FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

U. S. Department of Energy

Idaho Operations Office

Fiscal Year 2014 Consolidated Innovative Nuclear Research

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List of Acronyms

ARC - Advanced Reactor Concepts
ATR - Advanced Test Reactor
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 DOE - Department of Energy EPAct - Energy Policy Act of 2005
CTD – Crosscutting Technology Development
DE – Department of Energy (FOA Number)
DOE – Department of Energy
EPAct – Energy Policy Act of 2005
FC R&D - Fuel Cycle Research and Development
FDO - Federal Demonstration Partnership
FFATA - Federal Funding and Transparency Act of 2006
FFRDC- Federally Funded Research and Development Center
FOA - Funding Opportunity Announcement
FSRS - FFATA Subaward Reporting System
GOGO - Government Owned/Government Operated
GSI - General Scientific Infrastructure
ICHMI - Instrumentation, Control, Human, Machine Interface
ID - Identification
IRP - Integrated Research Project
LWRS - Light Water Reactor Sustainability
M&O - Management and Operating
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
NGNP - Next Generation Nuclear Plant Demonstration Project
NSUF - National Scientific User Facility
NNSA - National Nuclear Security Administration
NPPs - Nuclear Power Plants
PD - Program Directed
PDF - Adobe Portable Document Format
PIE - Post-irradiation Examination
PI - Principal Investigator
POC - Point of Contact
QA - Quality Assurance
R&D - Research and Development
RC RD&D - Reactor Concepts Research, Development and Demonstration
RPA - Request for Pre-Applications
RPS - Radioisotope Power Systems
RPV - Reactor Pressure Vessel
SAM - System for Award Management
SBIR - Small Business Innovative Research
SF – Standard Form
SMR - Small Modular Reactors
STTR - Small Business Technology Transfer
TAC - Total Allowable Costs
TIO - Technical Integration Office
TMI-2 - Three Mile Island Unit 2

PART I – FUNDING OPPORTUNITY DESCRIPTIONS

A. STATEMENT OF OBJECTIVES

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

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 Funding Opportunity Announcement (FOA) addresses the competitive portion of NE's R&D portfolio as executed through the Nuclear Energy University Programs (NEUP) and Nuclear Energy Enabling Technologies Crosscutting Technology Development (NEET CTD). NEUP utilizes up to 20 percent 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 (FCR&D), Reactor Concepts Research, Development and Demonstration (RCRD&D), and Nuclear Energy Advanced Modeling and Simulation (NEAMS). NEET CTD supports national laboratory, university and industry led crosscutting research in the areas of reactor materials, advanced sensors and instrumentation, and advanced methods for manufacturing.

NE reserves the right to respond to potential shifts in R&D priorities during FY 2014 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.

2. Major NE-Funded Research Programs

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 U.S.

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.

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 (ARC) and Advanced Small Modular Reactors (Adv SMRs). In addition, R&D for the manufacturing of radioisotope power systems for national security and space exploration missions is supported through the Space and Defense Infrastructure Program.

Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program. The mission of the NEAMS program is to create modern computer simulation codes and methods that give the user state-of-the-art physics models that can take advantage of powerful multi-processing computers in order to better understand the behavior of nuclear reactor and fuel systems during normal operations and/or transient events. In particular, NEAMS is aimed at creating an advanced mechanistic toolkit that is applicable to a wide range of reactor designs for use by industry, academia, and the national laboratories. The NEAMS Toolkit will help engineers and scientists form new insights into the safety and economics of current and next generation reactor and fuel systems. It will provide much higher fidelity than current methods and incorporate well-defined and validated prediction capabilities.

This will be achieved by employing advanced software environments and modern high-performance computers to create a set of engineering-level codes in which fuels and materials continuum properties are informed by first-principles modeling of materials at the atomistic and meso-scale. A set of simulation tools will be developed that promote interoperability of codes with respect to spatial meshing, materials and fuels models, and achieve a common "look and feel" for setting up problems and displaying results. The tool set to be developed aims to achieve scalability in terms of computing power and the types and couplings of the physics that dominates the system behavior.

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 reactor materials, advanced methods for manufacturing, and new instrumentation and sensor technologies.

B. RELATED COLLABORATIVE OPPORTUNITIES

Utilization of acquired equipment and infrastructure, as a result of other collaborative opportunities, may enhance a R&D project. Therefore, opportunities exist to leverage equipment and infrastructure capabilities as outlined below.

1. *Scientific Infrastructure Support for Consolidated Innovative Nuclear Research (Infrastructure)*. DOE-NE funds reactor upgrades and general scientific infrastructure support as part of a separate FOA (DE-FOA-0000999). The Infrastructure FOA seeks applications from U.S. Universities and National Laboratories to support equipment and infrastructure needs. NE is facilitating the ability of university researchers to coordinate and enhance their proposed R&D applications in response to this CINR FOA with equipment and infrastructure applications made in response to the Infrastructure FOA, as appropriate and as described below.

   University researchers may submit a separate application to DE-FOA-0000999 to request related equipment. Applications submitted through this joint mechanism will be reviewed and ranked according to the criteria and processes described in the respective FOA. As funding permits, applications selected by both review processes will be funded. Both applications must be successful for either to be considered for award.

2. *Advanced Test Reactor National Scientific User Facility (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 post-irradiation examination facilities as well as technical assistance in 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 to the relationship including reactors, beamlines, state-of-the-art instruments, hot cells, and most importantly, expert mentors. 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, university researchers and their collaborators

are building on current knowledge to better understand the complex behavior of materials and fuels in the radiation environment of a nuclear reactor.

Applicants are not required to utilize NSUF capabilities as part of this FOA; however, award recipients may consider NSUF capabilities for future project activities. Access to the NSUF and its partner facilities is granted through a competitive proposal process. Proposals submitted for the NSUF Partnership Program are reviewed and awarded according to the criteria and processes described at http://atrnsuf.inl.gov/Partners/tabid/57/Default.aspx.

C. FUNDING OPPORTUNITIES

DOE is seeking applications from U.S. universities, national laboratories and industry to conduct *Program Supporting*, *Mission Supporting* and *Program Directed* nuclear energy-related research in support of the major NE-funded research programs.

Additionally, DOE has interest in leveraging multiple needs to the extent possible. 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.

The definitions that apply to these different areas are as follows:

1. Program Supporting R&D – Program supporting (PS) R&D is focused more directly on programmatic needs and is defined by the statement of objectives developed by the responsible programs. This R&D is up to three years in duration and should be focused and responsive to the representative statement of objectives, which are not specific to a discipline but can be limiting as defined by the project objective.

    - *U.S. University Principal Investigators (PIs) may apply in support of FC R&D, RC RD&D, NEAMS, and NEET CTD.*

    - *National Laboratory, U.S. University, and U.S. Industry PI's may apply in support of NEET CTD.*

2. Mission Supporting (MS) R&D – Mission Supporting (MS) R&D is generally more creative, innovative, and transformative, but must also support the NE mission. Mission supporting activities up to three years in duration that could produce breakthroughs in nuclear technology are also invited in response to this FOA, including 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 identified in this FOA.

    - *U.S. University PI'S may apply in support of FC R&D, RC RD&D and Nuclear Energy.*

3. Program Directed R&D: Integrated Research Projects (IRPs) – IRPs comprise a significant element of DOE's innovative nuclear research objectives and represent the Program Directed (PD) component of the NE strategy to provide R&D solutions that are 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 up to three years in duration and 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 bring together the skills and talents of interdisciplinary investigators to enable fundamental research of a scope and complexity that would not be possible with the standard individual investigator or small group research project. As such, the IRPs will strengthen and complement the existing portfolio of the single PI and small group research projects currently supported within NE. The IRPs will foster unique scientific collaboration that will be critical to success and must be backed by a meaningful and sustained investment. The 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 have a lead university and at least one other university, the proposed project team may include multiple universities and non-university partners (e.g., industry/utility, international, minority-serving institutions (MSI), national laboratory, and underrepresented groups).

   Key elements for successful IRP management include: 1) A clear lead university with strong scientific leadership and central location for the IRP; 2) To the extent that there is geographic distribution of the IRP participants, a clear commitment to applying state-of-the-art technology and frequent virtual meetings to enable meaningful long distance collaboration; and most importantly 3) a clear organization and management plan for achieving the collaborative and synergistic goals of an IRP and "infusing" a culture of empowered central research management throughout the IRP.

   - *U.S. University PI'S may apply in support of FC R&D, RC RD&D and Nuclear Energy.*

Workscopes for the respective areas may be found in the appendices to this FOA as follows:

- Appendix A: Program Supporting and Mission Supporting workscopes for applications led by university PI's
- Appendix B: Program Supporting workscopes for applications led by national laboratory, industry, or university PI's
- Appendix C: Program Directed workscopes led by university PI's

PART II – AWARD INFORMATION

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

A. TYPE OF AWARD INSTRUMENT

DOE anticipates awarding cooperative agreements under this funding opportunity announcement (See Section VI.B.6 Statement of Substantial Involvement).

B. ESTIMATED FUNDING

The estimated amounts identified for each of the FOA areas is contingent upon Congressional appropriations and is subject to change.

1. Program and/or Mission Supporting Projects for U.S. University led Projects

DOE currently estimates that it will fund approximately ***$33 million*** in awards for this FOA area.

2. Program Supporting Projects for U.S. Universities, National Laboratories, or Industry led Projects

DOE currently estimates that it will fund approximately ***$12.4 million*** in awards for this FOA area.

3. Program Directed Integrated Research Project (IRP) for U.S. University led Projects

DOE currently estimates that it will fund approximately ***$15 million*** in awards for this FOA area.

C. MAXIMUM AND MINIMUM AWARD SIZE

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

1. Program and/or Mission Supporting Projects for U.S. University led Projects

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

Program Support: $800,000 (3 year project)
Mission Support: $400,000 (3 year project)

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

None.

2. **Program Supporting Projects for U.S. Universities, National Laboratories, or Industry led Projects**

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

NEET 1 (Advanced Methods for Manufacturing): $800,000 (3 year project)
NEET-2 (Advanced Sensors and Instrumentation): $1,000,000 (3 year project)
NEET-3 (Reactor Materials): $1,000,000 (3 year project)

Floor (i.e., the minimum amount for an individual award made under this announcement):

None.

3. **Program Directed Integrated Research Project (IRP) for U.S. University led Projects**

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

IRP-RC (Integrated Approach to Fluoride High Temperature Reactor Technology and Design Challenges): $5,000,000 (3 year project)
IRP-FC-1 (Sensors and Delivery Devices for Dry Storage of Used Nuclear Fuel): $3,000,000 (3 year project)
IRP-FC-2 (Forced Helium Dehydration/Vacuum Drying of Used Nuclear Fuel): $4,000,000 (3 year project)
IRP-NE (Transient Test Instrumentation R&D): $3,000,000 (3 year project)

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 area is identified below. The number of awards is dependent on the size of the awards.

1. **Program and/or Mission Supporting Projects for U.S. University led Projects**

DOE anticipates making up to approximately 40 awards under this area.

2. **Program Supporting Projects for U.S. Universities, National Laboratories, or Industry led Projects**

DOE anticipates making up to 13 awards under this area.

3. Program Directed Integrated Research Project (IRP) for U.S. University led Projects

DOE anticipates making 4 awards under this area (1 award per IRP workscope).

E. ANTICIPATED AWARD SIZE

The anticipated award size for each of the three FOA areas are identified below.

1. Program and/or Mission Supporting Projects for U.S. University led Projects

DOE anticipates that awards will be no more than $800,000/award for Program Supporting projects and no more than $400,000/award for Mission Supporting projects.

2. Program Supporting Projects for U.S. Universities, National Laboratories, or Industry led Projects

DOE anticipates that awards will be no more than $800,000 for awards under NEET-1, and $1,000,000 for awards under NEET-2 and NEET-3.

3. Program Directed Integrated Research Project (IRP) for U.S. University led Projects

DOE anticipates that awards will be no more than:

IRP-RC: $5,000,000
IRP-FC-1: $3,000,000
IRP-FC-2: $4,000,000
IRP-NE: $3,000,000

F. PERIOD OF PERFORMANCE

DOE anticipates making awards for up to 3 years for each area.

G. TYPE OF APPLICATION

DOE will accept only new applications for each FOA area under this announcement.

PART III - ELIGIBILITY INFORMATION

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

A. ELIGIBLE APPLICANTS

This FOA is open to U.S. universities, national laboratories and U.S. 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 tackle a problem together, overcoming impasses by attacking the issue from fresh angles and discovering novel solutions.

The Department 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 U.S. The Department will evaluate 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.

No more than 20 percent of the total funds provided by the government to a university (excludes NEET CTD) can go to non-university collaborator.

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 recipient (only educational institutions may apply as a prime recipient for Program and/or Mission Supporting Projects for U.S. University led Projects and Program Directed IRPs for U.S. University led Projects) or as a subrecipient.

State, local, and tribal government entities are eligible to apply for funding as a subrecipient (for Program and/or Mission Supporting Projects for U.S. Universities, National Laboratories, or Industry led Projects only).

DOE/NNSA Federally Funded Research and Development Centers (FFRDCs) and DOE Government-Operated Government-Owned laboratories (GOGOs) are eligible to apply for funding as a prime recipient (for Program Supporting Projects for NEET CTD), team member or subrecipient. If an FFRDC is proposed as a team member or subrecipient, the requirements contained in Section III.C. apply.

Non-DOE/NNSA FFRDCs and non-DOE GOGOs 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, 1005, 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 (for Program Supporting Projects for NEET CTD)

Foreign entities, whether for-profit or otherwise, are eligible to apply for funding under this FOA as either a prime recipient or subrecipient subject to the following.

Other than as provided in the "Individuals" or "Domestic Entities" sections above, all prime recipients (for Program Supporting Projects for U.S. Universities, National Laboratories, or Industry led Projects only) receiving funding under this FOA must be incorporated (or otherwise formed) under the laws of a State or territory of the United States. If a foreign entity applies for funding as a prime recipient, it must designate in the full application a subsidiary or affiliate incorporated (or otherwise formed) under the laws of a State or territory of the United States to be the prime recipient. The full application must state the nature of the corporate relationship between the foreign entity and domestic subsidiary or affiliate.

3. Incorporated Consortia (for Program Supporting Projects for NEET CTD)

Incorporated consortia, which may include domestic and/or foreign entities, are eligible to apply for funding as a prime recipient (for Program Supporting Projects for U.S. Universities, National Laboratories, or Industry led Projects only) or subrecipient. For consortia incorporated (or otherwise formed) under the laws of a State or territory of the United States, please refer to "Domestic Entities" above. For consortia incorporated in foreign countries, please refer to the requirements in "U.S. Incorporated Foreign Entities" above.

Each incorporated consortium must have an internal governance structure and a written set of internal rules. Upon request, the consortium must provide a written description of its internal governance structure and its internal rules to the DOE Contracting Officer.

4. Unincorporated Consortia (for Program Supporting Projects for NEET CTD)

Unincorporated consortia, which may include domestic and foreign entities, must designate one member of the consortium to serve as the prime recipient/consortium representative (for Program and/or Mission Supporting Projects for U.S. Universities, National Laboratories, or Industry led Projects only). The prime recipient/consortium representative must be incorporated (or otherwise formed) under the laws of a State or territory of the United States. The eligibility of the consortium will be determined by the eligibility of the prime recipient/consortium representative.

Upon request, unincorporated consortia must provide the DOE Contracting Officer with a collaboration agreement, commonly referred to as the articles of collaboration, which sets out the rights and responsibilities of each consortium member. This agreement binds the individual consortium members together and should discuss, among other things, the consortium's:

- Management structure;
- Method of making payments to consortium members;
- Means of ensuring and overseeing members' efforts on the project;
- Provisions for members' cost sharing contributions; and
- Provisions for ownership and rights in intellectual property developed previously or under the agreement.

5. Restricted Eligibility

University Principal Investigators (PIs) with a currently funded IRP, or three or more R&D projects that will still be active after December 31, 2014, or who have a no-cost extension (NCE) on any DOE-NE funded project which will still be active beyond December 31, 2014, 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. Additionally, 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. Further, applications submitted in response to Program Supporting research requested by the NEET CTD are limited to three pre-applications per entity per objective 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.

B. COST SHARING

For applications led by universities, cost sharing is encouraged, but not required. If cost sharing is provided, see 10 CFR 600 for the applicable cost sharing guidance and UNDERSTANDING COST SHARING REQUIREMENTS in Part VIII.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, a cost share of at least 20% of the total allowable costs (TAC) 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 TAC of the project) and must come from non-Federal sources unless otherwise allowed by law. (See 10 CFR 600.30 for more information on the cost sharing requirements.)

C. OTHER ELIGIBILITY REQUIREMENTS

FFRDC Contractors

FFRDC contractors may be proposed as a 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."

- *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/NNSA will fund a DOE/NNSA FFRDC contractor through the DOE field work proposal 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. FFRDC costs are included as part of the government cost share.

- *FFRDC Contractor Effort (expect for project(s) in support of NEET CTD):*

  - 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. Parts II and III Summary

		Estimated Available Budget	Maximum Award Size	Project Duration	Tie to GSI	Collaboration
University Led Projects (Area 1)	**Program Supporting**	$33,000,000	$800,000	3 years	Yes	University, National Laboratory, Industry, Foreign Collaborations are encouraged but no U.S. funding can go to entities that are not incorporated in the U.S.
	Mission Supporting		$400,000			
University, National Laboratory, or Industry Led Projects (Area 2)	**NEET-1**	$12,400,000	$800,000	3 years	Yes (if project lead is a University)	
	NEET-2		$1,000,000			
	NEET-3		$1,000,000			
Integrated Research Projects (Area 3)	**IRP-RC**	$15,000,000	$5,000,000	3 years	No	
	IRP-FC-1		$3,000,000			
	IRP-FC-2		$4,000,000			
	IRP-NE		$3,000,000			

PART IV - APPLICATION AND SUBMISSION INFORMATION

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

A. ADDRESS TO REQUEST APPLICATION PACKAGE

Apply at http://www.NEUP.gov

Application forms and instructions are available at the NEUP website. To access these materials, go to http://www.NEUP.gov, select "Login" from the top right hand corner of the screen, enter your user credentials, select "Applications" from the menu, and then click on "Create New Application" for the type of application you are creating.

B. LETTER OF INTENT AND PRE-APPLICATION

1. Letter of Intent

Letters of Intent are not required.

2. Pre-applications (Mandatory)

Pre-applications are a mandatory requirement for Program and/or Mission Supporting Projects for U.S. universities, national laboratories, or industry led projects. Pre-applications are not required for Program Directed IRPs. Pre-applications must be submitted by the date and time specified in Part IV, Paragraph E.2.

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

Pre-applications are to be prepared using standard 8.5" X 11" paper with 1 inch margins (top, bottom, left, right), using a font size not smaller than Times New Roman 11 point.

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

a. Pre-application Narrative (3 page limit, Name File: 2014 RPA Narrative "Insert ID #")

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

- Title of Project
- Technical Work Scope Identifier No. (enter the number that appears in the Technical Work Scope appendix)). 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/Principal Investigator(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
- Logical path to work accomplishment
- Deliverables and outcomes the R&D will produce
- Quality assurance (QA) principles and requirements used to conduct R&D activities
- Estimated cost of project
- Timeframe for execution of proposed project (specify if the R&D is for a one-, two-, or three-year period)

b. Benefit of Collaboration (2 page limit, Name File: 2014 RPA Benefit of Collaboration "Insert ID #")

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 this 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).

c. Principal Investigator Vita (2 page limit, Name File: 2014 RPA Last Name of Collaborator "Insert ID #")

Applicant shall provide a vita for the PI. Vitae must include:

- Contact Information
- Education and Training: Undergraduate, graduate and postdoctoral training. Identify 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.

3. **Agreement Requirements**

Institutions will be expected to follow quality assurance (QA) principles and requirements in conducting R&D activities (see Part VI, Section B.2). The integrity of R&D products and their usability by NE is predicated on meeting QA requirements as they apply to a specific scope of work and associated deliverables. In most cases, an institution's process for peer review in support of publishing research results will serve as a basis for QA requirements; however, there may be some instances where additional QA requirements are specified.

While QA requirements are not new to universities and colleges, it is recognized that familiarity with NE programmatic-specific QA requirements will vary; therefore, during the full application process, DOE will provide assistance, as needed, in understanding possible QA requirements for a specific workscope and in developing options to meet those QA requirements. By submission of an application, the applicant is agreeing to abide by and incorporate QA requirements into its project. At any time during performance of the project, DOE may conduct an on-site visit to verify QA requirements are being implemented.

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

C. CONTENT AND FORM OF APPLICATION: PS and MS 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 is a semi-blind process. Please be sure to review the requirements below carefully as non-compliant applications may be excluded from review.

1. **SF 424 (R&R)**

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

Name File: 2014 CFA SF424RR "Insert ID #.pdf"

2. RESEARCH AND RELATED Other Project Information

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

Name File: 2014 CFA R&R Other Project Information "Insert ID #.pdf"

a. 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/principal investigator(s), the project title, the objectives of the project, a description of the project, including 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 the Department may make it available to the public after awards are made. The project summary must not exceed 2 pages when printed using standard 8.5" by 11" paper with 1" margins (top, bottom, left and right) {single spaced} with font not smaller than 11 point. To attach a Project Summary/Abstract, click "Add Attachment."

Name File: 2014 CFA Technical Abstract "Insert ID #.pdf"

b. Project Narrative (10 pages for Program/Mission Supporting, 50 pages for Program Directed)

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. (Do not use all CAPS for application title.)
- Final Technical Workscope Identification: refer to the communication provided by the DOE program integration office describing the results of the pre-application selection process.
- 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.A. Provide sufficient information so that reviewers will be able to evaluate the application in accordance with these merit review criteria.

- Relevance and Outcomes/Impacts: This section will explain the relevance of the effort to the objectives in the program announcement and the expected outcomes and/or impacts.
- Milestones and Deliverables.
- Type/description of facilities that will be used to execute the scope (N/A is acceptable).
- Schedule: Define timelines for executing the specified workscope.
- The roles and responsibilities of each partnering organization in the execution of the workscope.
- Unique challenges to accomplishing the work and innovations expected to mitigate such challenges.
- Information, data, plans, or drawings necessary to explain the details of Applicant's application.
- Quality Assurance (QA): Describe the applicable QA requirements and how they will be met. This can be a simple statement agreeing to comply with the QA requirements as described by DOE on the application website and any additional requirements deemed necessary.
- References are included in the 10 and 50 page limit.

The R&D technical narrative (Program/Mission Supporting only) **shall NOT include** the following information:

- Cost and pricing information.
- Identification, by individual name or name of institution, of any teaming partner. 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.

Name File: 2014 CFA Technical Narrative "Insert ID #.pdf"

c. Other Attachments

1) Vitae - Technical Expertise and Qualifications (2 Pages Each)

Applicant shall name all teaming partners by name and organization, as well as their proposed roles and responsibilities. For the Principal Investigator and collaborators, the Applicant shall provide a brief vita that lists the following:

- <u>Contact Information</u>

- 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.

Name File: 2014 CFA "Last Name of Individual" "Insert ID #.pdf"

Technical expertise and qualifications are to be provided for a maximum of five individuals. Submitted individuals (and/or their recipient institutions) must receive at least $50,000 over the life of the project to be considered a collaborator. Minor contributors—anyone not expected to materially participate in the project, such as consultants or national laboratory personnel who are not to be paid more than $49,999 to participate in the project—**should be listed on the application form, but do not need to be represented in this section.**

2) Capabilities (2 Pages)

Infrastructure Requirements: In a separate document, Applicant shall identify the infrastructure (e.g., facilities, equipment, and instrumentation) required to execute the proposed scope of work. 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.

If applicant is requesting funds through the General Scientific Infrastructure Solicitation (DE-FOA-0000999) to support this research, provide summary detail of the request here.

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.

Name file: 2014 CFA Capabilities "Insert ID#.pdf"

3) Benefit of Collaborations (Program Directed (IRP) Only) (4 Pages)

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 this 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).

Name file: 2014 CFA Benefits of Collaboration "Insert ID#.pdf"

4) Letters of Support (Program Directed (IRP) 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 (e.g., 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 signed by an appropriate company official.

Name File: 2014 CFA Letter of Support "Insert ID#.pdf"

5) Current and Pending Support

As requested by the submission form, Applicant shall identify all Federal funding sources by agency source, project name, monetary amount, and length of term that are pending or currently in place for the university PI or collaborators within the past five years.

Name File: 2014 CFA Current and Pending Support "Insert ID #.pdf"

6) Budget for DOE/NNSA Federally Funded Research and Development Center (FFRDC) Contractor, if applicable

If a DOE/NNSA FFRDC contractor is to perform a portion of the work, applicant must provide a DOE Field Work Proposal in accordance with the requirements in DOE Order 412.1 Work Authorization System. This Order and the DOE Field Work

Proposal form are available at http://energy.gov/management/office-management/operationalmanagement/financial-assistance/financial-assistance-forms.

Name File: 2014 CFA FWP “Insert ID #.pdf”

7) Data Validation Needs

Researchers should evaluate their applications 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.

Name File: 2014 CFA Data Validation “Insert ID #.pdf”

8) Environmental Checklist

Applicants must complete the environmental checklist available at www.NEUP.gov.

Name File: 2014 CFA Env “Insert ID #.pdf”

9) Conflict-of-Interest Statement

Conflicts of interest may exist due to previous efforts performed by the Labs or assistance provided in program direction and other mission related activities. Accordingly, for each applicant or (or subapplicant) that is a national laboratory or DOE and/or Non-DOE FFRDCs, identify any potential conflicts of interest, fully explain the conflict, whether you feel it is significant or not, along with your rationale, and, if significant, how you will avoid, neutralize, or mitigate the potential conflict.

Name File: 2014 CFA COI “Insert ID #.pdf”

10) Authorization for DOE/NNSA FFRDCs

(REQUIRED FOR NATIONAL LABORATORIES, DOE AND NON-DOE FFRDCS APPLICANTS AND SUBAPPLICANTS)

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."

Name File: 2014 CFA CO Authorization "Insert ID #.pdf

3. RESEARCH AND RELATED BUDGET (TOTAL FED + NON-FED)

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.G.).

Name File: 2014 CFA Budget "Insert ID #xls"

Budget Justification. Provide the required supporting information for the following costs (See R&R instructions): 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.

Name File: 2014 CFA Budget Justification "Insert ID #.pdf"

4. R&R SUBAWARD (TOTAL FED + NON-FED) FORM

Budgets for Subrecipients, other than DOE FFRDC Contractors. Applicant must provide a separate cumulative R&R budget for each subrecipient that is expected to perform work estimated to be more than $100,000 or 50 percent of the total work effort (whichever is less). Download the R&R Budget Attachment from the R&R SUBAWARD BUDGET (Total Fed + Non-Fed) FORM and e-mail it to each subrecipient that is required to submit a separate budget. After the Subrecipient has e-mailed its completed budget back to you, attach it to one of the blocks provided on the form. Use up to 10 letters of the subrecipient's name as the file name.

Name File: 2014 CFA Subaward Budget "Insert ID #xls"

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 Standard Form - LLL, "Disclosure Form to Report Lobbying."

Name File: 2014 CFA SF-LLL "Insert ID #.pdf"

6. CERTIFICATIONS AND ASSURANCES

Applicants must complete 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: 2014 CFA Cert & Assurances "Insert ID #.pdf"

Table 8: Summary of Required Forms/Files

Name of Document	Format	File Name
SF424 (R&R)	Form	2014 CFA SF424RR "Insert ID #.pdf"
RESEARCH AND RELATED Other Project Information	Form	2014 CFA R&R Other Project Information "Insert ID #.pdf"
Project Summary/Abstract	PDF	2014 CFA Technical Abstract "Insert ID #.pdf"
Project Narrative	PDF	2014 CFA Technical Narrative "Insert ID#.pdf"
Other Attachments	PDF	See Below
Vitae - Technical Expertise and Qualifications (2 Pages Each)	PDF	2014 CFA "Last Name" "Insert ID #.pdf"
Capabilities (2 pages)	PDF	2014 CFA Capabilities "Insert ID#.pdf"
Benefits of Collaborations (Program Directed (IRP) Only) (4 Pages)	PDF	2014 CFA Benefits of Collaboration "Insert ID#.pdf"
Letters of Support (Program Directed (IRP) only)	PDF	2014 CFA Letter of Support "Insert ID#.pdf"
Current and Pending Support	PDF	2014 CFA Current and Pending Support "Insert ID#.pdf"
Budget for DOE National Laboratory Contractor or FFRDC, if applicable	PDF	2014 CFA FWP "Insert ID #.pdf"
Data Validation Needs	PDF	2014 CFA Data Validation "Insert ID #.pdf"
Environmental Checklist	PDF	2014 CFA Env "Insert ID #.pdf"
Conflict-of-Interest Statement,	PDF	2014 CFA COI "Insert ID #.pdf"

Name of Document	Format	File Name
applicable to National Laboratories, DOE and Non-DOE FFRDC applicants and subapplicants		
Authorization for DOE/NNSA FFRDCs	PDF	2014 CFA CO Authorization “Insert ID #.pdf”
RESEARCH AND RELATED BUDGET (Total Fed + Non-Fed)	Form	2014 CFA Budget “Insert ID #xls”
Budget Justification File	PDF	2014 CFA Budget Justification “Insert ID #.pdf”
R&R SUBAWARD BUDGET (Total Fed + Non-Fed), if applicable	Form	2014 CFA Subaward Budget “Insert ID #xls”
SF-LLL DISCLOSURE OF LOBBYING ACTIVITIES, if applicable	Form	2014 CFA SF-LLL “Insert ID #.pdf”
CERTIFICATIONS AND ASSURANCES	Form	2014 CFA Cert & Assurances “Insert ID #.pdf”

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:

- 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

1. Letter of Intent Due Date

Letters of Intent are not required.

2. Pre-Application Due Date

Applicants must submit a pre-application by December 2, 2013 at 8:00 p.m. Eastern Time (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.

3. Application Due Date

Applications should be received by April 3, 2014, not later than 8:00 PM 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 are contingent upon the availability of funds appropriated by Congress for the purpose of this program and the availability of future-year budget authority.

Cost Principles. Costs must be allowable, allocable and reasonable in accordance with the applicable Federal cost principles referenced in 10 CFR 600. The cost principles for commercial organization are in FAR Part 31.

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 10 CFR 600. 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

1. Where to Submit

APPLICATIONS MUST BE SUBMITTED THROUGH 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 208-526-1507 or send an email to NEUP@inl.gov.

2. Application Validity Timeframe

By submitting an application in response to this FOA applicants agree that their applications are valid for at least 1 year from the date set forth for receipt of applications to this FOA.

PART V - APPLICATION REVIEW INFORMATION

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

A. CRITERIA

1. Pre-Application Review (PS and MS)

Selection of applying institutions invited to provide full applications shall be based on how well the pre-applications meet or exceed the technical and relevancy evaluation criteria provided below. All applications submitted under this solicitation will be reviewed and scored by two different groups as described below.

First, a panel of programmatic experts will assess each pre-application's relevancy to NE's R&D Program/Mission supporting workscopes. Points will be assigned according to the following relevancy attributes:

Relevancy attributes:

- Highly Relevant/High Program Priority (100 pts): The project is fully supportive of, and has significant, easily recognized and demonstrable ties to, the relevant program element(s).
- Relevant/Intermediate Program Priority (66 pts): The project is supportive of, and has significant and demonstrable ties to, the relevant program element(s).
- Low Relevance/Low Program Priority (33 pts): The project is minimally supportive of, and has some ties to, the relevant program element(s).
- Not Relevant/No Program Priority (0 pts): The project is not supportive of the relevant program element(s) – OR – sufficient work is already being performed.

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

Second, a separate technical expert/peer will assess each application on its technical merit. Points will be assigned according to the following attributes of technical merit.

Technical attributes:

- High Merit (100 pts): The project unquestionably advances the technical state of knowledge and understanding of the NE mission or program element, and is creative and based largely on original concepts. The scope is within the technical expertise of the proposed team, and can be executed fully in the facilities available within the proposed budget.

- <u>Moderate Merit (66 pts):</u> The project incrementally advances the technical state of knowledge and understanding of the NE mission or program element, and is somewhat creative and based contains several original concepts. The scope will be a challenge to the technical expertise of the proposed team, and may be difficult to execute fully in the facilities available within the proposed budget.
- <u>Low Merit (33 pts):</u> The project recognizes the technical state of knowledge and understanding of the NE mission or program element, and is only marginally creative and contains few original concepts. The scope will be a challenge to the technical expertise of the proposed team, and may be difficult to execute fully in the facilities available within the proposed budget. The scope will be a challenge to the technical expertise of the proposed team and require resources not named in the project or will require additional facilities or funding to execute.
- <u>No Merit (0 pts):</u> The project does not advance or recognize the technical state of knowledge and understanding of the NE mission or program element, and is not creative or original. The scope is beyond the technical expertise of the proposed team, and cannot be executed fully in the facilities available within the proposed budget.

The points determined by evaluating each application against the above criteria will then be weighted as defined in Table 9 to determine an overall evaluation score for each application.

After considering the overall evaluation scores, available funding, and the other selection factors (see Part V, Section A.5), as needed, NE will make a final determination of applicants who will be invited to provide full applications. Applicants who are not specifically invited to submit full applications may still do so at their own risk. There is no guarantee that uninvited full applications will receive a full review; however, all full applications will be re-reviewed for relevancy. Only those uninvited full applications that are scored as Highly Relevant will be forwarded for technical peer review during the evaluation phase for full applications described below.

2. Initial Review Criteria

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 that approval from DOE's Contracting Officer provided approval; (3) the information required by the announcement has been submitted; (4) all mandatory requirements are satisfied; and (5) the proposed project is responsive to the objectives of the Funding Opportunity Announcement. Only applications meeting these initial review criteria will be considered during the merit review and award selection decision.

3. PS/MS 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 listed in item 4. 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 relevancy evaluation criteria provided below and as weighted as described in Table 9. All invited full applications submitted under this solicitation will be reviewed and scored by two different groups. A panel of programmatic experts will assess each full application's relevancy to NE's R&D mission or program and three technical peer reviewers will evaluate the project for technical merit. Effective partnerships will be incorporated into the relevancy evaluation. Any application determined "Not Relevant" will not be evaluated further.

Relevancy attributes:

Same criteria used for PS/MS pre-application evaluation phase. See Section A.1 above.

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 (10 pts.)

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 (10 pts.)

DOE will evaluate the overall quality/acceptability of the proposed R&D project. In evaluating this criterion, DOE may consider the merit, feasibility, and realism of the proposed methodology and approach to the project; the schedule, including sequence of project tasks, principle milestones and times for each task, the planned assignment of responsibilities; proposed project efficiencies; the resources available to the applicant in carrying out the project, and the adequacy of the budget and its supporting justification.

Criterion 3 – Applicant Team Capabilities and Experience (10 pts.)

The extent to which the applicant team provides objective evidence that it has the professional resources and abilities to successfully complete the R&D 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 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, other key contributors are such that they can successfully accomplish the technical scope of the proposed project.
- That the applicant or its 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 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 9: PS/MS R&D Full Applications - Weighting of Evaluation Scores

Criterion	Description	
	Technical Application – Peer Review	**Percentage of Peer Review Points**
Scientific and Technical Merit	Advances the state of the knowledge in the relevant program element(s); practicality of scope with respect to specified funding range for work scope and period of performance.	35%
Technical Quality of the Proposed R&D Project	Logical path to work accomplishment.	35%
Team Capabilities, Qualifications and Experience	Demonstrate that labor and non-labor resources are adequate to accomplish the proposed work scope. Costs delineated on the budget worksheet will be considered within this section. Relevant credentials, publications, experience, and past accomplishments of Principal Investigator and collaborators.	30%
	Peer Review Score	Sum of ratings x weights
	Relevance[1] (Separate Review Process)	**Percentage of Relevancy Review Points**
Program Relevance	Alignment with the program-specific relevant technical objectives.	100%

Criterion	Description	
Partnership Relevance	The degree to which minority-serving institutions, 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: effective partnerships are not required for projects to be evaluated as unquestionably relevant, but effective partnerships will increase relevance score from 1 to 5 points, not to exceed 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 minority serving institution (MSI) collaboration; (2) a demonstrable contribution by an industrial, international, underrepresented group, or MSI collaboration; or (3) some relevant partnership with an industrial, international, underrepresented group, or MSI collaboration.	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) Program Supporting: 65:35 Mission Supporting: 80:20**	
[1] Supports Program Relevance: This element will be scored by the Program Offices, not by peer review. [2] Total relevancy points cannot exceed 100% of points available from the relevancy criteria.		

4. Program Directed Merit Review – Full Application

Selection for the Program Directed IRP for U.S. university led projects will be based on the following criteria and sub-criteria. The criteria are equally important.

Criterion 1 - Scientific and/or technical merit of the project (10 pts.)

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 addresses shifts in research directions towards promising developments. Evaluation 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 (10 pts.)

The appropriateness of the proposed IRP method or approach will be evaluated, including the extent that the strategy and the plan for the development and operation of the proposed IRP identifies an approach involving several senior/key personnel, the means for achieving an integrated 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, and encourages synergisms among investigators, thus demonstrating that the whole is substantially greater than the sum of the individual parts, whether its organization structure delineates 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 is 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 Principal Investigator, 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.
- Implications for environment, safety and health are responsibly anticipated and addressed.

Criterion 3 – Applicant Team Capabilities and Experience (10 pts.)

The extent to which the applicant team provides objective evidence that it has 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 PI, will be evaluated as it relates to the likely successful completion of the IRP. 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 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 - including access to research capabilities and resources outside of the IRP.
- 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 lead institution and the IRP Lead Principal Investigator have proven records of success in project, program, and personnel management of diverse teams of science and technical professionals.
- 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 Principal Investigator and senior/key personnel will be adequately involved in the proposed IRP, particularly taking into account their potential involvement in other major projects.
- Each participating institution possess adequate systems and processes for ensuring environmental, health and safety support and oversight for project execution.

Criterion 4 - Reasonableness and appropriateness of the proposed budget (10 pts.)

The proposed budget will be evaluated to determine the reasonableness and appropriateness of the budget from a technical perspective. DOE will consider whether requested funding aligns with the project description, whether the proposed costs are reasonable for the planned scientific program, whether costs for existing and new equipment and instrumentation are realistic, and whether all subawards, travel, student costs, and other ancillary expenses are adequately justified and estimated.

Table 10: PD IRP R&D Full Applications - Weighting of Evaluation Scores

Criterion	**Description**	
	Technical Application – Peer Review	**Percentage of Peer Review Points**
Scientific and Technical Merit	Advances the state of scientific knowledge and understanding relative to the IRP and addresses key scientific challenges and addresses shifts in research directions towards promising developments.	25%
Appropriateness of the Proposed Method or Approach	Objective evidence of professional resources and abilities to successfully complete the IRP project in a technically defensible manner.	25%
Applicant Team Capabilities and Experience	Professional resources and abilities available to successfully complete the IRP project in a technically defensible manner.	25%

Criterion	Description	
Reasonableness and Appropriateness of the Proposed Budget	Reasonableness and appropriateness of the budget from a technical perspective.	25%
	Peer Review Score	Sum of ratings x weights
	Relevance[1] (Separate Review Process)	**Percentage of Relevancy Review Points**
Program Factors	Relation of the proposed project to the core research activities within the DOE-NE programs.	40%
Cost Factors	The degree to which award of the proposed project optimizes use of the available DOE funding to achieving NE program goals.	40%
Collaboration Factors	Potential for developing synergies between the proposed IRP and other DOE-NE research activities	20%
Partnership Relevance	The degree to which minority-serving institutions, 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: effective partnerships are not required for projects to be evaluated as unquestionably relevant, but effective partnerships will increase relevance score from 1 to 5 points, not to exceed 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 minority serving institution (MSI) collaboration; (2) a demonstrable contribution by an industrial, international, underrepresented group, or MSI collaboration; or (3) some relevant partnership with an industrial, international, underrepresented group, or MSI collaboration.	Up to 5 points, not to exceed the maximum relevancy points available.)

Criterion	Description	
	Relevancy Score	Sum of ratings[2] x weights
Weighting	**Weighted Score Ratio (Peer : Relevancy) Program Directed 50:50**	
[1] Supports Program Relevance: This element will be scored by the Federal Program Offices and TIO offices, not by peer review. [2] Total relevancy points cannot exceed 100% of points available from the relevancy criteria.		

5. Other Selection Factors

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

a. Degree to which proposed project optimizes/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 how the R&D and IRP projects support other complementary efforts or projects, which when taken together, will best achieve program research goals and objectives.
b. Applications selection may optimize appropriate mix of projects to best achieve DOE-NE research goals objectives.
b. Relevance to agency's programmatic needs.
c. Cost/Budget considerations including cost reasonableness of the proposed cost elements to achieve the proposed objectives, and availability of funding.
d. Past Performance considerations including the type of project/work previously performed and how success the applicant was at perform the project/work.
e. Underrepresented Groups and Minority-Serving Institutions that submit a competitive application.
f. Extent or degree to which projects provide a balanced programmatic effort and a variety of research capabilities among various sizes and kinds of organizations and their geographic distribution.

Any of the above factors used will 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.

B. SUMMARY OF THE REVIEW AND SELECTION PROCESS

1. PS/MS Pre-Applications

Pre-application projects will be evaluated against the technical and relevancy criteria described above. This peer and program evaluation process will produce a list of recommended projects for each workscope provided in Appendix A. The Department 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 who are not specifically invited to submit full applications may still do so at their own risk. There is no guarantee that uninvited full applications will receive a full review; however, all full applications received will be re-reviewed for relevancy. Only uninvited full applications that are scored as Highly Relevant will receive a technical peer review during the evaluation phase for full applications.

2. PS/MS Full Applications

Three peer reviewers will independently employ a semi-blind process to evaluate the applications in accordance with the peer review evaluation criteria described above. Also, a relevancy 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.

3. IRP Full Applications

A minimum of three peer and two 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.

4. Selection Official Considerations

The Selection Official will consider the merit review recommendation and subjective factors such as program policy considerations, research portfolio diversity, and the amount of funds available.

C. ANTICIPATED NOTICE OF SELECTION AND AWARD DATES

DOE will strive to make selections within six to eight months after receipt of applications.

PART VI - AWARD ADMINISTRATION INFORMATION

A. AWARD NOTICES

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.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.

2. Notice of Award

An Assistance Agreement issued by the contracting officer is the authorizing award document. It normally includes either as an attachment or by reference: (1) Special Terms and Conditions; (2) Applicable program regulations, if any; (3) Application as approved by DOE; (4) DOE assistance regulations at 10 CFR part 600; (5) National Policy Assurances To Be Incorporated As Award Terms; (6) Budget Summary; and (7) Federal Assistance Reporting Checklist, which identifies the reporting requirements.

For grants and cooperative agreements made to universities, non-profits and other entities subject to Title 2 CFR the Award also includes the Research Terms and Conditions located 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

1. Administrative Requirements

The administrative requirements for DOE grants and cooperative agreements are contained in 10 CFR 600 (See: http://ecfr.gpoaccess.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 web site at http://www.nsf.gov/bfa/dias/policy/rtc/index.jsp.

DUNS AND SAM REQUIREMENTS

Additional administrative requirements for DOE grants and cooperative agreements are contained in 2 CFR, Part 25 (See: http://ecfr.gpoaccess.gov). Prime awardees must keep their data at SAM current. Subawardees at all tiers must obtain DUNS numbers and provide the DUNS to the prime awardee before the subaward can be issued.

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://ecfr.gpoaccess.gov). Prime awardees must register with the new 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.

2. Special Terms and Conditions and National Policy Requirements

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 (QA) To Be Incorporated As Award Terms (Applicable to educational institutions only). While DOE will normally reply on the institution's 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 he 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, 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 <u>prior to use</u> 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 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: assumptions and the methods used; the results obtained so that independent qualified experts can evaluate how data was interpreted; methods used to identify and minimize measurement uncertainty; the analytical models used; and 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.

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.

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.

5. Corporate Felony Conviction and Federal Tax Liability Representations

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

1) 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.

2) 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.
3) 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.

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 Statement of Substantial Involvement may be negotiated with the recipient prior to award. It will be something similar to the following:

The recipient's responsibilities are listed in paragraph (a), and DOE's responsibilities are listed in paragraph (b).

a. **Recipient's responsibilities**. The recipient is responsible for:
   (1) Performing the activities supported by this award, including providing the required personnel, facilities, equipment, supplies and services;
   (2) Defining approaches and plans, submitting the plans to DOE for review, and incorporating DOE's comments;
   (3) Managing and conducting the project activities, including coordinating with a DOE management and operating (M&O) contractor on activities performed under the M&O contract that are related to the project;
   (4) If requested, attending program review meetings and reporting project status;
   (5) Submitting technical reports as stated in the Federal Assistance Reporting Checklist, and incorporating DOE comments;
   (6) Update project costs and performance data in the DOE-NE Performance Information Collection System (PICS). Recipient personnel will update project information at the work breakdown level agreed to in separate negotiations. Schedules will be developed at the appropriate level of detail to define work, key milestones will be provided with the reasonable costs assigned, and personnel will be assigned clear responsibility to update and submit work package information; and
   (7) Presenting the project results at appropriate technical conferences or meetings as directed by the DOE Project Officer.

b. **DOE responsibilities**. DOE is responsible for:

(1) 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;

(2) If necessary, conducting review meetings to ensure adequate progress and that the work accomplishes the program and project activities. Redirecting work or shifting work emphasis, if needed;

(3) Promoting and facilitating technology transfer activities, including disseminating program results through presentations and publications; and

(4) Serving as scientific/technical liaison between awardees and other program or industry staff.

c. 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 Funding Opportunity Announcement (FOA) must be submitted to the Agency Contact listed in Part VII, B. Questions regarding workscopes may be submitted to the DOE federal and technical points of contact listed in Appendices A, B and C. All answers to questions submitted will be posted at www.NEUP.gov . DOE will try to respond to a question within 3 business days, unless a similar question and answer have already been posted on the website.

Questions and comments concerning this FOA shall be submitted not later than 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. Aaron Gravelle
E-mail: gravelap@id.doe.gov

PART VIII - OTHER INFORMATION

A. MODIFICATIONS

Notices of any modifications to this announcement will be posted on the FedConnect portal, Grants.gov and www.NEUP.gov. You can receive an email when a modification or an announcement message is posted by registering with FedConnect as an interested party for this FOA. It is recommended that you register as soon after release of the FOA as possible 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.

Availability of Funds. 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 its application, consents to the use of non-Federal reviewers/administrators. Non-Federal reviewers must sign conflict of interest 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 paragraph G below.)

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

Special Protected Data Statutes. This program is covered by a special protected data statute. These Special Protected Data Statutes apply to only those applicants who cost share. The provisions of the statute provide for the protection from public disclosure, for a period of up to five (5) years from the development of the information, of data that would be 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 (10 CFR Part 600 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 such 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/patents-licensing-and-patent-waivers 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 (EPAct). The DOE Financial Assistance Rules at 10 CFR 600 implement cost sharing requirements (see §600.30, §600.123, §600.224, or §600.313). The FOA requires a minimum of 20% cost sharing by awardees, except for applications led by US 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; or

   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; or
   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) x (***total project cost***)
Cost Share = (20%) x ($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) x (total project cost)
Cost Share = (20%) x ($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 funding opportunity announcement 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 under this FOA. All no cost time extensions must receive approval from the Contracting Officer.

PART IX - APPENDICES/REFERENCE MATERIAL

Appendix A – Workscope for Program and Mission Support – University Only
Appendix B – Workscope for Program Support – University, National Laboratory, or Industry
Appendix C – Workscope for Program Directed Integrated Research Project – University Only
Appendix D – Data Needs for Validation

Appendix A – Workscopes for Program and Mission Support – University Only

Program Supporting: Reactor Concepts Research Development and Demonstration

Computational Methodologies for Gas-Cooled Reactors (RC-1)

(Federal POC – Steve Reeves & Technical POC – Hans Gougar)

Computational methodologies R&D is focused on providing practical tools to analyze the gas-cooled reactor core neutronics/thermal-hydraulics performance; reactor gas-coolant thermal fluids behavior during normal and transient conditions, and accident scenarios; and safety evaluations for advanced gas reactor reactors and design of scaled experiments. Additionally, the computational fluid dynamics code validation, verification, uncertainty, and qualification benchmark effort is focused on validating practical tools to analyze advanced gas reactor passive cooling systems.

Research efforts have been initiated and/or completed in the areas of gas reactor neutronics, thermal-hydraulics, and multiphysics, in terms of time-dependent coupled fuel/neutronics/thermal fluids modeling, reactor kinetics effects, and mechanical-neutronics-thermal fluid interactions during graphite dimensional changes under irradiation with thermal and neutronics feedback. Advanced reactor plant simulation and safety analysis methods development has been initiated for uncertainty and sensitivity analysis for statistical importance ranking. Integral effects experiments focused on in-vessel thermal fluids are underway at the High Temperature Test Facility (Oregon State University) and complementary separate and mixed effects experiments have been planned and initiated. Similarly, an ex-vessel integral test is being constructed at Argonne National Laboratory (Natural Circulation Shutdown Test Facility) with complementary experiments underway at some universities to generate data on ex-core heat removal and cavity cooling. A range of supporting scaled fundamental, separate, and mixed effects experiments are needed to complement these integral tests. Strong consideration should be given to utilizing existing experimental facilities and capabilities as a source of data for model validation.

Gas-cooled reactor thermal-hydraulics methods applications focused on verification and validation or experimental results are sought in the areas of:

- Steam ingress flow and chemistry particularly among lower support structures;
- Plenum-to-plenum heat transfer under natural circulation;
- Experimentally-validated analyses of heated two-component stratified or bypass flow;
- Methods that integrate externally initiated events (e.g. earthquake, flooding) and core/reactor dynamics and structures vibrations (e.g. graphite reflector and prismatic block movement); and
- Validation of models using safety analysis and CFD codes (e.g. RELAP5, TRAC, STAR-CCM+, FLUENT, and other NRC or reactor vendor computer simulation codes will also be considered).

Advanced Technologies, Development and Demonstration (RC-2)

(Federal POC – Brian Robinson & Technical POC – Bob Hill)

Advanced non-light water reactors differ from current commercial plants in their fundamental design features, associated technological challenges and may involve an increased dependence on passive systems 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 small modular reactors, in the following areas: develop and demonstrate advanced reactor technology solutions for modeling hybrid energy systems, in-service inspection techniques for innovative reliability and maintenance applications, and alternate designs for heat exchangers (e.g. printed circuit, twisted tube designs). Experimental demonstration and validation is encouraged.

Advanced Structural Materials (RC-3)

(Federal POC – Bill Corwin & Technical POC – Jeremy Busby)

Specific areas of materials technology supporting the development of advanced reactor systems are recognized as needing additional research. The two areas in which work is being solicited are: 1) scoping irradiations on advanced alloys for advanced, high-temperature reactors; and 2) the experimental measurement and analytical predictions of negligible creep in ferritic steels for high-temperature reactor systems.

RC-3.1: ADVANCED HIGH TEMPERATURE ALLOY SCOPING IRRADIATIONS

Accurate predictions of the effects of fast spectrum neutron irradiation damage on the design properties of next generation, advanced structural materials for reactor internals and pressure boundary applications in advanced, high-temperature reactors are critical for safety and design, but are limited by experimental data and understanding of their damage mechanisms. Hence, applications are sought to develop a mechanistic understanding of irradiation-induced microstructural evolution and its effect on mechanical properties through surrogate irradiation tools (e.g., proton and/or heavy ions irradiations). Materials of interest include ferritic-martensitic steel, Grade 92, with an optimized chemistry and thermo-mechanical treatment, and an austenitic stainless steel, Alloy 709, such as those being evaluated in DOE's Advanced Reactor Concepts Program. The proposed research should focus on the correlations of ion irradiation results to neutron irradiation damage and proper use of ion irradiation data to guide future neutron irradiation experiments, with the eventual goal of providing guidance on useful irradiation life of these improved alloys. Approaches might include novel experimental methods and modeling with substantial experimental validation. The outcome of selected projects is expected to provide significant input into future neutron irradiation campaign for qualification of these advanced alloys for applications in advanced fast reactors.

RC-3.2: DISSIMILAR TRANSITION WELD ISSUES FOR HIGH TEMPERATURE REACTORS

Design and analysis of dissimilar metal weld joints has been identified as an issue for high-temperature reactors repeatedly since at least as early as NRC's Safety Evaluation Report of the Clinch River Breeder Reactor.* The useful service life of such dissimilar metal welds (DMWs), or transition joints, depends on a wide range of factors related to service conditions, welding parameters, and alloys involved in the DMW. Potential premature failure can be attributed to sharp changes in microstructure and mechanical properties, large differences in coefficient of thermal expansion (CTE), formation of interfacial carbides, and preferential oxidation of ferritic steels within the joint. An example of such a weld is proposed for optimization of the performance of the steam generator of a small modular Very High Temperature Reactor (VHTR) by using two materials approved for high temperature nuclear service in the ASME Code: Alloy 800H in the hotter section and annealed 2 1/4Cr-1Mo steel in the cooler section. This method of construction would require welding of alloys that have quite different properties. Applications are sought that develop testing strategies to Code-qualify Alloy 800H-to-2 1/4Cr-1Mo steel DMWs for VHTR steam generator applications and to select or develop optimized filler metals and novel techniques to improve creep rupture and creep-fatigue properties of the DMWs, including the heat affected zone, such as graded composition joints. Models for the local stress state in DMWs during creep and creep-fatigue service conditions and models for microstructure and phase stability resulting from post-weld heat treatment and elevated temperature exposure during service are highly desirable. Data from the study will be used to improve the overall current technical basis for ASME Code rules and acceptance criteria for DMWs.

**Reference: NUREG-0968, Safety Evaluation Report Related to the Construction of the Clinch River Breeder Reactor Plant, Vol. 1, Main Report, U. S. Nuclear Regulatory Commission, March 1983*

Non-Destructive Evaluation of LWR Materials under Extended Service (RC-4)

(Federal POC – Rich Reister & Technical POC – Jeremy Busby)

Material aging under extended service is an important consideration for long-term operation. Non-destructive evaluation of material performance is expected to be a key resource in continued safe and efficient operation. However, development of new NDE techniques relies on knowledge of the impact of material state on detection signal. Models predicting the interaction of NDE signals with relevant material status could provide optimization or new directions for NDE development and deployment. Applications providing for advanced modeling and simulation of the interaction of non-destructive evaluation techniques with aged materials are sought.

Specifically, the development and validation of tools that model the interaction of NDE signals with aged material microstructures are requested. Detection signals of interest include, but are not limited to acoustic, ultrasonic, x-ray and others. Materials used in water reactor applications (e.g. stainless steels, low-alloys steels, Ni-base alloys, concrete, and cable insulation) in conditions relevant to extended service such as irradiated microstructures, oxide layers, fatigue damage (or others) are valued.

Economic Valuation Techniques for Integration with Safety Margin Characterization (RC-5)

(Federal POC – Rich Reister & Technical POC – Curtis Smith)

A current gap in modeling for nuclear facilities is the modeling and quantification of economic impacts as part of risk-informed margin management (RIMM) approaches. Currently, mechanistic tools such as RELAP are used to predict consequences associated with scenarios that result from different RIMM alternatives – however the associated economics of these scenarios are not being considered. Universities helping in this activity will be expected to provide models and tools that can be integrated into the Risk Informed Safety Margin Characterization (RISMC) Toolkit in order to provide a probabilistic valuation approach related to the RIMM alternatives. The approach that is proposed should be compatible with the INL-developed MOOSE (Multiphysics Object Oriented Simulation Environment) platform, the platform used for the RISMC Toolkit development as part of the LWRS program. It is the goal of the research and development to provide a way to determine a variety of economic implications related to safety (plant degradations, outages, accidents, worker impacts, etc.) such that the additional information can be incorporated into the plant decision-making processes.

Note that traditional “asset management” and plant lifecycle considerations are not desired within this workscope.

Performance of Joint Human-Machine Systems (RC-6)

(Federal POC – Rich Reister & Technical POC – Bruce Hallbert)

Methods and measures that can be used to evaluate the performance of joint human-machine systems, such as for nuclear power plant control rooms where changes in human-system interfaces and automation may change the role of operators and the way they interact with plant systems. The emphasis of this research will be on qualitative and quantitative approaches that can be used to measure the quality and other performance dimensions of human-system performance both with advanced digital I&C technologies as well as with existing analog-based I&C technologies, and mixtures of both.

Program Supporting: Reactor Concepts Research Development and Demonstration

RCIC Performance under Severe Accident Conditions: Multi-Phase Analysis (RC-7)

(Federal POC –Damian Peko & Technical POC – Douglas Osborn)

Current accident analysis models of steam-driven reactor core isolation cooling systems (RCIC) are highly simplistic in nature, making use of table lookup to determine steam draw and pump flow characteristics that are based on normal operational conditions. The RCIC pump requires at least DC power to be available to control reactor water level by shutting down the pump to avoid overfilling the RPV and flooding the steam line. It is common among both industry and regulatory analysts to assume that loss of DC power will result in overfilling the steam line and passing liquid water into the RCIC turbine where it is assumed that the turbine would then be disabled.

Normally this means that the RCIC emergency cooling system is generally considered unavailable after 4 to 8 hours as this is the anticipated battery power time to depletion. This behavior was not observed in the Fukushima accidents, where the Unit 2 RCIC pump was observed to function uncontrolled without DC power for nearly 3 days. This is believed due to a self-regulating function where steam line flood and liquid water carryover results in decreased pump flow rather than pump failure. This decreased flow results in a lowering of the RPV water level where the turbine subsequently returns to full operation and full water injection. In this way the pump self-regulates and remains operable for an indefinite period of time.

The importance of this is that assumption of pump failure at 4 hours on failure of DC power effectively rules out planning for extended pump operability under emergency conditions and could limit operator options to recover from near accident conditions.

Research is sought in novel technologies to develop a thermodynamically-based analytical model of RCIC operation with mechanistic accounting of liquid water carryover and pump performance degradation, to be done with a multi-phase flow code. Effects of operator actions should also be included. The Fukushima Unit 2 accident reconstruction should be used as the basis for validation of the multi-phase flow model.

An initial survey of currently available codes with respect to multi-phase flow and turbo machinery will be required. For the selected code, a thorough understanding of the code's documentation (i.e., exact understanding of what equations are being solved and what assumptions and closure rules are being applied) will be needed. Also, a code result comparison to multi-phase flow experiments that are documented in literature will be required.

Mission Supporting: Reactor Concepts Research Development and Demonstration

Reactor Concepts RD&D (MS-RC-1)

(Federal POC – Sal Golub & 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 such as the gas fast reactor, molten salt reactor or lead fast reactor), 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 small modular reactors with unique capabilities to address operational missions other than the delivery of base load electric power, such as industrial process heat or mobile reactors that can provide temporary power during emergency situations. 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.

Radioisotope Power Systems R&D (MS-RC-2)

(Federal POC – Rebecca Onuschak & 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 uniquely enable missions that require a long-term, unattended source of electrical power and/or heat in harsh and remote environments. These systems are reliable, maintenance free, and capable of producing heat and electricity for decades. These systems convert the decay heat from Pu-238 into electricity – either using thermoelectric couples to induce direct current electricity flow or through a dynamic energy conversion system. Both types of RPS designs use the General Purpose Heat Source (GPHS) – an aero shell module which contains four ceramic fuel pellets clad in iridium and nested in layers of graphitic structures to provide thermal and impact protection. Materials used in the early designs for these systems are increasingly difficult to obtain.

Applications are sought for the development of alternate, more readily available materials for the aero shell module that protects radioisotope power system fuel during potential atmospheric reentry events. The material will need to demonstrate ablation resistance, thermal conductivity and structural strength (compressive and tensile) that meet or exceed historical performance characteristics.

Additionally, applications are sought for alternate thermal insulating materials with properties useful for RPS designs. The proposed new insulating materials would be an integral part of the power system and thus require properties such as low mass, tolerance to a variety of space environments, and high absorption of kinetic energy.

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. The campaign supports research through the full range of use-inspired basic research through process engineering with multi-institutional, multi-disciplinary teams comprised of national laboratory researchers with full radioactive laboratory capabilities teamed with industry and university researchers. Priority research efforts revolve around achieving near-zero radioactive off-gas emissions; developing a simplified, single-step recovery of transuranic elements; and significantly lessening the process wastes. Exploratory paths include developing fundamental understanding of material recovery processes and waste form behavior; understanding the underlying driving forces; exploiting thermodynamic properties to effect separations; elucidating waste form corrosion mechanisms; and investigating novel new approaches to used fuel treatment and associated waste forms with significantly improved performance. Key university research needs for material recovery and waste forms campaign include:

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 via (1) determining fundamental thermodynamic properties (e.g., activity and electrochemical potential) of transuranic elements in molten salt systems; (2) deducing phase equilibria in binary and higher order molten salt systems that contain actinide halides; and (3) developing molten salt recycle methods that have the potential of significantly reducing the complexity and cost of technology, proliferation risk, and waste generation.

FC-1.2: Advanced Separations Methods

(Federal POC – Jim Bresee & Technical POC – Terry Todd)

- Critical gaps exist in our knowledge of underlying aqueous separations processes currently being considered for used fuel recycle. Understanding is generally needed on control of actinide oxidation states, complexation of actinides in aqueous solution, and selectivity of solvent extraction systems for actinides, lanthanides, and fission products. For example, knowledge is very limited regarding redox mechanisms, structure of coordination complexes, and complex speciation in extraction solvents. Research should be directed toward questions dealing with structure, thermodynamics, and kinetics specifically dealing with established or developing process concepts such as ALSEP, SANEX, GANEX, advanced TALSPEAK, or methods making use of the high oxidation states of Am.

FC-1.3: Advanced Waste forms

(Federal POC – Kimberly Gray & Technical POC – John Vienna)

- Innovative waste forms with orders of magnitude higher chemical durability and equal of lower processing costs compared to currently-employed waste forms such as borosilicate glass particularly for long-lived fission products such as iodine-129 and technetium-99 and for grouped fission products high-level waste; and
- Fundamental understanding of waste form performance over geologic time scales; particularly for multi-phase oxide waste forms.

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 fuel and materials technologies that are robust, have high performance capability, and are more tolerant to accident conditions than traditional fuel systems. Key university research needs for this activity include:

FC-2.1: Advanced Nuclear Fuel

High performance nuclear fuels with improved behavior during normal operation as well as during off-normal accident conditions are of interest to this funding opportunity. Improved fission gas retention, thermal properties, reduced oxidation, reduced pellet-cladding interaction and reduced fracture during thermal cycle are examples of improved performance that would be of interest.

FC-2.2: High Performance Cladding and Core Components

High performance cladding and core components are needed to increase competitiveness of nuclear reactor technology in the areas of corrosion resistance, increased strength and creep resistance, defect-free fabrication, and enhanced material property performance in general. These performance improvements are needed in both steady state normal operations as well as during off-normal and accident conditions. Core components capable of withstanding extremes of accident conditions with enhanced performance would improve the competitive advantage of the nuclear technology base.

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

Nuclear Materials Control and Instrumentation (FC-3)

(Federal POC – Daniel Vega & Technical POC – Mike Miller)

This program element develops technologies and analysis tools to support next generation nuclear materials management and safeguards for future U.S. fuel cycles. Of specific interest are technologies and approaches to the safeguarding and monitoring of used fuel storage installations and electrochemical recycling technologies. Both sensor designs and system model/approaches are needed to improve the safeguardability of these facilities.

The monitoring of commercial used fuel storage installations can include methods for imaging, identifying, and measuring cask contents, using both nuclear and non-nuclear methods for verification and continuity of knowledge. For electrochemical recycling, new and improved sensors capable of detecting key elements and isotopes in a timely fashion while handling the harsh environments involved are needed. In addition, modeling tools that can assist in safeguards approach development are needed.

Program Supporting: Fuel Cycle Research and Development

Used Nuclear Fuel Disposition (FC-4)

(Federal POC – JC De La Garza & Technical POC – Peter Swift)

This program element develops technologies for storing, transporting, and disposing of used nuclear fuel and high-level radioactive waste and assessing performance of the used fuel and waste forms in the associated storage and disposal environments.

FC-4.1: STORAGE

Key university research needs for the storage activities include:

- Innovative approaches to evaluating degradation and aging phenomena of used nuclear fuel, containers and internals, and storage facilities under extended storage;
- Data and risk informed assessment methods for high-burnup used nuclear fuel for extended storage applications;
- Development of a superior concrete by chemical additives and curing improvements to increase the compressive strength, tensile strength and weather ability of the concrete. This work would not include the addition of mechanical additives such as fiberglass or metal wire. This concrete could then be used for extended used nuclear fuel storage;
- Development of non-destructive techniques to monitor long-term effects of wet/dry, freeze/thaw, marine environment effects, the temperature fluctuations and radiation effects on reinforcing steel and concrete used in the over pack of dry storage system; and
- Innovative research in developing poison materials for long-term criticality control.

FC-4.2: TRANSPORTATION

Technical issues related to transportation of used nuclear fuel has been generally addressed by past industry studies. However, issues related to transportation of used nuclear fuel after prolonged storage periods provide new challenges. Key university research needs for transportation activities include:

- Materials research that would facilitate transportation of used nuclear fuel;
- Structural integrity assessment for transporting used nuclear fuel with uncertainty in input considerations;
- Advanced modeling approaches for radiological analyses of disruptive scenarios relevant to transportation; and
- Data relevant to risk-informed cask qualification and transportation behavior of high-burnup and advanced fuels.

FC-4.3: DISPOSAL

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. 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;

Program Supporting: Fuel Cycle Research and Development
• 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; • 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 – Kenneth Kellar & Technical POC – Temi Taiwo)** This program element is interested in systems economic studies looking at the potential impact of and sensitivity to natural gas prices on the future of the U.S. nuclear fleet. (e.g., potential for early plant closures and impact on replacement builds in the near-term and longer-term (much of the U.S. fleet, assuming 60 year life, will go off line between 2030-2050). Applications should include the impact of projected coal power changes as well.

Mission Supporting: Fuel Cycle Research and Development

Fuel Cycle R&D (MS-FC-1)

(Federal POC – Andy Griffith & 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 key challenge 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 separations processes, and innovative fuel designs. Areas of interest for the transmutation of used 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.

Fuel Resources (MS-FC-2)

(Federal POC – Stephen Kung & Technical POC – Sheng Dai)

The secure and economical supply of nuclear fuel is essential for the long-term use of nuclear power for energy applications. Continued federal R&D investment in uranium resources will be the foundation to enable future nuclear power expansion. The focus of fuel resources R&D is to identify “game-changing” approaches not presently being addressed by private industry or non-governmental organizations. Specific areas of interest include: (1) molecular-level understanding of the coordination modes, sorption mechanisms, and kinetics of uranium extraction; (2) design and synthesis of functional ligands with architectures tailored chemical performance; (3) physical and chemical tools for characterizing of adsorbent materials; (4) development of new polymer sorbents via advanced manufacturing and surface grafting techniques; (5) development of innovative elution processes; and (6) green uranium mining alternatives.

Program Supporting: Nuclear Energy Advanced Modeling and Simulation

Nuclear Energy Advanced Modeling and Simulation (NEAMS-1)

(Federal POC – Dan Funk & Technical POC – Keith Bradley)

The Nuclear Energy Advanced Modeling and Simulation (NEAMS) program is developing a simulation toolkit that takes advantage of modern computing architectures and state-of-the-art mechanistic physics models to allow scientists and engineers to better understand the behavior and phenomena inside nuclear energy systems. This "pellet-to-plant" simulation toolkit will predict 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 standalone and coupled simulations, is essential for ensuring the toolkit is accurate, robust, and useful.

We are seeking applications that contribute to validation of NEAMS tools in the toolkit [MARMOT, BISON, SHARP, RELAP-7; for detailed descriptions, see the Nuclear Energy Advanced Modeling and Simulation (NEAMS) Program Plan]. Applications may include new experimentation designed explicitly for validation, analysesis of existing benchmark datasets, development of new benchmark datasets, calibration of models, as well as direct comparison of datasets with toolkit simulations. Validation can span the entire hierarchy from single-effects experiments designed to address individual phenomena to integrated experiments that address strong coupling of multiple phenomena. Applications to conduct experiments at DOE laboratories in support of application validation are encouraged, though experimentation at university laboratories is equally acceptable. Collaboration with members of the NEAMS development team residing at DOE laboratories is strongly encouraged. Since we are soliciting applications that directly validate models already incorporated in the NEAMS toolkit, we will not consider applications that aim to develop new mechanistic models.

Mission Supporting: Nuclear Energy

Integral Benchmark Evaluations (MS-NE-1)

(Federal POC: Rob Versluis & Technical POC: J. Blair Briggs)

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 and produce 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 being 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 twenty-four 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 reactor safety and design, criticality safety, nuclear data, and analytical methods development specialists to perform necessary validations of calculational techniques and are expected to be valuable resources for future decades.

Proposed benchmark evaluations should be of existing experimental data applicable to Fuel Cycle Safety and Fast, Gas Cooled, and Small Modular Reactors. 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.

Control System Modernization for the Advanced Test Reactor Critical Facility (ATRC) (MS-NE-2)

(Federal POC— Jason Tokey & Technical POC—Craig D. Jackson)

The ATRC at Idaho National Laboratory is a low-power reactor designed and constructed in the early 1960s. The mission of the ATRC is to obtain accurate and timely data on nuclear characteristics of the ATR core such as rod worths and calibrations, excess reactivities, neutron flux distributions, gamma-heat generation rates, fuel loading requirements, and effects of insertion and removal of experiments. The ATRC typical operating power level is 600 Watts (W) or less, with a maximum allowable power of 5kW. The core is cooled via natural convection of light water, is light water moderated and reflected by beryllium. Some of the ATRC-generated information is used to ensure that the Advanced Test Reactor (ATR) core, 250 MWth, can be operated safely within its safety basis envelope during performance of various nuclear research activities.

The majority of the existing ATRC control system is original 1960's or early 1970's vintage equipment and is well beyond its expected product life cycle. Spare parts availability and technical support for much of the instrumentation and control (I&C) equipment currently in use at ATRC is virtually nonexistent, making continued operation and maintenance extremely difficult. The goal of this workscope is to design a reliable I&C system for operation of ATRC for 15 to 20 years following system replacement.

The Department is seeking applications to modernize the control system of the ATRC. The workscope includes the design changes necessary to make the reactor shutdown system compliant with current standards and requirements, but limits the application of digital processor technology to non-safety functions. All safety class functions would continue be performed with analog I&C components.

This design effort would include the following systems:

- Reactor Shutdown System (RSS)
    - Neutron Level Subsystem

    - Log-N/Period Subsystem
    - Manual Scram Subsystem
    - Scram Logic Subsystem
- Log Count Rate Meter (LCRM) System
- Non-RSS Scram System
    - Seismic Switch Subsystem
- Rod Control System
    - Safety Rod Controls Subsystem
    - Outer Shim Controls Subsystem
    - Neck Shim Controls Subsystem
    - Neutron Start-up Source Control Subsystem
    - Control Element Drive Interlock Function Subsystem
- Digital Reactivity Measurement System
- Annunciator System and Indicator Lights System

This effort is expected to be funded at a maximum of $400,000 over 2 years.

Appendix B – Workscope for Program Support – University, National Laboratory and Industry

Program Supporting: Nuclear Energy Enabling Technologies Crosscutting Technology Development (NEET CTD)

Advanced Methods for Manufacturing (NEET-1)

(Federal POC – Alison Hahn & Technical POC – Jack Lance)

(Up to 3 years and $800,000 total project cost)

The Advanced Methods for Manufacturing program seeks applications for research and technology development to improve the methods by which nuclear equipment, components, and plants are manufactured, fabricated, and assembled. The initial focus and emphasis will be placed on technologies that can be deployed in the near-term, such as Small Modular Reactor (SMR) technologies. The success of the SMR Initiative depends heavily on the ability of the U.S. to deliver on the SMR's expected advantages – the capability to manufacture them in a factory setting, dramatically reducing the need for costly on-site construction – thereby enabling these smaller designs, which lack the "economies of scale" of their larger Advanced Light Water Reactor (ALWR) counterparts, to be economic. "Modular construction" has been proven in shipbuilding and other industries, and is being exploited to a limited degree in modern ALWR construction. It must expand dramatically for SMRs to deliver their full potential as economic competitors in U.S. and global markets. Most important, reducing the cost of construction here in the U.S. for both ALWRs and SMRs will result in cheaper electricity for American families and businesses. Applications should pursue innovative methods to manufacture or fabricate components faster and with better quality; and to improve factory assembly and field deployment of plant modules, thereby reducing the cost and schedule requirements for new nuclear plant development. Specific goals include:

- Accelerate deployment schedule by 3 to 6 months compared to current new plant construction estimates;
- Reduce component fabrication costs by 20% or more; and
- 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 strength assistance tooling, heavy lift and load leveling equipment, advances in verification of designed configuration and improvements in manufacturing technologies such as advanced (high speed, high quality) welding technologies;
- Assembly and material innovation to enhance modular building techniques such as advances in high performance concrete and rebar, design innovation using concrete composite and steel form construction methods, inspection processes and equipment, and innovative rebar pre-fab and placement systems;
- Advances in modular construction to include improved design codes and advancements in integrated prefabrication; and
- Improved concrete inspection, measurement and acceptance technology, techniques and methods to facilitate the pour and curing of nuclear plant concrete.

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.

Details of these areas for innovation can be found in the NEET 2010 Workshop report (http://www.ne.doe.gov/pdfFiles/Neet_Workshop_07292010.pdf).

Program Supporting: Nuclear Energy Enabling Technologies Crosscutting Technology Development (NEET CTD)

Advanced Sensors and Instrumentation (NEET-2)

(Federal POC – Suibel Schuppner & Technical POC – Bruce Hallbert)

(Up to 3 years and $1,000,000 total project cost)

The Advanced Sensors and Instrumentation program seeks to develop the scientific and technical basis for advanced sensors and instrumentation to address critical technology gaps for monitoring and controlling advanced reactors and fuel cycle systems.

The goal of this program is to provide crosscutting research that:

- Contributes to the success of the NE R&D programs by obtaining the needed Instrumentation and Control (I&C) technologies that support experiments, tests, or demonstrations, and that deliver unique sensors and related technologies for reactor and fuel cycle research and development;
- Enables the broader mission of the Office of Nuclear Energy, by supporting common ASI technology development objectives; and
- Can overcome current barriers to nuclear energy system deployments or may sustain their long term safe and economical operation.

Organizations performing this research will be expected to produce concepts, techniques, capabilities, and technologies for advanced measurement, control, communications, or concepts of operation that are or can be demonstrated in simulated or laboratory test bed environments representative of the intended nuclear system applications.

Successful applications will describe truly innovative sensors and instrumentation that offer the potential for revolutionary gains in reactor and fuel cycle performance and that can be applied to multiple reactor designs or fuel cycle concepts.

Improvements and advancements are needed in the technical area of Advanced Sensors and Instrumentation technologies to enhance economic competitiveness for nuclear power plants and promote a high level of nuclear safety. Specific ASI research and development applications are sought for the following topics:

NEET-2.1 Power Harvesting Technologies for Sensor Networks

This program element focuses on development and demonstration of power harvesting technologies to power sensor networks in a nuclear environment and includes:

- Develop sensor requirements and sensor simulator to test and demonstrate concepts prior to full development;
- Develop, design, and fabricate power efficient solid-state devices; and
- Demonstrate that conceptual system design is capable of surviving in the intended environments representative of nuclear power plants.

Reference: Power Harvesting Practices and Technology Gaps for Sensor Networks (ORNL/TM-2012/442)

Program Supporting: Nuclear Energy Enabling Technologies Crosscutting Technology Development (NEET CTD)

NEET-2.2 Recalibration Methodology for Transmitters and Instrumentation

This program element focuses on development and demonstration of online calibration methodologies for transmitter and instrumentation calibration interval extensions.

- Develop a methodology to provide virtual sensor estimates and high-confidence signal validation, and provide the capability to integrate with uncertainty quantification methodologies;
- Evaluate the impact of emerging sensors and digital instrumentation on the proposed recalibration methodology(ies); and
- Demonstrate the candidate recalibration methodology(ies) in an appropriate test-bed or facility.

References:

- *A Review of Sensor Calibration Monitoring for Calibration Interval Extension in Nuclear Power Plants (PNNL-21687)*
- *"Online Sensor Calibration Assessment in Nuclear Power Systems," IEEE I&M Magazine article (Vol. 16, No. 3 June 2013)*

NEET-2.3 Design for Fault Tolerance and Resilience

This program element focuses on development and demonstration of control system technologies that are resilient to anticipated faults and transients and can achieve high plant and system availability and lead to improvements in safety.

- Develop and test fault-diagnosis algorithms for current and next generation plant components;
- Develop computer-enabled implementation of control algorithms for a simulator-based test;
- Develop a fully-integrated operator-support system for demonstration including fault detection, fault diagnosis, and control actions to mitigate fault(s);
- Perform full-scale simulator shakedown tests of integrated fault diagnosis and automated control for a thorough spectrum of faults; and
- Develop technical requirements for broad application of the operator support technology across multiple plant systems.

References:

- *Design to Achieve Fault Tolerance and Resilience (INL/EXT-12-27205)*
- *Description of Fault Detection and Identification Algorithms for Sensor and Equipment Failures and Preliminary Tests Using Simulations (ANL/NE-12-57)*

NEET-2.4 Embedded Instrumentation and Controls for Extreme Environments

This program element focuses on development and demonstration of embedded instrumentation and control technologies in major nuclear system actuation components (e.g. pumps, valves) that can achieve substantial gains in reliability and availability while exposed to harsh environments.

- Employ a multidisciplinary research effort to integrate sensors, controls, software, materials, mechanical and electrical design elements to develop highly embedded I&C in major component design;

- Construct and demonstrate a bench-scale and a loop-scale component with embedded controls; and
- Develop methods and metrics for assessing resulting system performance enhancements and demonstrate fault-tolerant control, high efficiency, and reliability in a test bed or representative facility environment.

Reference: Embedded Sensors and Controls to Improve Component Performance and Reliability (ORNL/TM-2012/433)

NEET-2.5 High Temperature Fission Chamber

This program element focuses on fabrication and characterization of high temperature fission chambers that provide high-sensitivity, high-temperature neutron flux monitoring technology.

- Fabricate and test a high temperature fission chamber capable of operating from start-up to full power at 800°C;
- Design and fabricate a fission chamber followed by characterization at high temperature in a reactor that
  - Demonstrates sensitivity;
  - Demonstrates mechanical/thermal robustness; and
  - Enables path to safe high-temperature reactors.

Reference: Materials Selection for a High-Temperature Fission Chamber (ORNL/LTR-2012/331)

NEET-2.6 Advanced Measurement Sensor Technology

This program element focuses on development and fabrication of advanced sensors for improved performance measurement technology that provides revolutionary gains in sensing key parameters in reactor and fuel cycle systems. These new sensor technologies should be applied to multiple reactor or fuel cycle concepts and address the following technical challenges:

- Greater accuracy and resolution;
- Detailed time-space, and/or energy spectrum dependent measurements;
- Reduced size; and
- Long-term performance under harsh environments.

Reactor Materials (NEET-3)

(Federal POC – Sue Lesica & Technical POC – Jeremy Busby)

(Up to 3 years and $1,000,000 total project cost)

The NEET Crosscutting Reactor Materials program seeks applications for the development of advanced joining techniques for materials for nuclear fission reactor applications. As advanced materials are developed to increase the energy efficiency, cost efficiency, safety and security of the operation of nuclear reactors, advanced joining techniques must also be developed. Advanced welding or joining techniques will overcome traditional component limitations as well as allow for the use of more advanced materials in nuclear reactor applications. These advanced joining techniques must maintain or improve properties at the joint, such as strength, irradiation resistance, corrosion resistance, and creep. Innovative methods to control and understand residual stress, heat affected zones, and/or phase stability during joining are also of interest.

Appendix C – Workscope for Program Directed – University Only

Program Directed: Reactor Concepts Research Development and Demonstration

Integrated Approach to Fluoride High Temperature Reactor (FHR) Technology and Design Challenges (IRP-RC)

(Federal POC – Janelle Zamore & Technical POC – David Holcomb)

(Up to 3 years and $5,000,000 total project cost)

Fluoride salt-cooled, solid-fuel, high-temperature reactors have the potential to support base-load and peak electricity production as well as industrial process heat applications with superior economics, increased passive safety, a more robust waste form, strong nonproliferation characteristics, and improved physical security as compared to light water reactors. FHRs have technical similarities to molten salt reactors; however, they use a solid fuel form rather than having the fuel dissolved in the liquid salt. Although promising, this reactor class has several remaining developmental challenges.

Applications are sought for an Integrated Research Project (IRP) focused on an integrated approach to solving multiple technology challenges associated with FHRs. Favorable consideration will be given to applications having potential impact beyond FHRs and that address multiple technology challenges, as described below. Note that fuel fabrication and/or qualification activities are not of interest and should NOT be included under this workscope.

Developmental challenges for FHRs include tritium management, liquid salt coolant redox control and impurity removal, the lack of validated design tools and methods, and the significantly different process environment for instrumentation.

Qualified materials for use as in-vessel structures in salt-cooled, solid-fuel, high-temperature reactor environments are needed. Both carbon-carbon continuous fiber composites (CFCs) and SiC-SiC CFCs show promise for in-vessel structural application. R&D to develop composite architecture and fabrication methods for large complex structures and associated design rules, codes and standards for in-vessel components is a key area of interest. Testing of improved performance alloys for potential application to FHRs is also needed. Detailed qualification pathways for the high-nickel alloys required to obtain a completed ASME Section III Code Case for their use in liquid salt reactors for pressure boundaries, heat exchangers, and reactor internal are needed. Based on the qualification needs defined, the short- to medium-term mechanical properties testing required for Code Case approval of the more promising material should be performed.

Heat exchangers are an especially important and challenging hydraulic component for high temperature reactors. R&D needs include the design, testing, and life-cycle analysis of salt-to-salt, salt-to-gas, salt-to-liquid metal and salt-to-water heat exchangers. Both neutronic and hydraulic design codes will require benchmarking and validation for use in reactor licensing. FHRs use a variety of components that present unique design and reliability challenges. Reducing technical uncertainty would be supported by testing of materials and components under prototypic thermal, chemical, and in some cases irradiation conditions.

Applications should provide an integrated approach to reducing the technical uncertainty associated with salt-cooled solid-fuel high-temperature reactors by addressing multiple design challenges through synergistic efforts. The integrated approach will identify R&D needs and technology gaps, detail how this R&D will be conducted and describe how results will achieve the ultimate goal of deploying a salt-cooled solid-fuel high-temperature reactors for commercial use.

Applications should include detailed descriptions on: 1) use of new and existing experimental facilities at universities, national labs or industry, if any; 2) how the application will build upon work previously done on salt-cooled, solid-fuel, high-temperature reactors; 3) how the application presents work which is different from work previously done on salt-cooled, solid-fuel, high-temperature reactors; 4) how the application will leverage international activities if any; and 5) how the application will support other reactor types.

Program Directed: Reactor Concepts Research Development and Demonstration
Applications should also include both cost and schedule estimates and descriptions of the technical approach for each technology challenge being addressed and its proposed outcome of sufficient detail in order to determine the feasibility of the application within the time and budget allocated for this project. The Department currently estimates that it will fund approximately $5 million in response to this IRP; however, this estimate is contingent on Congressional appropriations and is subject to significant change.

Program Directed: Fuel Cycle Research and Development

Sensors and Delivery Devices for Dry Storage of Used Nuclear Fuel (IRP-FC-1)

(Federal POC – JC De La Garza & Technical POC – Peter Swift)

(Up to 3 years and $3,000,000 total project cost)

INTRODUCTION

The U.S. commercial nuclear power industry is quite diverse with power stations located inland and on seaboards. Nearly all plant operators are moving used nuclear fuel from wet to dry storage, and have been doing so since 1986. It appears likely used fuel will remain in dry storage for several more decades. It is important that the "health" of dry storage systems be confirmed and maintained. This Integrated Research Project (IRP) focuses on the development of methodologies that can help industry and DOE resolve potential technical issues associated with dry storage of used fuel.

BACKGROUND

While other projects have focused only on instrumentation development and monitoring systems, this IRP focuses on developing new sensors for difficult locations and the associated delivery of these tools to dry storage systems. There are many challenges associated with this. First, there are several dry storage systems in use today and there are several variants depending on a utility's specific needs. The dry storage systems are located at Independent Spent Fuel Storage Installations (ISFSIs) and are highly secure. However, the used fuel stored in these systems present radiological and safety hazards, as well.

WORK TO BE PERFORMED

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

- **Innovative approaches for Acquiring Samples**

  Innovative approaches for acquiring samples from the surfaces of used nuclear fuel dry storage system components (such as the concrete overpack and used fuel canisters) are needed. Sampling approaches should consider:

- **Access into Dry Storage Systems**

  How to gain access into dry storage systems, including inside concrete over-packs to access used fuel canisters (where used). Remotely operated systems requiring minimal, or preferably, no human interaction are of interest.

- **Sensor Development Access into Dry Storage Systems**

  Although many sensors exist, some of the sensors may need to be smaller and more accurate for placement inside high radiation conditions and in areas that are not easily reachable.

- **Surface Sample Collection**

  A system must be developed to acquire surface dusts and deposits that can accumulate on the surface of the dry storage system components. The all of the following parameters need to be analyzed. The analysis could be done by having a system to gather the samples and delivering them to the outside for analysis or developing remote sensors to analyze these parameters in place.

  The items to be analyzed by collecting samples or remote sensors include:

  - Deliquescent salts;
  - Organic and inorganic matter (e.g. microbes, pollen, dirt, clay, etc.);
  - Chemical signatures of potential reactions (e.g. microbial corrosion or other chemical reactions);

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- Concrete degradation products; and
- Performance of radiological surveys to determine integrity of seals and welds.

- **Inspecting Dry Storage Systems**

  Innovative approaches for inspecting dry storage system components are of interest, including:

  - Inspection of difficult to access locations (e.g. the base of canisters inside storage over-packs, or along rails used to support canisters in horizontal systems);
  - Characterization/Inspection of canister welds and other welds;
  - Inspection of bolts and seals (where used);
  - Characterization/Inspection of potential cracks in concrete for those systems with exposed concrete;
  - Determination of the presence of water (e.g. inspection for water staining or pooling);
  - Measurement of surface temperatures;
  - Visual inspection of surfaces; and
  - Documentation of the locations of samples and inspections to allow re-inspection in the future.

- **Remote Sample Analysis**

  Innovative approaches to perform sample analysis remotely are of interest. Analyzing samples in situ reduces the need for radiological surveys to release samples for analysis outside the ISFSI, and it allows more data to be taken. Integration of the delivery system with sampling and analysis is desired. Deployment of existing instruments, sensors, detectors, as well as novel approaches is desired.

- **Data Collection**

  Innovative approaches to data collection, management and storage. It is anticipated that a data-gathering device could accumulate hundreds to thousands of individual data and samples in varying formats (e.g. video, spectroscopic, elemental, solids, etc.). Data quality must be ensured and protected, particularly in a challenging environment that includes heat and radiation.

- **Cyber Security**

  Cyber security is an important consideration while working inside a utility's ISFSI, and creative solutions for potential transmission of data from a highly secure environment is also sought.

- **Systems Performance**

  A successful project will develop: A system where all the features discussed analyzed can be evaluated either through at least one delivery/analysis system prototype for testing and evaluation in mock-ups of different used fuel dry storage systems. While it may be possible for one device to be deployed on multiple dry storage systems, it is acceptable to develop system-specific devices. The proposed approach to be taken should be documented in the application.

  If sensors are proposed to be used to generate the desired data, they should be developed to analyze the materials in place and transmit the data so it can be collected outside the cask.

DELIVERABLES

- **Alternatives Analysis**

  Because of the variability of solutions that can be used, within 6 months after award, a progress report should be submitted to the DOE discussing how the data required above will be collected.

- **Progress Report**

  Eighteen months into the project, a progress report must be submitted to the DOE that discusses the technical progress made toward solving the issues discussed above.

- **Final Report**

  Thirty-six months into the project, a report will be submitted to the DOE that discusses the technologies developed and how they can be effectively implemented.

Forced Helium Dehydration/Vacuum Drying of Used Nuclear Fuel (IRP-FC-2)

(Federal POC – JC De La Garza & Technical POC – Peter Swift)

(Up to 3 years and $4,000,000 total project cost)

INTRODUCTION

NUREG–1536, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility," states that an accepted method for vacuum drying of canisters is to evacuate to a pressure less than or equal to 4 x 10^{-4} MPa [3 torr], with demonstration that the canister will maintain that pressure for 30 minutes after being isolated from the pumping system. It is believed that water in the cask provides a mechanism for possible deterioration of the materials. This would evaluate the drying effectiveness and options for improving the drying processes.

BACKGROUND

As an alternative to the vacuum drying technology, an alternative drying technology has been accepted that involves the circulation of non-reactive gas at temperature and pressure corresponding to a water vapor pressure of 4 x 10^{-4} MPa [3 torr] to dehydrate the loaded canister. The 4 x 10^{-4} MPa [3 torr] criterion is based on calculations of the quantity of oxidizing gases that would remain in the canister after drying. The level of dryness has not been confirmed by actually measuring the quantity of residual water that remains in the canister. Residual water could cause corrosion of the cladding and internal structures or lead to a flammable condition if hydrolysis of water creates free hydrogen and oxygen. Drying too rapidly can cause ice formation in the canister, which may be a particular concern at confined locations (e.g., breached or waterlogged fuel rods) or where there is a tortuous path for water to exit the canister. If ice forms, the canister could meet the pressure specification even though water remains in the canister.

IRP OBJECTIVE

The objective of this IRP is to measure the quantity of unbound liquid water and ice that remains in a canister following drying performed according to typical industry practices. Models should be developed and underlying data should be collected to accurately predict unbound liquid water after drying and to reasonably estimate physically and chemically bound water.

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

- **Fuel Assembly Mockups**

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

  As needed, multiple mockups may be fabricated to represent different assembly designs or the range of features from different designs may be incorporated in a single mockup. Ideally, the mockup should be kept at full-length to avoid scaling effects, such as temperature and pressure gradients, that could complicate the interpretation of results. Finally, the mockup should have the ability to be heated to represent the decay heat load of used nuclear fuel.

- **Canister Mockups**

  Full-sized canister mockups are not required for the test program, but they should be able to accommodate full-length mockup assemblies. Canister mockups could be fabricated from pipe segments or other cylindrical structures fitted with bolt-on lids to allow for insertion and removal of the mockup assembly. Except for any modifications that are needed for making measurements, the ports for connection between the canister and drying system, as well as the configuration of the vacuum siphon tube, should be similar to those in industry systems.

- **System Testing**

  The tests will involve the performance of drying operations in a manner consistent with industry practice, after which the quantity of water remaining the canister will be measured. In a series of drying runs, specific variations of certain parameters should be made to determine if these affect the quantity of residual water.

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

  The other parameter to be evaluated is the decay heat load of the used fuel, as represented by heaters on the mockup assembly. The decay heat load for used fuel will depend on burnup and time since it was removed from the core. Fuel with lower decay heat load should be more susceptible to ice formation. Tests should be performed for at least one low decay heat load and one high decay heat load to determine if this affects the quantity of residual water. The tests should account for the expected increase in cladding temperature that will occur during the drying process.

  Prior to performing the drying operation, water may be introduced into the system by fully flooding the canister and/or placing quantities of water in specific locations where it is thought that it may be trapped. Flooding the canister may not, in itself, be adequate to fill water in confined locations such as breached fuel rods. For these locations, water should be manually added. Methods should be devised to determine the quantity of water present after drying by measurements such as water mass balance, pressure, dew point, or temperature.

TASKS TO BE PERFORMED

- **Task 1:** Development of Test Plan – 6 months after beginning of performance period;
- **Task 2:** Development of Analytical Models for Drying Simulation – 9 months after beginning of performance period;
- **Task 3:** Setup and Verification of Test System – 9 months after beginning of performance period;
- **Task 4:** Performance of Drying Tests – 24 months after beginning of performance period; and
- **Task 5:** Complete Project Report – 36 months after beginning of performance period.

DELIVERABLES

Specific deliverables must include:

- **Progress Report**

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Report on project test plan will be submitted 6 months after beginning of performance period;

- **Setup and Verification Progress Report**

  A status report on test setup and verification activities will be submitted 18 months after beginning of performance period;

- **Analytical Models**

  Report on analytical models developed for simulation of drying processes will be submitted 24 months after beginning of performance period; and

- **Final Project Report**

  Thirty-six months after beginning of performance period a Final Project Report will be delivered that documents the work performed and discusses the final conclusions and recommendations.

Program Directed: Nuclear Energy

Transient Test Instrumentation R&D (IRP-NE)

(Federal POC – Bradley Williams & Technical POC – Dan Wachs)

(Up to 3 years and $3,000,000 total project cost)

This project meets a need for advanced, integrated transient fuel testing imaging/measurement instrumentation that is coupled with a data management system and existing performance codes. Transient testing involves placing fuel or material into the core of a reactor and subjecting it to short bursts of intense high-power radiation. Testing fuel behavior in a prototypic neutron environment under high-power, accident-simulation conditions is an essential step in licensing new nuclear fuels for use in existing and future U.S. nuclear power plants. Transient testing of nuclear fuels is needed to develop and prove the safety basis for advanced reactors and fuels. The reactor system safety basis requires a complete understanding of what could happen to the fuel if it were subjected to accident conditions such as large power increases and loss-of-cooling events. Additionally, modern fuel system development and design increasingly relies on modeling and simulation efforts that must be informed and validated using specially designed material performance separate effects studies. These studies will require a testing platform able to support variable scale, highly instrumented experiments.

There are currently efforts underway to develop advanced light water reactor (LWR) fuels with enhanced performance and accident tolerance. Advanced reactor designs will also require new fuel types. These fuels could be quite different from the ones that were tested in the past: different geometries to enhance their cooling, different compositions to help significantly reduce the amount of waste generated during the production of nuclear energy, and different materials to improve their thermal and safety performance. These new fuels need to be proof tested in a controlled environment and researched extensively in order to learn how they respond to accident conditions. This understanding will help guide the design of fuels with much better performance.

In order to maximize the value of transient testing, there is a need for in situ, real-time imaging technology (i.e., using a neutron detection system such as a hodoscope) to see fuel motion during rapid transient excursions. There exists a need for line-of-sight sensors and instrumentation capable of collecting data on pellet clad interactions or TRISO kernel and particle layer interactions during rapid transient excursions. The ability to monitor fuel behavior in real-time will provide information on the time evolution of fuel damage, which is important to develop a thorough understanding of the underlying science of fuel behavior, while reducing the reliance on post irradiation examination (PIE), which only provides data on the final damage state.

In order to fully realize the potential of transient testing, development and demonstration of specific technologies for real-time in situ monitoring to support transient testing are desired. Applications should provide an integrated approach to address the following technology needs:

- Concepts leading to the design of a next generation fuel motion monitoring system to support transient testing. Concepts should take advantage of 'line-of-sight' core layout to record high resolution fuel movement during simulation of high energy, rapid transient events.
- Development of novel instrumentation to support separate effects testing (e.g., transient pressure transducers, fast response temperature indicators, acoustic sensors, optical technologies, and fission product measurement)
- Continued development of coupled thermal-nuclear reactor and fuel performance codes that can be used to design complex transient experiments. Code development efforts should build upon and be closely integrated with the activities currently underway in NE's modeling and simulation programs (http://energy.gov/ne/advanced-modeling-simulation), (http://www.casl.gov/strategy.shtml).

The expected outcome of this project is an integrated design approach leading toward rapid demonstration and utilization of the aforementioned technology needs.

A final decision regarding the resumption of transient testing is anticipated in the near future. Details related to potential options can be found at: http://energy.gov/ne/articles/resumption-transient-testing. Applications should provide an integrated solution to the aforementioned needs and include specific design assumptions and requirements which may be specific to the selected alternative.

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 Nuclear Energy aka the Consortium for Advanced Simulation of Light Water Reactors (CASL). If a 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.

As the Energy Innovation Hub for Nuclear Energy, CASL 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 CASL 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; and
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., 5x5) 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.