INL/EXT-17-41224

LDRD Strategic R&D Fund – Fiscal Year 2018 Research Priorities

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February 2017

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Laboratory Directed Research and Development Program

LDRD Strategic R&D Fund – Fiscal Year 2018 Research Priorities

Introduction

Our core mission at Idaho National Laboratory (INL) is to discover, demonstrate, and secure innovative nuclear energy solutions, other clean energy options, and critical infrastructure. Achieving mission objectives and outcomes executes INL's vision to change the world's energy future and secure our critical infrastructure to address the Department of Energy's (DOE's) critical missions in scientific discovery and innovation, clean energy, and global security and, in doing so, expand the nation's economic opportunities. INL's ability to achieve its vision depends on the integration and application of our core capabilities in use-inspired basic and applied research and world-class capabilities. We align INL's broad range of research capabilities with the goal of providing world leadership in nuclear research, development, demonstration, and deployment (RDD&D); providing clean energy systems integration and demonstration and complementary environmental solutions at-scale; and developing and deploying critical national and homeland security capabilities and solutions.

INL is focused on high-impact outcomes; we are in the process of modernizing and enhancing INL's core capabilities and recruiting some of the world's top science and technology (S&T) talents. INL's Annual Laboratory Plan is used to communicate to DOE the status of INL's core capabilities and our focus on strategic S&T initiatives for the future. Senior leadership and management have committed to following the Laboratory Agenda, which includes goals and milestones for our strategic initiatives.[a] Fiscal Year (FY) 2018 discretionary investment is, therefore, being made available to strengthen INL's core capabilities and to further integrate and apply our strengths in use-inspired basic and applied research and development (R&D) to accomplish our mission and achieve our critical outcomes.

The objectives of the LDRD program are to (1) maintain INL's scientific and technical vitality; (2) enhance INL's ability to address current and future DOE missions; (3) foster creativity and stimulate exploration of forefront areas of S&T; (4) serve as a proving ground for new R&D concepts; and (5) support high-risk, potentially high-value R&D.

In FY 2018, the LDRD Strategic R&D Fund will be used to encourage INL's research staff to develop proposals focused on these objectives as they pertain to advancing the FY 2017 Laboratory Agenda[a] and to enhance our distinctive capabilities that will extend our core capabilities[b] and advance outcomes and achievement in the following three areas:

1. ***Advance nuclear energy:*** The strategic intent is to advance nuclear energy competitiveness and leadership and develop integrated nuclear fuel cycle solutions while advancing INL's nuclear science and technology (NS&T) computational and experimental capabilities.
2. ***Energy and environment technology innovations and integration:*** The strategic intent is to: (1) provide at-scale energy system RDD&D and complementary environmental solutions and (2) accelerate the pace of innovation for energy technologies through focus on key research areas, synergistic offerings, and strategic partnerships.
3. ***Advancing Critical National and Homeland Security:*** The strategic intent is to deliver cyber-physical innovations to solve urgent national challenges in control systems and infrastructure security; ensure the peaceful use of nuclear energy technology through innovations in

a. See INL's FY 2017 Laboratory Agenda (Draft).

b. See Core Capabilities list.

nonproliferation technologies; and provide advanced technologies that enable preparation for superior military and emergency response.

Proposals should focus on transformative and/or breakthrough science and technologies that lead to impacts aligned with the success of DOE's and INL's strategic plans. Proposals should discuss (1) new knowledge and innovations and how they extend the current state of the art, (2) approaches to communicating new knowledge and innovations (peer-reviewed publications, conferences, Intellectual Property, industry groups, etc.); (3) collaborations (university, industry, other national laboratories) and how they will enhance knowledge, leverage capabilities, and provide the foundation for building future programs; and (4) critical science and engineering skills development through engaging undergraduates, M.S. and Ph.D. candidates, and postdocs. Proposals may also identify follow-on funding or, more generally, the S&T and business strategy that will continue and expand the work beyond the LDRD funding.

Employees interested in responding to this call are encouraged to contact the identified point of contact or Mission Area Point of Contact (MAPOC) for the areas they are interested in. These individuals can provide guidance for tailoring proposals to best meet the needs of the focus area.

Applicants should be aware of the potential for RDD&D concepts to be classified or export controlled. To address any potential classification concerns for the information within a proposal, an INL proposal team lead should contact an appropriate derivative classifier prior to preparing a proposal. As necessary, INL's National & Homeland Security Division has systems available for preparing classified proposals to enable cleared INL staff to directly emphasize potential classified requirements, applications, or potential users. Examples of potential classified topics include, but are not limited to: design or manufacturing processes related to nuclear weapons, radiological dispersal devices, improvised nuclear devices or other weapons of mass destruction; specific vulnerabilities or consequences from kinetic or non-kinetic attacks on critical infrastructure or strategic systems; armor designs when related to defeating specific blast or ballistic threats; vulnerabilities or material diversion pathways related treaty verification processes or safeguards systems; and specific descriptions of counterterrorism requirements, applications, or systems.

Partnerships with universities, industry, and other national laboratories are encouraged. When a proposal includes university students, the lead applicant should plan for, and encourage, these students spend a period of time at INL to coordinate/collaborate with the INL researchers. Lead applicants are encouraged to consider investments in postdocs as much as feasible and reasonable.

The format for Director's R&D Fund proposals and the procedure[c] for submittal are described on the LDRD Program website. Questions related to these aspects should be addressed to Rekha Pillai, Director of Strategic Planning and Investment (526-1378, Rekha.Pillai@inl.gov).

c. Note: Publications and reports are expected and important outputs of LDRD investments. This output is managed, tracked, measured, and reported to DOE and also used to evaluate performance. To improve the S&T measures and quality, principal investigators (PIs) and co-PIs (internal and collaborators) are expected to include their Open Researcher and Contributor Identification (ORCID) as part of their LDRD proposal package. ORCID will be used to track and report publications. The Laboratory Overhead Investment – Electronic Submission System (LOI-ESS) will automatically pull ORCID data from INL's Human Resources system if PIs and co-PIs are in the INL system. For external proposal collaborators, PIs should obtain an ORCID and enter this in the LOI-ESS to complete the proposal submission process. Exceptions to this requirement may be obtained for classified LDRD project PIs and Co-PIs.

1. Delivering the Nation's Nuclear Science and Technology Laboratory

Proposals are sought in priority areas that support the following strategic initiative areas:

1. Nuclear Energy Competitiveness and Leadership
2. Integrated Nuclear Fuel Cycle Solutions
3. Core Capabilities to Support Current and Future Missions.

The LDRD Program offers an invaluable opportunity to support innovation, exploration of new ideas and concepts, and investment in our future. Hence, proposals focused on discovery, development, and demonstration of transformative nuclear S&T and the corresponding advancement of INL's nuclear computational and experimental capabilities are of particular interest. Proposed projects should utilize INL's core capabilities in nuclear systems analysis, design, and safety; nuclear fuels and materials; fuel cycle technologies; and computational engineering. As applicable, proposed projects should also fully leverage INL's unique experimental and computational facilities and capabilities. Proposals that combine theory development, experimentation, and modeling and simulation (M&S) into a unified approach to address key technical challenges are strongly encouraged. Proposals involving M&S should use the MOOSE framework to the extent applicable and possible.

The DOE Office of Nuclear Energy mission is to advance nuclear energy as a resource capable of meeting the nation's energy, environmental, and national security needs by resolving technical, cost, safety, proliferation-risk, and security barriers through research, development, and demonstration (RD&D). In support of the DOE mission, INL has established strategic initiatives to accelerate deployment of advanced nuclear energy technologies and advance technologies to address nuclear waste management and disposition.

In support of the DOE and INL missions and strategic initiatives, high-quality proposals are sought in the following NS&T initiative areas. Principal investigators (PIs) are encouraged to contact the technical point of contact designated after each area for additional information and/or clarification.

Mission Area Points of Contact:
John Wagner, 208-533-7977, john.wagner@inl.gov, Nuclear Science and Technology
David Schoonen, 208-533-4887, david.schoonen@inl.gov, Advance Test Reactor
Mitchell Meyer, 208-533-7155, mitchell.meyer@inl.gov, Materials and Fuels Complex

1.1 FY 2018 LDRD Initiatives

1.1.1 Nuclear Energy Competitiveness and Leadership

1.1.1.1 Transformational Nuclear Reactor Concepts and Technologies

This category supports INL's nuclear energy leadership role in the area of nuclear reactor engineering and concept development to ensure safe, reliable, and higher economic performance of existing and future nuclear reactors and to accelerate deployment of advanced systems and technologies. Novel ideas, technologies, concepts, and capabilities that support INL leadership in addressing the current and future commercial viability of nuclear energy systems are of particular interest.

Possible topics include new and novel reactor concepts that have the potential to dramatically reduce the capital and operating costs of future reactors. This includes topics that advance small modular reactors, advanced reactors, and "micro" or Mega Watt-class (MW-class) reactors. Also of interest are transformational materials development and enhancements to existing concepts and designs, such as development and demonstration of new fuels and structural and cladding materials that enable substantially improved fuel utilization and reduced cost through very-long-operation reactor cores in

advanced nuclear energy systems; technologies that enable passive safety in existing reactors; improved integration and utilization of current and future reactors within a diverse and evolving national energy mix; development and demonstration of means to monitor the in-service condition of safety-significant reactor materials and components that can be relied on for early detection of failures and substantially reduce maintenance and inspection frequency and cost; and technologies that reduce the cost, schedule, uncertainties, and/or risk associated with deployment of new reactors. Innovative concepts that include cost and risk reduction in the balance of plant cost of deployment and design strategies, including modular fabrication and construction, are encouraged.

Points of Contact:
Phil Sharpe, 208-526-5985, phil.sharpe@inl.gov
David Petti, 208-526-7735, david.petti@inl.gov
Hans Gougar, 208-526-1314, hans.gougar@inl.gov

1.1.1.2 Transformational Approaches to Accelerate RDD&D

Fuels and materials irradiation, post-irradiation examination (PIE), out-of-pile testing, theory development, and advanced M&S capabilities are key to INL's role in advancing nuclear energy. Despite the incredible scientific advances of the past several decades in both computing and measurement resources and capabilities, the long time durations and substantial costs and uncertainties associated with developing and licensing new nuclear fuels, materials, and technologies stifle innovation and deployment.

Proposals exploring ways to substantially reduce the time, cost, and uncertainty for developing and qualifying new nuclear fuels, materials, and technologies are requested. Topics of interest include, but are not limited to, advanced instrumentation; innovative approaches and capabilities for reducing requirements and irradiation times; novel approaches for reducing time needed for PIE; new approaches for collecting and processing experimental data; and integration of theory development, M&S, and experimental research efforts to improve RDD&D efficiency and outcomes.

Proposals that address grand challenges are of particular interest, such as reducing the development and qualification timeline for new nuclear fuels and materials to less than 10 years, developing and demonstrating a means to achieve hundreds of displacements per atom per year that is relevant/applicable to nuclear fission systems, and reducing the time required for PIE by a factor of 10 or more. Additionally, proposals that would position INL to lead a national, collaborative initiative to address these grand challenges through a combination of some or all of the topics listed above is of high interest.

Points of Contact:
Mitch Meyer, 208-533-7155, mitchell.meyer@inl.gov
Steven Hayes, 208-526-7255, steven.hayes@inl.gov
Rita Baranwal, 208-526-3256, rita.baranwal@inl.gov

1.1.1.3 Blue Sky: Advancing Nuclear Energy

Proposals for other innovative, high-risk, potentially high-value R&D that is not covered above but would support nuclear science and technology and further the INL mission and strategic objectives are encouraged. Of particular interest are disruptive methods, technologies, and concepts that could transform the state of the art and/or knowledge in nuclear energy RDD&D.

Point of Contact:
David Petti, 208-526-7735, david.petti@inl.gov

1.1.2 Integrated Nuclear Fuel Cycle Technologies and Solutions

Addressing the current and future inventory of civilian and defense-related spent nuclear fuel (SNF) and high-level radioactive waste (HLW) is essential to the continued viability and long-term sustainability of nuclear energy.

Proposals are sought that support INL leadership in developing and demonstrating integrated nuclear fuel cycle solutions. Proposal may include topics related to long-term storage, transportation, and disposal of SNF and HLW, integration of the waste management system, and improved material utilization, recovery, and waste forms. Topics of interest include, but are not limited to: fundamental research and laboratory-scale demonstrations in support of safe and economic processes for recovery of SNF for reuse in next-generation reactors and fuel cycle systems; this includes development of technology that allows the use of Experimental Breeder Reactor II spent fuel treatment product to fuel a future test or demonstration reactor; research that supports improved understanding and characterization of SNF and canister integrity during extended storage periods and transportation; advanced monitoring techniques and systems that support SNF safety and safeguards objectives; and concepts and technologies that support improved integration of the waste management system. Additionally, proposals that would advance INL leadership relative to fundamental understanding and demonstration of salt properties, chemistry, and processes for molten salt reactors are of interest.

Point of Contact:
Terry Todd, 208-526-3365, terry.todd@inl.gov

1.1.3 Core Capabilities to Support Current and Future Missions

1.1.3.1 Advanced Manufacturing

Advanced manufacturing has great, yet unproven, potential for nuclear energy applications, e.g., the potential to expand design space by fabricating components with characteristics that are not currently possible or are prohibitively difficult to achieve, improve quality and predictability of nuclear-grade components, and reduce cost. For nuclear fuel, it may be possible to optimize fuel performance through varying enrichment, burnable neutron absorbers, and/or thermal conducting material within the fuel pellet in ways that are not currently possible. For nuclear materials, it may be possible to systematically control and manipulate material compositions and microstructure, perhaps even building materials at the atomic level. Fabrication of functionally graded material to eliminate the need for dissimilar metal welds in nuclear power plant components is also an interesting prospect. However, numerous and significant research challenges must be overcome to develop and qualify such capabilities and materials for nuclear applications.

Proposals are sought that position INL in a leadership role in the field of advanced manufacturing for nuclear energy applications. Topics of interest include development and demonstration of advanced manufacturing techniques for nuclear fuels, materials, and embedded sensors; approaches to optimize manufacturing; improved understanding of the implications for current and future nuclear systems; characterization and performance in nuclear environments; novel inspection techniques for complex components, and approaches to qualifying and licensing materials from advanced manufacturing processes.

Points of Contact:
John Jackson, 208-526-0293, john.jackson@inl.gov
Robert Mariani, 208-526-7826, robert.mariani@inl.gov
Gabriel Ilevbare, 208-526-3735, gabriel.ilevbare@inl.gov

1.1.3.2 Modeling and Simulation

Combining M&S with experiments into a unified approach to NS&T RDD&D will enhance both simulation and experimental capabilities and improve RDD&D efficiency and outcomes. Performing high-resolution simulations *before* the experiment is conducted gives the experimentalists insight as to where and what measurements need to be performed and possibly how they should be performed. An advanced simulation capability *will provide a simulation-based confidence in the experimental programs*. During the past several years, INL has made significant progress in regards to developing "world class" M&S capabilities and is now a leader in advanced, multi-physics M&S for nuclear energy applications. Combining these M&S capabilities with INL's leading experimental capabilities—e.g., the Advanced Test Reactor (ATR), Transient Reactor Test Facility (TREAT), and Materials and Fuels Complex—provides unique opportunities to enhance the safety, utilization, and science impact of those facilities while supporting the goals of developing and demonstrating predictive M&S capabilities.

Proposals are sought to maintain and expand INL leadership in nuclear M&S, through securing enduring leadership in existing areas, expanding capabilities relevant to emerging opportunities, adapting and/or expanding capabilities relevant to future computing architectures, and influencing change in the current regulatory paradigm through the demonstration of predictive M&S capabilities. Topics of interest include development and application of predictive M&S capabilities to address key challenges related to the performance, safety, and economics of current and future nuclear energy systems; design and safety of experiments and experimental facilities; advanced manufacturing; and advanced fuel cycle systems and facilities. Advanced methods and approaches for uncertainty quantification and multi-physics validation are also of interested. Additionally, proposals that would position INL to lead a national, collaborative initiative to establish M&S capabilities that change the nuclear systems design and regulation paradigm from reliance on measured data to reliance on simulations with limited new experimental data for confirmatory purposes are of high interest.

Points of Contact:
Richard Martineau, 208-526-2938, richard.martineau@inl.gov
Jason Hales, 208-526-2293, jason.hales@inl.gov
Mark DeHart, 208-526-1279, mark.dehart@inl.gov

1.1.3.3 Nuclear Experimental Capabilities

State-of-the-art nuclear experimental facilities and capabilities are essential to INL leadership in nuclear energy RDD&D, as well as the success of the Gateway for Accelerated Innovation in Nuclear (GAIN) and the Nuclear Science User Facilities (NSUF).

Proposals are sought that advance the state of the art and support INL's continued leadership in this area. Topics of interest include: advanced instrumentation that allows in-reactor measurements that expand the types of data being measured and improve the quality of the irradiation data obtained to improve understanding and reduce the time and cost associated with irradiation and PIE cycles for materials and fuels); advanced material science instrumentation and techniques for radioactive and highly radioactive materials to support computational model development and validation; and advanced techniques to improve post-irradiation data quality and throughput. Proposals that combine experimentation and M&S into a unified approach are strongly encouraged, and many of the topics of interest in this area support the Transformational Approaches to Accelerate RDD&D area.

Proposals for advanced PIE capabilities should address deficiencies in current capabilities and/or challenges associated with testing of large numbers of highly irradiated samples. Proposals for in-reactor studies should address the development of compact, radiation-resistant sensors and multi-use in-pile standardized irradiation test vehicles intended to reduce the cost and effort of performing irradiation tests for fuels and materials. Phenomena of interest include dimensional changes, material mechanical response to mechanical load (force, elastic strain, and creep strain), thermal transport, microstructure

evolution, crack propagation in materials, and fission gas release, analysis, and pressure. Development of practical techniques that are non-intrusive with respect to irradiation specimens is encouraged, as are proposals that determine the feasibility and practical use of non-traditional methods such as optical fibers, acoustic and ultrasonic techniques, laser based techniques, and, specifically for in-reactor environment, wireless transmission techniques.

Points of Contact:
Rory Kennedy, 208-526-5522, rory.kennedy@inl.gov
John Jackson, 208-526-0293, john.jackson@inl.gov
Mitchell Meyer, 208-533-7155, mitchell.meyer@inl.gov

1.1.3.4 Transient Testing

Transient testing of nuclear fuels is needed to improve fundamental understanding and to develop and prove the safety basis for advanced reactors and fuels; the restart of TREAT in 2018 will provide a unique research capability at INL.

Proposals are sought that fully realize the potential of this capability to address fundamental science questions and challenges related to nuclear fuel performance and qualification. Proposals that expand upon separate effects testing capability that will drive understanding of the dynamic thermal/mechanical response of fuel during transient irradiation, microstructural response of fuel to irradiation, in-situ thermal physical and mechanical properties of materials under irradiation, and radionuclide transport are of particular interest. This research will require continued enhancement of TREAT capabilities, such as technologies for real-time in situ monitoring of experiments, including fuel motion monitoring and visualization, novel instrumentation and approaches to support separate effects testing (e.g., transient pressure transducers, fast response temperature indicators, acoustic sensors, optical technologies, and fission product measurement), and development and validation of multi-physics M&S capabilities that can be used to design complex transient experiments.

Point of Contact:
Dan Wachs, 208-526-6363, daniel.wachs@inl.gov
Steven Hayes, 208-526-7255, steven.hayes@inl.gov,

1.1.3.5 Methods, Tools, and Concepts for Utilizing of Existing INL Reactors and Other Experimental Facilities

Innovative research is invited on topics that would encourage novel use and leveraging of INL reactors and major experimental facilities (e.g., the Neutron Radiography Reactor, TREAT, ATR, ATR-Critical, Safety and Tritium Applied Research (STAR), Hot Fuel Examination Facility, Irradiated Materials Characterization Laboratory, etc.). Ideas that are sought may range from the development of methods for experiment planning and analysis, to the assimilation of data, to the characterization of the facilities (e.g., spectra and damage function determination) that enhance INL's ability to address current and future DOE/National Nuclear Security Administration missions. Limited experimental activities may be considered if they are aimed at the goals stated above.

Points of Contact:
Gilles Youinou, 208-526-1049, gilles.youinou@inl.gov,
David Schoonen, 208-533-4887, david.schoonen@inl.gov
Heather Chichester, 208-533-7025, heather.chichester@inl.gov

1.1.3.6 Advanced Safety and Regulatory Research

Proposals are sought for development and demonstration of risk-informed and cost-informed methodologies for probabilistic risk assessment (PRA), human factors, and human reliability analysis (HRA) associated with advancing reactor safety and licensing. This includes enhanced PRA/HRA modeling and quantification methods, techniques that address risk management and the regulatory

framework, and cutting-edge online monitoring tools in support of real-time living PRA models. Also of interest are innovative techniques to measure, predict, and enhance human performance to enable advanced technologies in the nuclear industry. This includes the development and application of new human/machine interface technologies to support control room design for modernization of existing designs and support for advanced reactor concepts. Successful proposals will clearly show the potential major impacts of new methods/technologies on the safety, economics, and regulatory framework for current and/or advanced reactors.

Points of Contact:
Martin Sattison, 208-526-9626, martin.sattison@inl.gov,
Phil Sharpe, 208-526-5985, phil.sharpe@inl.gov

2. Energy and Environment Technology Innovations and Integration

The strategic intent is to (1) provide at-scale energy system RDD&D and complementary environmental solutions and (2) accelerate the pace of innovation for energy technologies through focus on key research areas, synergistic offerings, and strategic partnerships, including emphasis on regionally relevant technology innovation and impact.

The objective of investment in projects in this area is to strengthen INL RDD&D and core competencies around energy and environmental systems innovation and integration with the following expected outcomes:

- Enable and expand innovative energy technology by leveraging INL, private sector, and academic capabilities.
- Advance synergistic, integrated, and environmentally sound energy solutions, including applications relevant to advancing nuclear energy, fossil energy, renewable energy, and alternative transportation.
- Expand U.S. leadership, job creation, and influence in global energy markets by leveraging regional energy technology partnerships and regional energy deployment for global markets.
- Maintain INL's unique scientific and technical capabilities to sustain its competitiveness.

PIs are encouraged to contact the technical point(s) of contact designated at the end of the subsequent subsections for additional information and to obtain answers to questions about the technical area.

Mission Area Points of Contact:
Anita Gianotto, 208-526-0551, anita.gianotto@inl.gov
Richard Hess, 208-526-0115, jrichard.hess@inl.gov

2.1 FY 2018 LDRD Initiatives

In support of advancing energy and environment technology innovation and integration, this portion of the FY 2018 LDRD call focuses on the following initiatives: (1) hybrid energy systems; (2) advanced energy integration; (3) advanced manufacturing; and (4) chemical, biological, and environmental impacts and threats.

2.1.1 Hybrid Energy Systems

Achieving the full value of nuclear energy requires coupling of the grid and industrial manufacturing via heat and electricity with carbon resources, including CO_2, biomass, coal, natural gas, and other petroleum resources. This is a paradigm shift, enabling fission-generated radiation and heat to drive industrial processes in addition to reliably generating electricity in decentralized, hybrid energy systems. The realization of functional hybrid energy systems will require S&T advances in (1) integrated, hybrid thermal/electrical generation configurations;(2) advanced industrial processes that utilize nuclear and other non-carbon energy resources as the primary energy source, and (3) revolutionary concepts in materials design that incorporate new understandings of processes that are initiated and propagated using radiation, heat, and electricity. In accordance with INL's mission in advancing the value and benefit of nuclear energy, proposals are sought that foster creativity and stimulate exploration to:

- Advance processes integrating nuclear energy and carbon resources (e.g., CO_2, biomass, coal, natural gas, petroleum) to produce higher-market-value products, including fuels, chemicals, and materials. Examples include, but are not limited to, technologies that hybridize nuclear energy generation (direct radiation, heat, electricity) with coal/biomass combustion to produce electricity and other higher-value, carbon-based energy products.

- Advance natural gas reforming and hydrogen product by substituting natural gas combustion with nuclear energy heat and electrical energy inputs.
- Advance knowledge and R&D concepts by proof-of-principle testing of methods and protocols for nuclear-energy-coupled, process-intensification technologies, including, but not limited to, alkane activation and de-hydrogenation at reduced temperatures; co-electrolysis in solid oxide electrolysis cells; non-thermal plasma dry reforming with CO_2; electrochemical alkene and hydrogen production with proton conducting electrolytes, etc.

Points of Contact:
Richard Boardman, 208-526-3083, richard.boardman@inl.gov
Richard Hess, 208-526-0115, jrichard.hess@inl.gov

2.1.2 Advanced Energy Integration

Advanced energy integration (i.e., dynamic reconfiguration systems and high-energy advanced technologies) is the main driver of growth for scientific research in mitigating risk in the design and operation of power and energy systems, including connected and automated vehicle systems. To maintain energy security and resiliency while coordinating several modern technologies in a power system, a robust scientific approach is essential for dynamic and transient testing of systems.

The focus of proposal ideas in this initiative should be on combining various approaches (such as the use of real-time, hardware-in-the-loop experiments), advancing data sciences, and pushing the state-of-the-art applications (such as faster-than-real-time simulations, survivability). Developing longer-term strategic collaborations for sharing intellectual and hardware capital among laboratories and universities through data connectivity will be an enabler for accelerated progress. INL has established itself strongly in the domains of electric grid research focused at the distribution level, including the impact of vehicle connectivity and automation. This work should continue to be supplemented with cutting-edge ideas and also leveraged into adjacent uses, such as mobile systems and fixed infrastructure. One such adjacent use is organized under the High Energy Advanced Technology (HEAT) Lab initiative, which focuses on resolving power and thermal constraints when integrating pulsed power systems onto military mobile platforms.

R&D proposals are requested in the following areas:

- Innovations/proof-of-principle tools, techniques, and demonstrations for establishing integrated national and defense laboratory systems for cutting-edge research in the areas of advanced power, pulse load, thermal management, directed energy, and high-energy systems
- Innovations in high-performance-computing-based, advanced control systems and predictive analytics techniques for reconfigurable power system dynamics and transient simulations
- Innovations and proof-of principle tests that explore combining testing program protocols and advanced data analytics (i.e., advance data sciences) to model, analyze, and improve performance in the next generation of advanced power systems, energy storage, and transportation systems
- Innovations/proof-of-principle tools, techniques, and demonstrations to advance transmission grid protection systems for coordinated design and operation with distribution grids.

Previous INL collaborations with other DOE national laboratories and universities have enabled the development of new capabilities. The applications in the abovementioned areas are expected to achieve similar goals, extending the present knowledge and capabilities in power and transportation systems and enabling new high-impact RDD&D.

Points of Contact:
Rob Hovsapian, 208-526-8217, rob.hovsapian@inl.gov
Dan Herway, 208-526-2362, dan.herway@inl.gov

2.1.3 Advanced Manufacturing

Advancements in manufacturing technologies is essential to ensure US competitiveness now and well into the future. Over the past several years, INL has made significant advances in this technology area including a) advanced catalysis synthesis; b) recycle/reuse technologies and c) chemical separations. This has helped solidify INL's position and enhanced INL's capabilities and offerings in industrial water cleanup/separations, critical materials recover, recycle and reuse of waste stream resources and advance catalysis systems for industrial process intensification. Going forward, there is significant opportunity and cross-cutting programmatic need to deepen INL's capabilities in advanced materials to be consumed in manufacturing (e.g., light weighting, advance material properties for challenging applications, etc.) and advanced materials for manufacturing processes (e.g., "smart materials", resilient materials, etc.).

To strengthen INL's advanced manufacturing capabilities and technologies offerings, including fundamental science offerings, proposals that provide innovations to existing capabilities and proof-of-principle tools, techniques, and demonstrations are being sought for:

- Exploration of smart materials for harsh or demanding environments,
- Testing of processes, controls and predictive tools, that result in efficient component manufacture for harsh or demanding systems and environments,
- Experiments and analysis that offer advances in light weighting, including advanced metallic materials and processes that join composite materials, including carbon fiber.

Proposed work should provide a foundation to better pursue opportunities in basic science areas. Collaborations with academic entities and the use of postdoctoral candidates or interns are highly encouraged for the purpose of strengthening INL's personnel and partnership capabilities in this technology area.

Point-of-Contact:
Gabriel Ilevbare, 208-526-3735, gabriel.ilevbare@inl.gov
Richard Hess, 208-526-0115, jrichard.hess@inl.gov

2.1.4 Chemical, Biological, and Environmental Impacts and Threats

There is a growing need within the Nation to address large scale environmental issues including, protection from potential chemical and biological threats. The ability to detect and characterize biological and chemical contaminants (e.g., industrial chemicals, toxic metal in drinking water, chemical agents in an airport) at low environmental concentrations is a priority both to counter deliberate acts and unintentional accidents. Specifically, sensing, prevention and remediation technologies are needed that can detect, mitigate and recover from contamination events that pose significant potential for human, environmental and economic loss. Currently the sensing of biological and chemical contaminants utilize obsolete collection and characterization methods that result in significant response, mitigation and recovery delays. To provide improved response times for responders, enhanced methods for rapid screening, detection, and hazard mitigation is essential. Additionally, there are critical capability gaps that would otherwise provide decision makers needed data and options to improve resiliency, optimize responses, improve remediation and minimize losses.

R&D proposal ideas are sought to:

- Advance the state-of-the art in chemical and biological sensing, including both collection and speciation at low concentrations.
- Test proof-of-principle concepts of rapid screening techniques to discrimination between target contaminants and background materials.
- Develop and test novel sorbents that provide more effective capture of targeted contaminants.
- Develop and test novel methods that combine multiple sensing approaches into a broad spectrum analysis.
- Test systems design approaches that result in coordinating multiple data sets into a tool suitable for actionable decision making.

Proposals that leverage one or more existing INL program capabilities to address chemical, biological and environmental impacts and threats are strongly encouraged (e.g., SCADA, GIS tools/capabilities, risk and threat assessment, decision science and analysis, etc.).

Point-of-Contact:
Frederick Stewart, 208-526-8594, frederick.stewart@inl.gov
Garold Gresham, 208-526-6684, garold.gresham@inl.gov

2.1.5 Blue Sky: Energy and Environment Technology Innovation and Integration

Proposals for other innovative research not covered above supporting energy and environment technology innovations and integration that would further the INL mission are encouraged. We seek proposals that describe discovery science or proof-of-principle experimentation that will serve as the foundation for future initiatives and programs.

Point of Contact:
Anita Gianotto, 208-526-0551, anita.gianotto@inl.gov

3. Critical National and Homeland Security Capabilities – RDD&D Priorities

INL secures critical infrastructure and ensures the peaceful use of nuclear technology through discovery of scientific knowledge, innovations in engineering, and deployment of advanced technologies. INL conducts LDRD with the objective to build the science foundation that enables achievement of the national security objectives of the DOE, National Nuclear Security Administration, U.S. Department of Defense, Department of Homeland Security, and public safety/emergency response organizations. LDRD outcomes will lead to a positive impact on the growth and security of the U.S. economy, energy supply, and critical infrastructure. LDRD priorities within this section of the call are derived from national objectives for research in the protection of critical infrastructure; nuclear nonproliferation and the elimination of threats from terrorism and other weapons of mass destruction; and advancement in force-multiplying capabilities for our military and emergency responders.

INL is a globally recognized major center for national security technology development and demonstration utilizing multidisciplinary teams; industrial-scale test beds; and secure-grid, wireless, cybersecurity, and nuclear/radiological ranges and facilities. Our mission-relevant technology RDD&D include:

- Protection of national and international critical infrastructure through RDD&D of transformational technologies focused on industrial control systems cybersecurity, wireless communications, grid reliability and security, and physical security
- Achievement of national objectives for reduction of threats from weapons of mass destruction and terrorism through RDD&D of transformational technologies focused on nuclear nonproliferation, nuclear and radiological material safeguarding, nuclear energy cybersecurity, and emergency response
- Creation of solutions applicable to immediate and long-term capability requirements that evolve from military, law-enforcement, and public-safety organizations.

LDRD proposals within this area should describe innovative concepts and experimentation that develops and demonstrates the proof of principle of transformational technology and describe ‘what success will look like.’

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3.1 FY 2018 LDRD Initiatives for Critical National and Homeland Security Capabilities – RDD&D

3.1.1 Control Systems Cybersecurity

The vision of the Center is to lead the global transformation of cyber-informed science and engineering as applied to control systems in critical infrastructure. Cybercore’s three-fold mission is to:

- Create a research park unifying INL and national resources toward solving urgent national challenges in control-systems and infrastructure security
- Provide a holistic approach to enable people, partnerships, and innovative technologies and methodologies to ensure progress on difficult challenges across multiple agency missions
- Facilitate the development of a talent pipeline for unique and exciting interdisciplinary domains within cybersecurity.

Cybercore's research vision is to fundamentally re-engineer control systems that, under cyberattack, are designed to be resilient for critical functions, to provide situational awareness of the presence of adversaries, to autonomously mitigate adversarial effects, and to be restored to safe and trusted operation. Cybercore, founded on the fundamental science and engineering of secured cyber-physical systems, is the key to the next several decades of automation and interconnected lifestyles. New cyber-informed engineering methods based on the science of physical effects are needed to ensure resilience response and prevent high-consequence failures in mission-critical infrastructure, platforms, and functions. Any digital system can ultimately be "hacked" by a persistent adversary, and the effects are only bounded by the physical process limits of the programmable device, interdependencies between devices and systems, and the creativity of the attacker and defenders. Without science-based, systematic re-engineering, many approaches deployed or under development based on information technology are not applicable to cyber-physical systems. A new engineering design basis that bounds this digital complexity opens the door for broader innovation in both the physical process components and the digital technology systems.

One set of solutions could include creation of digital disruption zones that purposely limit the functionality of the device or system to only those modes required by the physical process. The challenge is developing innovative technologies, with verifiable methods, which implement performance limits at the engineering design phase of a physical process. When applicable, these technologies need to scale to a variety of applications (electrical, chemical, gas/fluid flow, mechanical, nuclear, etc.,) and a variety of isolated and integrated configurations (i.e., different implementations on energy facilities, chemical plants, etc.). Successful deployment of solutions to this challenge will require deeper understanding of fundamental interactions across traditionally different physical, behavioral, and digital systems-science disciplines; successful deployment of solutions will also require the modeling and simulation of complex systems to identify and predict digitally induced physical effects and their risks against multiple isolated, sequenced, or simultaneous cyber or physical phenomena.

Another set of solutions is based on creating resilience in components and systems—engineering the integration of intelligent technology and modifying design basis and/or operations to prevent catastrophic impact. Technology solutions may be achieved by developing new forms of "cyber state awareness" in control systems and new systems that are immune to, or limit, the effects of malicious digital components. The operational solutions may be achieved with holistic engineering practices to remove unacceptable cyber consequences and institutionalizing the processes for detection and response to anomalies. Currently, there is no consistent set of methods, technologies, or tools with the scientific or systematic basis to achieve cost-effective, resilient, and reliable end states.

Finally, to prioritize research and mitigation efforts that are the most urgent and to leverage national investments that will result in the most impact, there also is a need for solutions that result in systematic or automated methods to identify high-consequence events that meet national security thresholds, stakeholder acceptable risk limits for public safety and asset survivability, dissemination of actionable threat and mitigation information with technical context for asset owners, and strategic forecasts of the impacts from the evolution of future technologies and threat actor activities.

FY 2018 LDRD priorities include projects to explore science and engineering concepts that may have future application to the long-term challenges to meet national security requirements for energy systems, nuclear-cyber systems, and other critical infrastructure. INL is seeking proposals describing research, development, and proof-of-principle demonstration of innovations within the areas of:

- Fundamentals of cyber-physical effects science, interdependency models, and critical experiment matrices to validate the discoveries
- Development of cyber-informed engineering and risk methods, modeling, and simulation
- Protection, detection, and situational awareness of cyberattacks in control system operational technologies and embedded systems

- Disruption zones for protection of physical process systems with digital interfaces
- Cyber-state awareness for control loops out-of-band anomaly detection and response systems
- New technologies to secure and use wireless communications in control systems
- Automated vulnerability assessment tools, virtualization of embedded systems, and forensic tools for embedded and field control devices
- Analytic methods to automate threshold analysis for high-consequence events, baselining threats against these thresholds, and translation of threats to actionable information with appropriate context
- Next generation of distributed test beds and ranges that are reconfigurable and scalable, and that seamlessly integrate visualization and real hardware with the required fidelity and experimental measurements
- R&D workforce development and student, team, and instructor competency measures across different disciplines and professions (physics, engineering, computer science, operations, etc.) and a variety of critical infrastructure sectors (electric, oil and gas, nuclear, chemical, etc.)

For maximum impact, application priorities for these innovations should be aligned with one or more of the following areas: (1) digital relays that are fundamental to the protection of multiple types of critical power grid assets; (2) modern transformers, including digital tap changers and other embedded controls; (3) power generators, including core systems and support systems; and (4) modern grid architectures, smart devices, and systems that are part of modern bi-directional power/load control. For example, this might translate into:

- General approaches for detection and prevention of incoming threats to critical field control devices
- Forensic tools to search for malware or malicious settings on an end device
- Repeatable, systematic engineering methods for robust protection schemes that reduce risk from individual cyberattacks
- Out-of-band detection/protection methods for unauthorized firmware or setting modifications to a field control device
- RD&D to drive the next generation of safety/physical protection components and systems
- Innovative approaches to intrusion or attack detection.

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3.1.2 Secure and Resilient Critical Infrastructure

INL's critical infrastructure protection capabilities and programs are focused on RDD&D resulting in recognized science and engineering leadership in control systems cybersecurity, electric power grid protection and resilience, radiofrequency spectrum sharing wireless communications, and infrastructure interdependency modeling and simulation. Research innovations are applied to securing all sectors of critical infrastructure identified within Presidential Policy Directive 21, "Critical Infrastructure Security and Resilience." FY 2018 LDRD proposals should address one or more of the following research topics.

3.1.2.1 Cybersecure Control Systems

Recognized as global leader in control system cybersecurity, INL encourages LDRD proposals that expand the technical understanding of this technology field by seeking unique control system cyber scientific discovery and experimentation. Proposals of most interest will address how the project builds researcher skills, discovers vulnerabilities, advances innovation in vulnerability mitigation, develops new test and evaluation capabilities, and applies to:

- Development of new, science-based methods to measurably improve capabilities to assess critical system and/or component vulnerabilities of inter- and intra-control system communications;
- Applications of "Big Data" relational analysis techniques to large reverse-engineering efforts to generate more insightful information about data and execution flow; or
- Advancements in the state of the art in reverse engineering to further innovations in controls-system cybersecurity. Proposals of most interest will include descriptions of how the proposed concept pushes the boundaries of existing methods of reverse engineering, solves fundamental limitations of existing practices, and tailors approaches to unique demands of the control systems.

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3.1.2.2 Secure and Resilient National Power Grid

INL has unique power-generation, -transmission, and -distribution RDD&D capabilities that include research expertise, laboratory modeling and experimentation systems, and full-scale testing capabilities. Proposals are sought that describe novel approaches to developing solutions relevant to cybersecurity and physical security threats to the national power grid. Research of interest includes development of tools and methods to characterize and resolve the challenges of a grid 'black start,' an electromagnetic pulse, or geomagnetic disturbance event.

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3.1.2.3 Integrated All-Hazards Vulnerability Assessments for Cyber/Control Systems/Power/Wireless/Physical Security

Critical infrastructure stakeholders require advanced knowledge discovery tools and reliable decision support methodologies to improve national capabilities to conduct vulnerability discovery and infrastructure interdependency analysis. Proposals are sought on concepts leading to innovations in vulnerability discovery and analysis tools. Proposals should describe objectives and experimentation demonstrating measurable improvements in capabilities to perform all hazards-security analyses that enhance situational awareness. Proposals on this topic area should emphasize how the research, if successful, will influence the direction of future research applicable to:

- Development of leading-edge approaches to visualizing and analyzing infrastructure dependencies and interdependencies; and/or
- Development and demonstration of innovative approaches to integrate critical infrastructure cybersecurity and physical-security information and risks within common framework(s) that enable effective stakeholder decisions based on understanding multiple threats (e.g., natural, physical, or cyber).

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3.1.2.4 Advanced Wireless Communication Technologies

The increasing demand for wireless connectivity for communications, data sharing, Internet of Things (IoT), and control systems requires innovations to provide security and assurance. Advances in connectivity, security, and system modeling must also apply to the interoperability and testing of next generation systems as well as legacy systems. Proposals should emphasize innovation and build expertise in wireless security, connectivity, systems engineering techniques, and electronic warfare. Proposals in the following areas are of significant interest:

- In collaboration with the Cybercore, development of methods and capability to analyze how an unknown wireless device communicates, frequencies used, protocols employed, and deconvolution of the wireless communications stream with an end goal to establish a communications session with the device – this should include approaches for the development of techniques for effective mitigation and/or risk management that improves operational integrity and system cybersecurity.
- Innovative wireless physical layer techniques to enhance the cyber security, protection, and assurance of wireless communications in the presence of eavesdroppers, interferers, and jammers that cannot be prevented, mitigated, or resolved by authentication, authorization, and cryptography techniques.
- Optimization and scalability of radiofrequency propagation models for use in signal-rich operational environments.

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3.1.3 Innovative Solutions for Nuclear Nonproliferation

Future deployment of nuclear power plants will benefit from the success of nuclear-nonproliferation RDD&D that leads to innovations in design, operation, and inspection of nuclear facilities. Proposals are being solicited that identify and pursue solutions to future nonproliferation challenges; analyze the impacts of safeguards and security technology solutions on economic and energy issues; or advance the successful implementation of national nonproliferation strategies to deter, delay, or eliminate proliferation programs. FY 2018 LDRD priorities include the topics described below.

3.1.3.1 Investigative Technologies for Nonproliferation and Nuclear Forensics

INL is a global leader in the development of ultratrace and bulk measurements of materials for nuclear forensics and treaty compliance verification, including the production of isotopic and inspection standards for ensuring the quality of measurements performed by national and international programs. Proposals are requested for R&D of advanced technology concepts that may provide nonproliferation treaty compliance organizations or nuclear forensic teams with improved confidence in detection, measurement, and investigation of nuclear and radiological sources and debris.

Point of Contact:
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3.1.3.2 Advanced Technology Development for Safeguards and Security Utilizing the Transient Reactor Test Facility (TREAT)

INL technical leadership in addressing threats to national security depends on the innovation of researchers to anticipate threats, technology gaps, and potential solutions. To be at the forefront of peaceful deployment of nuclear energy technologies, INL seeks proposals describing proof-of-principle research and demonstration of novel concepts for enhancing safeguards, security, treaty verification, and/or proliferation detection that utilize the unique research and operations capabilities of TREAT. Proposals should clearly delineate the innovative nature of the nonproliferation research as applicable to TREAT and clearly align the experimental outcomes of the work to user community interests.

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3.1.3.3 Innovative Solutions for Characterizing Particle Dispersion and Transport for Emergency Response

INL has developed capabilities for use of nuclear and radiological materials in training emergency responders to improve their methods for detection, recovery, and consequence management when

participating in events related to a nuclear or radiological event. Included in these capabilities are testing and experimentation with novel dispersion materials that involve short-lived radioactive isotopes. Proposals are requested that develop novel dispersal materials; improve training capabilities for in-field sampling and detection; and enhance methods to predict and characterize particle dispersion.

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3.1.4 Future Defense Systems for National Security and Public Safety

INL conducts research, development, testing, and deployment of technologies that result in new capabilities for the U.S. Department of Defense, law-enforcement organizations, and emergency responders to plan, prepare, and execute their national-security and public-safety missions. FY 2018 LDRD priorities include the topics described below.

Proposals are sought for performing applied R&D, engineering, and demonstration of proof-of-principle concepts for advanced armor materials and systems. Successful projects will result in scientific information supporting the future research principles of integrated armor research. Proposals should focus on technical advancements in weight, space, and cost effectiveness of protective solutions for personnel, vehicles, and facilities against a full-spectrum of ballistic and explosive threats. Areas of materials science and experimentation that are of most interest include:

- Ideas for formulation and fabrication improvement processes that enable the production of hard-to-manufacture shapes and structures while retaining ballistic protection properties
- Ideas for formulation and fabrication improvement processes that enable the production of state-of-the-art ultraincompressible (high bulk and shear moduli) and super hard bulk materials
- Innovations in design analysis methodologies for armor that lead to the understanding of projectile defeat mechanisms or material microstructure optimization principles, including the creation of experimental data that support the modeling of armor performance during high-velocity impact events.

Point of Contact:
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3.1.5 Blue Sky: Transformational Concepts for Critical National and Homeland Security Priorities

Components of INL's missions and future RDD&D programs will result from visionary concepts developed by our researchers. We seek proposals that describe discovery science or proof-of-principle experimentation that will serve as the foundation for future national security research objectives.

Point of Contact:
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4. Recommendations for Successful LDRD Proposals

Submitted proposals should address specific scientific and technical challenges within the areas described above. Proposals should also describe how the proposed work will fill gaps in INL's current research portfolio, strengthen INL's capabilities and position in the scientific and engineering field, show potential publications and intellectual property, strengthen strategic collaborations, ensure programmatic growth, and increase our market share. The proposals should clearly describe how the proposed work takes advantage of capabilities and resources across INL and builds on INL's long-standing strengths of interdisciplinary research and integration of use-inspired basic and applied science.

Proposers are encouraged to build on INL strengths and facilities (Materials and Fuels Complex, ATR/ATR-Critical, TREAT, etc.) and integrate, when and where appropriate, advanced computational and data-analysis methods. Successful LDRD proposals will (1) address a specific scientific and application area challenge within the areas described above; (2) show how the proposed investment will position INL for a leadership role—enhancing core capabilities, knowledge, partnerships, and intellectual property; and (3) provide a plan for developing outside funding to sustain and grow the effort beyond the initial LDRD investment period.

5. LDRD Strategic R&D Fund – Call for Proposal Key Dates

Date	Task
February 17, 2017	Call for proposals for FY 2018 LDRD funding issued by Director of Strategic Planning and Investment.
February 27, 2017	Deputy Director for Science and Technology and Associate Laboratory Directors communicate critical area strategy, proposal requirements, proposal evaluation criteria, etc.
March 20, 2017	Deadline for submittal of preliminary, short proposals by PIs to LOI-ESS.
March 27, 2017	Deadline for Division Director approval of preliminary proposals in LOI-ESS.
April 17, 2017	LDRD office notifies PIs of selections and invites those selected to develop full proposals.
May 22, 2017	Deadline for submittal of full proposals and progress reports of renewal projects (projects seeking continuation funds for FY 2018) by PIs to LOI-ESS.
May 30, 2017	Deadline for Division Director approval of full proposals and progress reports of continuing projects submitted to LOI-ESS.
July 26, 2017	Funding decisions communicated to PIs. Request summary reports for all FY 2017 projects. Poster request for projects completing in FY 2017.
July 31, 2017	Deadline for PIs to submit revised proposals to LOI-ESS if so instructed by strategic area committee. Proposals/projects concurrence review requests are submitted to the DOE Idaho Operations Office.
August 29–31, 2017	Poster session for projects completing in FY 2017.
September 12–14, 2017	PIs finish entering summary reports into LOI-ESS.
October 1, 2017	Begin opening FY 2018 LDRD project accounts.