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 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 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 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.