INL/EXT-10-18630

INL Initial Input to the Mission Need for Advanced Post-Irradiation Examination Capability

A Non-Major System Acquisition Project

April 2010

The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance.

Idaho National Laboratory

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Prepared for the
U.S. Department of Energy
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U.S. Department of Energy
Idaho Operations Office

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Approved by

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Assistant Secretary of Nuclear Energy

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ACRONYMS

AL	Analytical Laboratory
ATR	Advanced Test Reactor
DOE	U.S. Department of Energy
EML	Electron Microscopy Laboratory
FASB	Fuels Applied Science Building
FCF	Fuel Conditioning Facility
FMF	Fuel Manufacturing Facility
GPP	General Plant Project
HEPA	High Efficiency Particulate Air
HFEF	Hot Fuel Examination Facility
INL	Idaho National Laboratory
LIB	Line Item Building
LWRS	Light Water Reactor Sustainability
MFC	Materials and Fuels Complex
MWh	megawatt-hour
NE	Office of Nuclear Energy
NEPA	National Environmental Policy Act
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NNSA	National Nuclear Security Administration
NRAD	Neutron Radiography Reactor Facility
NRC	Nuclear Regulatory Commission
NSUF	National Scientific User Facility
PIE	Post-Irradiation Examination
R&D	research and development
RCRA	Resource Conservation and Recovery Act
RERTR	Reduced Enrichment Research and Test Reactor
ROM	rough order of magnitude
TEC	total estimated cost
TREAT	Transient Reactor Test Facility

Advanced Post-Irradiation Examination Capability

Mission Need Statement

1. STATEMENT OF MISSION NEED

Consolidated and comprehensive post-irradiation examination (PIE) capabilities will enable the science and engineering understanding needed to develop the innovative nuclear fuels and materials that are critical to the success of the U.S. Department of Energy's (DOE) Office of Nuclear Energy (NE) programs. Existing PIE capabilities at DOE Laboratories, universities, and in the private sector are widely distributed, largely antiquated, and insufficient to support the long-range mission needs. In addition, DOE's aging nuclear infrastructure was not designed to accommodate modern, state-of-the-art equipment and instrumentation.

Currently, the U.S. does not have the capability to make use of state-of-the-art technology in a remote, hot cell environment to characterize irradiated fuels and materials on the micro, nano, and atomic scale. This "advanced PIE capability" to make use of state-of-the-art scientific instruments in a consolidated nuclear operating environment will enable comprehensive characterization and investigation that is essential for effectively implementing the nuclear fuels and materials development programs in support of achieving the U.S. DOE-NE Mission.[1]

2. ALIGNMENT

2.1 DOE-NE Mission

The mission of DOE-NE is to advance nuclear power as a resource capable of meeting the nation's energy, environmental, and national security needs by resolving technical, cost, safety, security, and proliferation resistance, through R&D and demonstrations, as appropriate. A program of science-based research is required to develop the technology that will ensure continued advances in nuclear energy technology. The need for knowledge to support reactor sustainability programs, develop new nuclear fuels technologies, and develop new applications for nuclear energy are not being met in a cost-effective and timely manner at present.

Nuclear power has reliably contributed almost 20% of the electrical generation in the United States over the past two decades. It remains the single largest contributor (more than 70%) of electric power generation in the United States that does not emit greenhouse gases. By the year 2030, domestic demand for electrical energy is expected to grow to levels of 16 to 36% higher than 2007 levels. Achieving the DOE-NE mission goals will result in the deployment of fission power systems that produce electricity and generate process heat in a socially acceptable, environmentally sustainable, and economically beneficial manner.

Energy is needed if we are to meet the needs of an ever expanding global population and raise the standard of living for all human beings. Man-made climate change must also be addressed and the President has issued mandates for the U.S. to reduce the emission of green house gases (GHG) by 83% below 2005 levels by 2050. Globally it is realized that renewables and conservation must play a key role in reducing GHG emissions, but it is also realized that the benefits from these will be slow to realize. The U.S., China, and India rely heavily on coal and other petrochemical products for the majority of their energy production and subsequently are the world leaders in GHG. In the U.S. nuclear energy fulfills about 20% of the base energy load followed by hydro around 15%. With pressure to reduce the dependency on coal and additional environmental pressures to reduce hydro (dam removal and restoration of native fish habitat), the U.S. must increase energy production wherever else possible and that includes nuclear.

It is now clear that nuclear energy will be required to meet U.S. and global energy needs. The U.S. operates the world's largest nuclear reactor fleet. One hundred four reactors supply 20% of U.S. electricity demand. To ensure a stable energy supply, these reactors will operate far beyond their original design lifetimes. Degradation of reactor materials has surfaced as the key issue facing reactor life extension. In partnership with the DOE under INL leadership, the Light Water Reactor Sustainability (LWRS) program was formed to resolve these issues. Other INL led DOE research initiatives, such as the Fuel Cycle Research and Development (FCRD), Next Generation Nuclear Plant (NGNP), and Generation IV programs focus on the development of new reactors and fuel cycles. All rely on the development of new radiation resistant materials and robust fuels that allow higher plant efficiency and longer plant life times.

As the U.S. nuclear fleet ages, the realization that there is a large economic benefit (potentially $300 billion) in extending plant lifetimes beyond 60 years will drive additional research into materials degradation. Many current fuels and materials issues that affect commercial nuclear plant operation, reliability, and license extension remain to be addressed. The U.S. nuclear industry also continues to push for increases in fuel reliability. Currently, engineering analysis of nuclear plant material performance is often based on sparse and incomplete data. Another potential affect is the unnecessary termination of currently operating plants due to the application of overly conservative component lifetimes. Acquisition of state-of-the-art research tools and application of these tools to nuclear fuels and materials research in specialized facilities will allow issues that potentially inhibit advancements in nuclear technology to be understood and overcome.

2.2 Priority

As identified in the FY 2011 President's Budget Request to Congress, DOE-NE accomplishes the mission through the execution of programs such as Reactor Concepts R&D, Fuel Cycle Research and Development, Nuclear Energy Enabling Technologies, and RE-ENERGYSE Programs that depend on state-of-the-art nuclear research capability. The NGNP program relies on post-irradiation examination for development and licensing of fuel and in-core materials. The National Nuclear Security Administration (NNSA) also requires these capabilities for forensic analysis of nuclear materials and to support major non-proliferation programs such as the Reduced Enrichment Research and Test Reactor (RERTR) Program. The U.S. commercial nuclear industry is currently considering the extension of operating plant lifetimes to 80 years, which will require an in-depth understanding material degradation that does not currently exist. The U.S. commercial nuclear industry is also, in partnership with DOE under the LWRS program, is pursuing the development of nuclear fuels and reactor materials with enhanced reliability, increased performance, and reduced waste production.

All of these programs require advanced PIE capability to support the science-based approach to nuclear materials and fuel development research that leads to the continued safety and long-term sustainability of nuclear power as an essential source of energy in the United States.

2.3 Internal/External Drivers

DOE-NE issued the *Nuclear Energy Research and Development Roadmap Report to Congress* in April 2010. The R&D Objectives from the DOE-NE Roadmap are listed below along with the associated DOE scientific emphasis.[2]

- R&D OBJECTIVE 1: *Develop technologies and other solutions that can improve the reliability, sustain the safety, and extend the life of current reactors.* DOE will focus on aging phenomena and issues that require long-term research and are generic to reactor type.

- R&D OBJECTIVE 2: *Develop improvements in the affordability of new reactors to enable nuclear energy to help meet the Administration's energy security and climate change goals.* DOE will provide R&D support ranging from fundamental nuclear phenomena to the development of advanced fuels that could improve the economic and safety performance of these advanced reactors.
- R&D OBJECTIVE 3: *Develop Sustainable Nuclear Fuel Cycles.* DOE will work to develop the best approaches within each of these tracks to inform waste management strategies and decision making.
  - *Once-Through* – Develop fuels for use in reactors that would increase the efficient use of uranium resources and reduce the amount of used fuel requiring direct disposal for each megawatt-hour (MWh) of electricity produced.
  - *Modified Open Cycle* – Investigate fuel forms and reactors that would increase fuel resource utilization and reduce the quantity of long-lived radiotoxic elements in the used fuel to be disposed (per MWh), with limited separations steps using technologies that substantially lower proliferation risk.
  - *Full Recycling* – Develop techniques that will enable the long-lived actinide elements to be repeatedly recycled rather than disposed.
- R&D OBJECTIVE 4: *Understand and minimize the risks of nuclear proliferation and terrorism.* DOE will focus on assessments required to inform domestic fuel cycle technology and system option development. These analyses would complement those assessments performed by the NNSA to evaluate nation state proliferation and the international nonproliferation regime.

2.4 R&D Approach

According to the DOE-NE Roadmap[2], a goal-driven, science-based approach is essential to achieving the stated objectives while exploring new technologies and seeking transformational advances. This science-based approach, depicted in Figure 1, combines theory, experimentation, and high-performance modeling and simulation to develop the fundamental understanding that will lead to new technologies. Advanced modeling and simulation tools will be used in conjunction with smaller-scale, phenomenon-specific experiments informed by theory to reduce the need for large, expensive integrated experiments. Insights gained by advanced modeling and simulation can lead to new theoretical understanding and, in turn, can improve models and experimental design.

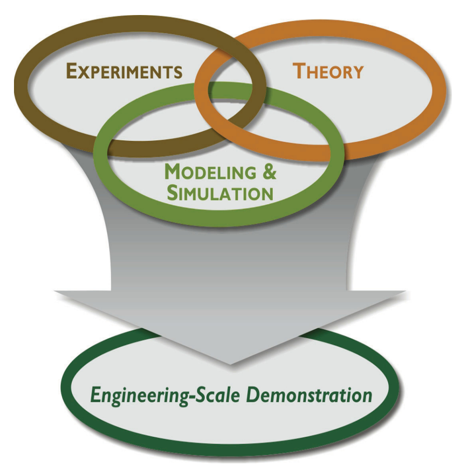

Figure 1. Major Elements of a Science-Based Approach

DOE-NE's approach to providing national nuclear research capability in support of the four NE Roadmap objectives is to concentrate high-risk nuclear facilities at the remote Idaho site, maintain unique capabilities at other sites, reverse the deterioration of vital university infrastructure, negotiate equitable capability exchanges with trusted international partners, refurbish and re-equip essential facilities, and make efficient use of modeling, simulation and single-effect experiments. Major facilities will be converted to user facilities following the model of the Advanced Test Reactor (ATR) National Scientific User Facility (NSUF).

Development of consolidated and comprehensive state-of-the-art post-irradiation examination capability is critical to accomplishing the DOE-NE mission. The completion of a unique and purposely designed PIE facility is necessary for remote operations with specialized equipment and instruments to produce advanced analysis on irradiated nuclear fuels and materials. This "advanced PIE capability" will enable national and international scientists to conduct the R&D necessary to support continued operation of the current nuclear fleet and development of sustainable future nuclear energy systems, subsystems, and components. The design and construction of a facility would be a line item capital project.

3. CAPABILITY GAP

To achieve the DOE-NE mission, advanced PIE capability is required that does not exist elsewhere in the world. The capability will require a location where extremely high hazard materials can be routinely examined in a safe and secure environment, yet allow the boundaries of nuclear energy research to be pushed to levels consistent with other advanced energy technologies. The use of state-of-the-art analytical instruments and technology in a highly radioactive setting is a capability that has been nearly lost in the United States.

The behavior of fuels and materials in a nuclear reactor irradiation environment is extremely complex and the limiting factor in plant safety, longevity, efficiency, and economics. This complexity currently limits the full exploitation of the potential of nuclear fission as an energy source. Understanding of the complex nature of irradiation-driven phenomena in materials and fuels at an atomistic scale can only be understood through a scientific program that includes experimental irradiation testing and post-irradiation examination coupled with modeling and simulation. A major shortfall, which currently hinders our ability to advance the state of nuclear energy science and technology, is state-of-the-art PIE capability in radioactive environments. Faculty and student access to cutting-edge and one-of-a-kind tools needed to conduct research in nuclear science and technology, fuels, and materials has been limited for the past 15 years. Providing state-of-the-art nuclear research tools that are accessible to university researchers is essential to maintaining a viable nuclear energy research program in the United States.

Over the last 15 years, much of the nation's nuclear research capability has been lost. During the same time period, stunning advancements in analytical research instrumentation have been made. Nano-scale (10^{-9} meter) characterization of materials is becoming routine, with capabilities for sub-angstrom (10^{-10} meter) investigation increasingly available. As an example of the power of these new tools, electronic technology continues to advance at a remarkable rate as material structures are understood on the nano and atomic scales. Significant advances in nuclear energy require that the U.S. nuclear research infrastructure be elevated to the state of the art that is currently afforded to non-nuclear scientific research. The nation needs comprehensive, consolidated, modern post-irradiation examination capability. Acquisition of, and the platform for development of, new research tools and application of these tools to nuclear fuels and materials research will allow the issues that inhibit advancements in nuclear technology and life extensions of our existing nuclear fleet to be understood and overcome. To bridge this gap, state-of-the-art PIE capability must be available through various university programs and user facilities.

The advanced PIE capability will serve as a national R&D center for advanced fuels and materials characterization, as well as development of new processes, tools and instruments to further the research. The capability will provide a flexible footprint with a variety of laboratories in both fixed and reconfigurable space. Radiological confinement will be provided in the form of fume hoods, glove boxes (general purpose, alpha, shielded, combined), and reconfigurable hot cells (utilizing modular cubicle inserts). Open laboratories will provide the space necessary to accommodate instruments with specific shielding and confinement requirements. The flexibility of the capability will allow it to remain relevant and current for over a 40 year projected useful life. It will contain start-of-the-art equipment and provision for future equipment. It is anticipated to be of modular design to facilitate equipment specific shielding and flexibility for future equipment deployment, configuration alteration, new equipment installation and ease of replacement.

3.1 Confirmation that the Capability Closes the Gap

The development of capabilities that do not exist elsewhere in the world for comprehensive irradiated fuels and materials analysis defines this Mission Need. The real measure of success will be the impact on the energy future of the United States. This will come through better understanding of nuclear fuels and materials that lead to increases in existing and future nuclear plant performance, solving back-end waste issues, decreased cost, increased reliability, etc.

Confirmation of success in closing the advanced PIE capability gap includes recognition by leading experts within academia (measured through joint publications, citations, joint projects, number of collaborations), commercial industry (measured through number of work-for-others contracts, publications, industrial surveys) and other national laboratories (measured by staff assignments, joint projects and collaborations, publications, citations), unique equipment developed in-house (measured by patents, industrial collaborations, technology transfer, licenses granted), and unique analyses of data (measured by publications, awards, citations). Such capabilities will be primarily aimed at making measurements with at high resolution (micro and sub-micron scale) at the grain and sub-grain level to support the science-based understanding of nuclear fuel and irradiated materials behavior. Maintaining this world-leading capability requires a continuous, dedicated effort to stay ahead with continuous improvements.

3.2 Current Needs

Consolidated, advanced PIE capability, where a comprehensive set of materials analyses can be performed, is essential for efficiently implementing fuel and material development programs in a cost effective manner. The facility infrastructure and human capital exists at INL to serve basic needs for examination, material handling, and waste disposal. This infrastructure provides the foundation from which a modern, world-class PIE capability will be built. Other alternatives do not meet DOE needs because:

- Maintaining multiple nuclear research complexes with duplicate capabilities is cost prohibitive over the next 40-60 years.
- Data obtained at different locations using different samples and instruments are more difficult to consolidate and reconcile.
- Extensive shipping of irradiated fuel samples raises concerns about cost, safety, security, and potential damage to samples.
- Shipping of material can significantly extend durations and increase the cost and risk of R&D projects.

The focus of the new capabilities is on nuclear fuels and high-dose (highly activated) non-fuel materials (such as fuel clad, assembly hardware, and reactor internal components).

3.3 Benefits of Filling the Gap

Ensuring the long-term availability of nuclear energy as an energy source in the United States is the key goal of the DOE-NE Roadmap. All four of the DOE-NE Roadmap objectives benefit from filling the current gap in advanced PIE analytical capability. Reestablishing this capability will result in sustaining the existing fleet of nuclear reactors by assuring that material degradation issues can be understood and overcome and continued improvement in the fuel reliability can be achieved. Development of new high-temperature nuclear plants that can replace fossil fuel for the production of industrial process heat requires extensive testing of high-temperature fuels and structural materials. Technology that uses process heat from these plants may be the key to recovery of petroleum from tar sands and oil shale. Advances in

PIE capability will facilitate development of closed fuel cycles that greatly reduce long-term radiotoxicity.

There is no quick fix for these challenges and a continuing effort must be made to overcome them. Concurrent with that effort must be the assurance that nuclear power be kept safe and protected from use by those who would harm others.

The benefits of the advanced PIE capability include:

1. Results that lead to improvements and understanding of the performance of existing fuels and materials. Understanding how these materials behave is critical to sustaining and extending the life of the Nation's fleet of nuclear power reactors.
2. Results that support qualification and licensing of new fuels and materials for use in existing reactors and future nuclear power concepts.
3. Results that lead to a fundamental scientific understanding of irradiation performance of fuels and materials with the objective of supporting advanced materials and fuel forms that allow for improved performance, reduced waste, and production of high-temperature process heat.
4. A consolidated capability that would bring scientists, engineers, and researchers from around the world together in a user facility designed to support collaboration and cooperation in the fields of nuclear fuels and materials R&D.

3.4 Strategic risk

DOE-NE is the steward of the majority of the Nation's nuclear energy R&D capabilities. Thus, DOE-NE has the responsibility for ensuring that objectives for nuclear energy can be met, now and in the future. The current state of the DOE's non-reactor nuclear facilities and research capabilities are currently not viable and will continue to degrade if not renewed. No new capital facilities for the purpose of nuclear power related R&D have been constructed in the U.S. since the commissioning of the Hot Fuel Examination Facility (HFEF) at the INL site 25 years ago. Across the nation, the DOE nuclear infrastructure is aging. The cost to maintain these older facilities across the DOE Complex is enormous.

Unification of PIE capabilities at a single site reduces the long-term liability for DOE and allows critical limited resources to be spent on the attainment of knowledge and the advancement of technology. Operation of the capability as a user facility ensures access to researchers from all DOE's Laboratories, universities, industry, as well as opening the doors to collaboration with researchers globally.

If state-of-the-art PIE capabilities are not reestablished, a technical basis for a sustainable nuclear energy will not be achieved according to the DOE's overarching mission to advance the national, economic, and energy security of the United States and to promote scientific and technological innovation in support of that mission. Within this, the mission of DOE-NE to secure nuclear power as a resource capable of making major contributions in meeting the nation's energy, environmental, and energy security needs by resolving technical, cost, safety, security, and regulatory issues through research, development, and demonstration will be severely compromised.

3.5 Impacts of Not Fulfilling the Mission Need

Within 10-20 years, the DOE's ability to sustain nuclear energy R&D will be minimal without investments such as the proposed advanced PIE capability. The needs of the research community will have surpassed the functional capability of existing facilities. The requirements of the needed instruments (e.g. power, electromotive force interference, vibration, sample size, relatively sterile work environment) were not envisioned in the 1950s, 1960s, and 1970s when large scale empirical experimentation dominated nuclear energy research.

All significant advances in nuclear energy technology rely on understanding of irradiation effects on the performance of materials and fuels. Understanding of these effects relies on experimental programs ranging from tests aimed at targeted scientific questions to integral effects under representative and prototypic conditions. Within the new DOE paradigm of a science-based approach, aimed at more fundamental understanding of performance, more specialized experiments and measurements are needed.

The exponentially growing energy demand in rapidly developing countries threatens the availability of energy resources and places greater emphasis on nuclear energy globally. The U.S. operates the world's largest nuclear reactor fleet, with 104 LWRs, which supply 20% of the US electricity demand. New materials are needed to serve as robust cladding materials and to allow longer plant lifetimes. In addition, the U.S. commercial nuclear industry is pursuing development of nuclear fuels with enhanced reliability, increased performance, and reduced waste production.

The ability to build a technical foundation to sustain the contribution of nuclear generation to meet U.S. energy needs will not be achieved if the capability shortfall is not resolved, and future long term advances in nuclear energy development will likely not be achieved within the United States. This will impact the success of national and international NE-Programs.

3.6 Operational Impacts

The successful completion of the DOE-NE Roadmap-driven missions will be jeopardized without the establishment of advanced PIE capability. Related to the aging facilities and infrastructure, the impacts are

- Increasing operation and maintenance costs
- Decreasing availability of existing PIE capability
- Increasing cost and schedule of PIE program execution
- Increasing environmental, safety, health, and security compliance risks.

The INL is working to develop a world-leading capability in support of DOE-NE's vision for nuclear energy R&D. The INL focuses on DOE-NE missions as its highest priority and is uniquely qualified to establish the world-leading user facility for PIE due to its location, facilities, labor force, and overall focus. In addition, universities will have access to a consolidated set of capabilities through the NE-NSUF. Consolidated facilities increase research productivity leading to discovery.

Locating this vital capability at other laboratories, whose core missions and principal supporters are not nuclear energy related, increases schedule and cost risk to the NE program. Maintaining multiple aging nuclear facilities with duplicate capabilities is cost prohibitive from an operations, maintenance, and security perspective. Extensive shipping of irradiated fuel and material samples is a risk to safety, security, sample integrity, and cost.

3.7 High-Level Interdependencies

The INL is the nation's only DOE Laboratory with a core mission of supporting the development of nuclear energy. The goal of establishing advanced PIE capability to achieve excellence in nuclear fuel and materials R&D is a primary strategic objective for the INL, and is supported by the following attributes:

- The INL has a long and productive history in PIE supporting various DOE, university, and industry programs.
- An existing trained workforce, with internationally recognized expertise in fuels and materials technology, forms a foundation upon which to build new capabilities that will ensure DOE's mission requirements are met years into the future.

- The core nuclear and radiological facilities needed to support PIE R&D capabilities already exist, such as the Transient Reactor Test Facility (TREAT), Neutron Radiography Reactor Facility (NRAD), HFEF, Analytical Laboratory (AL), Fuel Conditioning Facility (FCF), Fuel Manufacturing Facility (FMF), Fuels Applied Science Building (FASB), and Environmental Measurements Laboratory (EML) at the Materials and Fuels Complex (MFC).
- Proximity to major irradiation facilities, such as the ATR and the TREAT facilities, and having the ability to handle large irradiated objects (test trains, test assemblies, test loops, large fuel elements and assemblies) is essential to the success of the capability. Nowhere else in the DOE Complex do these capabilities exist on this large scale. The capability will span existing and new PIE facilities to ensure a step-change improvement in providing timely feedback between fuel fabrication activities, the observed fuel performance, and modeling and simulation efforts.
- Expanding the research capabilities offered by the NE NSUF to the national and international research communities will more effectively harness the intellectual capital represented by universities, industry, national laboratories, and regulators to address nuclear energy issues and enhance the process of scientific discovery.
- Nuclear fuel cycle R&D requires a "nuclear" safety and security infrastructure that protects the public, site workers, and the critical infrastructure. The INL nuclear capabilities are ideally located away from major population centers and population encroachment. This is a critically important consideration for long-term future nuclear research.

4. APPROACH

Key outcomes during the pre-conceptual design studies will be the initial evaluation of the Functional and Operating Requirements that will define the functional capability needs of advanced PIE. A feasibility study and cost estimate trade study will also be initiated during pre-conceptual design and finalized during conceptual design.

4.1 Mission Need Strategies

The Advanced PIE Capability Project will conduct an alternative analysis to select a preferred approach to establish the facility needs within the capability. A new Line Item Building (LIB) will be required to achieve and sustain world class PIE capability. The following four alternatives will be evaluated in the analysis:

1. Do nothing - No Line Item Consolidated Building will be constructed. Existing facility modifications will be completed to support current PIE capabilities.
2. Addition of small laboratories will be constructed through General Plant Project (GPP) $10M or minor capital funding requests at less than $20M each.
3. Evaluate the potential for distributed PIE capability across multiple DOE complex-wide facilities.
4. Construct a modern non-reactor nuclear research facility integrated with other capabilities at the INL to form a consolidated advanced PIE user facility.

4.2 Mission-Level Assumptions

The following mission-level assumptions are necessary to complete the DOE-NE objectives.

- The United States must develop and deploy clean, affordable, domestic energy sources as quickly as possible to achieve energy security and greenhouse gas emission reduction objectives.
- Nuclear power will continue to grow as a key component of a portfolio of technologies that meets the Nation's energy goals.
- U.S. Commercial industry will pursue development of nuclear fuels and materials with enhanced reliability, increased performance, and reduced waste production.
- World-class PIE capabilities are needed to implement science based programs in the development of advanced fuels and materials.
- The mission of DOE-NE is to promote nuclear power as a resource capable of making major contributions in meeting the nation's energy, environmental, and energy security needs by resolving technical, cost, safety, security, and regulatory issues through R&D.
- DOE-NE will implement the *Nuclear Energy Research and Development Roadmap, 2010.*[2]
- Unique consolidated capabilities in modern facilities with fully integrated operations are required to achieve timely world-class PIE.

4.3 Preliminary Functional and Operational Performance Objectives

The Functional and Operational Performance requirements will be developed during the preconceptual design phase of the project. The preliminary functional and operational performance objectives and criteria that would meet the initial complement include the following:

A. Basic function of structure, system, or component:

The basic function of advanced PIE capability is to provide radiation and biological shielding for current and future nuclear fuels and materials characterization instruments. Additional high level requirements include:

- Next generation radiation-shielded enclosures designed for regular manned access when radioactive samples are not present. The shielded enclosures will be flexible and reconfigurable to accommodate all instruments operational requirements for use with all known and undefined future radioactive fuels and materials characterization instruments.
- The ability to develop equipment, instruments, and models to meet future nuclear fuel development R&D needs.
- Operational flexibility and stream-lined workflow processes.
- Efficient and cost effective radioactive fuels and materials handling.
- Interim storage of radioactive fuels and materials as needed.
- Procurement of the initial complement of PIE instrumentation and equipment that is available worldwide, but not currently utilized for PIE characterization will be included.
- Current state-of-the-art PIE instrumentation and equipment.
- Related infrastructure including electrical, sewer, water, data collection and control, security, etc.

B. Space allocation Requirements:

For flexible operations, separate areas within a facility must contain individual instrument enclosures or modules, each performing discrete investigations. Facility space must include common use areas for sample preparation and staging, access corridors, mechanical and electrical utility distribution, High Efficiency Particulate Air (HEPA) exhaust system equipment, and electrical distribution gear. Sufficient office space will be provided to support the applicable functional and operational requirements.

C. Performance Requirements:

To accommodate the anticipated experimental fuels and materials requiring examination, it must be classified as a Hazard Category II nuclear facility. It must also include vibration isolation and electromagnetic interference isolation for successful instrumentation operation. It is anticipated that the nuclear laboratory capability will be designed to meet DOE-STD-1189.

D. Interface Requirements:

Large-scale operations and initial sizing and handling of characterization materials are not envisioned for this advanced PIE facility. The HFEF will be utilized for initial sample and material receipt and handling. It will also serve as the location for initial non-destructive (e.g. gamma scanning, metrology, radiography, optical documentation) and gross destructive examinations (e.g. pin puncturing, fission gas sampling, size reduction, primary sample preparation, and optical microscopy). The advanced PIE facility must be located relatively close to a facility equipped to receive large casks and handle irradiated materials. Samples initially examined, sized, prepared, and packaged in HFEF would be analyzed using instrumentation house by the needed capability.

E. Special Code Requirements:

Building and commercial standard codes associated with laboratories, including air emissions and irradiated nuclear sample handling laboratories, are applicable to this capability.

F. Safeguards and Security Requirements:

Safeguards and security requirements, both functional and procedural, would be implemented as applicable in accordance with DOE M 470.4-6

G. Environmental, Safety and Health Requirements:

The project would include personnel radiation monitoring stations, integrated facility radiation detectors, alarm annunciation, and infrastructure support to house a full complement of radiological protection professionals. Chemical safety equipment (safety showers, fire-rated cabinets for chemicals, chemical exposure monitors, etc.) and space to house chemical safety professionals will needed. Radiological suspect exhaust systems with a National Emission Standards for Hazardous Air Pollutants (NESHAPs) compliant stack emission monitoring system will be provided in the facility. A pneumatic transfer system will be installed to move radioactive samples between the facilities that comprise the overall capability. Appropriate permitting process, such as air, Resource Conservation and Recovery Act (RCRA), National Environmental Policy Act (NEPA), etc., will be performed.

4.4 Mission Need Risks

Mission need risks have been identified as follows:

- Functional Risks. Unique consolidated capabilities in modern facilities with fully streamlined operations are required to achieve world class PIE capability. Functional & Operating Requirements will be developed to ensure the PIE capability meets the DOE-NE mission needs.
- Technical Risks. Core on-site nuclear and radiological facilities, and safety and security infrastructure are needed to support the PIE R&D Capabilities. Close proximity to irradiation facilities is also major advantage.

- Operational Risks. A long record of proven past performance of conduct of nuclear operations and performing PIE R&D to support various DOE programs is essential.
- Staffing Risks. A trained nuclear operations and R&D workforce, with considerable expertise in fuels and materials technology, is required to form the foundation to build new capabilities to respond to an increases in work load.
- Regulatory Risks. Regulatory risks associated with construction of a new nuclear facility on a green field site cannot be fully determined until near the end of design.
- Safety Risks. As a non-reactor Hazard Category 2 nuclear facility, the functional requirements for advanced PIE capability will include conforming to the DOE Standard 1189, Integration of Safety into the Design Process; preparation of a Safety Design Strategy; and preparation of a Safety Analysis Report that will support formation of the basis of the operating safety envelope.
- Cost and Schedule Risks. There are always schedule risks to the project, and there is more risk when designing and building a new nuclear facility. Uncertainty related to annual U.S. appropriations funding is significant and tends to negatively impact project costs through project schedule extension.

4.5 Nuclear Safety Requirements

The establishment of advanced PIE capability requires any new facility be constructed as Hazard Category 2 nuclear facility due to the quantity of high hazard isotopes contained in the samples that will be examined. Therefore, DOE Standard 1189 would apply to the Mission Need.

5. RESOURCE AND SCHEDULE FORECAST

This is a non-major acquisition project with a preliminary rough order of magnitude (ROM) total estimated cost (TEC) target of between $100 and $150 Million.

5.1 Estimated Critical Decision Dates

The current Critical Decision dates are estimated:

- CD-0 – FY10 – Early FY11
- CD-1 – FY11 – Early FY12
- CD-2 – FY12 – FY 13
- CD-3 – FY13 (Long Lead Procurements CD-3A) – FY 14
- CD-4 – FY17

5.2 Five Year Planning Funding

Operating funding of $1.5M to initiate pre-conceptual design in FY 2010 is provided from program sources. An additional estimate of $5M is planned utilizing other project cost program funding to complete conceptual design in FY 2011 and FY 2012. The funding preliminary Rough order of magnitude planning profile by fiscal year for the FY 2012-FY 2015 planning window is contained in the chart below. This will be confirmed during the pre-conceptual and conceptual design.

Table 1. Five Year Planning Window

Fiscal Year	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
ROM Estimate of PED Profile	$9.2M	$13.9M			
ROM Estimate of Project Funds Profile		$10M	$25M	$35M	$30M
ROM OPC funding	$1M	$1M	$1M	$1M	$1M

6. REFERENCES

1. DOE-NE, Draft *2010-2019 Ten-Year Site Plan, DOE-NE's National Nuclear Capability – Developing and Maintaining the INL Infrastructure*, February 2010
2. DOE-NE, *Nuclear Energy Research and Development Roadmap, Report to Congress*, April 2010, http://nuclear.gov/pdfFiles/NuclearEnergy_Roadmap_Final.pdf