Institute for Nuclear Energy Science and Technology

2013 LDRD Call

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Summary:

The Institute for Nuclear Energy Science and Technology (INEST) will sponsor and oversee laboratory directed research aligned with the strategies of four Centers of Research and Education (CORE): Fuel Cycle, Nuclear Fuels and Materials, Safety and Licensing, and Space Nuclear Power. Additional information about INEST and the COREs can be found at: https://inlportal.inl.gov/portal/server.pt/community/institute_for_nuclear_energy_science_and_technology/692/home. The criteria to be used in selection of the LDRD proposals are:

Essential

1. Technical merit
2. Develop capabilities supportive of INEST CORE strategies
3. Strengthen collaborations with universities

Additional

4. Attract expertise to INL
5. Encourage student participation

Specific guidance in each area is provided below:

Space Nuclear Power CORE LDRD Call

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Estimated budget $300K for FY2013

Recent re-direction of the NASA strategic plan indicates that interest in nuclear propulsion and power is growing. NASA has recently expressed interest in “game changing” technologies that could radically alter space exploration missions. The CSNR intends to position itself and the INL to be a major participant in the NASA programs should they materialize.

The INEST Space Nuclear Power CORE sponsors and oversees laboratory directed research in the strategic area of advanced space propulsion and power systems that can support both manned and unmanned exploration of our solar system and beyond. Most recently, the Space Nuclear Power CORE has sponsored research under the FY

2010, FY 2011 & FY 2012 Mars Hopper LDRD and the FY 2012 Radioisotope Thermo-photovoltaic (RTPV) LDRD projects. The Mars Hopper LDRD project is developing a thermally capacitive radioisotope fuelled propulsion technology that allows for the long-lived, long-ranged exploration of the surface of Mars via the direct use of the mars atmosphere as a rocket propellant. The RTPV LDRD project is developing combined power conversion and radioisotope heat source technologies that offer significant improvement of the performance of radioisotope power systems that may be scaled from small spacecraft to flagship class mission applications. Both of these projects are developing game changing technologies and mission strategies that will help NASA and its collaborating institutions efficiently gather and enhance science return.

Areas of interest for 2013

The INEST Space Nuclear Power CORE currently seeks proposals for laboratory directed research that address the development of novel power production and/or propulsion system technologies, and the mission architectures that can be augmented by them. Of particular interest are nuclear hybrid and multi-modal concept component technologies and systems that may be used to enhance robotic exploration, human exploration of, or sample return from planetary surfaces. The proposed research should aim to address one or more of these applications. Additionally, it should be shown that upon conclusion, the studies are expected to deliver system or technology concepts that are at or exceed TRL3 such that follow-on funding may be sought from NASA or other industrial institutions.

Goal 1: development of advanced power or propulsion system to support small satellite architecture.

Power systems should have low specific mass or enable missions not currently feasible. Propulsion systems should enable new missions or significantly reduce mission costs. The SNP seeks concepts that make revolutionary changes in the current state of the art. Some examples of concepts are:

1. Radio-fluoro photovoltaic power conversion- inducing fluorescence in a medium that emits light tuned to the PV band gap;
2. Dual mode RTR/REP propulsion to launch small satellites (e.g., the USAF FalconSAT) to the outer planets affordably;
3. Co2 electrolysis to produce fuels for ascent from Mars.

Goal 2: support for a summer fellows program that enables selected students to work at the CSNR for 10 weeks to perform feasibility assessments.

In addition, proposals should include an active student program. Development of game changing technologies can depend on demonstrating that the proposed technology dramatically changes mission characteristics. Past feasibility studies at the CSNR, for example, have shown that the nuclear rocket enables a high performance Mars Sample Return mission, that low specific mass power sources are possible, and that the Hopper concept can be extended to other planetary bodies. Further expansion of the feasibility studies is needed.

Fuel Cycle CORE LDRD Call

Contact: Terry Todd, 526-3365, Terry.Todd@inl.gov

Estimated budget $220K for FY2013

The Fuel Cycle CORE of the Institute for Nuclear Energy Science and Technology (INEST) will help define Idaho National Laboratory's long-term advanced nuclear fuel cycle systems research and development strategic investments in research to maintain its leadership role in fuel cycle research and development. R&D efforts to simplify and reduce processing cost of nuclear processing/recycling technologies or to develop new strategic R&D capabilities at the INL are of interest to the Fuel Cycle CORE. These new advanced separations will potentially reduce processing and disposal costs of used nuclear fuel.

Proposals are encouraged in the following areas:

Development of innovative separation methods to recover actinide elements in a simple, cost effective manner, while reducing waste volumes may significantly enhance the viability of a sustainable nuclear fuel cycle. Additionally, the separation methods must have high stability in the extreme radiation environments encountered in processing used nuclear fuel. Development of single phase separations techniques for the transplutonium elements could possibly simplify used fuel processing and reduce waste volume from used fuel treatment. Utilizing electrochemical methods in aqueous or non-aqueous media may elucidate new technologies that achieve the goal of a single phase processing technique. Additionally, methods to enhance the radiation stability or tolerance of a separation process to create a more robust separation method would potentially open new avenues for the separation of transplutonium elements from used fuel. In addition, research proposals that address new paradigms for nuclear proliferation risk reduction will also be considered for funding.

Because the mission of INEST is looking for long-term solutions (5-10 year window), research proposals should be focused on addressing the feasibility and practicality of new, novel approaches to used fuel treatment, that offer clear potential advantages to current technologies. Research proposals that address incremental improvements in existing technologies are not encouraged. Projects must be led by an INL principal investigator and include an academic partner.

Nuclear Fuels and Materials CORE LDRD Call

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Estimated budget $200K for FY2012

The Institute for Nuclear Energy Science, and Technology, Fuels and Materials Center for Research and Education (INEST F&M CORE) will sponsor and oversee laboratory directed research in the strategic category of uranium dioxide fuel degradation. This new topic area is described below. Additionally proposals will be accepted in the areas of Stress Corrosion Cracking of Austenitic Steels and Zr-alloy metallurgy and performance for applications in light water reactor systems, research areas promoted by the F&M CORE in 2010 and 2011.

The ability of the fuel pellet to remove heat from fission is critical to fuel performance. As fission commences, high-energy fission products initiate damage from both electronic and nuclear interactions, while changing the composition of the fuel while adding new phases and defect structures. The net result of these complex changes in microstructure and microchemistry are a reduction in thermal transport.

The thermo-physical properties of UO_2 are critical to the performance of a nuclear fuel rod. Currently, models of the phonon contribution to such properties typically represent the total thermal conductivity of the UO_2 ceramic, λT, as the sum of three contributions: a phonon-lattice term (λPL), an ambipolar term accounting for small-polaron production at higher temperatures (λAP), and a radiation term (λR), or $\lambda T = \lambda PL + \lambda AP + \lambda R$. Based on empirical data analyses, the primary contribution to the thermal conductivity, λPL, is usually expressed as an inverse linear $(A+BT)-1$ or quadratic $(A+BT+CT^2)-1$ relationship. The inverse linear relation is based on three-phonon scattering processes and the inverse quadratic relation also considers (anharmonic) thermal expansion. The decrease in thermal conductivity is associated with microstructural changes.

The fuels and materials CORE will support projects that push beyond simple models for UO_2 and provide understanding of thermal transport in the more complex materials that form as fission commences and the associated changes in the local microstructure and composition. A workshop on fuels will be planned in May 2012. Projects must be INL led with an academic partner. Preference is made to projects that combine experimental and modeling components. Well-constructed proposals using surrogate materials will also be considered.

Safety and Licensing CORE LDRD Call

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Estimated budget $200K for FY2013

The proposals for this research are to be made by INL researchers in close collaboration with researchers from academic institutions, to identify and pursue innovative research areas. The following are areas of interest, although they should not be considered limiting:

1. Reactor regulation – In the light of the Fukushima accident, major changes are planned in the way that the NRC will regulate the nuclear industry. These

changes include much greater oversight of protection against natural phenomena hazards and beyond design basis accidents. With the support of a Risk Management Task Force, Commissioner Apostolakis has developed the framework for a more risk-informed management process. Further development and implementation of this framework will require innovative technical assistance. It may also provide opportunities for new risk management support tools.

a. Improved approaches to technology neutral regulation, particularly related to the licensing of SMRs
b. Psychology of regulatory decision-making
c. Concept development for tools to support risk management
d. Risk-informing approaches to the regulation of natural phenomena hazards

2. Changes in the risk assessment paradigm – Probabilistic risk assessment in the form of fault-tree, event-tree methodology has been very successful as a means of identifying vulnerabilities in the design of Generation II reactors, on-line real-time support to minimizing the risk of reactor operations, and in focusing regulatory oversight. Improvements are needed in the basic methodology if risk assessment is to continue to support the regulation of nuclear power plants that rely on the performance of passive safety systems and if greater emphasis is to be placed on the risks from natural phenomena hazards.

   a. Treatment of the failure probability of passively safe features including the assessment of uncertainties in natural convection flow.
   b. Identification of low probability events and unknown unknowns
   c. Making the risk assessment more plant specific
   d. Improved methods of human reliability analysis
   e. Development of methods for the assessment of natural phenomena hazard risks
   f. Assessment of the impact of FLEX equipment and facility modifications on nuclear power plant risk, potentially within the context of SPAR models

3. Novel approaches to the validation of advanced simulation tools - There is considerable ongoing effort to develop advanced simulation tools, including tools that will be used for reactor safety analysis. Historically, the validation of safety analysis codes has been addressed in an ad hoc manner with considerable subjective judgment and limited consideration of range of applicability. The challenge for the validation of advanced simulation tools is enormous, particularly when the financial prospects for validation experiments are highly constrained.

   a. The development of approaches to code validation that provide input to the assessment of epistemic uncertainty as a function of plant state.
   b. Bayesian approaches to incorporating code validation results into an expression of code uncertainty.

Nuclear Hybrid Energy Systems CORE LDRD Call

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Estimated budget $250K for FY2013

U.S. energy security objectives (DOE Report on the First Quadrennial Technology Review, September, 2011) highlight the need for lower carbon, domestic energy options for both stationary power generation and transportation systems. In the former, objectives call for deriving 80% of America's electricity from clean-energy sources by 2035, while improving the modularity, scalability, and infrastructure compatibility of clean-electricity-supply technologies and reducing greenhouse gas emissions by 83% by 2050 (from a 2005 baseline). Renewable electric generation and small modular nuclear reactors (SMRs) are each identified as a priority focus for clean power generation, with energy storage for excess power generation specifically mentioned as a need. Transportation system objectives are tied fundamentally to goals of reducing greenhouse gas emissions and reducing the import of oil sources from overseas. Resulting objectives cover multiple pathways, including vehicle efficiency, fuel switching (e.g., electric and hybrid-electric vehicles, natural gas vehicles), biofuels, and synthetic fuels with low life-cycle carbon characteristics. Tangential to these outcomes are objectives to increase domestic manufacturing and export of U.S. manufactured products. Significant barriers to meeting these objectives include:

1. Large scale renewable electric generation can introduce significant intermittency in generation resulting in grid management, stability, and control challenges as well as resource utilization inefficiencies (low capacity factors);
2. Transportation fuels sourced from domestic carbon must have lower life-cycle greenhouse gas emissions than oil-derived fuels; electrification and natural gas vehicle introduction will take many years to fully deploy and will not displace the need for liquid transport fuels; cost effective biofuels production at scale will take much more time and development to realize;
3. Nuclear energy, including SMRs, deployed in present operational paradigms (baseload electricity generation) are fundamentally limited in their ability to impact the broad transportation market and do not enable greater penetration of renewable energy or management of the increasingly dynamic electric grid.

Proposals are thus encouraged in the following areas:

Nuclear Hybrid Design Concepts and Analyses: Proposed nuclear hybrid energy system architecture concepts and related analyses should:

1. Have a reasonable opportunity to produce 5 million barrels per day of liquid transportation fuel (approximately 80% of present oil import derived fuels) or their precursors that are compatible with the present infrastructure;

2. Utilize domestic carbon resources (coal, shale, or biomass-derived);
3. Directly incorporate or enable efficient grid introduction of intermittent renewable electric generation (solar, wind, or geothermal);
4. Demonstrate greenhouse gas emissions reduction for transport fuels and electric generation of greater than 25% from present levels;
5. Demonstrate, via integrated electricity and chemical production, how (3 and 4) above are achieved, how the nuclear island would be configured (number of reactors, grid integration, reactor / chemical plant operation paradigm, etc), sourcing of carbon, and related attributes;
6. Utilize at least 95% of available exergy in the systems via efficient heat and electrical energy integration within the system.

Proposals should address key enabling technology challenges, potential expansion of the SMR market as compared to baseload electric markets, and other attributes. Researchers are encouraged to examine published work on hybrid systems design and attributes (see list of references below).

Temperature Amplifying: Proposals that provide options for and assess implications of boosting the reactor outlet working fluid energy. Concepts are sought that could efficiently and effectively (in terms of cost, greenhouse gas emissions, and practical deployment potential) raise the temperature of a liquid or gas energy carrier from 250°C to 500-800°C (plus) in a manner suitable for use in an industrial process via a hybrid nuclear energy system;

Hydrogen Production via Nuclear Energy: Novel H_2 production techniques that could be integral to systems described in (A) and/or using techniques as called for in (B);

Policy Strategy: Proposals that develop technical and sociopolitical strategies for integrating the disparate technologies and regulatory paradigms associated with complex, integrated nuclear hybrid systems are encouraged. Policy-related proposals should address key non-technical challenges to fielding a nuclear hybrid energy system and should propose research that will allow those challenges to be surmounted in a time and cost-efficient manner.

References: (Contact Richard Boardman 208-526-3083/Richard.Boardman@inl.gov for electronic copies)

DOE Report on the First Quadrennial Technology Review, September, 2011

Energy and Environmental Science, Large HES for Making low CO2 load-following power and synthetic fuels

Energy Policy, Using Excess Electric Generation Capacity to Make Synthetic Fuels at the National Scale

Energy, Multiple Hybrid Energy Systems for Load-Following and Offsetting Renewable Generations Variability

Energy, Dynamic Analysis of Hybrid Energy Systems under Flexible Operations and Variable Renewable Generation

Energy, Development of Multifunctional Energy Systems (MES)

INL/EXT-09-16942, Integration of High Temperature Gas Cooled Reactors into Industrial Process Applications

INL/EXT-11-23008, Integration of High Temperature Gas Cooled Reactors into Selected Industrial Process Applications

LBNL-1248E, Advanced Coal Wind Hybird: Economic Analysis

ICAPP 2012, A Nuclear Wind/Solar Oil-Shale System for Variable Electricity and Liquid Fuels Production