REQUEST FOR PRE-APPLICATIONS NO. NEUP-001-11

For Nuclear Energy R&D Proposals

By Battelle Energy Alliance on behalf of the Department of Energy, Office of Nuclear Energy

ISSUE DATE: **October 27, 2010**

PRE-APPLICATION DUE DATE: **December 8, 2010**

SUBCONTRACT ADMINISTRATOR:

TELEPHONE NO.: (208) 526-1336

FACSIMILE NO.: (208) 526-8076

E-MAIL: neup@inl.gov

FY 2011 Request for Pre-Applications Amendments

Changes made to the FY 2011 Nuclear Energy University Programs Research and Development Request for Pre-Applications are provided below.

<u>Section 10 Evaluation Criteria</u>

The following text is no longer applicable to this Request for Pre-Applications:

> Note: For “Blue Sky,” the scale will be Relevant, Low Relevance, and Not Relevant.
>
> Only those uninvited full proposals that are scored as Highly Relevant (or Relevant for “Blue Sky”) will be forwarded for technical peer review during the RFP evaluation phase.

<u>Program Supporting: Fuel Cycle R&D Workscope Table</u>

The following workscope has been added to the Fuel Cycle R&D program:

SYSTEMS ANALYSIS

Fuel Cycle Simulator (FC-7) - Systems analysis provides the integrating analyses of nuclear energy and fuel cycle systems to inform fuel cycle option development and evaluation. Systems analysis is used as a predictive/strategic tool, enabling a more proactive approach to understanding the behavior of various fuel cycles and their technical, political and economic impacts. The key university research need for this activity is the development of modules for the Fuel Cycle Simulator, including fuel cycle modules, interface modules and data modules. These modules will focus on specific aspects of the nuclear fuel cycle simulator and should be created in such a way that they can plug into an overall framework, which will be developed in coordination with the Systems Analysis Campaign.

This advanced fuel cycle simulator will not only support integrating analyses of fuel cycle systems, but also inform fuel cycle R&D, programmatic decisions, strategy formulation, and policy development as well educate and communicate with stakeholders. If successful, the simulator could revolutionize the decision-making process wherein the decision maker will not be presented with a 3,000+ page analysis and asked to decide, but rather using a PC, laptop or tablet computer can run simulation and in real-time manipulate key variables to see how the system option responds in order to make an informed decision.

The first step in development of the Fuel Cycle Simulator will be design and development of the over-arching framework, or information backbone, for the FCS and will be lead by the Fuel Cycle Technologies Systems Analysis Campaign. This will include the minimum data sets, underlying database, hardware architecture to support the heavy computational load while providing access via PCs, laptops, or tablet computers, and modular approach to provide an extendable simulation capability.

Proposals should focus on the development of specific modules as described above, but proposals related to the areas listed below will also be considered:

- basic modules for each function of the fuel cycle
- front end GUI development to support a wide range of users
- flexible back end GUI development to support range of module output information
- assistance in building libraries of historic facility/infrastructure information (national/global)
- innovative concepts for interaction with and communication of simulator results to decision makers and other non-expert users, including determination of the key factors on public decision making as related to the deployment of complex technologies.

Successful proposals should describe a team approach that delivers an innovative mix of expertise (as appropriate for the areas targeted in the bulleted list above) that can account not only for the technical aspects of the analyses but also the software design, visualization, human/machine interface and decision analysis aspects: for example, including nuclear engineering, systems engineering, physics, chemistry, computer science, video gaming, game theory, sociology, and decision theory.

Program Supporting: Reactor Concepts RD&D Workscope Table

The following workscope has been modified and now reads as the following:

> ***VHTR Materials (NGNP-2)*** – VHTR reactor materials research is focused on the development of graphite, ceramics, composites and high temperature structural materials. Proposals are sought in the VHTR materials that (a) seek to elucidate fundamental mechanisms of creep, creep-fatigue, dynamic strain aging, stress relaxation and environmentally assisted crack growth in heat exchanger and steam generator alloys and for pressure vessel steel use (b) to determine mechanisms responsible for creep resistance of pressure vessel steels and prediction of negligible creep limits. Proposals are also sought in VHTR materials development that supports (a) graphite for fuel blocks and core structures, and (b) advanced CFC, SiC/SiC, composites and ceramics for ceramic components such as insulation blocks, insulating blankets/weaves, tiles and columns. Improved Non-Destructive Examination (NDE) techniques are needed for predicting the component lifetimes for (i) CFC, SiC/SiC, and composites for ceramic components, and (ii) detecting small flaws ($\leq$ 100 microns) in large graphite components ($>400mm^3$).

1 INTRODUCTION

This solicitation is the fiscal year (FY) 2011 Request for Pre-Applications (RPA) for nuclear energy-related research and development (R&D) for the United States Department of Energy's (DOE) Office of Nuclear Energy's (NE) Nuclear Energy University Programs (NEUP). This RPA supports the NE and NEUP missions and goals described below:

> *The primary mission of the Office of Nuclear Energy is to advance nuclear power as a resource capable of meeting the Nation's energy, environmental and national security needs by resolving technical, cost, safety, proliferation resistance and security barriers through research, development and demonstrations as appropriate.*
>
> *The Nuclear Energy University Programs mission is to engage the U.S. university community to conduct program directed, program supporting and mission supporting research and development, related infrastructure improvements and student fellowship and scholarship support to build world class nuclear energy and workforce capability as an integral component of the Office of Nuclear Energy.*

The goal of NEUP is to support outstanding, cutting-edge, and innovative research at U.S. universities through the following:

- Administering NEUP R&D awards to support NE's goal of integrating R&D at universities, national laboratories, and industry to revitalize nuclear education and support NE's R&D program objectives as defined in the NE R&D Roadmap
- Attracting the brightest students to the nuclear professions and supporting the Nation's intellectual capital in Nuclear Engineering and relevant Nuclear Science, such as Health Physics, Nuclear Materials Science, Radiochemistry and Applied Nuclear Physics
- Improving relevant university and college infrastructures for conducting R&D and educating students
- Supporting NE's goal of facilitating the transfer of knowledge from an aging nuclear workforce to the next generation of workers

This RPA includes mandatory requirements and evaluation criteria that will be used to select a set of applications whose applicants will be invited to submit full proposals in response to a subsequent Request for Proposals (RFP).

The primary point of contact for questions regarding this solicitation is Dr. Marsha Lambregts from the NEUP Integration Office. However, all technical scope questions must be submitted through the question and answer feature on the RPA website accessible via the NEUP home page located at www.ne-up.org.

A NEUP workshop was held on July 27-28, 2010, in Rockville, Maryland, to assist in the preparation of this R&D RPA. Workshop outcomes were captured as proceedings and are available at the www.ne-up.org website.

This workshop product is an important source of background information on the R&D areas that will be included in this solicitation. Applicants are encouraged to read and familiarize themselves with these documents before responding to the solicitation or entering the proposal submittal system (online).

A stand-alone pre-application is required for each scope of work of interest. Applicants may submit more than one pre-application. Availability of funding, technical merit, and program relevancy will factor into the determination of the final number of proposals selected for each technical area.

NOTE: All information and instructions required to respond to this solicitation are accessible at www.ne-up.org. Applicants may request login credentials at www.ne-up.org beginning at 8 a.m. October 27, 2010 MST. Applicants MUST submit their responses electronically. NO hard copy responses will be accepted.

2 Research Areas of Interest

NEUP will fund R&D that facilitates meeting NE's programmatic objectives. NE's strategic goals for nuclear energy are clearly defined within the Nuclear Energy Research and Development Roadmap (http://nuclear.gov/pdfFiles/NuclearEnergy_Roadmap_Final.pdf).

2.1 NE Roadmap Objectives

- Develop technologies and other solutions that can improve the reliability, sustain the safety and extend the life of current reactors
- Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals
- Develop sustainable nuclear fuel cycles
- Understand and minimize the risks of nuclear proliferation and terrorism

NEUP components covered by this RPA are *Program Supporting* and *Mission Supporting* R&D in Fuel Cycle Research and Development, Reactor Concepts and Nuclear Energy Enabling Technologies.

Program Supporting R&D is focused more directly on programmatic needs and defined by the scope statements issued by the responsible programs. This work should be focused and responsive to the representative scope. The scope statements are not prescriptive to a discipline, but can be limiting as defined by scope objective.

Mission Supporting R&D is considered creative, innovative, and "blue sky," but must also support the NE mission. Mission-supporting activities that could produce breakthroughs in nuclear technology are also invited to this solicitation. This includes research in the fields or disciplines of nuclear science and engineering that are relevant to NE's mission though may not fully align with the specific initiatives and programs identified in this solicitation. This includes, but is not limited to, Nuclear Engineering, Nuclear Physics, Health Physics, Radiochemistry, Nuclear Materials Science or Nuclear Chemistry. Examples of topics of interest are new reactor designs and technologies, advanced nuclear fuels and resource utilization, instrumentation and control/human factors, radiochemistry, fundamental nuclear science, and quantification of proliferation risk and creative solutions for the management of used nuclear fuel.

Program supporting research requested by this solicitation is detailed as discreet workscopes in Appendix A. The information is organized by program area with each specified workscope providing the basis for a stand-alone R&D pre-application submittal.

Follow-on R&D work from previous projects may be submitted as new proposals for consideration under this RPA. All proposals submitted under this RPA will be considered equally.

2.2 MAJOR NE FUNDED PROGRAMS

Fuel Cycle Research and Development (FCR&D) Program. The mission of the FCR&D program is to research, develop and demonstrate options to the current U.S. commercial fuel cycle to enable the safe, secure, economic and sustainable expansion of nuclear energy while minimizing proliferation and terrorism risks.

In the near term, the goal for FCR&D is to define and analyze fuel cycle technologies to develop options that increase the sustainability of nuclear energy. In the medium term, the goal is to select a preferred fuel cycle option for further development and by 2050 deploy the preferred fuel cycle.

Current challenges include the development of high burnup fuel and cladding materials to withstand irradiation for longer periods of time; the development of simplified separations, waste management and proliferation risk reduction methods; and development of optimized systems to maximize energy production while minimizing waste.

Reactor Concepts (RC) Program. The mission of the RC 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), Next Generation Nuclear Plant Demonstration Project (NGNP) and Advanced Reactor Concepts (ARC).

Nuclear Energy Enabling Technologies (NEET) Program. NEET directly supports and complements RC and FCR&D by providing transformative solutions across the full range of nuclear energy technologies. The mission of NEET is to develop crosscutting technologies that directly support and complement the development of new and advanced reactor concepts and fuel cycle technologies; encourage the development of transformative, "out-of-the-box" solutions across the full range of nuclear energy technology issues and focus on innovative research relevant to multiple reactor and fuel cycle concepts that offer the promise of dramatically improved performance. For the purposes of NEUP, NEET identifies five technical areas under its crosscutting technologies arena: Reactor Materials, Proliferation Risk Assessment, Advanced Sensors and Instrumentation and Advanced Methods for Manufacturing.

3 ESTIMATED FUNDING

The FY 2011 allocation of the overall NE R&D budget for new R&D awards under this solicitation is approximately $43.7 million. Through this solicitation, DOE may issue awards in multiple phases throughout the FY pending availability of funds and program priorities.

The actual level of funding for each research area will depend on the FY 2011 appropriation for the NE R&D programs. If additional funds become available later in FY 2011, DOE may invite additional highly ranked respondents to this RPA to submit full proposals and make awards in accordance with the proposal review and evaluation process outlined in this solicitation and the subsequent RFP.

4 ELIGIBILITY INFORMATION

The lead applicant must be a U.S. university or college. Collaborations between universities and industry or national laboratories are permitted. A maximum of 20 percent of an award can be awarded to industry and national laboratories. **Note that funding is for U.S. based researchers only. Although collaborations with foreign organizations are encouraged if their role is focused on fundamental research and they are not a denied party or a party that requires an export license, such participants are not eligible for U.S. government funding.** Universities that partner with minority-serving institutions will receive additional points during the full proposal review. The following link provides the list of minority-serving institutions: http://www.ed.gov/about/offices/list/ocr/edlite-minorityinst.html.

5 CONTENT OF R&D PRE-APPLICATION AND BASIS FOR AWARD

5.1 SUBMITTAL CONTENT AND FORMAT

Each applicant's R&D pre-application shall include the items found in Table 1. Applicants may input these pre-application elements on the NEUP R&D pre-application form provided at the RPA website. Access instructions are available at www.ne-up.org.

Table 1: Submittal Content and Format

Item	Description	Page Limit
Pre-Application Narrative	Size 11 font minimum; Three single-spaced pages maximum; One-inch margins all around minimum.	3
Benefit of Collaborations	Size 11 font minimum; Two single-spaced pages maximum; One-inch margins all around minimum.	2
Vita	Size 11 font minimum; Two single-spaced pages maximum; One-inch margins all around minimum.	2
Quality Assurance Requirements	Check box on the pre-application form.	N/A
Mandatory Requirements	Check box on the pre-application form.	N/A
Commitment of Partner(s)	Check box on the pre-application form.	N/A

5.2 PRE-APPLICATION NARRATIVE

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 Table)
- Name of Project Director/PI(s) and associated organization(s)
- A summary of the proposed project, including a description of the project and a clear explanation of its importance and relevance to the objectives covered by this work scope area
- Explanation of the importance and relevance of the proposed work to the objectives covered by this work scope area
- Logical path to work accomplishment
- Deliverables and outcomes the R&D will produce
- Timeframe for execution of proposed scope (specify if the R&D is for a one-, two-, three-, or four-year period)
- For **Program Supporting** research, estimated cost of proposal (order of magnitude); proposals shall not propose costs of more than $400,000/year and $1,200,000/contract for an up to 4 year project.

- For **Mission Supporting** research, estimated cost of proposal (order of magnitude); proposals shall not propose costs of more than $200,000/year and $600,000/contract for an up to 4 year project.

5.3 BENEFIT OF COLLABORATORS

This document will contain 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 collaborators and descriptions of the facilities wherein the research will be conducted. Please indicate within this section if this proposal has benefit or influence on other ongoing or proposed NEUP projects (e.g. modeling and simulation in one proposal and effect validation in a separate proposal).

5.4 VITA

A two-page vita shall be provided for the PI from the lead college or university. It should include his/her relevant credentials, experience, and five most recent publications or commensurate accomplishments.

5.5 QUALITY ASSURANCE REQUIREMENTS

Institutions will be expected to follow quality assurance (QA) principles and requirements in conducting R&D activities. The integrity of R&D products and their usability by NE is predicated on meeting QA requirements as they apply to a specific scope of work and associated deliverables. 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 RFP process, the NEUP Integration Office will provide assistance, as needed, in understanding possible QA requirements for a specific work scope and in developing options to meet those QA requirements. Examples of typical implementation documents which meet the QA requirements are posted on the NEUP website.

Acceptance of these requirements is indicated by the lead applicant checking the appropriate box on the application form.

5.6 MANDATORY REQUIREMENTS

A mandatory set of requirements (go/no-go) is provided below as Table 2. The lead university or college is required to obtain its institutional commitment, as well as the commitment of each collaborating organization, to each of the specified mandatory requirements. Only pre-applications that accept these mandatory requirements shall be eligible for continued evaluation. Acceptance of these requirements is indicated by the lead applicant checking the appropriate box on the application form.

Table 2: Mandatory Requirements

Requirement	Description	Evaluation
Commitment to financial and administrative (overhead) guidance	All participating organizations' adders shall be in accordance with their current negotiated rate agreement with the Department of Health and Human Services or the Office of Naval Research	Go/No-Go
Commitment to reporting and budget requirements	Commitment to submit quarterly billing. Commitment to submit quarterly reports through the NEUP website. Reports approved by NE Program Management	Go/No-Go
Commitment to comply with QA Requirements	The college or university is required to acknowledge that it will comply with QA requirements. Additional explanation is provided below.	Go/No-Go
Note 1: If the lead institution has a current master blanket subcontract in place with BEA and is awarded a R&D subcontract in response to the RFP, then the NEUP R&D award will be added to the existing subcontract as a task release. Note 2: If an applicant proposes work scope to be conducted at a DOE facility, the work performed at DOE facilities shall be conducted in accordance with 10 CFR 851, Worker Safety and Health Program requirements. Note 3: Applicants that progress to the full proposal stage will be required to agree to the terms and conditions of the Standard Research Subcontract.		

5.7 Collaboration Commitment

Each institution identified in the RPA as a team member shall be identified in the pre-application, with their commitment made to collaborate in the RFP process, and their agreement with the mandatory requirements. Minor contributors—anyone not expected to materially participate in the proposal, such as consultants or national laboratory personnel who are not to be allocated more than $50,000 to participate in the project—should not be listed. Acceptance of these requirements is indicated by the lead applicant checking the appropriate box on the application form.

6 PRE-APPLICATION INSTRUCTIONS

Submit, in writing (electronically), any administrative questions or requests for additional information on this solicitation to neup@inl.gov. Technical scope questions should be made using the question and answer feature on the NEUP home page located at www.ne-up.org. NEUP will provide a response to substantive inquiries by restating the question and furnishing a response to all potential applicants by posting the question and response on the RPA website. Points of contact (POC) for program areas are posted on the NEUP website. NEUP encourages applicants to contact these POC's as necessary.

Pre-applications that fail to provide ALL items and quantities specified in this RPA may be deemed non-responsive in their entirety and may not be invited to submit full applications in response to the subsequent RFP.

7 APPLICATION AND SUBMITTAL INFORMATION

NEUP reserves the right to amend the solicitation schedule as needed.

7.1 APPROXIMATE SOLICITATION SCHEDULE

Table 3: R&D Schedule

Issue Request for Pre-Applications	October 27, 2010
Pre-Applications Due	December 8, 2010
Request for Proposals Released	February 9, 2011
Full Proposals Due	March 9, 2011
Selection Announced	May 11, 2011
Awards Completed	August 31, 2011

7.2 PRE-APPLICATION DUE DATE

In accordance with the schedule above, pre-applications are due by 5:00 p.m. MST on December 8, 2010. Submittals to the R&D solicitation MUST be made electronically by using the "Submit Pre-application for Review" option on the pre-application form. Please read the instructions on the form carefully. Pre-applications not submitted via this option will be treated as incomplete and will not be evaluated.

7.3 LATE PRE-APPLICATIONS

Pre-applications received after the designated date and time, i.e., late, will be treated as nonresponsive and returned without opening. Extension of the R&D pre-application due dates shall be determined at the sole discretion of the NEUP Integration Office on behalf of NE.

8 WORKSCOPE DESCRIPTIONS

Appendix A contains detailed descriptions of research needs in support of each programmatic element for submission to the Program Supporting and Mission Supporting sectors of the call. <u>It should be noted that for Mission Supporting "blue sky" proposals, the submission of novel and creative solutions to the research challenges is strongly encouraged beyond the detailed needs described in Appendix A</u>.

9 PROGRAM CONTACTS

The NEUP website, www.ne-up.org, provides a list of technical contacts for each program who can be contacted for further information on their respective areas of work as well as the programs' websites that also provide relevant technical information.

10 EVALUATION CRITERIA

Selection of universities and colleges to be invited to provide full applications in response to the subsequent RFP shall be based on how well the pre-applications meet or exceed the weighted evaluation criteria provided below in Table 4. After considering the evaluation criteria and available funding, NE will make a final determination of applicants who will be invited to provide full applications in response to the subsequent RFP.

In FY 2011, NEUP will institute a modified method for evaluating pre-applications. Please read carefully the following criteria and process descriptions.

All pre-applications submitted under this solicitation will be reviewed and scored by two different groups. First, a panel of programmatic experts will assess each pre-application's relevancy to NE's R&D mission. Scores will be assigned on the subjective scale of Highly Relevant, Relevant, Low Relevance and Not Relevant. Proposals scored as "Not Relevant" will not be evaluated further because NE has received clear Congressional direction that in no instance can NE allocate funds to activities that are not relevant to its mission. Second, a separate panel of technical experts/peers will assess each application on its technical merit. Scores will be assigned on the subjective scale of High Merit, Moderate Merit, Low Merit, and No Merit.

The two scores will be weighted per Table 4 below. Pre-applications will be arranged within each Program Area and technical area using the ranked information. Then, after evaluating the recommendations of the reviewers, the Source Selection Official will determine which applicants will be invited to submit full proposals in response to the subsequent RFP.

NOTE: Applicants who are not specifically invited to submit full proposals may do so at their own decision/risk. **There is no guarantee that uninvited full applications will receive a full review; however, all full applications received in response to the subsequent RFP will be re-reviewed for relevancy.**

Table 4: Weighting of Scores

Criterion	Description	Weight (Percent)
Scientific/Technical Merit[1]	**Program Supporting:** *Advances the state of knowledge in the selected program workscope*; • practicality of scope with respect to the *program workscope*; • practicality of scope with respect to requested funding and period of performance; • logical path to work accomplishment; ability of team to perform work.	65
	Mission Supporting: *Advances the state of knowledge in an area supporting the overall NE mission*; • practicality of scope with respect to *NE's mission*; • practicality of scope with respect to requested funding and period of performance; • logical path to work accomplishment; ability of team to perform work.	80
Relevance[2]	**Program Supporting:** *Aligned with, and directly relevant to, program objectives.* • Submission should define and describe the significance of the proposal to the needs described by program workscopes.	35
	Mission Supporting: *Aligned with, and relevant to the overall NE mission.* • Submissions should sufficiently capture a clear and supportive connection to the NE mission.	20

1. Scientific Technical Merit: The technical section of the application will clearly define the research being proposed and its relationship to the selected program workscopes. This criterion will consider the technical merit of the application, including proposed technical objectives and deliverables as well as the likelihood of achieving them.
2. Proposals must recognize work currently underway under earlier NERI and NEUP awards to ensure that the work is not duplicative of those already approved.

Appendix A: Workscope Descriptions

PROGRAM SUPPORTING: FUEL CYCLE R&D (~$14.5M)

SEPARATIONS AND WASTE FORMS

Separations and Waste Forms (FC-1) – The separations and waste forms campaign develops the next generation of fuel cycle and waste management technologies that enable a sustainable fuel cycle, with minimal processing, waste generation, and potential for material diversion. Today's technology challenges concern meeting current air emission requirements; the economical recovery of transuranic elements for recycle/transmutation; and minimizing waste generation (including both high level and low level waste). Grand Challenges 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 separation processes and waste form thermodynamics; understanding the underlying separation driving forces; exploiting thermodynamic properties to effect separations; elucidating microstructural waste form corrosion mechanisms; and developing improved sampling and process monitoring technologies. The results of this R&D should develop the predictive capability for separation and waste form performance over a broad range of operational conditions and novel separations technologies. Specific university research needs include:

- Off-gas treatment. Development and application of computational methods to design and predict the structure and properties of sorbents for off-gas treatment, including selective removal of iodine, krypton, and xenon.
- Design of new chemical processes: Computer-aided molecular design of sequestering agents for solvent extraction applications. Apply modeling and simulation, with experimental validation, to the identification of alternate ligands for solvent extraction applications.
- Validation data. Experimental collection of fundamental data to characterize and quantify chemical processes of electrochemical separation, validation of modeling approaches as well as to develop a better understanding of electrochemical separation methods.
- Interfacial electrochemistry. Fundamental methods and models for interfacial electrochemistry of actinides and fission product elements important in the fuel treatment process.

ADVANCED FUELS

Advanced Fuels (FC-2) – The advanced fuels element is primarily focused on research and development of innovative fuel and target concepts, for both thermal and fast spectrum nuclear reactors. These systems potentially have the ability to achieve significantly higher fuel and plant performance requirements, including major increases in burn-up than yet achieved. We are interested in advanced nuclear fuel and materials technologies that support these goals. Research and development in the areas of fabrication, characterization, and performance of advanced fuel, materials, and target systems are within the scope of this program element. Fuel types of interest are high burnup-high performance metallic, ceramic, and coated particle fuels. As examples, specific areas of research and development of interest are; advanced fabrication technology and research with potential for decreasing fabrication process losses while increasing fuel quality and consistency, fabrication process models, such as compaction and sintering models, fuel materials studies, and associated technology development that supports increased understanding of fuels performance, while simultaneously supporting the development of predictive, physics-based fuels performance models at a micro- structural level. At completion of the project, the university shall provide a summary report of the research conducted and results obtained.

TRANSMUTATION R&D

***Nuclear Theory and Modeling (FC-3)* –** The investments made in nuclear experiments can only be fully realized when evaluated in a more comprehensive theoretical treatment. This research topic will cultivate the capability to perform inclusive multi-channel nuclear physics evaluations, capable of delivering inter-reaction covariance data as a function of incident neutron energy. Improved nuclear models will be developed and validated in collaboration with the nuclear physics working group. In addition, these models will be employed to evaluate and construct new data sets for key fuel cycle nuclides. University teams will perform a systematic evaluation of how advanced measurement techniques can be used to help guide improved nuclear theory and theory, resulting in a strategic plan at the end of the first year. The following years will focus on nuclear model development with periodic reporting on validation and cross-section evaluation studies

***Improved Measurement Techniques (FC-4)* –** This research topic will pursue advanced measurement techniques that could complement the ongoing measurement program. In particular, fission multiplicity and fission neutron spectrum measurements as a function of incident neutron energy have been identified as important data in recent sensitivity analyses. Innovative ideas for detector development and testing are needed to facilitate the high fidelity requirements of the nuclear physics effort. University teams will develop new measurement systems to address the data needs noted above. Candidate systems will be reviewed and refined in conjunction with the nuclear physics working group. The following years will focus on construction and testing of a prototype device.

MATERIALS PROTECTION, ACCOUNTANCY, AND CONTROLS TECHNOLOGIES

***Materials Protection, Accountancy, and Controls Technologies (FC-5)* –** The Materials Protection, Accounting, and Controls Technologies (MPACT) program develops technologies and analysis tools to support next generation nuclear materials management and safeguards for future U.S. fuel cycles. This includes both the extrinsic measures and safeguards over-laid on a nuclear energy system, as well as the intrinsic design features incorporated into system design. The key university research needs for this activity are 1) Development of new sensor materials and measurement techniques; 2) Development of novel methods for data integration and real-time analysis; 3) development of advanced concepts for achieving real-time, online and continuous nuclear materials accountancy.

New sensor materials may include advanced materials and process electronics that can offer a higher degree of accuracy and/or efficiency for any number of material measurement techniques. These techniques may include neutron coincidence/anti-coincidence counting, spectroscopic analysis, non-nuclear methods, and other novel methods. New methods for data integration and analysis include cutting-edge work in multi-variant statistical techniques for process motoring and other MC&A techniques. Finally, the utilization of material accounting data should be done in such a way that enables modeling & simulation efforts and proliferation risk analysis to benefit from these improved methods.

USED NUCLEAR FUEL DISPOSITION

Used Nuclear Fuel Disposition (FC-6) – The used fuel disposition and waste form technical areas develop technologies for storing, transporting, and disposing of used nuclear fuel and assessing performance of the waste forms associated with recycling and disposal technologies. Key university research needs for this activity include 1) innovative approaches to evaluating degradation and aging phenomena of fuel, cladding, containers, and storage facilities, relevant to extended interim storage; 2) material research that would facilitate transportation of used nuclear fuel:3) advanced modeling approaches for radiological consequence analyses of disruptive scenarios relevant to storage transportation, and disposal; 4) data relevant to risk-informed cask qualification and the storage and transportation behavior of high-burnup and advanced fuels; and 5) 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 or shale, granite, and salt, and deep boreholes in granitic rocks. Examples of modeling and data needs include waste form and container performance in a broad range of environmental conditions, coupled thermal-mechanical-hydrologic-chemical models for disposal environment behavior, and experimental programs to support model validation.

Research needs for waste form and assessment of 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. Particular needs include: (1) quantitative chemical descriptions for used fuel, glass, ceramic and metallic waste form degradation in severe aqueous environments, corrosion and leaching, leading to validated rate laws for dissolution and release of radionuclides from degrading waste forms; (2) systematic experiments under controlled conditions targeted to model validation; (3) methods to upscale atomistic descriptions into continuum-scale models, and generate validated predictions over geologic time scales; (4) aqueous speciation and surface sorption at high temperature and high ionic strengths anticipated in near field conditions; (5) radiation and thermal effects in used fuel and waste forms, upscaling to validated models constitutive models for radionuclide transport, cracking and impacts on aqueous-accessible surface; (6) refined geochemical transport based on fundamental kinetics and thermodynamics; and (7) improved methods for modeling actinide chemistry, first principles and molecular dynamics, and experimental data to validate these models are needed. Extending these approaches to develop mechanistic first-principles-based model for waste form design and assessment to tailor composition and processing to specific waste streams and disposal environments are of interest. Particular need is for quantitatively assessed performance of waste material, requiring well-characterized modeling and experiment, with validated models typically requiring closely coordinated modeling and experimental efforts.

PROGRAM SUPPORTING: FUEL CYCLE R&D (~$14.5M)

SYSTEMS ANALYSIS

***Fuel Cycle Simulator (FC-7)* -** Systems analysis provides the integrating analyses of nuclear energy and fuel cycle systems to inform fuel cycle option development and evaluation. Systems analysis is used as a predictive/strategic tool, enabling a more proactive approach to understanding the behavior of various fuel cycles and their technical, political and economic impacts. The key university research need for this activity is the development of modules for the Fuel Cycle Simulator, including fuel cycle modules, interface modules and data modules. These modules will focus on specific aspects of the nuclear fuel cycle simulator and should be created in such a way that they can plug into an overall framework, which will be developed in coordination with the Systems Analysis Campaign.

This advanced fuel cycle simulator will not only support integrating analyses of fuel cycle systems, but also inform fuel cycle R&D, programmatic decisions, strategy formulation, and policy development as well educate and communicate with stakeholders. If successful, the simulator could revolutionize the decision-making process wherein the decision maker will not be presented with a 3,000+ page analysis and asked to decide, but rather using a PC, laptop or tablet computer can run simulation and in real-time manipulate key variables to see how the system option responds in order to make an informed decision.

The first step in development of the Fuel Cycle Simulator will be design and development of the over-arching framework, or information backbone, for the FCS and will be lead by the Fuel Cycle Technologies Systems Analysis Campaign. This will include the minimum data sets, underlying database, hardware architecture to support the heavy computational load while providing access via PCs, laptops, or tablet computers, and modular approach to provide an extendable simulation capability.

Proposals should focus on the development of specific modules as described above, but proposals related to the areas listed below will also be considered:

- basic modules for each function of the fuel cycle
- front end GUI development to support a wide range of users
- flexible back end GUI development to support range of module output information
- assistance in building libraries of historic facility/infrastructure information (national/global)
- innovative concepts for interaction with and communication of simulator results to decision makers and other non-expert users, including determination of the key factors on public decision making as related to the deployment of complex technologies.

Successful proposals should describe a team approach that delivers an innovative mix of expertise (as appropriate for the areas targeted in the bulleted list above) that can account not only for the technical aspects of the analyses but also the software design, visualization, human/machine interface and decision analysis aspects: for example, including nuclear engineering, systems engineering, physics, chemistry, computer science, video gaming, game theory, sociology, and decision theory.

PROGRAM SUPPORTING: REACTOR CONCEPTS RD&D (~$15.2M)

SMALL MODULAR REACTORS

Novel Sensors (SMR-1) – Novel sensors to enable direct measurement of nuclear and process variables in small modular reactors (SMRs). Emerging design concepts for SMRs, such as integral pressurized-water reactors (iPWRs) and pool-type liquid metal or salt cooled reactors, pose unique constraints on measurement of operational conditions that challenge the application of conventional sensors. Specifically, integral/pool reactor designs require in-vessel measurement capabilities that are subject to more severe environments and complex geometries, while advanced reactor concepts based on different coolant types suggest the need to address measurement challenges related to materials compatibility, higher-temperature exposure, or other unique sensing conditions. Development of innovative sensing technologies to provide direct measurement capabilities that address unique conditions or resolve engineering challenges associated with SMR design concepts are sought. Universities performing this research will be expected to demonstrate the viability of an innovative measurement approach for key SMR phenomena under benchtop or laboratory conditions that are reflective of the intended application.

Instrumentation, Control, and Human-Machine Interface (SMR-2) – Instrumentation, control, and human-machine interface (ICHMI) technologies to support extended operational cycles and optimized maintenance for small modular reactors (SMRs). To support the operational goals of SMR design concepts, there is a need to reduce demands for labor-intensive surveillance, testing, and inspection, minimize forced outages, and provide monitoring of the physical condition and performance of critical plant components. Effective strategies (e.g., predictive or condition-based maintenance) for maintenance scheduling to accommodate infrequent outages, innovative techniques for online, in-situ condition determination and monitoring, and novel human-system interaction mechanisms to enable remote or optimized in-service maintenance are sought. Universities performing this research will be expected to produce concepts, techniques, and capabilities that are or can be demonstrated in simulated or laboratory test bed environments representative of SMR applications.

Advanced Concepts (SMR-3) – Advanced small modular reactor concepts for improved performance, affordability, and functionality. SMR concepts offer the opportunity to expand nuclear energy to a broader range of customers and energy-intensive applications, including base-load electricity for remote communities or dedicated facilities, dispatchable electricity to stabilize local grids with high renewable fractions, process heat applications, etc. Innovative concepts are sought that are designed from the outset to provide these new functionalities while also maintaining or improving the operational and economic performance. The concepts may utilize advanced technologies or innovative engineering but should be viable for eventual commercial deployment. The scope of the proposed project should include: a thorough viability assessment of the advanced concept, a detailed technology gap analysis, and a comprehensive technology development roadmap.

Assessment Methods (SMR-4) – Methods for assessment of SMR risk factors. SMRs differ from larger plants in the fundamental design features and operational approaches. In order to properly account for the differences in a risk-informed regulatory process, it will be necessary to adapt existing methods or develop new analysis methods to quantitatively characterize the new risk factors associated with SMRs, for example: reduced source term, different source term release and dispersion paths, extended refueling

PROGRAM SUPPORTING: REACTOR CONCEPTS RD&D (~$15.2M)

and maintenance cycles, and greater use of intrinsic security features. Innovative approaches to the application of deterministic or probabilistic risk analysis methods for modeling and predicting unique SMR risk factors are encouraged.

NEXT GENERATION NUCLEAR PLANT

The VHTR is a helium-cooled, graphite moderated reactor with a core outlet temperature between 750 and 850°C with a long-term goal of achieving an outlet temperature of 950°C. The reactor is well suited for the co-generation of process heat and electricity and for the production of hydrogen from water for industrial applications in the chemical and petrochemical sectors. This program component is organized along the following major categories:

Computational Methodologies (NGNP-1) – VHTR reactor analysis methods research is focused on providing practical tools to analyze the reactor core neutronics/thermal-hydraulics, performance, and reactor gas-coolant helium thermal fluids behavior during normal operations, transient and accident scenarios, and safety evaluations for VHTRs.

Proposals are sought for computational methodologies for VHTR phenomena and scaled experiments that can be used for benchmarking analysis methods. This includes experimental confirmation of VHTR phenomena during transient and accident scenarios that include scaling analysis, experimental design, fundamental phenomena identification, costing and PIRT review for of the following area: (a) High Temperature Test Facility (b) Natural Circulation in the core (Plenum-to-Plenum) (c) Steam Ingress Flow and Chemistry (d) Core and Boundary Heat Transfer experiments, (e) Ex-core Cooling (Reactor Cavity Cooling) and (f) non-isothermal Lower Plenum and Bypass flows.

In the area of VHTR neutronics, thermal-hydraulics, and multiphysics areas, proposals are sought that address the modeling of reactor core phenomena: (a) reactivity transient effects, (b) time-dependent coupled fuel/neutronic/thermal fluids modeling, and (c) mechanical-neutronic-thermal fluid interactions during graphite dimensional changes under irradiation with thermal and neutronic feedback; and (d) core temperature and flux measurement/reconstruction techniques for VHTR/HTGRs. Proposals are also sought in the area of VHTR plant simulation and safety analysis including: (a) experimental and theoretical methods for determining credible fission product transport mechanisms that support the mechanistic source term approach for VHTRs under normal operating conditions, off-normal events, and accident conditions, including both air and/or moisture ingress events; (b) design-basis limiting licensing accident simulations, with mechanistic source term and fission product transport analyses that include fission product transport mechanisms for aerosols and graphite dust-carried fission products, and (c) uncertainty and sensitivity analysis for statistical importance ranking. Proposals that have a special emphasis on experimental validation and uncertainty and sensitivity analysis to benchmark computer simulation methods are particularly sought.

VHTR Materials (NGNP-2) – VHTR reactor materials research is focused on the development of graphite, ceramics, composites and high temperature structural materials. Proposals are sought in the VHTR materials that (a) seek to elucidate fundamental mechanisms of creep, creep-fatigue, dynamic strain aging, stress relaxation and environmentally assisted crack growth in heat exchanger and steam generator alloys and for pressure vessel steel use (b) to determine mechanisms responsible for creep resistance of pressure vessel steels and prediction of negligible creep limits. Proposals are also sought in VHTR materials development that supports (a) graphite for fuel blocks and core structures, and (b) advanced CFC, SiC/SiC, composites and ceramics for ceramic components such as insulation blocks, insulating blankets/weaves, tiles and columns. Improved Non-Destructive Examination (NDE) techniques are needed for predicting the component lifetimes for (i) CFC, SiC/SiC, and composites for ceramic components, and (ii) detecting small flaws (≤ 100 microns) in large graphite components (>400mm^3).

VHTR TRISO Fuels (NGNP-3) – VHTR TRISO fuel development and qualification activities are focused on producing robust fuel particles that can retain fission products during normal and accident conditions and have very low failure rates, as demonstrated by irradiation and accident safety testing programs. TRISO fuel designs for current pebble bed and prismatic VHTRs are based on historical designs that build upon large experimental fuel performance databases and historical fabrication methods, and ensure robust performance and fission product retention. TRISO fuel research is focused on the development of novel TRISO fuel particle designs, fabrication methods, characterization techniques, and radiation source term and fission product transport effects.

Proposals are sought for Innovative VHTR TRISO fuel fabrication methods and particle designs that can accommodate high outlet temperatures and increase fuel operational and safety margins for either the current pebble bed and prismatic block fuel designs, and advanced VHTRs designs. Design options may involve changes in kernel size, layer thicknesses, layer materials (i.e., ZrC vs.SiC), burnable absorber materials, particle packing fraction, fuel-element geometry and include innovative TRISO fuel particle, compacting manufacturing techniques. Novel approaches for advanced characterization measurement methods that can improve techniques for finding defects, measure materials microstructures, properties, layer thicknesses and densities, that can rapidly and economically characterize TRISO particles are particularly sought.

VHTR Heat Transport, Energy Conversion, Hydrogen and Nuclear Heat Applications (NGNP-4) – The VHTR Heat Transport, Energy Conversion, Hydrogen and Nuclear Heat Applications area focuses on the development of approaches to coupling of the heat source with the wide variety of process heat applications (co-generation, coal-to-liquids, chemical feedstocks).

Proposals are sought on approaches that can greatly improve the economics, ease of coupling, the operability of the combined system Research that addresses modeling of VHTR energy transfer, conversion systems in terms of: (a) dynamic simulation of Reactor-driven Process Heat Plants, including interactions of multiple modules, (b) economic and optimization analysis of coupled VHTR-process heat plants, and (c) analysis of alternative coolants is requested. Proposals are sought that can improve hydrogen generation high temperature steam electrolysis technology in the areas of cell materials, performance, and modeling.

LIGHT WATER REACTOR SUSTAINABILITY

Advanced Mitigation Strategies (LWRS-1) – Advanced mitigation strategies and techniques. Extended operating periods may reduce operating limits and safety margins of key components and systems. While component replacement is one option to overcome materials degradation, other methods (e.g. thermal annealing or water chemistry modification) may also be developed and utilized to ensure safe, long-term

PROGRAM SUPPORTING: REACTOR CONCEPTS RD&D (~$15.2M)

operation. Validation and/or development of techniques to reduce, mitigate, or overcome materials degradation of key LWR components are sought. Mitigation strategies for pressure vessel steels, core internals, weldments, or concrete are encouraged. Universities engaging in this effort will be expected to produce concepts, supporting data and/or model predictions demonstrating the viability of mitigation strategies for key LWR components.

Risk-Informed Safety Margin Characterization (LWRS-2) – R&D should address the Risk-Informed Safety Margin Characterization (RISMC) methodology. Areas of high priority include advanced modeling and simulation methods to support the development, verification, and validation of next-generation system safety codes that enable the nuclear power industry to perform analysis of a nuclear power plant's transients and accidents. An especially important need in this analysis is a very clear understanding of the real uncertainties in the analysis. This requires not just propagation of parameter uncertainty via sampling techniques, but also meaningful quantification of the underlying distributions, addressing not only epistemic uncertainty but also variability in phenomena, including variability in component behavior (variability in stroke times, pump head curves, heat transfer coefficients, and so on). Universities performing this research will be expected to produce results that integrate multiple mechanistic processes.

Instrumentation and Control (LWRS-3) – Digital instrumentation and control technologies for highly integrated control and display, improved monitoring and reliability. Research is needed to improve upon available methods for online monitoring of active and passive components to reduce demands for unnecessary surveillance, testing, and inspection and to minimize forced outages and to provide monitoring of physical performance of critical SSCs. In addition, methods are needed to analyze the reliability of integrated hardware/software technologies that comprise digital systems. Research should investigate NDE technologies to characterize the performance of physical systems in order to monitor and manage the effects of aging on SSCs. High priority research areas include the following: 1) methods and technologies that can be deployed for monitoring nuclear plant systems, structures, and components, and that can be demonstrated in test bed environments representative of nuclear plant applications; and 2) methods for analyzing the dynamic reliability of digital systems, including hardware and software systems based on formal methods that can be demonstrated on systems that are proposed or representative of systems proposed for nuclear plant control and automation. This research is expected to support the development of methods and technologies to support digital instrumentation and control integration for monitoring and control as well as for noting areas of improved reliability and areas requiring further information and research. Universities performing this research will be expected to produce results that integrate multiple mechanistic processes.

ADVANCED REACTOR CONCEPTS (ARC)

Advanced Reactors Concept Development (ARC-1) – Development of new reactor concepts that use advanced technologies or innovative engineering is sought. The goals of the advanced reactor system should be to provide electricity at the same cost or lower than light water reactors with improved safety and system performance. This category could include either radically new systems or the incorporation of advanced systems and components into existing reactor concepts. Components within this scope include, but are not limited to innovative design for containment, seismic, fuel handling, pumps, safety systems, and instrumentation for both operations and maintenance. The scope of the proposed project should include a thorough viability and applicability assessment of the proposed reactor system, advanced

PROGRAM SUPPORTING: REACTOR CONCEPTS RD&D (~$15.2M)

systems and/or components, a detailed technology gap analysis, and a comprehensive technology development roadmap.

Advanced Energy Conversion (ARC-2) – Development of new energy conversion systems that use advanced technologies or innovative engineering is sought. Supercritical CO_2 shows promise as a working fluid suitable for fast and thermal reactors because of its compatibility with materials and thermodynamic properties. Basic R&D is needed in turbomachinery performance and loss mechanisms. System optimization requires a detailed modeling of the system components and their response to steady-state and off-normal conditions. The university participants could contribute detailed CFD modeling of key components, such as the main compressor, for comparison to one-dimensional system level models and experimental data from ongoing small-scale testing. Alternately, contributions could be made to the development of plant dynamics models and control strategies, including the investigation of alternative cycle layouts (e.g., having turbomachinery on multiple shafts). The efficiency of different power conversion cycles is degraded by leaks at component interfaces. R&D is needed to develop models and/or test beds to predict the performance of seals (labyrinth, dry liftoff seal, brush, etc.) and bearings. Another topic could be projects that explore coupling of the reactor heat source with diverse process heat applications (cogeneration, coal-to-liquids, chemical feedstocks) and/or other energy products with an emphasis on novel approaches that can greatly improve the ease of coupling, the operability of the combined system, and the ultimate economics. The scope of the proposed project should include a thorough viability assessment of the advanced energy conversion system, a detailed technology gap analysis, and a comprehensive technology development roadmap.

Advanced Structural Materials (ARC-3) **–** Development of new materials for advanced reactor systems is being sought for high temperature liquid metal, high temperature molten salt, and other advanced reactor applications. There are several key needs to support this effort.

- The microstructure stability of advanced structural materials must be validated at elevated temperatures and extended lifetimes under irradiation, elevated temperature and/or exposure to coolants. Novel test techniques and approaches to provide long-term performance data on key candidate-alloys and materials are sought. Such tests must be closely coordinated with advanced alloy development efforts in the supporting program.

- Semi-empirical modeling of material aging and irradiation degradation mechanisms need to be developed to predict neutron damage and temperature effects on bulk/macrostructural mechanical properties, including yield strength, creep, fatigue, ductility, etc. Such a model provides a near-term tool for future experiments by allowing interpolation and deeper understanding of the physical data and, in addition, provide a tool for designers to explore different operating conditions while having at least some understanding of the effects on materials performance, but is not expected to be atomic level detail. Such a model should be based on sound materials science and mechanistic understanding.

- In conjunction with the above, the development of validated materials models and methods that lead to accurate continuum simulations of materials response, with appropriate quantitative consideration of uncertainties at every scale are also needed. Targeted research areas include:

PROGRAM SUPPORTING: REACTOR CONCEPTS RD&D (~$15.2M)

- Predictive Models for Material Degradation at Different Scales. Aging and degradation mechanisms of different structural materials under various thermal and irradiation environments need to be better understood, quantified, and validated. Specific needs include (1) Development of atomistic chemical kinetics parameters and upscaling into meso-scale models; (2) Meso-scale models of microstructural and chemical evolution (e.g., phase field, Potts model, kinetic Monte Carlo and rate theory) with extraction of physical parameters for continuum scale materials models; (3) Validated prediction of physical/mechanical property degradation, i.e., thermal conductivity, yield strength, ductility and fracture toughness, creep resistance, etc., to populate continuum scale constitutive models.

- Small-Scale Separate Effects Experiments for Model Validation. Small scale separate effect experiments are needed to validate models for different phenomena at various scales.

- Methodology Development for Scale Bridging. Multi-scale approaches (from atomic-level to meso-scale to continuum, and from picoseconds to years) are needed. New algorithms to achieve upscaling are key components to the development of integrated reactor performance and safety codes.

NUCLEAR ENERGY ADVANCED MODELING AND SIMULATION (NEAMS)

Advanced modeling and simulation has approximately $6M of available funding for projects listed here AS well as scope detailed under the FC-1, FC-6, and ARC-3 areas.

ADVANCED MODELING AND SIMULATION

Modeling and simulation cuts across all other programmatic research areas in this solicitation, and proposals that contain both experimental and modeling work could be considered for funding in more than one area. Proposals that emphasize modeling methodologies and technologies should be submitted in the Advanced Modeling and Simulation category. Proposals that emphasize modeling and simulation related to a specific topical area; those that are more experimental in nature; or those that contain facets of both should be submitted in the appropriate category of the corresponding program and if applicable indicated within the Benefit of Collaboration section.

Development of Phenomena-based Methodology for Uncertainty Quantification (NEAMS-1) – To promote quantitative confidence in the results, explicit consideration of verification of simulation codes, validation of modeling methods and applications, and quantitative assessment of physical and computational uncertainties (VVUQ) is an expected element of all computational and experimental work proposed under this call.   In addition to this routine application of good computational practices, there are needs for targeted university research in methods in data analysis and VVUQ in support of:

- Propagating uncertainties through inter-fidelity multiscale physics models—upscaling. The uncertainty associated with model prediction of material behaviors need to be mathematically propagated through different scales, systematic approaches for managing uncertainties stemming simultaneously from abstraction into reduced (compact) models and in populating parameters in those reduced physics models. Conversely, methods are needed to propagate solutions sensitivities downwards, to identify inadequacies in constitutive model formulations, and prioritize important sub-scale phenomena.
- Evaluating parameter sensitivities and uncertainties in tightly-coupled multi-physics models. Improved methods for efficient evaluation of sensitivities and uncertainties are needed for intra-fidelity simulations of highly coupled, non-linear multiphysics (e.g., thermal-chemical-mechanical) phenomena.
- Interpretation of large experimental data sets. Advanced modeling and computer simulation methods are needed to process and extract information from large data sets obtained from NDE measurements, and to establish the relationships between microstructural evolution and measured properties.
- Design and develop experiments at various scales in quantifying uncertainties for different phenomena to enable model validation of the mathematical uncertainty propagation approach.

***Development of More Efficient Computational Tools (NEAMS-2)* –** Efficient multi-level solvers are needed in the neutronic and thermal hydraulic modeling area of reactor simulation that are better suited for strongly coupled systems of second-order partial differential equations.

MISSION SUPPORTING: “BLUE SKY”

FUEL CYCLE R&D (~$3.7M)

Fuel Cycle R&D (MS-FC) – 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. Proposals should address the technologies and system options that would allow for the sustainable management of used nuclear fuel that is safe, economic, and secure and widely acceptable to American society by 2050. Examples of topics may include revolutionary transmutation concepts, advanced fuel treatment or separations processes, and innovative fuel designs. The program is especially interested in proposals focused on Modified Open Fuel Cycles, as outlined in the Nuclear Energy Research and Development Roadmap.

The development of new and creative approaches to extend uranium resources and potentially transmute actinides from used Light Water Reactor (LWR) used fuel is a key area of interest Areas of interest for the transmutation of waste include, but are not limited to, existing LWRs, other thermal, fast or mixed-spectrum reactors, accelerator driven systems, fission-fusion hybrids, and non-neutron based transmutation concepts which could help minimize the heat load from fission products in used fuel or processed waste.

Extended use of nuclear power may drive improvements in defining resource availability and on fuel resource exploration and mining. 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) using recent developments in nano-science and nano-manufacturing technology to enable technical breakthroughs in developing advanced adsorbent materials with architectures tailored for specific chemical performance; (2) using physical and chemical tools to gain a molecular-scale understanding, characterizing and manipulating of the physical structure, chemical properties, speciation, concentration and distributions of uranium in marine environments; and (3) using modern computing and modeling capabilities to create new uranium adsorbents and separation technology with dramatically improved efficiency, selectivity, and cost-effectiveness.

REACTOR CONCEPTS RD&D (~$3.4M)

Reactor Concepts RD&D (MS-RC) – Identification, investigation and development of revolutionary transformational advanced reactor system concepts and features having the potential to significantly improve performance in sustainability, safety, economics, performance, security or proliferation resistance. Such transformational advanced reactor concepts could include designs employing advanced coolants, fuel configurations and operational characteristics. Concepts could also include small modular reactors with unique capabilities to address operational missions other than the delivery of baseload 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.

MISSION SUPPORTING: "BLUE SKY"

NUCLEAR ENERGY ENABLING TECHNOLOGIES (~$6.9M)

Identification, investigation, research and development of revolutionary technologies in crosscutting areas such as Reactor Materials, Proliferation Risk Assessment, Advanced Sensors and Instrumentation, and Advanced Methods for Manufacturing, having the potential for radical improvement in reactor or fuel cycle performance, safety, and economics. 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.

Reactor Materials (MS-NT1) – Research new classes of materials, not yet developed for use in nuclear reactors, which may enable transformational reactor performance. The custom design of innovative materials using modern materials science techniques, industrial knowledge, and previous experience can improve performance over traditional materials by a factor of five to ten, increasing the maximum operating temperature by 200 degrees Celsius for a period of at least 80 years. Concepts that may be evaluated include optimized alloy composition, engineered microstructures, age-tempered microstructures, or combinations thereof. Other, more radical concepts that may be explored to enable even greater performance include bimetallic layers, metal/ceramic composites, ion-beam or surface-modified alloys. A wide range of operating conditions will be considered, with the general goal of improved strength and radiation and corrosion resistance.

Proliferation and Terrorism Risk Assessment (MS-NT2) – This area will develop new tools and approaches for understanding, limiting, and managing the risks of proliferation and physical security for fuel cycle options. These analytical/predictive tools for comprehensive proliferation risk assessments will provide important information for discussions and decisions regarding fuel cycle options. Research should focus on the following:

- Exploiting science-based approaches for analyzing difficult-to-quantify proliferation and terrorism risk factors or indicators (e.g., capabilities, motivations and intentions); addressing issues identified in several National Academy of Sciences studies related to risk assessment; and leveraging current state-of-the-art academic research in this field.
- Evaluating the diverse decision factors (including economics, public health and safety, public perceptions, environmental benefits and proliferation and terrorism risk reduction) for different fuel cycle options to understand the tradeoffs and potential synergies between these decision criteria.
- Provide tools to study nuclear energy system options and displaying the results in a useful format for decision makers.

Advanced Sensors and Instrumentation (MS-NT3) – The Advanced Sensor and Instrumentation Activity within the Crosscutting Technology Development will conduct necessary R&D on sensors and infrastructure technology to address critical technology gaps to monitor and control new advanced reactors. The key university research needs for that activity are to (1) develop a fundamental understanding of advanced sensors to improve physical measurement accuracy and reduce uncertainty, (2) develop novel adaptive digital monitoring and control technology to provide increases in control system performance and self calibration capability, (3) develop fundamental understanding of integrated control system architectures for multiple reactor module, and (4) develop novel fiber optic and wireless

MISSION SUPPORTING: “BLUE SKY”
digital instrument communication systems. ***Advanced Methods for Manufacturing (MS-NT4)*** – The Advanced Methods for Manufacturing within the Crosscutting Technology Development will conduct necessary R&D to reduce cost and schedule for new nuclear plant construction and make fabrication of nuclear power plants (NPP) components faster and cheaper with better reliability. A parallel intention is to restore the U.S. position as a manufacturer and constructor of NPP designs both domestically and worldwide. Based on past work and new stakeholder input, the program will focus on opportunities that provide simplified, standardized, and labor-saving outcomes for manufacturing and construction. The key university research needs solicited are to develop (1) innovations in seismic design using base isolation systems, (2) modeling and simulation of weld metal solidification, (3) advanced NDE sensors for use on real time welding inspection systems, (4) new formulations in high0strength concrete, and (5) modeling methods for advanced steel plate concrete composite structures.