces that are otherwise inaccessible or prohibit direct access by workers due to
    - Unsafe, unstable, or unknown physical or structural conditions
    - Configurations that are hard to reach or beyond reach without taking extraordinary mechanical measures
    - The presence or potential presence of radiological, chemical, biological, or physical hazards that will or may result in unacceptable occupational exposure or increased health or safety risk
    - Other conditions that preclude safe entry or are otherwise uninhabitable such as areas or spaces that have or potentially have: oxygen-depraved environments or other conditions of poor air quality; explosive gases, materials or devices; extreme temperatures; extreme pressures; poor or no visibility or direct line of sight due to lack of lighting or obstructions; and submerged or substantially liquid-covered surfaces
- Non-Destructive Testing and Evaluation
  - Radiation hardened/tolerant acoustic, optical, radiographic, thermographic, electromagnetic, and other tooling and methods for non-destructive sensing, detecting, monitoring, measuring, characterizing, and assaying a wide variety of radiological, chemical, environmental, and physical parameters
- Imaging, Surveying, Mapping, and 3D Rendering
  - Radiation hardened/tolerant tooling and methods for the generation of graphical depictions and representations as well as virtual replications, simulations and models of the real world
- Manipulation and End-Effectors
  - Radiation hardened/tolerant systems for remotely performing tasks in harsh environments or work conditions to keep occupational exposure to hazards as low as reasonably achievable (ALARA)
- Worker Assistance
  - Wearable and prosthetic-like radiation hardened/tolerant robotic devices (a.k.a., co-robots) that improve worker health and safety, enhance worker performance and endurance, or compensate for physical limitations of extremities by relieving physical stresses on the body and avoiding occupational injuries such as those caused by:

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repetitive and forceful exertions and motions; frequent, heavy, or overhead lifts or tasks; ergonomically incorrect work positions; use of vibrating (shock-inducing) equipment; and muscle fatigue.

- Heavy Operations
  - Radiation hardened/tolerant systems for performing tasks that are beyond worker capability and require substantially greater strength, dexterity, reach and access, or capacity.
- Task Automation
  - Radiation hardened/tolerant systems for more efficiently performing routine or repetitive tasks and operations such that worker interface is needed only for performance monitoring and quality control

To facilitate the advancement of robotics technologies for nuclear applications, DOE-EM is establishing the capability for "radioactive" test beds, which are existing EM nuclear facilities and assets that are utilized as physical platforms for researchers and technologists to demonstrate innovative tooling, treatment technologies, and other technical solutions. These rad test beds would provide researchers and technologists with the unique opportunity to conduct research and technology demonstrations (1) in spaces and areas having radiation fields, (2) are contaminated with surface and/or fixed radioactivity, (3) are inaccessible, inhabitable, or not safe for worker entry, and/or (4) under conditions and configurations of nuclear facilities that are difficult or too expensive to replicate or mock-up. Researchers and technologists would also be given to opportunity to use, albeit in small amounts, radioactive wastes and nuclear materials for research and technology demonstrations.

The radioisotopes resulting from the nuclear fuel cycle and nuclear weapons production that are of particular interest to EM are the:

- Medium-lived fission products of cesium-137 and strontium-90;
- Long-lived fission products of technetium-99 and iodine-129; and
- Actinides of uranium-235, plutonium-239, plutonium-240, americium-241, and americium-243.

There are other radioisotopes of concern such as, but not limited to, hydrogen-3 (tritium) and the irradiated corrosion wear products of iron-55, cobalt-60, and nickel-59.

Nuclear facilities of particular interest to EM for this application of robotics include, but are not limited to, the underground areas of the Waste Isolation Pilot Plant, the Savannah River Site H-Canyon Exhaust Air Tunnel, and the Hanford Site Purex Plant Tunnels. These spaces are expected to have irregular (uneven, unleveled) surfaces, poor visibility and limited lighting, and wetted and even pooled surfaces. They can have high levels of radiation and high levels of radioactivity (loose surface/removable and fixed) contamination.

Smaller, more compact robotic systems are desired for nuclear facilities with limited access and complex configurations such as, but not limited to, the single shell and double shell underground tanks at the Hanford Site, the type I, II, III, and IV underground tanks at the Savannah River Site, and the black cells within the Pretreatment Facility of the Waste Treatment and Immobilization Plant that is still under construction at the Hanford Site.

Requirements

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Proposals submitted in response to this IRP must

- Indicate the intention for collaboration with at least one other US university/college having established robotics expertise and assets,
- Indicate the intention for collaboration with at least one DOE national laboratory/technology center OR
- Indicate the intention for collaboration with a laboratory/technology center of another federal agency having established robotics expertise and assets such as Naval Research Center (US Department of Navy) and Johnson Space Center (National Aeronautics and Space Administration),
- Demonstrate full functionality of the robotics system to meet the aforementioned technical objective at a field mock-up,
- Provide a strategy for advancing the robotic solution to the next phase of EM radioactive test bed demonstration, and
- Demonstrate utility at one of EM's nuclear facilities.

ADVANCED CAPABILITIES FOR UNDERWATER NUCLEARIZED ROBOTICS (IRP-EM-2)
(FEDERAL POC – RODRIGO RIMANDO & TECHNICAL POC – STEVEN TIBREA)
(UP TO 3 YEARS AND $3,000,000)

Technical Objective

This Integrated Research Project (IRP) seeks a functional prototype of a underwater or submersible robotic solution that will: (1) remotely maneuver in a water-filled basin, pool or tank within a nuclear facility while afloat and while submerged at depth; (2) obtain high-resolution color video footage; (3) perform simultaneous localization and mapping (SLAM); (4) perform radiation measurements; (5) perform appropriate non-destructive *in situ* measurements of the materials of construction to help determine structural integrity; and (6) integrate and correlate data for analysis, scientific visualization and computer simulation.

Introduction

This IRP is intended to promote the development of robotics technologies for use in nuclear facilities and related nuclear applications. While DOE Office of Environmental Management (EM) is the lead Program Secretarial Office for this IRP, there are inter-mission commonalities, cross-cutting applications, and opportunities for knowledge and technology sharing that warrant DOE-NE/DOE-EM collaboration. DOE-NE derives direct benefit from the mission-relevant research conducted under this IRP.

DOE-EM is placing emphasis on the application of robotics for: (1) handling of high-hazard, high-consequence materials and waste, (2) performing worker/operator tasks that are dirty (contaminated, toxic, nuisance), dull (routine, labor-intensive, repetitive, mundane), and dangerous (pose significant occupational hazards); (3) easing the performance of worker/operator tasks that are physically demanding on or stressful to human body or are otherwise ergonomically challenging; (4) performing tasks that are beyond human abilities; (5) improving the ability to response to and recover from unplanned events or operational emergencies; and (6) improving the safety, quality, efficiency, and

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productivity of facility operations.

This IRP is intended to support the National Robotics Initiative as part of the President's Advanced Manufacturing Partnership to accelerate the development and use of robots in the U.S. that work beside or cooperatively with people. This IRP is intended to implement, in part, broader collaboration with other federal agencies, colleges and universities, and other non-federal technology and research centers as described in the Secretary's response to the Secretary of Energy Advisory Board Task Force on Technology Development for Environmental Management.

Background

For the purpose of this IRP, "robotics" refers to the study, science and engineering of technologies associated with the theory, design, fabrication, testing, and application of mechanical devices and systems capable of performing a variety of investigative or manipulative tasks (1) as directed by human command or control or (2) according to pre-determined or programmed instructions. As such, this IRP seeks integrated robotic systems that will remotely gain access to and maneuver within areas and spaces of interest and then perform data and information gathering tasks and/or perform a wide variety of manipulative tasks.

"Radiation hardened systems" refers to systems that are immune or unaffected by the effects of ionizing radiation or radioactivity. "Radiation tolerant systems" refers to systems that are resistant to the effects of ionizing radiation or radioactivity to certain threshold limits.

Areas of Interest

Topics and areas of academic, scientific and engineering pursuit for the application of DOE-EM robotics technologies include, but are not limited to:

- Remote Access
  - Radiation hardened systems and radiation tolerant systems that provide remote entry into areas and spaces that are otherwise inaccessible or prohibit direct access by workers due to
    - Unsafe, unstable, or unknown physical or structural conditions
    - Configurations that are hard to reach or beyond reach without taking extraordinary mechanical measures
    - The presence or potential presence of radiological, chemical, biological, or physical hazards that will or may result in unacceptable occupational exposure or increased health or safety risk
    - Other conditions that preclude safe entry or are otherwise uninhabitable such as areas or spaces that have or potentially have: oxygen-depraved environments or other conditions of poor air quality; explosive gases, materials or devices; extreme temperatures; extreme pressures; poor or no visibility or direct line of sight due to lack of lighting or obstructions; and submerged or substantially liquid-covered surfaces
- Non-Destructive Testing and Evaluation
  - Radiation hardened/tolerant acoustic, optical, radiographic, thermographic, electromagnetic, and other tooling and methods for non-destructive sensing, detecting,

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monitoring, measuring, characterizing, and assaying a wide variety of radiological, chemical, environmental, and physical parameters

- Imaging, Surveying, Mapping, and 3D Rendering
  - Radiation hardened/tolerant tooling and methods for the generation of graphical depictions and representations as well as virtual replications, simulations and models of the real world
- Manipulation and End-Effectors
  - Radiation hardened/tolerant systems for remotely performing tasks in harsh environments or work conditions to keep occupational exposure to hazards as low as reasonably achievable (ALARA)
- Worker Assistance
  - Wearable and prosthetic-like radiation hardened/tolerant robotic devices (a.k.a., co-robots) that improve worker health and safety, enhance worker performance and endurance, or compensate for physical limitations of extremities by relieving physical stresses on the body and avoiding occupational injuries such as those caused by: repetitive and forceful exertions and motions; frequent, heavy, or overhead lifts or tasks; ergonomically incorrect work positions; use of vibrating (shock-inducing) equipment; and muscle fatigue.
- Heavy Operations
  - Radiation hardened/tolerant systems for performing tasks that are beyond worker capability and require substantially greater strength, dexterity, reach and access, or capacity.
- Task Automation
  - Radiation hardened/tolerant systems for more efficiently performing routine or repetitive tasks and operations such that worker interface is needed only for performance monitoring and quality control

To facilitate the advancement of robotics technologies for nuclear applications, DOE-EM is establishing the capability for "radioactive" test beds, which are existing EM nuclear facilities and assets that are utilized as physical platforms for researchers and technologists to demonstrate innovative tooling, treatment technologies, and other technical solutions. These rad test beds would provide researchers and technologists with the unique opportunity to conduct research and technology demonstrations (1) in spaces and areas having radiation fields, (2) are contaminated with surface and/or fixed radioactivity, (3) are inaccessible, inhabitable, or not safe for worker entry, and/or (4) under conditions and configurations of nuclear facilities that are difficult or too expensive to replicate or mock-up. Researchers and technologists would also be given to opportunity to use, albeit in small amounts, radioactive wastes and nuclear materials for research and technology demonstrations.

The radioisotopes resulting from the nuclear fuel cycle and nuclear weapons production that are of particular interest to EM are the:

- Medium-lived fission products of cesium-137 and strontium-90;
- Long-lived fission products of technetium-99 and iodine-129; and
- Actinides of uranium-235, plutonium-239, plutonium-240, americium-241, and americium-243.

There are other radioisotopes of concern such as, but not limited to, hydrogen-3 (tritium) and the irradiated corrosion wear products of iron-55, cobalt-60, and nickel-59.

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Nuclear facilities of particular interest to EM for this application of robotics include, but are not limited to, the Hanford Site Waste Encapsulation and Storage Facility within which over 1,900 cesium-137 and strontium-90 capsules are in underwater storage and the Savannah River Site L-Basin within which over 18,400 fuel assemblies are in underwater storage. Underwater spaces may have poor visibility or clarity and limited lighting. They have high levels of radiation.

Requirements

Proposals submitted in response to this IRP must

- Indicate the intention for collaboration with at least one other US university/college having established robotics expertise and assets,
- Indicate the intention for collaboration with at least one DOE national laboratory/technology center OR
- Indicate the intention for collaboration with a laboratory/technology center of another federal agency having established robotics expertise and assets such as Naval Research Center (US Department of Navy) and Johnson Space Center (National Aeronautics and Space Administration),
- Demonstrate full functionality of the robotics system to meet the aforementioned technical objective at a field mock-up,
- Provide a strategy for advancing the robotic solution to the next phase of EM radioactive test bed demonstration, and
- Demonstrate the utility at one of EM's nuclear facilities.

Appendix D: Data Needs for Validation

Data Needs for Modeling and Simulation

As you formulate your applications in response to this FOA, consider that there are cross-cutting data needs that support NE's modeling and simulation efforts. High priority data needs are listed below for both the Nuclear Energy Advanced Modeling and Simulation program (NEAMS) and the Energy Innovation Hub for Modeling and Simulation. If an application addresses any of these critical data needs, please highlight this possibility in your application and work with the Department to ensure that data are captured in a useable format. Application submission will include an opportunity to specifically highlight this connection.

NEAMS is an advanced modeling and simulation codes and methods development program. NEAMS is focused on providing a Toolkit that can be used in whole or in part to simulate a wide range of nuclear processes for both light water reactors and advanced reactors. Key components of the NEAMS Toolkit are already in use by the national laboratories, academia, and industry. CASL is an important user of NEAMS technologies. Additional information on NEAMS can be found at http://energy.gov/ne/advanced-modeling-simulation. The Energy Innovation Hub for Modeling and Simulation is developing predictive capability for addressing technical issues in currently operating nuclear power plants' performance and safety. Termed "Challenge Problems," these issues include complex phenomena that are multi-physics and multi-scale in nature. Challenge Problems include: Crud-Induced Power Shift (CIPS); Crud-Induced Localized Corrosion (CILC); Pellet-Cladding Interactions (PCI); Grid-to-Rod-Fretting (GTRF); Departure from Nucleate Boiling (DNB); Loss of Coolant Accident (LOCA); and Reactivity Initiated Accident (RIA). Additional details about the Challenge Problems and M&S Hub can be found at: http://www.casl.gov/strategy.shtml.

Critical Data Needs for Nuclear Energy Advanced Modeling and Simulation (NEAMS)

The data needs for the NEAMS product lines are described as follows.

Fuels Product Line

Engineering-scale Fuel Performance (BISON Validation):

For fission gas behavior models, improved temperature-dependent diffusion coefficient measurements of Xe in UO_2 are needed. Also, fission gas release histories (as opposed to just end-of-life measurements) are needed to validate gas release models, especially during power transients.

Mechanical behavior (yield stress, creep behavior, failure data) for zircaloy cladding that has been irradiated and exposed to chemical environments conducive to stress corrosion cracking. Data is needed for various Zr alloys, heat treatments, etc.

For pellet-cladding mechanical interaction, data that captures 3D effects in defective LWR fuel, such as a missing pellet surface (MPS), is needed to validate our 3D models. Data could include cladding and/or fuel temperatures, cladding stress/strain, diameter evolution in the vicinity of the MPS.

Meso-scale Microstructure Evolution (MARMOT Validation):

Property measurements as input to microstructure simulations are needed. Specifically, well-controlled and characterized experiments that measure the grain boundary mobility, grain boundary energy, grain boundary structure, and defect properties in UO_2 specimens with no porosity are of interest.

For validation, grain growth data either in bicrystals or polycrystals for UO_2 for which grain boundary properties are available is needed. We also need experiments showing temperature gradient-driven migration of pores or grain boundaries in UO_2. We need data showing fission gas bubble behavior correlated with microstructure in UO_2 (e.g., grain boundary type, dislocations, etc.) and data from well-controlled experiments showing the impact of defects on UO_2 thermal conductivity.

Lower Length-scale Model Development (i.e., atomistic simulations)

Fission gas and fission product diffusivities in $UO_{2\pm x}$ under controlled conditions (i.e., known oxygen potential or non-stoichiometry, well characterized microstructure, and known irradiation history/conditions) is needed. The measurements should be performed to allow determination of effective activation energies and pre-exponential factors, which implies measurements over a reasonably wide range of temperatures. Diffusion at microstructure features such as grain boundaries is also of interest. Validation is also needed or at least desired for the defect properties underlying the prediction of fission gas and fission product diffusivities.

The distribution of fission gas bubbles and fission product precipitates in irradiated UO_2 as well as the elemental distribution within UO_2 grains, ideally as function of time, chemistry, irradiation history and temperature is needed.

The thermal conductivity of $UO_{2\pm x}$ and $UO_{2\pm x}$ containing fission gas/fission products, as well as $UO_{2,}$ with well-characterized irradiation histories is needed.

Reactor Product Line

Thermal Fluid Simulations (Nek5000 Validation)

Time-resolved turbulent heat transfer/transport data is needed for validation of computational fluid dynamics tools applied to advanced reactor coolants (e.g., liquid sodium, helium, and liquid salts) and operating conditions. Data should support validation of turbulence field predictions using high-resolution methods such as Large Eddy Simulation and Direct Numerical Simulation. Data for realistic fuel assembly geometries and data sets that include well-resolved characterizations of conjugate heat transfer in structural elements are of particular interest.

Also of interest is high-resolution data that supports validation of predictive capabilities for assessment stability of thermal fluid transport phenomena, particularly in natural or mixed convection flow regimes. Data relevant to advanced reactor coolants and/or conditions is preferred.

Structural Mechanics Simulations (Diablo Validation)

In advanced reactor applications, deformation of core structural components is often an important reactivity feedback that must be accurately represented in assessments of the reactor's transient response. Validation data is needed to confirm the accuracy of predictions of deformation of core structural component (e.g., fuel assembly ducts, core plates, upper internal structures, control rod drive lines) as a result of thermal cycles, creep, swelling and combinations of the above. Data sets that provide well-resolved characterizations of the response of single components as well as multicomponent systems with load pads or other contacts are especially desirable.

Data is also needed to support validation of predictions of inelastic creep and irradiation swelling in structural (non-fuel) component materials at anticipated advanced reactor (e.g., SFR, VHTR, FHR) conditions (e.g., pressure, temperature, irradiation). Consistent uni-axial and multi-axial loading data for classes of materials at selected conditions is desirable.

Integrated Multiphysics Simulations (SHARP Toolset Validation)

Data is needed to support validation of the integrated SHARP Toolset, which includes neutronics (PROTEUS), thermal fluid (Nek5000) and structural mechanics (Diablo) capabilities. While collection of integrated reactor dynamics data for validation the system of three components is likely beyond the scope of NEUP, there is significant interest in data for validation of bi-lateral combinations of the three toolset components. For example, thermal fluid and structural response data for components subjected to transient thermal stratification or thermal striping conditions is of interest.

Validation Data to Support the Consortium for Advanced Simulation of Light Water Reactors (CASL) Challenge Problems

A recent survey of validation data needed to support Challenge Problems identified several areas where additional data are highly desirable. In particular, the study highlights the need for accurate measurements of low length scale phenomena and multi-physics interactions modeled in CASL computer codes.

Further, value of a dataset for a Challenge Problem validation depends on relevance and scaling of experimental conditions (including geometry, materials), and uncertainty of measured data. Accurate estimates of experimental uncertainties will be valuable.

In addition to experimentation, meeting the data needs for validation of advanced modeling and simulation requires substantial efforts in (i) development of advanced diagnostics methods; (ii) using advanced simulation and VUQ methods to design and guide the validation experiments; and (iii) collection, characterization, warehousing, and preparation of data for an integrated model calibration and validation process. Your coordination of relevant efforts in these areas with CASL is also strongly encouraged.

The data needs for the CASL Challenge Problems are described as follows.

CRUD Challenge Problems (CIPS, CILC)

While extensive databases exist for CRUD from plant observations and measurements, detailed phenomena in CRUD are poorly characterized. Most critical are phenomena at the interface between reactor coolant chemistry, materials, and thermal-hydraulics.

The following topics are identified CRUD validation data needs:

1. Crud deposition thermo-dynamics
2. Chemical reactions in crud
3. Composition of complex spinel and other oxide phases in crud
4. Crud deposition efficiency as a function of dub-cooled boiling rate
5. Measure erosion rate of previously deposited crud on fuel rods after sub-cooled boiling stops
6. Measure mass evaporation rate as a function of heat flux on PWR fuel rods
7. Fuel assembly crud mass
8. Fractalline properties of crud
9. Crud growth rate vs. peak clad temperature
10. CILC failure mechanism.

It is important that validation experiments are performed (when practical) under conditions that scale well to PWR prototypic conditions (high pressure, high heat fluxes, low concentrations of chemicals). It is noted that it is difficult to obtain well-scaled data on crud transport and deposition from integral-effect tests. High priority is given to a program of small-scale tests. Innovative experimental approaches are needed to investigate the basic chemistry and thermo-hydraulics inside a manufactured crud deposit (with accurately characterized morphology). Advanced instruments may be needed to obtain spatially and temporarily resolved temperature, chemical concentrations, B^{10} precipitation, boiling velocity, etc. during the experiment. A new kind of sample probe may be needed to accurately measure reactor coolant particle concentrations and crud concentrations at critical locations.

GTRF Challenge Problem

Experimental data is needed in three main areas.

Wear measurements of different couples of irradiated materials (oxide/oxide, oxide/metal, metal/metal) under different vibration modes (sliding, impact, etc.) at different amplitudes are needed.

Time dependent cross-flow effect on rod vibration, as part of turbulence pressure on fuel rod studies is needed. Direct measurement of instantaneous dynamic pressure on fuel rod surface is critical data to validate CFD simulation. Tests can be based on small scale rod bundle (e.g., 5 × 5) with grid spacers and three spans.

Data related to grid-to-rod gap formation is needed. This is a complex process, involving dimensional changes due to fuel rod creep down, grid spring relaxation, and complex creep behavior due to variations in local cold work, and grid cell growth. High precision experiments are needed to characterize these processes.

PCI Challenge Problem

Experiments are needed in two main areas: fuel pellet cracking and relocation and Zr-alloy multi-axial thermal creep. In both cases, out-of-pile separate-effect tests and in-pile integral-effect tests would provide complementary data to support validation.

The out-of-pile experiment would evaluate pellet cracking and fragment movement during normal operation. UO_2 fracture behavior and frictional interaction between pieces would be studied under representative thermal and stress conditions. Such separate effects tests include using electrically heated pellets to obtain fracture characteristics and crack roughness parameters.

In-pile tests would measure pellet-cladding mechanical interaction during in-pile power maneuvers to evaluate gap closure and pellet mechanical compliance. In-pile testing would use single rod experiments under different burnup, peak power, and power ramp rates. On-line diameter and temperature measurements would be needed. Design of such experiments and development and demonstration of in-pile measurement techniques are of high priority.

DNB Challenge Problem

Existing datasets have been successfully used for fuel design improvement and DNB prevention, as well as for assessment of sub-channel codes. However, the data quality is not adequate for validating DNB simulations under the plant design conditions, and for calibration and validation of advanced mechanistic DNB and/or two-phase flow CFD models. Areas where additional data are most needed include the effect of rod surface characteristics on DNB, void measurements in subcooled flow boiling in rod bundles, high-fidelity turbulent mixing, including the impact of spacer grid design features `on DNB, and transient DNB testing.

High precision void fraction distributions in boiling channels under reactor prototypic conditions are identified as a cross-cutting area of the highest priority for calibrating and improving thermo-hydraulics methods (THM) used in CRUD, DNB and other Challenge Problems. Experiments with void measurements by radiographic imaging or other techniques are needed for subcooled and saturated boiling conditions at high pressures and flow conditions simulating reactor operational, transient and accident conditions. Design of such experiments and development and demonstration of high-fidelity imaging techniques are of high priority.

Appendix E: Accessing Nuclear Science User Facilities

As previously described in this document, the NSUF provides cost-free access to DOE, University, and Industry facilities. The access to these facilities also includes the support of the technical staff at each facility to ensure that the applicant is able to successfully complete their research. With the integration of NSUF access into this FOA, the process for application for NSUF access will be different from stand-alone NSUF solicitations occurring prior to FY 2015. An additional requirement to forward fund awards also significantly differs from the stand alone NSUF solicitation process. Figure E-1 depicts the new process that implements these changes. Note that NSUF rapid turn-around experiments are not part of this FOA or new process and will continue on a three calls per year frequency.

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 will be required to contact the NSUF Program Office to identify a NSUF technical lead and submit a letter of intent to apply for the FOA. After the LOI is received, the applicant and NSUF technical lead will work together to develop the Pre-Application and begin the process to define the scope of the application and estimate cost.

For all applications, the NSUF facility technical lead will work with the applicant to define the scope in the form of a Statement of Work (SOW). The SOW will be reviewed and approved by the NSUF Program Office. As a minimum, the SOW will include the following (as applicable):

1. Specific requirements for specimen acquisition (e.g., material acquisition, fabrication requirements, and specimen configuration)
2. 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.)
3. Specific requirements for post-irradiation examination (PIE) of each specimen (e.g., visual examination, dimensional examinations, tensile testing radiography, microscopy, etc.)
4. Proposed time-line.

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

1. Concept for the irradiation device including fabrication and assembly plans
2. Irradiation position and duration
3. Experiment shipping
4. Disassembling and cataloging the experiment
5. Specimen preparation and shipping
6. Specimen examination details
7. Waste disposal

8. Resource loaded schedule.

The information in the execution plan will then be used by the NSUF facility to develop a cost estimate for the proposed scope of work. The cost estimate will then be reviewed by the NSUF Program Office to determine if the proposed scope of work will fit into the anticipated award budget for this FOA. If the cost estimate is higher than the budget, the NSUF Program Office may negotiate a scope decrease, if appropriate, with the PI and technical lead in order to properly size the scope of work. After negotiation, the SOW and cost estimate will be updated to match the negotiated scope so that this information can be incorporated into the full application.

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 F contains a typical User Agreement. 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

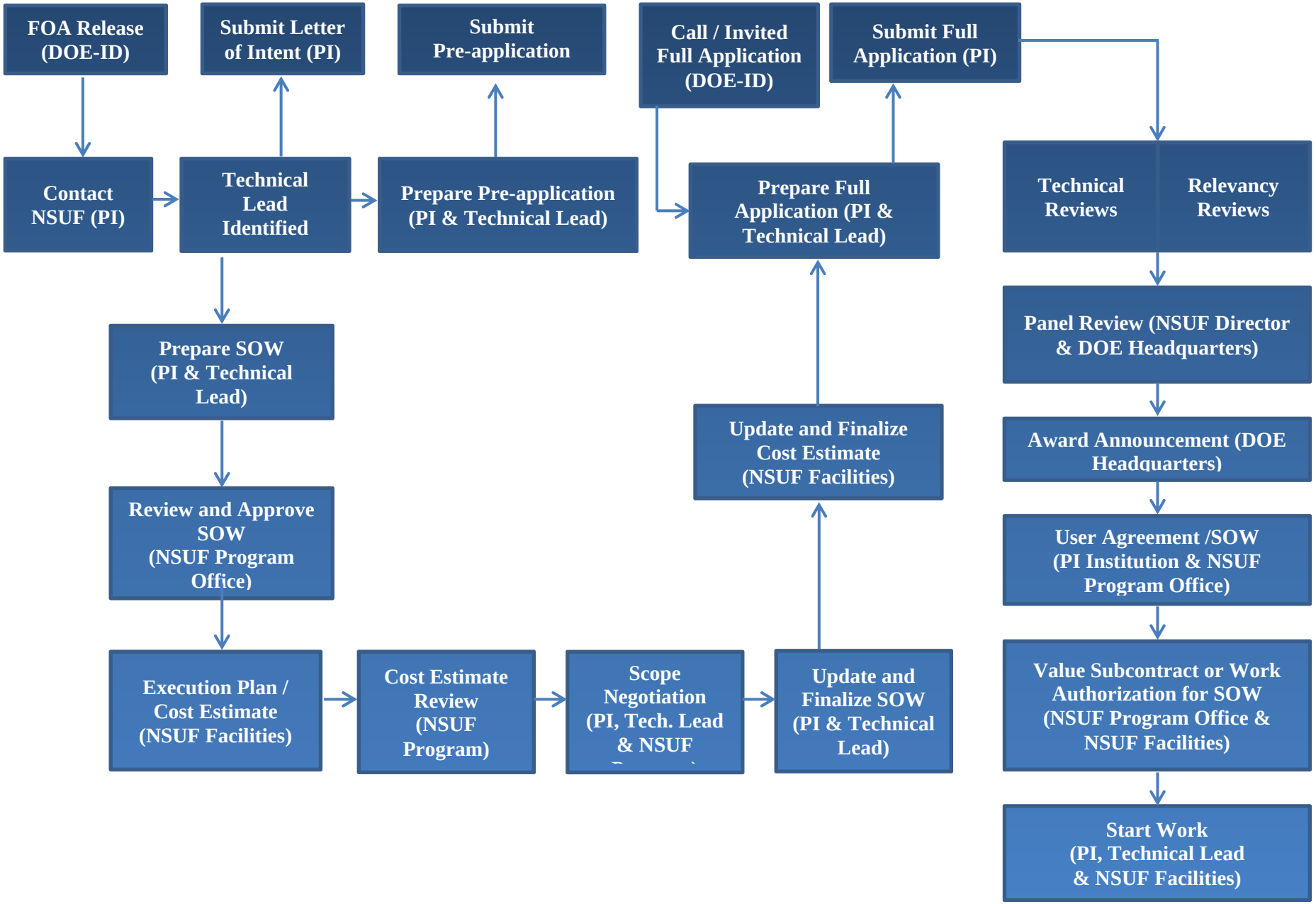
Irradiation of materials in test reactors requires additional rigor and quality assurance requirements beyond those described in other sections of this FOA. Specific requirements will depend on the reactor license, the irradiation vehicle design and specimen constituents. NSUF Technical leads will assist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

Budget Development for NSUF Applications

As previously described, applicants may apply for NSUF access with or without support from other works scopes in this FOA. Bridge funding will no longer be available through NSUF, so applicants need to ensure that the following cost elements are covered within the R&D budget for NEET-NSUF-1 in this FOA or via another fund source for NEET-NSUF-2:

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

Figure E-1. New process showing implementation of changes.



Appendix F: Draft Nuclear Science User Facilities User Agreement

Idaho National Laboratory

Non-Proprietary User Agreement

User Facility Agreement No. 10-008 BETWEEN

BATTELLE ENERGY ALLIANCE, LLC

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

AND

The Regents of the University of

(“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. FACILITIES AND SCOPE OF WORK

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 10 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 as specified in the attached Funding Statement.

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. 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. Materials (including residues and/or other contaminated material) remaining after performance of the work or analysis will be removed in their then condition by USER at USER's expense. 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.

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 U.S. and U.S. 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 U.S. and U.S. 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.

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.

E. **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: PATENT RIGHTS***

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:
   d. Are not generally known or available from other sources without obligation concerning their confidentiality.
   e. Have not been made available by the owner to others without obligation concerning their confidentiality
   f. Are not already available to the CONTRACTOR or the Government without obligation concerning their confidentiality.
   g. 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 of the U.S. Department of Energy (DOE), which are 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 person acting on their behalf: (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

3. 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:
   h. 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
   i. 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.
4. 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 U.S. 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: Todd Allen
TITLE: Deputy Laboratory Director, Science and Technology

DATE: _____

User's Formal Name (USER):

BY: _____
Signature

NAME: _____
Printed

TITLE: _____

DATE: _____

ADDRESS: _____

TELEPHONE: _____

***** Any changes to the *** or substantive changes to the non *** provisions will require formal written approval by DOE.**