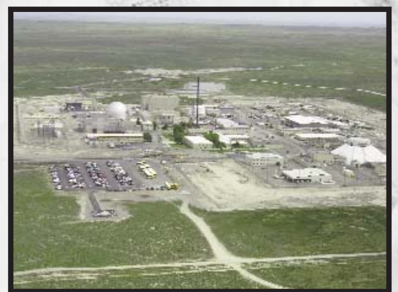
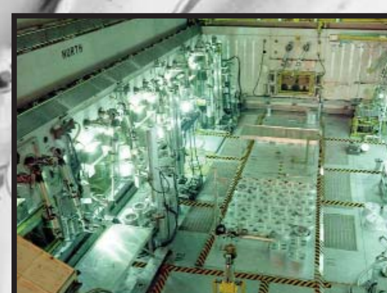
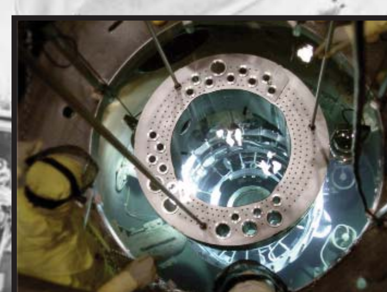
Draft Revision 4

Facilities for the Future of Nuclear Energy Research:
A Twenty-year Outlook

November 17, 2008







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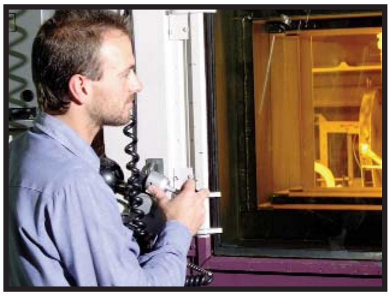
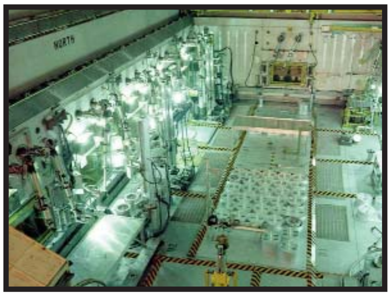
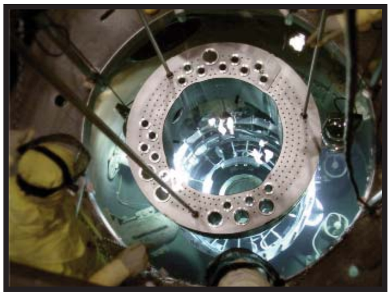
Meeting the Nation's Technical Needs To Ensure a Clean, Reliable Energy Supply in the 21st Century







EXECUTIVE SUMMARY

Acronyms

AFCF	Advanced Fuel Cycle Facility
ANL	Argonne National Laboratory
ATR	Advanced Test Reactor
DAF	Device Assembly Facility
DOE	Department of Energy
EBR-II	Experimental Breeder Reactor-II
EPACT	Energy Policy Act of 2005
FCF	Fuel Conditioning Facility
FDP	Fluorinel Dissolution Process Facility
FFTF	Fast Flux Test Facility
FMF	Fuel Manufacturing Facility
FPF	Fuel Processing Facility
HFEF	Hot Fuels Examination Facility
HFIR	High Flux Isotope Reactor
IFEL	Irradiated Fuels Examination Facility
IMET	Irradiated Materials Examination and Testing Facility
INL	Idaho National Laboratory
JMTR	Japan Materials Test Reactor
LANL	Los Alamos National Laboratory
LTA	Lead test assembly
LWR	Light Water Reactor
MIT	Massachusetts Institute of Technology
MURR	University of Missouri Research Reactor
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NEAC	Nuclear Energy Advisory Committee
NGNP	Next Generation Nuclear Plan
NHI	Nuclear Hydrogen Initiative
NNSA	National Nuclear Security Administration
NRC	Nuclear Regulatory Commission
NSRR	Nuclear Safety Research Reactor
NTS	Nevada Test Site
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
RAL	Remote Analytical Laboratory
R&D	Research and development
REDC	Radiochemical Engineering Development Center
RERTR	Reduced Enrichment for Research and Test Reactor
RPS	Radioisotope power systems
SRNL	Savannah River National Laboratory
SSPSF	Space and Security Power Systems Facility
TREAT	Transient Test Reactor
UREX	Uranium extraction

1.0 INTRODUCTION

Nuclear power is an essential component of the world's energy production. Its role is expected to grow as both the world and the U.S. reduces its dependence on foreign sources of fossil fuels. With 372 GWe of nuclear energy worldwide and some 35 nuclear energy plants presently under construction, nuclear energy is an important element of many nations' current energy portfolios and will become more so in the future. The International Atomic Energy Agency forecasts that nuclear energy could double by 2030 worldwide to meet growing demands for energy.[1] To respond to energy demand in the U.S., industry is planning to build new nuclear plants in the next decade and is taking steps to ensure that the existing light water reactor (LWR) fleet can continue to supply electricity through the middle of this century.

Historically, the U.S. has been a leader in the global nuclear marketplace, especially in reactor development, nuclear safety, licensing, and repository science. The U.S. has also led advances in nonproliferation and nuclear security. The federal government retains responsibility for management of special nuclear material and disposition of nuclear waste, a major challenge requiring focused research and development (R&D). In addition, federal R&D allows the U.S. to play a meaningful role in all aspects of global nuclear energy development, which is important to U.S. energy security, economic competitiveness, and national security.

The Office of Nuclear Energy *Facilities for the Future of Nuclear Energy Research: A Twenty-year Outlook* represents the Department of Energy's (DOE's) analysis of capability needs over the next 20 years and identifies the suite of primary facilities that currently exist or will be needed to support nuclear technology development. In addition, the plan identifies secondary and tertiary facilities that can provide additional capacity as required. The plan focuses on the high-hazard, complex, expensive, and unique-to-nuclear-energy facilities needed over the next two decades. These are the core capabilities, as represented by materials test reactors, hot cells, and other specialized laboratory facilities, that would be needed to support nuclear energy R&D.

This plan will be used to develop more detailed strategies for investment and recapitalization of existing core research facilities and to inform the development of future budget requests. It is intended for use by other DOE programs and laboratory directors to make sound business decisions on the need to maintain individual capabilities by clarifying the needs and planning assumptions of nuclear energy R&D.

The development of this plan follows the recommendations of the National Academy of Sciences and several other external reviews conducted in 2008 of DOE nuclear energy R&D and related infrastructure. Its development is informed by the review and recommendations of the Nuclear Energy Advisory Committee (NEAC), an independent advisory committee of DOE.[2]

The Office of Nuclear Energy anticipates that the details of the plan may change as new technical challenges arise and nuclear energy R&D matures; nevertheless, it represents the best estimate of both the Government and stakeholders at present. It provides a baseline from which to evaluate future investments to maintain, upgrade, and construct facilities as well as a road map for preparation and revision of a programmatic nuclear R&D 10-year plan with more detailed analyses of alternatives and costs.

2.0 NATIONAL ACADEMY OF SCIENCES AND OTHER RECOMMENDATIONS

In Fiscal Year 2006, Congress appropriated funds identified in the DOE budget request for the National Academy of Sciences (NAS) to undertake a "comprehensive independent evaluation of the Department of Energy's nuclear energy research program." The evaluation was chartered to "result in a comprehensive and detailed set of policy and research recommendations and associated priorities (for) activities that can best advance the Office of Nuclear Energy's fundamental mission of securing nuclear energy as a viable, long-term commercial energy option to provide diversity in energy supply."

[1] *2008 edition of Energy, Electricity and Nuclear Power Estimates for the Period up to 2030, International Atomic Energy Agency.*

[2] *Nuclear Energy: Policies and Technology for the 21st Century, Nuclear Energy Advisory Committee (November 2008).*

The NAS published its report in 2008[3]. The review provided significant guidance to DOE in establishing and implementing its R&D priorities and capabilities. In summary, NAS guidance was to:

- Give the highest priority to supporting industry consistent with the Nuclear Power 2010 program
- Evaluate the need for a reinvigorated R&D program aimed at improving performance of existing LWRs
- Emphasize the Next Generation Nuclear Plant (NGNP) program, following through on U.S. commitments to develop the technology and licensing strategy to develop a very high-temperature gas-cooled reactor for electricity and process heat production
- Expand the Nuclear Hydrogen Initiative (NHI) to include industrial and international partners
- Provide a modest but sustained level of funding to reduce deferred maintenance and build capability in existing facilities important to sustaining a useful scientific capability
- Emphasize R&D using facilities at the laboratory and engineering scale to address fuel reprocessing and recycle before committing to large commercial facilities in order to inform the best path forward.

A common thread among the recommendations offered by the NAS is the need to invest in research facilities that enable the Office of Nuclear Energy to meet its research priorities and to develop a process for prioritizing, evaluating, and obtaining those capabilities. While the NAS report did not focus on specific facilities needed to implement the recommendations, it recognized the need to "acquire and maintain state-of-the-art facilities and equipment used by researchers to lead the development of nuclear power as a valued energy option nationally and internationally."

To respond, the Office of Nuclear Energy asked Battelle Memorial Institute to identify and report on the types of facilities that would be needed and the functionality required of those facilities to support nuclear energy research and development. That effort resulted in a report, *Nuclear Energy for the Future: Required Research and Development Capabilities*,[4] which obtained industry and university perspectives about the capabilities and types of facilities needed to further R&D in support of nuclear energy over the next 20 years. The Battelle report addresses the general capabilities required and identifies gaps between what exists today and what will be needed in the future. It summarizes required near-term capabilities and facility priorities. The Battelle report and that of a Battelle Executive Committee[5] reached similar conclusions regarding the focus and goals for nuclear energy R&D.

DOE commissioned Idaho National Laboratory (INL) to do a third and final study[6] to inventory the facilities in the U.S. and internationally and to assess their condition, suitability, and readiness to support government nuclear energy R&D, including potential needs of industry. The INL report also identifies the additional or new capabilities and facilities that will be needed over the next 20 years.

In November 2008, NEAC issued a report on nuclear energy policy and nuclear energy technology

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[3] *Review of DOE's Nuclear Energy Research and Development Program, Committee on Review of DOE's Nuclear Energy Research and Development Program, Board on Energy and Environmental Systems, Division on Engineering and Physical Sciences, National Research Council of the National Academies, 2008, page 7.*

[4] *Nuclear Energy for the Future: Required Research and Development Capabilities, Battelle Memorial Institute, August 2008.*

[5] *Nuclear Energy for the Future: Executive Recommendations for Research and Development Capabilities, Batelle Memorial Institute, July 2008.*

[6] *Required Assets for a Nuclear Energy Applied R&D Program, Idaho National Laboratory, September 2008 DRAFT.*

infrastructure. NEAC concluded that DOE should provide an analysis for the next administration that looks at the current status and suggests a multi-year program, including facility upgrades and new facilities necessary for its research. As with the Battelle reviews, NEAC concluded DOE should conduct a systematic examination of facilities to identify the facilities that should be maintained, abandoned, or built new and noted that many high priority facilities will require moderate to significant investment before they can serve the functions intended.

Based on all of the input received from these reports and reviews, including the most recent NEAC review, the Office of Nuclear Energy established the following priorities to guide the development of its R&D programs over the next 20 years (see footnote 2):

- Improve the safety, reliability, and sustainability of the existing commercial reactor fleet
- Increase deployment of new Advanced LWRs
- Deploy new, advanced reactor technologies for nontraditional applications
- Support the development of spent fuel management technology options, including reprocessing and fast reactors to recycle used fuel
- Develop and sustain an affordable facility infrastructure to support the nuclear energy R&D.

Other Office of Nuclear Energy Responsibilities with Facility Implications

Radioisotope Power Systems

DOE supports the National Aeronautics and Space Administration (NASA) and other customers by providing radioisotope power systems (RPS) for energy supply in space and other harsh environments. These systems convert heat from plutonium-238 to electricity. Although RPSs are not an element of the nuclear energy R&D portfolio, their production is a responsibility of DOE under the Atomic Energy Act, and they are, therefore, within the scope of the capabilities report. RPSs are managed as a service to NASA and national security users as needed.

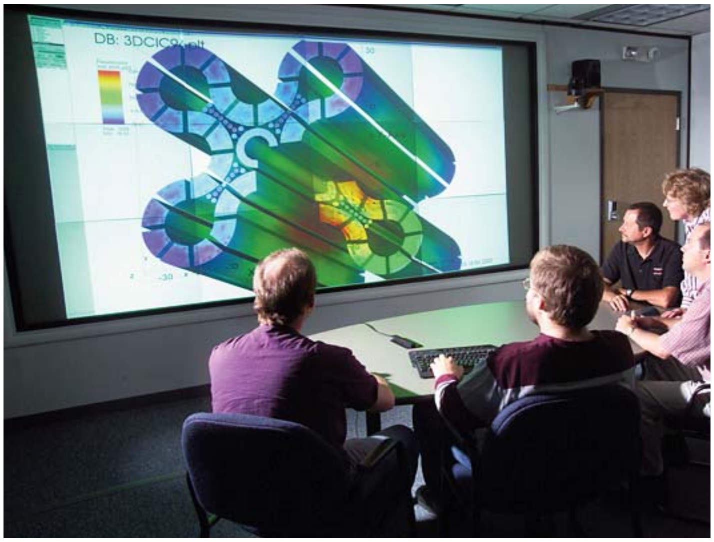
Although the Office of Nuclear Energy has had responsibility for this program for many years, it has not had responsibility for the specialized facilities used to produce plutonium-238 fuel. Plutonium-238 was produced and funded as a mission that was ancillary to the defense nuclear materials production mission of the Department. Production of plutonium-238 ended more than a decade ago when targets from the last campaigns were processed. Since then, DOE has been drawing down its domestic stockpile while supplementing its total plutonium-238 inventory with purchases from Russia. Both sources are expected to be exhausted by 2015. DOE is currently evaluating options for establishing new production capabilities using existing facilities and/or by building new facilities. A current National Academy of Sciences review is seeking to determine the future requirements for plutonium-238.

However, the Office of Nuclear Energy operates a relatively new facility at Idaho National Laboratory for the purpose of assembly and test of RPSs. It also uses a facility at Los Alamos National Laboratory (LANL) to pelletize and clad the fuel. Because the LANL facility will require significant upgrades in the future, the Office of Nuclear Energy is considering other options for this function.

Role of Scientific Computing

Advances in scientific computing that have occurred over the last 30 years have created the opportunity to incorporate science in simulations at a scale from smallest to largest, on a much greater scale than previously possible. Modeling and simulation combined with experimental data can shorten design and testing processes, reduce uncertainties associated with models and improve fidelity, and can ultimately reduce the burden on the infrastructure. Modeling and simulation can also be used to optimize facility operations, thus providing greater capacity.

Though powerful tools, modeling and simulation must be validated with experimental data. This data can come from separate effects tests, integral tests, and operational data from earlier and current reactors, both foreign and domestic. As an example, special effects experiments could be used to improve modeling of subcomponents of large systems codes. Modeling and simulation can both inform and improve the design of experiments and improve physical models for key nuclear phenomena. This needs to be conducted in concert with rescue and preservation of



Modeling and simulation supporting research and development at the Advanced Test Reactor, Idaho National Laboratory

data from legacy experiments that will be needed for model validation.

Although important to nuclear energy R&D, scientific computing hardware is not addressed in this capabilities plan. Scientific computing is ubiquitous, and demands of modeling and simulation for nuclear energy research do not justify purchase of dedicated, leading-edge, or other high-performance computers. Rather, it is expected that commercially available state-of-the-art high performance computers that are typically 2 years behind leading-edge computers will be available when needed. In special cases where leading-edge computers are needed, the Office of Nuclear Energy would expect to obtain access to these resources from other DOE offices such as the Office of Science and the National Nuclear Security Administration (NNSA). The Office of Nuclear Energy will focus on developing models, software, and a validation data archive.

3.0 APPROACH FOR EVALUATING EXISTING CAPABILITIES

The focus of this plan is on the core capabilities, that is, the materials test reactors, hot cell facilities, and specialized facilities needed to support materials and fuel irradiations, postirradiation examination and related mechanical testing, and laboratory and engineering-scale R&D that support development of advanced separations technologies, development and qualification of waste forms, and fabrication of fuels and targets.

Significant capabilities in reactor and fuel cycle development exist in the U.S. at national laboratories, with industry, and at universities. Generally, the core capabilites that are the subject of this plan are located, often remotely, where safeguards and security infrastructures are adequate to support handling of radiological and nuclear material and scale up of technology from laboratory to engineering scale and beyond. In addition, most of the existing core research facilities, that is the materials test reactors, hot cells, and specialized laboratory facilities that are capable of supporting fuels, materials, and reactor and fuel cycle development programs are owned by the government. Many of these DOE facilities have been operating to support nuclear energy R&D for many years, and have been specifically maintained and upgraded for that purpose. In addition, with adequate investment many of these existing facilities are in a condition that supports their continued operation for the next 20 years.

There are also research reactors available at universities that could assist the DOE in meeting its needs for irradiation testing and their use is considered in this plan. Universities can engage in higher hazard work by participating in DOE's research, and using DOE's nuclear energy research facilities. DOE must continue its efforts to integrate experts from universities and national laboratories into its nuclear energy research by providing them access to the core research facilities, regardless of where they are located.

Another important route to obtaining needed future research capabilities is to use available resources at international research institutions. Where capabilities do not exist in the U.S., the plan calls for greater international collaboration to share or establish resources jointly. This is particularly important with respect to the longer-term, higher-cost R&D priorities, such as those that might involve prototypic reactor facilities. Similarly, the U.S. needs to make its capabilities available to international use. Finally, if no other viable option is identified, new construction should be considered.

This plan seeks to deliver capabilities economically and efficiently, by recognizing the economy already achieved by concentrating core capabilities at locations where the supporting infrastructure such as security and waste disposition is available, as well as the future economy achieved by increasing facility usage. Additionally, where possible the Office of Nuclear Energy will consider consolidation as a means of reducing facility duplication and associated infrastructure, with the goal of having the right mix of mission-driven facilities that can be kept up-to-date and operated safely. It does so by considering technology requirements today and for the next 20 years.

This plan results in the identification of a set of core existing and new facilities that are, or will be, necessary to meet nuclear energy research priorities over the next 20 years, and of secondary or tertiary facilities that could supplement or provide reserve capacity. Many of these facilities are currently operating in support of nuclear energy R&D and can be expected to operate in the future. There are, however, a few facilities that are expected to operate in support of nuclear energy R&D for the very near term, but which are not considered reasonable or necessary for the next 20 years, and are therefore, not addressed further in the plan. In addition, there are also instances in which further evaluation of reasonable alternatives is necessary and called for by the plan.

Considerations for Core Capabilities and Facilities

- Focus on core set of materials test reactors, hot cells, and specialized facilities needed to support nuclear energy R&D for 20 years
- Evaluate DOE's existing research facilities against needed capabilities, considering functionality, capacity and demand, operating status, adequacy of supporting infrastructure, and economy achieved through co-location with other needed facilities
- Use same criteria to assess university, industry, and international facilities
- Consider facilities in standby when no suitable operating facilities exist
- Consider building new facilities to be the last option
- New facilities should be located at remote sites, with existing infrastructure
- Facilities need not be co-located with research expertise, provided experts have access to the facilities.

4.0 FACILITY ANALYSES

This section addresses facility needs with respect to the research priorities identified above, the ability of these facilities to accomplish each of the Office of Nuclear Energy's research priorities, and secondary or additional facilities and approaches for meeting priorities where existing facilities are insufficient or require significant investment to improve their capabilities.

4.1 IMPROVE THE SAFETY, RELIABILITY, AND SUSTAINABILITY OF THE EXISTING COMMERCIAL FLEET

The 104 operating U.S. nuclear reactors provide nearly 20 percent of electricity and represent 70 percent of domestic noncarbon-emitting electricity. Continued safe and reliable operation of these plants is a national imperative, important to meeting U.S. electricity needs in decades to come.

The most important current nuclear R&D efforts should be focused on the sustainability of the current fleet of LWRs. Research on issues such as fundamental understanding of fuels and materials performance and degradation can help predict lifetime performance of facilities' critical components and systems and inform industry in making decisions on long-term safe and economical operation of plants.

Additionally, it is possible to make significant performance improvements in existing LWR plants through the application of advanced instrumentation and control systems, long-life fuels, and coupled neutronics, thermal-hydraulic, and mechanical performance tools. Research in these areas will also benefit future reactor designs. Sustainability of the existing fleet also requires some consideration of long-term waste disposition; however, lifetime operability of existing and new plants can safely depend on on-site storage for used fuel management.

Options to Implement This Research Priority

The essential, applied nuclear R&D capabilities needed to support reactor aging, power uprates, and performance improvements include a viable materials test reactor, postirradiation examination facilities capable of handling full-length fuel, and a transient testing reactor. These capabilities are available in existing Office of Nuclear Energy facilities at Idaho National Laboratory and the Office of Science facilities at Oak Ridge National Laboratory (ORNL). In addition, universities, principally Massachusetts Institute of Technology and the University of Missouri, have test reactors that could be used to do early, small-scale testing. Co-location of irradiation and postirradiation examination capabilities also helps avoid high costs associated with transportation of irradiated materials.

The Office of Nuclear Energy believes that existing facilities, if properly maintained and upgraded, are adequate. Decommissioning and replacing these facilities is not reasonable given their current condition, expected remaining lifetime, and the current level of nuclear R&D budgets. Additional information on these capabilities follows.

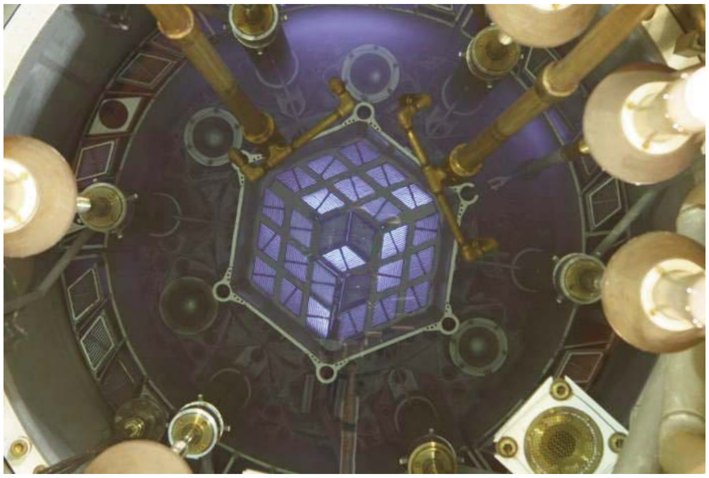
Materials Test Reactors for Steady-State Irradiations

The Office of Nuclear Energy operates the Advanced Test Reactor (ATR), a low-temperature and pressurized light-water-cooled reactor, multi-purpose irradiation test facility at the Idaho National Laboratory. ATR has historically supported fuel development for the Navy's nuclear propulsion program. Its use has expanded over the last decade to include other missions, such as development of fuels for NNSA's Reduced Enrichment for Research and Test Reactor (RERTR) program and fuel development for the high-temperature gas reactor and for recycling and reducing actinides contained in used nuclear fuel. In 2007, ATR was designated a national scientific user facility, enabling it to more fully support the irradiation testing needs of industry, universities, international researchers, and other federal agencies.

Reactor head, Advanced Test Reactor, Idaho National Laboratory

High Flux Isotope Reactor, Oak Ridge National Laboratory

ATR has a maximum power of 250 MW and can provide thermal neutron fluxes of 1×10^{15} neutrons/cm^2-sec and maximum fast (E>1.0 MeV) neutron fluxes of 5×10^{14} neutrons/cm^2-sec. These fluxes, combined with the 77 irradiation positions of varying diameter over an active core height of 1.2 meters (48 inches), make ATR a very versatile and unique facility. Four types of irradiation testing are employed: static sealed capsule tests with passive instrumentation, tests with active instrumentation for measurement and control of specific testing parameters, pressurized water loops that are connected to in-pile tubes and flux traps, and a new hydraulic shuttle irradiation system that allows insertion and removal of test specimens during reactor operation. Because the ATR's internal components are changed out periodically, it remains a valuable research and test machine capable of decades of service.



Research reactor at the Massachusetts Institute of Technology

DOE anticipates that the capacity for ATR irradiations will not be sufficient to meet irradiation testing needs over the next 20 years[7]; ATR will be almost fully subscribed meeting the needs of industry, academic user communities, and the federal government.

An important companion reactor is the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory, used principally to provide a stable neutron source for fundamental scientific experiments associated with neutron scattering. A flux trap located at the center of the HFIR fuel element provides a thermal neutron flux of $2x10^{15}$ neutrons/cm^2-sec; other positions are available with fluxes up to $1x10^{15}$ neutrons/cm^2-sec. HFIR retains an important complementary capacity for materials irradiation and testing.

The third prong of U.S. thermal irradiation capability is university research reactors, notably at the Massachusetts Institute of Technology (MIT) and the University of Missouri Research Reactor Center (MURR). Although these reactors operate at lower fluxes, they provide an important capability for scoping irradiation tests in advance of the more prototypic irradiations to be conducted in ATR. The Department is currently using the MIT reactor in conjunction with ATR irradiations, and these efforts are expected to expand in the future. The MURR reactor would be most suitable to support materials testing needs.

Collectively, these reactors should be adequate to meet the thermal irradiation needs of the Office of Nuclear Energy over the next 20 years. If additional needs are identified through the annual program planning processes, other options will be considered, such as the Halden reactor in Norway, the Petten reactor in Holland, the Japan Materials Test Reactor (JMTR), and the Jules Horowitz materials test reactor currently under construction in France.

Materials Test Reactors for Transient Testing

A transient test reactor is needed to provide a test platform with adequate space for testing partial-length LWR fuel bundles over a wide range of neutronic and thermal-hydraulic conditions under both steady state and transient operation conditions, up to conditions simulating severe reactor accidents. The only resource for this capability in the U.S. (and the world) that can accommodate both full-size fast reactor fuels and partial-size commercial LWR fuel is the Transient Test Reactor (TREAT), currently in cold standby at Idaho National Laboratory. TREAT has the

Transient Test Reactor, Idaho National Laboratory

[7] *Assuming Naval Reactors usage will continue at current level, work required to address the immediate, known issues presented in the Proactive Material Degradation Assessment published by the Nuclear Regulatory Commission (Muscara, USNRC NUREG CR 6923, 2007) and EPRI Material Degradation Matrix.*

capability to expose 36-inch sections of LWR fuel and full-length fast reactor elements, as well as assemblies and structural materials, to conditions simulating various types of severe nuclear and thermal transient situations, including fuel meltdowns, metal-water reactions, thermal interactions between overheated fuel and coolant, and transient behavior of ceramic and metal fuel for high-temperature systems. Other tests have included core physics experiments.

In addition to supporting extended operation of existing LWRs, TREAT could support licensing of new, advanced LWRs over the next 20 years. While other reactors are capable of transient testing on smaller fuel samples – e.g., the Nuclear Safety Research Reactor in Japan (NSRR) – TREAT is the only reactor capable of fully supporting the range of anticipated transient testing over the next 20 years. TREAT has also been identified as a facility of interest by international users.

Hot Cells for Postirradiation Examination and Mechanical Testing

There are many facilities in the DOE complex that have hot cells, but only a few are active with the capability to handle full-length fuel rods or assemblies and have required postirradiation examination and mechanical testing capability. The Hot Fuels Examination Facility (HFEF) at Idaho National Laboratory is one that can. HFEF is a large, heavily shielded hot cell facility specifically designed to remotely characterize highly irradiated fuel and structural materials. It consists primarily of two adjacent hot cells in a three-story building. The main cell utilizes an argon atmosphere and features 15 work stations, each with a viewing window and pair of manipulators. The secondary hot cell utilizes air and features 6 work stations.

Hot Fuels Examination Facility at the Materials and Fuels Complex, Idaho National Laboratory

HFEF was designed as a postirradiation examination facility and is fully equipped for destructive and nondestructive examinations. Following receipt of materials (e.g., irradiated test materials from the ATR or components from a commercial reactor), the material can be visually inspected, measured, documented, and subjected to gamma scanning, ultrasonic testing, and other examinations. Destructive testing begins with cutting and preparation for metallographic and ceramographic optical examination, micro-hardness testing, and mechanical properties testing. Further preparation can be performed and samples transferred to other facilities for continued analytic chemistry or electro-optical analysis using transfer casks or a pneumatic transfer system between facilities.

HFEF also houses a TRIGA reactor used for neutron radiography, which is being upgraded with a pneumatic rabbit to allow short-term irradiations of materials for testing purposes. The HFEF capabilities and associated laboratories that include radiochemistry laboratories complement the irradiation testing capabilities at ATR.

Over the last several years, both DOE and the Idaho National Laboratory contractor have invested about $20 million in new postirradiation analytical examination equipment at the site.

This equipment can determine the combined effects of irradiation and environment on macroscopic degradation of material properties. These investments, combined with planned upgrades, bring the capabilities in the DOE complex to a level that is world-class with respect to irradiated materials science. Increased utilization of these facilities through transitioning to multiple shifts could also help ensure sufficient capability will be available to meet national needs.

Other hot cells that can also be used in conjunction with the co-located reactors to support postirradiation examination are the Irradiated Fuels Examination

Irradiated Materials Examination and Testing Laboratory, Oak Ridge National Laboratory

Laboratory (IFEL) and the Irradiated Materials Examination and Testing facility (IMET) at Oak Ridge National Laboratory. These facilities are on the same site as HFIR. These Office of Science facilities have supported fuel and materials examination activities over the last three decades.

These hot cells at Oak Ridge are currently in operation, can handle full-length commercial fuel, and can provide basic functions similar to those of the hot cells at the Idaho National Laboratory. While not as large as the hot cells at the Idaho site, the Oak Ridge hot cells can perform some of the same nondestructive examinations, including optical and electro-optical examination and mechanical properties testing. However, ORNL does not have a disposition pathway for commercial used fuel; therefore, its ability to receive commercial used fuel is limited. With adequate maintenance by the host program secretarial office, these capabilities would be able to meet the requirements for the next 20 years provided that the waste disposition issues are solved.

4.2 INCREASE DEPLOYMENT OF NEW LWR DESIGNS BASED UPON DOMESTIC MARKET DEMANDS

Following years of preparation by industry and government, plans for new nuclear plants are moving forward in the U.S. In deploying reactor technologies, every potential owner seeks to be the first in line for the "second" plant, the beneficiary of the lessons learned from the first plants deployed. Licensing, design, and construction of new plants impose significant risk on first movers and, in general, the commercial sector is reluctant to take on that level of risk alone. Through the Energy Policy Act (EPACT) of 2005, loan guarantees, production tax credits, and standby support, the government is sharing the financial and regulatory risk with industry for the first few new nuclear plants.

DOE also retains capabilities to support advanced LWR designs. These include analytic capability in simulation and modeling, risk assessment, detailed design, manufacturing, nuclear materials management, fuel development, test reactor operation, security protection, and many others. These capabilities, which also support federally sponsored nuclear R&D, exist because of the expertise developed at both civilian nuclear energy and weapons laboratories over the years. It is expected that both industry and the Nuclear Regulatory Commission would take advantage of these capabilities, which involve both the workforce and DOE facilities.

Options to Implement This Research Priority

Nuclear facility requirements are identical to those described above for support of the existing fleet of light water reactors but with special emphasis on development of advanced, high-performance fuels. Accordingly, the same facilities as identified for support of the existing LWR fleet would be required. The ATR, TREAT, and HFEF at Idaho along with HFIR, IFEL, and IMET at Oak Ridge are the key facilities to support deployment of new LWR designs.

4.3 DEPLOY NEW, ADVANCED REACTOR TECHNOLOGIES FOR NONTRADITIONAL APPLICATIONS

Electricity generation accounts for about one-third of U.S. energy use; transportation and heating comprise the rest. The opportunity exists for nuclear to displace some of the CO_2 emissions in these sectors through use of heat from reactors – both high-temperature process heat and, in some locations, waste heat from electricity generation. High-temperature process heat is useful for production of hydrogen, conversion of coal-to-liquid fuel, and recovery of oil from tar sands. Lower temperature applications include desalinization of water and space heating.

Many of these potential applications are best served by a gas-cooled reactor that can provide high-temperature process heat coupled with high-temperature electrolysis for production of hydrogen. The demonstration of this capability is a high priority for DOE as directed by EPACT 2005, which also designated Idaho National Laboratory as the site for the demonstration. Such a demonstration would likely be sponsored by an industrial consortium, and, therefore, is not further addressed by this plan.

The principal focus of supporting research is on developing a reliable fuel and materials capable of withstanding high temperatures in an irradiation environment. For example, research to demonstrate the improved performance of coated-particle fuel is underway using ATR and HFEF. Fuel performance will need to be demonstrated under both steady-state and transient conditions. As such, the same facilities needed for LWR support described in Section 4.1 are also appropriate to development of the high-temperature gas reactors for process heat applications, except that transient testing would be best accomplished using a furnace installed in a hot cell, such as the Idaho National Laboratory's HFEF

In addition, to support the eventual design and deployment of a full-scale, very high-temperature gas-cooled reactor prototype, engineering or component development and testing capabilities will be needed. These capabilities do not currently exist in the U.S. A new U.S. component test facility or access to the capabilities that might be available in Japan and/or South Africa will be needed over the next 2-to-5 years. DOE approved Critical Decision-0, mission need for a new facility in December 2004. This proposed new facility would house up to three high-temperature, high-pressure loops. It is estimated that it would take about 2 years to build the facility at a cost of $400M, which would likely be funded by the reactor prototype project.

Options to Implement This Research Priority

To support the deployment of a high-temperature gas reactor for process heat applications, the same nuclear facilities supporting LWR research would be needed as well as a component test facility.

4.4 IMPROVING LONG-TERM MANAGEMENT OF THE FUEL CYCLE AND ITS WASTE

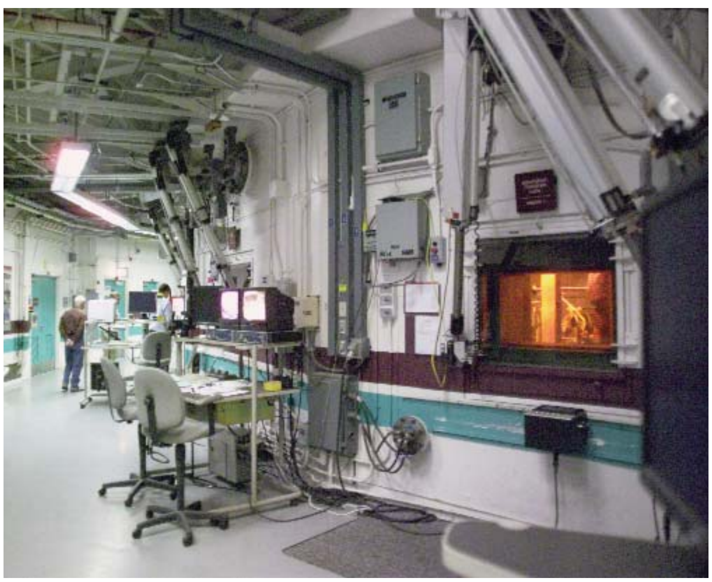
The present U.S. approach to fuel management assumes permanent geologic disposal of used nuclear fuel without reprocessing and recycle. The prospect of a global nuclear renaissance, including a major expansion of nuclear power in the U.S., may require a change in the existing approach if nuclear fuel and waste are to be managed effectively and energy resources are to be used efficiently. Developing advanced recycling technologies will require optimization of cost, safety, security, and proliferation resistance. Capabilities necessary to support the major R&D elements that will be required include the following:

- Hot cells to support reprocessing R&D with irradiated materials
- Hot cells to support development and qualification of the waste forms for permanent geologic storage
- Fuel fabrication facilities (samples, segments, pins, full-size/lead test assemblies) capable of accommodating recycled material
- Availability of thermal and fast spectrum reactors for irradiation of recycled fuel and a transient reactor for testing fuel under extreme conditions
- Postirradiation examination capability (discussed above).

Previous studies have looked at various options for providing these fundamentals, including international collaboration. Because the U.S. has not yet made a substantial investment in large-scale facilities for reprocessing commercial used fuel, there is an opportunity to use existing laboratory-scale facilities to support R&D with the objective of ultimately building larger-scale facilities employing advanced technologies. The major objective would be to develop an approach to fuel recycle that is safer, more secure, cost effective and more proliferation resistant than current generation technologies, and that minimizes the waste burden on the geologic repository. This provides a key opportunity for U.S. leadership that contributes to a safer and more secure international fuel cycle.

There are many potential approaches to reprocessing used nuclear fuel. In the U.S., two broad classes have emerged, one using aqueous-based chemistry and the other using molten-salt electrochemistry. Both technologies are being pursued. Laboratory-scale research on aqueous reprocessing technology is underway in Building 7920 of the Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory, supporting development of the uranium extraction (UREX) reprocessing options. The Fuel Conditioning Facility (FCF) at Idaho National Laboratory is currently conducting laboratory and engineering-scale research on electrochemical separations by treating the Experimental Breeder Reactor-II (EBR-II) used fuel. The facilities involved are sufficient for early work at each of the sites, but additional capabilities would be needed to support future commercial application.

Remote Analytical Laboratory, Idaho National Laboratory



Fuel Conditioning Facility, Idaho National Laboratory

Hot Cells to Support Reprocessing R&D

Aqueous Separations – Laboratory Scale

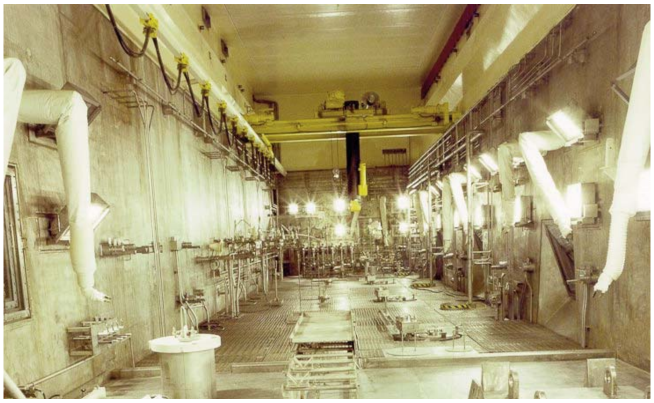
Laboratory scale testing of separation technologies could be performed over the next 3 to 5 years in REDC, Building 7920, which is the location of the current coupled-end-to-end demonstration that uses a bank of lab-scale mixer-settlers for testing separations chemistry. Because 7920 does not have space to use prototypic equipment for such integrated testing, a larger hot cell facility such as the 773-A E-wing shielded cells at Savannah River National Laboratory (SRNL) or the relatively modern Remote Analytical Laboratory (RAL) would be required. These hot cells, which are owned and operated by the Office of Environmental Management, can accommodate several lab-scale separation processes installed at the same time.

The Pacific Northwest National Laboratory (PNNL) radiochemistry laboratory, also owned and operated by the Office of Environmental Management, should also be considered as a possible backup facility for laboratory scale research on aqueous reprocessing.

Within the next 20 years, development of aqueous separations will require a dedicated hot cell facility. The RAL facility at Idaho would also be suitable for this longer term mission. More detailed cost and technical analysis of options for aqueous separations, in conjunction with evaluation of options for use of RAL for plutonium-238 target processing, will factor into any future decision. However, the use of RAL for other missions could affect its ability to support research on advanced aqueous reprocessing technologies.

Aqueous Separations – Engineering-Scale

The U.S. has no current capability for carrying out engineering-scale aqueous separations testing with



Fluorinel Dissolution Process cell at the Fuel Storage Area, Idaho National Laboratory

used fuel. One option being considered is to develop an Advanced Fuel Cycle Facility (AFCF)[8] for this purpose. The AFCF would be a new facility with capabilities for engineering-scale integrated testing of separation processes and fuel fabrication for lead test assemblies.

Another option would be to modify existing facilities, such as the Fuel Processing Facility (CPP-691) and Fluorinel Glovebox Process and Fuel Storage Facility (CPP-666) at the Idaho National Laboratory, where the necessary support infrastructure is in place. These hot cells can accommodate several laboratory-scale separations processes installed at the same time. Because of their potential future value, any decision to decontaminate and decommission these facilities should be made by the Secretary of Energy. International facilities at Marcoule, Tokai, and Sellafield have small, engineering-scale capabilities that potentially could be used on an interim basis.

Electrochemical Separations – Laboratory and Engineering-Scale

Hot cells are needed to support development and demonstration of electrochemical separation technologies for recycle of used nuclear fuel. Because water vapor and oxygen must be avoided, hot cells that employ an inert atmosphere, such as argon gas, are required.

The FCF at the Idaho National Laboratory is the only facility that is readily available to support engineering-scale electrochemical separations using spent fuel. It is anticipated that the capacity of FCF combined with limited usage of HFEF for waste form processing is sufficient to support both laboratory and engineering-scale testing of electrochemical separations.

Hot Cells to Support Waste Form Development and Qualification

Waste form testing with highly radioactive waste components from used fuel is usually done at laboratory scale. Facilities that were used to support Office of Environmental Management waste form development could be used to develop advanced aqueous processing waste forms. The two principal facilities are the Shielded Hot Cell Facility at the Savannah River National Laboratory and the Radiochemical Processing Laboratory at the Pacific Northwest National Laboratory. These hot cells are owned and operated by the Office of Environmental Management. While these facilities could be particularly useful for near term waste form development work, in the longer term it may be more suitable to co-locate it with the laboratory and engineering-scale research on aqueous reprocessing.

For electrochemical processing, engineering-to-full-scale waste processing furnaces are installed in HFEF, and this facility could support continued development efforts for electrochemical waste forms. AFCF would also have capabilities to demonstrate engineering-scale production of aqueous and electrochemical waste forms.

Fuel Fabrication Facilities Capable of Accommodating Recycled Material

Transmutation fuels heavily loaded with minor actinides have not been extensively developed. A fuel development program that includes development and testing of fuel pins and assemblies has been identified for transmutation fuels that will require fast-spectrum irradiation testing.

Metal fuel pins are currently fabricated using a glovebox line installed in the Fuel Manufacturing Facility (FMF) at Idaho National Laboratory. Additional

[8] *Evaluation of Existing Department of Energy Facilities to Support the Advanced Fuel Cycle Facility Mission (August 2008.)*

upgrades to the FCF are planned over the next several years to install remote capabilities for pin casting, demolding, pin loading, pin welding, pin testing, and weld radiography.

In order to manufacture lead test assembly transmutation fuel for testing in a fast reactor, a facility of the scale of AFCF would be needed, capable of housing large equipment and handling significant quantities of transuranic materials. Demonstration of the reprocessing technology would need to be coupled to production of these test assemblies, and AFCF would also have this capability.

Postirradiation examination of transmutation fuels could be performed using HFEF at Idaho National Laboratory or the hot cells at Oak Ridge National Laboratory.

Materials Test Reactors for Thermal, Fast, and Transient Testing of Recycled Fuel

The U.S. currently lacks a fast-spectrum irradiation test facility. Only limited resources are available internationally, and their availability for irradiation support over the next 20 years is uncertain. Fuel pin segment irradiations are currently being conducted using Phénix reactor in France, but these are the last irradiations that the U.S. will be able to conduct before the reactor permanently closes in 2009.

Capabilities exist for thermal spectrum testing in ATR as a surrogate to fast reactor testing, using small samples. Capabilities for fuel pin and lead test assembly testing exist at Joyo in Japan. For oxide transmutation fuels, the Monju reactor could potentially support assembly-scale and partial-core testing within a few years after it restarts in 2009. Monju may be able to support metal fuels testing after 2015. However, Monju is a demonstration power reactor that is not well suited for testing novel fuel forms, in that it has very stringent licensing requirements and is not designed to provide a full range of data during irradiation.

The U.S. has operated two successful fast-spectrum irradiation test facilities, EBR-II at Idaho National Laboratory, and the Fast Flux Test Facility (FFTF) at Pacific Northwest National Laboratory, which operated for 30 and 10 years, respectively. These reactors provide the U.S. with the necessary experience to move ahead with a fast-spectrum test facility with little technical risk if the lessons learned from EBR-II and FFTF are incorporated into the design and construction.

It is also anticipated that restart of the TREAT reactor would be needed to test full-length/large-scale fuel pins to verify performance and safety of transmutation fuel.

Options to Implement This Research Priority

In summary, many of the same types of facilities are needed for spent fuel management technology development as are needed to sustain the LWR fleet. In some cases, there is sufficient capacity to handle both activities in existing DOE facilities. However, because used fuel management requires developing new technologies for reactors, fuel, recycling, and waste disposal, ultimately more and larger facilities will be required than are needed for supporting the relatively mature LWR technology.

International options, which are being exercised to a small extent, provide some interim flexibility until a U.S. capability is in place. TREAT restart would provide a transient fuel testing capability that could be shared among all reactor fuel development programs.

The gaps that must be filled with new facilities for recycle and transmutation of used fuel are AFCF and a fast irradiation test reactor. A new AFCF could be a greenfield facility or the result of major modifications and additions to existing facilities.

4.5 OTHER NUCLEAR ENERGY RESPONSIBILITIES WITH FACILITY IMPLICATIONS

Radioisotope Power Systems: Domestic Production of Plutonium-238

Plutonium-238 has been used by NASA and other agencies desiring power generation in remote or hostile environments for the last 50 years. The domestic production of this radioisotope ceased in the early 1990s as a result of the end of the cold war and closure of the Savannah River Plant production reactors. The program of providing RPSs has continued through careful management of the remaining inventory of material, which includes approximately 40 kg of plutonium-238 purchased

Space and Security Power Systems Facility (SSPSF), at Idaho National Laboratory, where radioisotope power systems are assembled

from Russia. The Russian supply is also running out. The re-establishment of domestic production will enable the continued use of these devices for NASA and other agencies. Annual requirements are estimated to be 5 kg.

The production process for RPS units has several integral operations: 1) production of targets containing neptunium-237; 2) irradiation of neptunium-237 targets in a reactor to transform the neptunium-237 to plutonium-238; 3) separation of the plutonium-238 from the irradiated neptunium targets in a shielded alpha hot cell; 4) a heat source fabrication facility to form the oxide material into a sturdy, ceramic form and encapsulate it within a robust cladding; and 5) fueling and testing of the RPSs units within a secure, specialized engineering facility.

Options to Implement This Priority

There are two different pathways to accomplish the goal of re-establishing a production capacity for RPS units in the U.S. In one pathway, the processes take place at separate locations; in the other, functions are consolidated into new or remodeled co-located buildings. Recovery of material from scrapped units could also yield 15 to 20 kg of lower quality material as a stopgap measure until a new capability is in place.

Facility requirements include a large irradiation reactor with an irradiation volume of about 35,000 cm^3 and a thermal flux of at least $2x10^{14}$ neutrons/cm^2/sec. A combination of ATR and HFIR are capable of satisfying these needs, but each reactor has other programs that compete for irradiation volume. A novel TRIGA liquid-loop concept for production is also under preliminary evaluation. This approach would require one or more new reactors, but would require smaller support facilities and could potentially provide other precious isotopes.

Other requirements include a neptunium target production facility, an irradiated target separations facility, a plutonium storage facility and heat source fabrication facility to replace the glovebox laboratories within Building TA-55 (PF-4) at Los Alamos National Laboratory, and the new assembly and testing facility at Idaho National Laboratory that is currently operational and compliant with DOE safety requirements.

The facilities at Los Alamos have been used for heat source production for more than 30 years and need significant capital investment to meet modern safety requirements. As such, the Office of Nuclear Energy has concluded that it may be more cost effective and efficient to establish this capability elsewhere. The Device Assembly Facility (DAF) at the Nevada Test Site (NTS) is considered a candidate for this purpose because the facility is relatively new, highly secure, and has the ability to handle alpha-emitting radioisotopes.

Should consolidation of all plutonium-238 facilities be pursued, Idaho National Laboratory has been identified as a likely candidate for heat source production (pelletization). The characteristics of plutonium-238 (particularly very high specific alpha activity, a substantial fast fission cross section, and significant neutron emission) present technical challenges that limit facility and transportation options.

Glovebox facilities and a hot cell are required for target fabrication and separations. The FMF at Idaho, co-located with the site of the ATR where most of the target irradiations would occur, is considered the primary option for target fabrication. The Idaho RAL facility and Oak Ridge National Laboratory REDC Building 7930 are candidates for neptunium target separations.

5.0 FACILITY FACT SHEETS

The Appendix contains brief fact sheets that describe the key facilities addressed in this plan, with information about location, capabilities, functionality, and needed/planned enhancements.

6.0 FACILITIES FOR THE FUTURE OF NUCLEAR ENERGY R&D

Tables 6.1 and 6.2 show recommended research facilities that the Office of Nuclear Energy will invest in for the future of nuclear energy R&D. These tables reflect extensive review of earlier work in developing the inventory and conditions of existing facilities and site inspections. They include existing core facilities needed to support nuclear energy research (Table 6.1) and new capabilities and facilities (Table 6.2) needed to implement specific research priorities.

The Department will use its existing facilities to the extent possible, including those owned by the Office of Nuclear Energy and those available through other Departmental offices. In addition, the Department will pursue resources available at universities and internationally to supplement or provide new capabilities that do not exist in the DOE complex.

Consistent with the criteria outlined in Section 3.0, analysis supports the consolidation of federal nuclear facility capabilities at two sites: Idaho National Laboratory as the primary site and Oak Ridge National Laboratory as a secondary site. Access to facilities at other national laboratories, such as Pacific Northwest National Laboratory and Savannah River National Laboratory, as well as international facilities will be needed in the nearer term to support R&D on used fuel reprocessing and recycle.

Potential future requirements may necessitate preserving some facilities that are identified as surplus to current DOE needs. Additional analysis of options is needed to determine the most effective means of establishing capabilities to support plutonium-238 production and laboratory scale R&D on aqueous reprocessing.

Potential new facilities needed in the future include a fast test reactor, a component test facility for a high-temperature gas-cooled reactor prototype, and engineering-scale facilities for advanced reprocessing technologies. The timing and approach to obtaining these capabilities will depend on national commitment and future priorities. DOE would complete appropriate National Environmental Policy Act documentation should any major federal action be proposed.

Table 6.1

Core Nuclear Energy Research and Development Capabilities and Facilities

Core Capabilities		Existing Core and Supplementary Facilities			
Research Priority		Tier 1 Base Case	Tier 2 Secondary	Tier 3 Tertiary	Tier 4 Other
Materials Test Reactors					
I – IV	Thermal irradiation	INL ATR	ORNL HFIR	MIT, MURR	France JHR, Japan JMTR, Norway Halden, Holland Petten
V	Np-237 target irradiation	INL ATR	ORNL HFIR	NEW TRIGA[1]	
IV	Fast irradiation – small samples/surrogates	INL ATR	ORNL HFIR		
I – IV	Transient testing	INL TREAT		Japan NSRR	
Hot Cells					
I – IV	Hot cells capable of handling and examining full-length rods or fuel assemblies	INL HFEF	ORNL IFEL[3]		
I – IV	Hot cells capable of supporting high-level mechanical testing	INL HFEF	ORNL IMET		
IV	Aqueous separations – lab scale	ORNL 7920 and/or INL RAL[2]			
IV	Aqueous separations – lab scale integrated testing	SRNL shielded hot cells or INL RAL	PNNL radiochemistry lab		
IV	Aqueous waste form development – lab scale	SRNL shielded hot cells, PNNL radiochemistry lab or INL RAL			
IV	Electrochemical separations – lab scale	INL HFEF			
IV	Electrochemical separations – engineering scale	INL FCF			
IV	Electrochemical waste form development – engineering scale	INL HFEF			
IV	Hot fuel fabrication – test pins	INL FMF and FCF			
V	RPS final assembly and testing	INL SSPSF			

Research Priority Key

I. Sustain existing LWRs as long as possible
II. Build new LWRs as fast as possible
III. Deploy new, advanced reactor technologies for nontraditional applications
IV. Spent fuel management R&D
V. RPS/Pu-238 production

[1] *New TRIGA is a fallback option if there is a insufficient capacity, does not require a large separations facility.*

[2] *RAL is under consideration for several missions. Actual use of RAL for one mission could preclude its use for others.*

[3] *Currently used to chop fuel in support of the coupled end-to-end demonstration.*

Currently operating to provide the required capabilities for the Office of Nuclear Energy program.

Table 6.2

New Nuclear Energy Research and Development Capabilities and Facilities[1]

New Capabilities		New Facilities/Significant Modification to Existing Facilities	
Purpose		Tier 1 Base Case	Tier 2 Secondary
Materials Test Reactors			
Fast irradiation testing – full-length pins		NEW (Fast Test Reactor)	JOYO
Fast test reactor – full-scale fuel, LTAs		NEW (Fast Test Reactor)	Monju
Hot Cells			
Demonstrate advanced reprocessing	Aqueous separations – engineering scale including waste form development	NEW (AFCF) or modified INL CPP 666 and 691	France Marcoule, U.K. Sellafield, or Japan Tokai
Demonstrate reprocessing technologies	Hot fuel fabrication – engineering scale	NEW (AFCF)	Marcoule, Sellafield, or Tokai
Radioisotope Power Systems Pu-238 Production [2]	Neptunium target fabrication	INL FMF	
Radioisotope Power Systems Pu-238 Production	Irradiated target separations and processing	INL RAL[3] or ORNL 7930	
Radioisotope Power Systems Pu-238 Production	Fuel pellet fabrication and plutonium storage [4]	LANL TA-55, NTS DAF, or INL RAL	
Radioisotope Power Systems Pu-238 Production	RPS final assembly and testing		
Specialized Facilities			
Deploy HTGRs for industrial applications	HTGR component testing	NEW (CTF) or existing in Japan or S. Africa	

[1] The facilities described in this table would be funded by the specific research program.
[2] Managed as a service to NASA and other customers.
[3] RAL is under consideration for several missions. Actual use of RAL for one mission could preclude its use for others.
[4] Currently performed by LANL in building TA-55, facility availability is uncertain and upgrades are required. The Office of Nuclear Energy is considering completing current processing and then relocating pellet fabrication to another site. .

Advanced Test Reactor (ATR)

Location: Idaho National Laboratory
Research Priority(ies): I, II, III, IV, V
Operational status/current utilization: Currently Operating, Limited availability for new missions until 2018

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

ATR has been operating since 1967. It remains a valuable research and test machine capable of decades of more service because it was designed so that its internal components can be replaced to avoid material aging issues. ATR was established as a National Scientific User Facility by DOE in 2007. ATR internal components are changed out every 8-10 years.

A low-temperature and pressure water-cooled reactor designed to study the effects of intense radiation on reactor materials and fuels, ATR also irradiates targets to produce valuable isotopes for medical, industrial, and research applications.

Current capabilities include the following:

- Thermal spectrum irradiation testing, maximum flux 1E15 n/cm^2-s (thermal) and 5E14 n/cm^2-s
- 9 flux traps (3.5-5.0” D, 48” L)
- 66 additional test locations (0.5” – 5.0” D, all 48”L)
- Pressurized Water Reactor (PWR) test loop in 5 flux traps – individual experiment water flow, pressure, temperature, and chemistry conditions for each experiment
- Static capsule, instrumented lead, up to 1200 C temperature control
- Ability to provide individual cover gas
- Fuel and material tests
- Power “tilt” capability to operate at different powers (and fluxes) in different core corners in single operating cycle
- Renewal of all reactor core internals every 8-10 years => effectively no lifetime operating limit.

New capabilities and planned enhancements at ATR include the following:

Advanced Test Reactor at the Idaho National Laboratory

- Reactivation of one PWR test loop – total PWR loops available will be 6 (out of 9 flux traps).
- Experiment handling for disassembly and reassembly
- Dry packaging transfer cell
- Shuttle irradiation system – insert and remove experiments during operation
- Higher temperature experiment control systems – up to 1800 C
- Experiment in-reactor instrument development – creep measurements
- Distributed Control System Installation
- Console Display System Installation
- Physics analysis tool upgrades – accommodate wider variety of experiments, more accurate results, better fuel utilization, and shorter preparation time for core physics analysis.
- Safety Margin Improvements – Risk assessment comparison to current safety standards, then implementation of risk reduction improvements.

High Flux Isotope Reactor (HFIR)

Location: Oak Ridge National Laboratory
Research Priority(ies): I, II, III, IV, V
Operational status/current utilization: Currently operating

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

HFIR is an 85-MW, beryllium-reflected, light-water-cooled and moderated, flux-trap-type reactor that uses highly enriched uranium-235 as fuel. Constructed in 1965, the reactor underwent upgrades in 1986 to enlarge in-reactor irradiation facilities to allow experiments to be instrumented. A cold neutron source was commissioned in 2007.

Current capabilities are as follows:

- Thermal spectrum irradiation testing, maximum (thermal) flux in the 5-in. deep flux trap is 2E15 neutrons/ ($cm^2 \cdot s$), with instrumented capsules and loop test configurations.
- The neutron scattering research facilities contain instruments used for fundamental and applied research on the structure and dynamics of matter.
- Production of medical, industrial, and research radioisotopes.
- Neutron activation to examine trace elements in the environment.
- Projected to continue operation through the year 2040 and beyond.

The High Flux Isotope Reactor at Oak Ridge National Laboratory

- The reactor core consists of a series of concentric annular regions, each approximately 2-ft high. The fuel region is surrounded by a concentric ring of beryllium reflector approximately 1-ft thick. This, in turn, is subdivided into three regions: the removable reflector, the semi-permanent reflector, and the permanent reflector. The beryllium is surrounded by a water reflector of effectively infinite thickness. In the axial direction, the reactor is reflected by water.
- Reflector experimental facilities have thermal-neutron fluxes up to 1E15 neutrons/ ($cm^2 \cdot s$), and can contain static experimental capsules, complex fuel-testing engineering loops, and special experimental isotope irradiations.
- Access to some experimental positions is via a pneumatic tube to allow rapid insertion and removal during reactor operation.

Transient Reactor Test Facility (TREAT)

Location: Idaho National Laboratory
Research Priority(ies): Existing LWRs, Advanced LWRs, HTGRs, and Fast Reactors
Operational status/current utilization: Standby

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality and needed/planned enhancements

Completed in November 1958 and operated from 1959 to 1994, TREAT was designed for transient testing of fuels and structural materials. Its primary mission was to provide in-pile experimental data needed for phenomenological model development, integral code fuel behavior, advanced fuel designs, and qualifications of core-driver fuel. For much of its history, TREAT was used primarily to test liquid-metal reactor fuel elements, initially for the Experimental Breeder Reactor-II, then for the Fast Flux Test Facility, the Clinch River Breeder Reactor Plant, the British Prototype Fast Reactor, and finally, for the Integral Fast Reactor. Both oxide and metal elements were tested in dry capsules and in flowing sodium loops.

Principal reactor-safety and fuel-behavior issues addressed in TREAT experiment programs have been (a) fuel-cladding interactions; (b) the timing and extent of pre-failure, in-pin, axial fuel relocation; (c) cladding failure thresholds, margins, and characteristics; (d) post-failure, in-channel fuel motions and accumulations; (e) timing and composition of coolant channel blockages; and (f) energetics of molten fuel-coolant interactions. These issues tend to arise from changes in parameters such as fuel design, fuel composition, fuel irradiation characteristics, or transient initiators. Similar tests will be needed to develop the understanding of and qualification of future transuranic-bearing fuels.

Transient Reactor Test Facility, Idaho National Laboratory

The need for additional transient test data is expected in three areas: high burnup fuel qualification, utilization of MOX fuel to high burnup, and possible future use of advanced fuel systems in LWRs. Pushing the burnup of current LWR fuel designs to higher than average burnups currently achieved in the LWR fleet would be expected to provide confirmation of fuel behavior at high burnup.

TREAT was placed in standby in 1994, and minimal preventative maintenance on the reactor systems has taken place since. Some systems (criticality and radiation monitoring systems) have been maintained operational, but refurbishment and restart of the TREAT reactor will take significant funds and effort. Following restart of preventative maintenance, the biggest effort will be bringing TREAT to operational status in the current DOE operation environment.

Massachusetts Institute of Technology Reactor (MITR)

Location: Massachusetts Institute of Technology, Cambridge, MA
Research Priority(ies): I, II, III, IV, V
Operational status/current utilization: Currently operating
Remarks: Being relicensed for operation at 6 MW; design study ongoing for low-enriched uranium core conversion

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

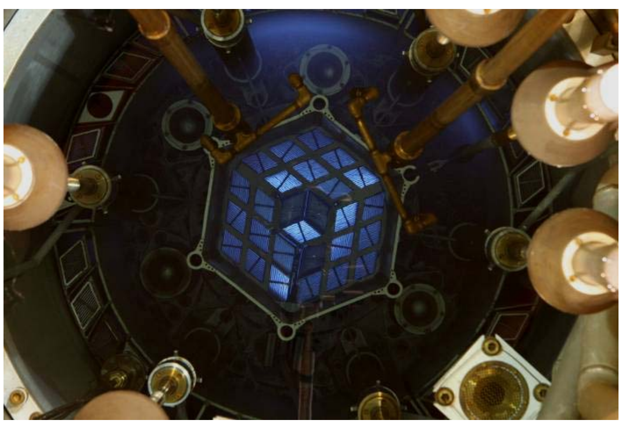
Facility functionality/needed/planned enhancements

Current capability:

Tank-type water-cooled research reactor. A graphite reflector surrounds the heavy water reflector tank.

The core has 27 fuel element positions and is normally configured with 24 fuel elements; making 3 positions available for in-core experiments. The close-packed hexagonal core design maximizes the thermal neutron flux in the heavy water reflector region where the re-entrant thimbles of the beam ports are located. The MITR is equipped with a wide variety of sample irradiation facilities, beam ports and a pneumatic sample transfer system.

The MITR operates at atmospheric pressure. The primary coolant core-inlet temperature is approximately 42°C and outlet temperature is about 50°C. The hexagonal core structure is about 38 cm across with an active fuel length of about 56 cm with fast, thermal, and gamma fluxes similar to those of a commercial LWR. The MITR operates 24 hours a day, 7 days per week and supports multiple research programs. A typical fuel cycle lasts about six weeks followed by a one-week refueling and maintenance outage.



The compact MITR core has fast and thermal neutron fluxes similar to those of a commercial LWR

The MITR has an active in-core experiment program to support materials and fuel development for advanced reactors. Each in-core irradiation facility can generally be tailored to meet the requirements of a particular experiment or multiple experiments/specimens. Examples of previous experiments include pressurized loops for studies of BWR and PWR coolant chemistry; investigation of shadow corrosion and irradiation assisted stress corrosion cracking; advanced cladding development; a scoping study of advanced LWR fuel; and a high-temperature gas reactor materials irradiation study in inert gas up to 1600°C.

University of Missouri Research Reactor

Location: University of Missouri-Columbia
Currently Supporting: Multiple programs
Status: Fully operational
Remarks: Life-extension upgrades completed and re-license application submitted to the Nuclear Regulatory Commission

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation *****	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

***** materials irradiation only

Facility functionality/needed/planned enhancements

At 10 MW, MURR is the highest-powered university research reactor in the U.S. Since 1977, MURR has operated at a schedule of more than 150 hours/week, every week of the year. During this period, the reactor has been on line for approximately 90% of all available time. The pressurized reactor uses highly enriched uranium, is light-water moderated and cooled, and is beryllium reflected. Eight fuel elements in the fuel zone form the core. Each fuel element is assembled from 24 fuel plates; each plate is a sandwich of uranium aluminide fuel with aluminum cladding, held in place by side plates and end boxes. The active core is 30 cm in diameter and 61 cm tall, with an active core volume of 33 liters.

Samples can be irradiated in the flux trap, the graphite reflector region, beam tubes, and in the bulk pool. The flux trap has a 4.5” annulus and provides a peak flux of 6 x 10^{14} n/cm^{2}sec. The graphite reflector region provides a much larger volume for irradiations and has the added advantage that even large targets can be accessed when the reactor is at full power. The irradiation positions are approximately 30” tall and have diameters ranging from 1” to 6” and peak fluxes ranging from 8.0 to 1.0 x 10^{13} n/cm^2 sec. The facility also has 2 pneumatically controlled irradiation positions with peak fluxes of 8.0 and 6.0 x 10^{13} n/cm^2 sec. The bulk pool facilities allow for larger or specially shielded irradiation positions. Currently there are three 5” O.D. positions 30” in length. The peak flux for the bulk pool facility is approximately 6 x 10^{12}n/cm^2 sec. Six neutron beam tubes surround the Be reflector and have source fluxes of 1.2 x 10^{14} n/cm^{2}sec. A state-of-the art triple-axis spectrometer occupies one beam tube and a high-resolution powder diffractometer with a resolution of 1.5 x 10^{-3} (Δd/d) is located on a second beam tube. A third beam tube houses a small-animal irradiation facility dedicated to boron-neutron-capture research.

University of Missouri Research Reactor Center

MURR’s operating schedule and our new external beam 16.7 MV cyclotron make the facility a unique national resource for human use diagnostic and therapeutic isotope production. In addition, the facility actively supports research programs in radiation effects on materials and neutron scattering studies of hard and soft matter.

Hot Fuel Examination Facility (HFEF)

Location: Idaho National Laboratory
Research Priority(ies): Postirradiation examination, electro-chemical separations
Operational status/current utilization: Operational / 50% utilized
Remarks: NRAD TRIGA reactor housed in same building

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

The HFEF comprises two adjacent large, heavily shielded hot cells in a three-story building, as well as a shielded metallographic examination shielded enclosure, an unshielded hot repair area and a waste characterization area. The main hot cell (with argon atmosphere) has 15 workstations, each with a viewing window and a pair of remote manipulators. A smaller, adjacent hot cell (with air atmosphere) has six similarly equipped workstations. The cells are equipped with overhead cranes and overhead electromechanical manipulators. The facility is linked to analytical laboratories and other facilities by pneumatic sample transfer lines.

The facility was built as to characterize highly irradiated fuel and structural materials remotely and to have the flexibility to conduct numerous other research, development, and demonstration tasks. It has both nondestructive and destructive examination capabilities. Nondestructive capabilities include dimensional measurements, visual inspection/optical photography, gamma scanning (including full-length fuel LWR fuel pins) and ultrasonic testing. Destructive examination includes fission gas sampling and analysis, cutting and sectioning to support metallographic/ceramographic examinations, microhardness testing, and mechanical testing (tensile/compression). Samples can be prepared for trans-shipment to other onsite facilities for analytical chemistry, electro-optical analysis, and other analyses. Neutron radiography can be conducted on fuel pins (152 inch length) and other components using the NRAD capability. Materials are introduced to the NRAD via the main HFEF hot cell.

Waste form development in support of advanced reprocessing research also is conducted in the cells. Much of this work is in support of EBR-II fuel disposition and involves electro-chemical treatment, high temperature consolidation, and hot-isostatic pressing of wastes.

Another support feature is a fully enclosed high bay for receiving and unloading shipping casks from trucks. A 50-ton crane can move any shipping cask (such as the NAC-LWT) from a vehicle and place it safely on a cask-handling cart used to move casks to the air hot cell for unloading full length LWR fuel rods and assemblies. A pneumatic “rabbit” system interconnects the HFEF with the Fuels Conditioning Facility and Analytical Laboratory.

Hot Fuel Examination Facility, Idaho National Laboratory

The INL is investing approximately $2 million to upgrade microscopy preparation capabilities for processing of approximately 250 samples/year for metallographic examination. The optical microscope has been upgraded to digital technology, and a new micro-hardness tester is now online. The INL is upgrading the safety basis for all of its nuclear facilities, including the HFEF.

Irradiated Fuels Examination Laboratory (IFEL)

Location: Oak Ridge National Laboratory
Research Priority(ies): I, II, III, IV
Operational status/current utilization: Currently Operating

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

The IFEL, Building 3525, at Oak Ridge National Laboratory is used principally for postirradition examination. This facility has handled a variety of fuels including aluminum-clad research reactor fuel, both stainless and zircaloy clad LWR fuel, coated-particle gas cooled reactor fuel, and one-of-a-kind fuel test experiments, as well as iridium isotope processing and irradiated capsule disassembly.

The IFEL contains a large, horseshoe-shaped array of hot cells divided into three work areas and constructed of 3-ft thick, high-density concrete walls with oil-filled, lead-glass viewing windows. The inside surfaces of the cell bank are lined with stainless steel. Special penetrations provide for the sealed entry of services. Each of 15 window stations has a pair of manipulators, and periscopes allow for magnified views of in-cell objects. Heavy objects within each cell bank can be moved by electromechanical manipulators or a 3-ton crane. Fuel materials enter and leave the cells through three shielded-transfer stations at the North cell. Two small-diameter (6.5 and 14.5 in) horizontal transfer stations are used for small objects (less than 8 ft in length). Items up to 4 by 4 by 6 ft in size can be transferred through the shielded air-lock door system. In addition, the facility can handle large casks such as the NAC LWT for handling full-length LWR fuel rods.

A variety of shears, machine tools, and cutoff saws are available within the cell for the disassembly of irradiation capsules and the preparation of fuel specimens. The facility has handled and cut Inconel, stainless steel, zircaloy, aluminum matrix, and graphite based materials. A gamma scanner is available for the nondestructive examination of moderate length fuel rods and individual specimens. Metrology equipment is available, and a new full-length fuel-pin examination station has been added. This instrument provides laser profilometry, gamma scanning, thermal imaging, and optical examination of full-length LWR fuel pins, and pin puncturing for fission gas analysis.

Metallographic equipment including precision cutoff saws, polishers, and a shielded metallograph is available for preparing, handling, and examining fuel specimens and clad material. The facility has prepared samples of oxide fuels, carbide fuels, and metal matrix fuels. The IFEL has three free-standing shielded cubicles that contain specialized equipment. A Scanning Electron Microscope provides both wavelength dispersive spectrometry and energy dispersive spectrometry capability.

Irradiated Fuels Examination Laboratory at Oak Ridge National Laboratory

The Irradiated Microsphere Gamma Analyzer cubicle is connected to the East Cell by an in-wall shielded elevator. The cubicle contains equipment for handling individual HTGR microspheres (coated particles). The cubicle has a shielded stereo-microscope and micromanipulator for handling individual particles. It houses the IMGA system, a high-resolution gamma-ray spectrometer.

The Core Conduction Cooldown Test Facility cubicle contains a fully programmable furnace facility with special sampling features. The furnace is capable of temperatures up to 2000°C when using an inert atmosphere such as helium.

Irradiated Materials Examination and Testing (IMET)

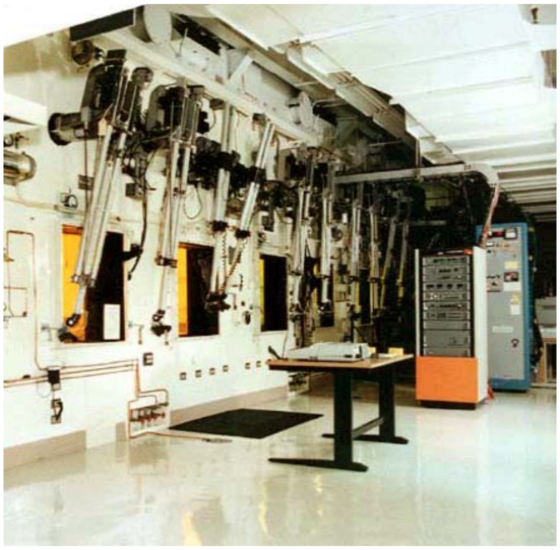
Location: Oak Ridge National Laboratory
Research Priority(ies): I, II, III, IV
Operational status/current utilization: Currently Operating

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

The IMET hot cell facility is a Hazard Category III nuclear facility located in Building 3025E at Oak Ridge National Laboratory. These hot cells are used for mechanical testing and examination of highly irradiated structural alloys and ceramics. The six interconnected (shielded drawers/doors) steel-lined hot cells contain 320 ft^2 of workspace and are maintained as a low alpha contamination facility (<70 dpm per 100 cm2) to facilitate transfer of specimens to other radiological laboratories after testing or sorting. An additional 600 ft^2 of workspace for test equipment control systems and R&D staff workstations is located in a contamination-free area in front of the hot cells.

The IMET facility contains 60 storage wells capable of storing seven cans (~0.2 ft^3) in each well. A 5-ton capacity overhead crane is used for transferring the carrier between cell roof ports and the storage area. A second overhead crane (1-ton capacity) is available in Cell 6 for handling equipment and large pressure vessel sections. The building has a convenient loading area for receiving and shipping carriers. A radiological specimen preparation area is located adjacent to the hot cells, consisting of three shielded glove boxes and a chemical hood. This specimen preparation facility is used for preparation of transmission electron microscopy specimens and other specialized activities.



The Irradiated Materials Examination and Testing Facility at Oak Ridge National Laboratory

The following functions can be performed:

- Multiple tensile testing machines (including high temperature testing to 1350°C and vacuum to10^{-7} torr)
- Laser profilometry
- Creep testing
- Charpy impact and fracture-toughness testing
- fatigue testing
- Slow strain rate testing (with corrosion chamber)
- Capsule disassembly
- Precision density measurements
- Microhardness testing
- Optical microscopic examination
- Scanning electron microscopy
- Welding, shearing, CNC machining, sawing
- Photography and video examination.

Radiochemical Engineering Development Center (REDC)

Location: Oak Ridge National Laboratory
Research Priority(ies): High Flux Isotope Reactor target preparation and processing and aqueous process development
Operational status/current utilization: Operating
Remarks: Volatile off-gas system replacement is needed

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

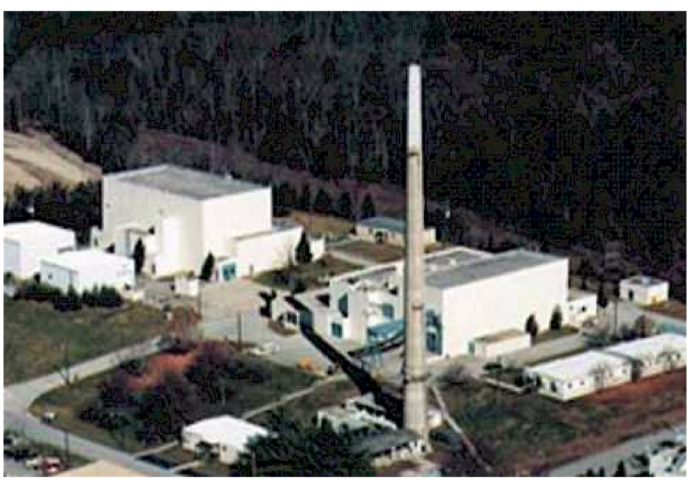
Facility functionality and needed/planned enhancements

REDC, constructed in the mid 1960s, includes two Hazard Category II, Security Category IV hot-cell facilities (Buildings 7920 and 7930), plus support facilities.

<u>Building 7920</u>

Building 7920 includes a series of nine 7-ft by 7-ft by 8.5-ft high air atmosphere hot cells with shield window and master/slave manipulators. Also, there are tank and waste pits of various sizes, a transfer cubicle, two caves 3.5-ft high, and a 4-ft wide by 3-ft deep by 4-ft high target decontamination cell. In addition, the facility includes analytical chemistry laboratories.

The hot cells were originally built in the 1960s to fabricate and process High Flux Isotope Reactor plutonium, americium, and curium targets, and to separate californium and other rare heavy actinides. It is still used for this mission, but the throughput requires processing only about once per year. One cell is currently being used to demonstrate the UREX aqueous separations process using fuel that is chopped in the IFEL as part of a coupled end-to-end demonstration. Competing programs leave little space available in Building 7920.



The Radiochemical Engineering Development Center at Oak Ridge National Laboratory

<u>Building 7930</u>

Building 7930 includes seven relatively large, air atmosphere hot cells. Cell A is 8-ft deep by 20-ft long by 24-ft high and unshielded. Cell B is 16 ft by 23 ft by 22.5 ft with concrete shielding and a stainless steel liner. Cell C is 20 ft by 33 ft by 24 ft with concrete shielding and a stainless steel liner. Cell D is 20 ft by 41 ft by 13 ft with concrete shielding and a stainless steel liner. Cell E is 20 ft by 17 ft by 30 ft with concrete shielding. A stainless steel liner is on the floor and 1 ft up the walls. Cell F is 15 ft by 37 ft by 13 ft with concrete walls. It is operated as a spent nuclear material storage vault. Cell G is 20 ft by 17 ft by 30 ft with concrete shielding and a stainless steel liner. Cells D and E have never been used and Cells A and B are operated as contamination free cells. Also, there is a small fuel storage pool that is 22 ft deep.

Fuel Conditioning Facility (FCF)

Location: Idaho National Laboratory
Research Priority(ies): SNF management research
Operational status/current utilization: Operational/electrochemical separations (engineering scale)

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

FCF was originally constructed in the early 1960s to demonstrate recycling of EBR-II metal fuel. Major modifications were completed and new process equipment was added in the 1990s for the Integral Fast Reactor program.

The facility consists of two hot cells: one with an air atmosphere and the other with an inert argon gas atmosphere, which enables work with both chemically reactive and radioactive nuclear materials. The rectangular air cell is 52 ft long by 25 ft wide and 22 ft high with nine operating stations. The air cell is used for handling, storage, and assembly/ disassembly of components. A pneumatic transfer system connects it with the Materials and Fuels Complex Analytical Laboratory hot cells for rapid transfer of radioactive samples for analysis. The argon cell is a much larger "doughnut" shaped cell, 62 ft in diameter by 22 ft high with 15 operating stations. The argon atmosphere is maintained at less than 100-ppm oxygen. Shielding walls are 5-ft thick, high-density concrete. Personnel can work from the outside corridor and monitor in-cell activities from an inner shielded space in the center of the hot cell. All equipment can be repaired remotely using externally controlled manipulators and cranes.

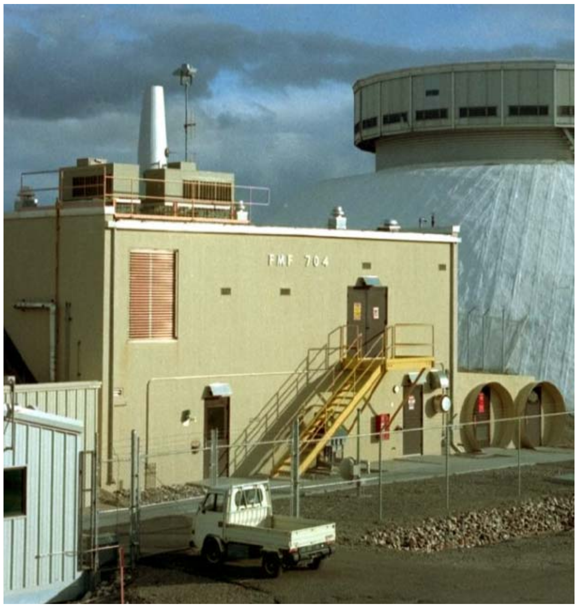
Currently, FCF is used for research and pilot-scale demonstration of electrorefining for irradiated, sodium-bonded, metal fuel. It also contains a mockup area to qualify and test new equipment, a spray chamber, special glove boxes, and a suited entry repair area where contaminated equipment can be decontaminated and repaired.

Identified upgrades include limited hot cell windows; roof modifications; and stack monitoring, emergency power, process monitoring, and equipment decontamination systems. In addition, the AFCI TRU fuel development campaign recently completed a study of upgrades and equipment needed for remote fabrication of metallic alloy fuel pins in the FCF. This is expected to require $20 million for design, procurement, and installation of needed equipment in a two-to-three year period. Specific equipment and upgrades would include fuel pin casting, demolding, pin loading, pin welding, pin leak testing and weld radiography.

Fuel Manufacturing Facility (FMF)

Location: Idaho National Laboratory
Research Priority(ies): Fuel fabrication
Operational status/current utilization: Operational

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test
Facility functionality/needed/planned enhancements			



Fuel Manufacturing Facility at the Idaho National Laboratory

Development and evaluation of fabrication processes currently takes place at FMF, which houses shielded glovebox lines capable of fabricating bench-scale quantities of actinide-bearing nuclear fuels. Originally, FMF housed the systems to fabricate EBR-II driver fuel, but it has since been converted to a general fuel fabrication facility. Although used primarily for metal fuel, it does have the capability to fabricate ceramic-based fuels and could be used for neptunium-237 target fabrication to support the plutonium-238 mission.

FMF needs minor upgrades to allow it to fabricate and handle larger quantities of fuel and feedstock materials; currently, it produces less than 1 kg of fuel per year. To move to larger amounts, the effluent stack will require installation of an online stack monitor system and a glovebox line for handling minor actinide feedstock materials in quantity. Approximate cost to upgrade FMF for larger throughput fabrications is $10 M. This would include the cost of an online stack monitoring system, second fabrication glovebox line, and a dedicated feedstock handling system.

Remote Analytical Laboratory (RAL)

Location: Idaho National Laboratory
Research Priority(ies):) Improve long-term management of fuel cycle and waste
Operational status/current utilization: Currently operational (until December 2008, then warm stand-by)
Remarks: Commissioned in 1985, represents one of the newest hot cell facilities in the DOE complex

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

Remote Analytical Laboratory at the Idaho National Laboratory.

The Remote Analytical Laboratory is an analytical laboratory designed for a wide range of organic, inorganic, and radiochemical chemical analyses. Commissioned in 1985, this two-story, metal-clad, steel-framed, 13,000-ft^2 facility contains a conventional chemical laboratory and an air atmosphere, analytical hot cell with a waste load-out cell.

The Analytical and Waste Handling Cells are constructed of reinforced concrete 36 in. thick and are on a separate foundation than the other facility structures. The analytical cell has six workstations with about 500 ft^2 of interior floor space for sample preparation and analysis. The waste load-out cell has two workstations with about 250 ft^2 of floor space. The analytical cell has pneumatic transfer lines to various nearby facilities, enabling radioactive samples to be pneumatically transferred and received. The Remote Analytical Laboratory construction was completed in 1985 and upgraded in 1995.

The Remote Analytical Laboratory was designed to provide remote analytical support for spent nuclear fuel dissolution, reprocessing, and waste solidification. It currently provides analyses for radioactive and nonradioactive processes, waste characterization, and process development activities. The analytical cell provides the capability to perform chemical analysis on highly radioactive materials. There also are work areas for bench-scale development work. The facility could be used for aqueous processing demonstrations at laboratory scale, waste form development at laboratory scale, and as a support facility to engineering scale demonstrations. The facility could potentially be used for plutonium-238 target separations or fuel pelletization. However, use of RAL for one mission could preclude its use for other missions. More detailed analyses of utilization of RAL, including analyses of costs for the aqueous reprocessing R&D and the plutonium-238 production missions, would be needed.

Shielded Cells Facility

Location: Savannah River National Laboratory
Research Priority(ies): Improving long-term management of the fuel cycle and waste
Operational status/current utilization: Operating
Remarks: Degrading windows will require replacement over the next 5-10 years

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

The shielded hot cells at SRNL are currently owned and operated by the Office of Environmental Management. These hot cells are currently suitable for waste form development at the laboratory scale, and could potentially support waste form development for aqueous reprocessing. They are also potentially suitable for integrated laboratory scale testing of aqueous reprocessing flow sheets.

The Shielded Cells Facility high-level hot cells consist of two cell blocks containing a total of 16 small, stainless steel lined, air atmosphere hot cells with a single operator position in each. Each cell module consists of an operating space approximately 6-ft wide × 6-ft deep × 15-ft high with shielding walls. The shielding is designed to protect operating personnel from 1 MeV gamma radiation from a 10,000 Ci source. Plutonium inventory is limited to 300 to 400 gm. The operator views the hot cell operations through a leaded glass window to perform tasks with manipulators.

Shielded Cells Facility at Savannah River National Laboratory

The cell modules within each cellblock are interconnected. Some walls can be removed to combine up to three cells. Overhead, in-cell, 1-ton bridge mounted cranes are used to move materials between the interconnected cells. The top and rear walls of the shielded cells are in a high-bay loading area with a 10-ton crane to facilitate the transfer of materials and equipment into and out of the cells. The cells are designed to allow easy modifications and the change out of processing equipment. Standard equipment and sample input to the cells fits within a 10-in. x 11-in. transfer port envelope. Larger items require removal of the cell roof hatch.

The Shielded Cells Facility includes support and auxiliary facilities that assist in cell operations. These facilities include a mockup shop used to test equipment before it is placed into radioactive service and maintenance facilities for the decontamination and repair of manipulators.

Radiochemical Processing Laboratory

Location: Pacific Northwest National Laboratory (PNNL)
Research Priority(ies): Improving long-term management of the fuel cycle and waste
Operational status/current utilization: Fully operational
Remarks: Life-extension upgrades are a part of the PNNL Capability Replacement Project

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

Radiochemical Processing Laboratory at the Pacific Northwest National Laboratory

The Radiochemical Processing Laboratory at the PNNL is Hazard Category 2 non-reactor facility. The facility is approximately 145,000 ft^2 and contains 12 small hot cells (about 850 ft^2 of floor space total) in two hot-cell annexes plus three smaller modular hot cells, multiple gloveboxes, and general-purpose radiochemical research laboratories. Two additional small hot cells, four additional modular hot cells, and four gloveboxes will be added to the facility as part of 20-year life-extension project with completion expected in the year 2011.

The High-Level Radiochemistry Facility hot cell annex includes three hot cells designed to shield 10^6 R/hr. The High-Level Radiochemistry Facility previously housed a spent fuel reprocessing line in support of the Nuclear Waste Vitrification Program. An adjacent truck lock and 30-ton capacity bridge crane with a 5-ton capacity auxiliary hook support fuel cask receipt in the High-Level Radiochemistry Facility. Full-length commercial reactor rods have been received and destructively examined in these cells. The Shielded Analytical Laboratory hot cell annex contains six interconnecting hot cells that handle radioactive samples up to 2000 R/hr.

Wet laboratories in the center of the facility support bench-scale radiochemical processing and separations research. A shielded glovebox contains a bank of sixteen 2-cm centrifugal contactors that enable solvent extraction research. A fuels development and evaluation laboratory contains an oxide fuel-fabrication line to produce research-grade fuels. The Radiochemical Processing Laboratory also includes irradiated materials destructive examination capabilities; thermal analysis equipment to evaluate thermo-physical properties of advanced fuels and irradiated materials, and a state-of-the-art flow-through system to evaluate the stability and durability of waste forms.

These facilities are considered an option for laboratory-scale waste-form-development research associated with aqueous reprocessing, and a backup option for integrated laboratory scale testing of aqueous reprocessing.

TA-55 Plutonium Facility

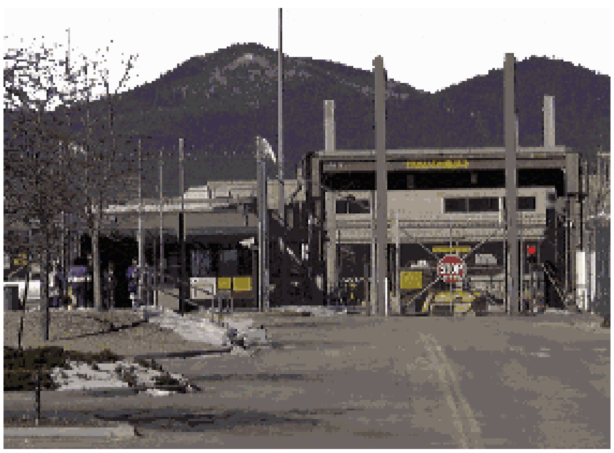
Location: Los Alamos National Laboratory
Research Priority(ies): Plutonium-238 production
Operational status/current utilization: Facility owned and operated by NNSA; NE using one wing of TA-55 to fabricate research quantities of plutonium-238 fuel pellets

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

The TA-55 Plutonium Facility is a large, 230,000-ft^2 nuclear facility within the Los Alamos National Laboratory Technical Area-55. It was constructed in the mid-1970s and began operation in 1978. Significant infrastructure upgrades to the facility are currently in progress.

The facility was designed and built to meet Security Category I and Hazard Category 2 requirements. It is primarily used for NNSA Defense Programs, but also hosts a broad portfolio of other programs. It has extensive, lightly shielded, inert glovebox capability and is designed with an integrated overhead trolley system for moving material between glovebox lines and to different parts of the building. These gloveboxes are capable of handling kilogram quantities of nuclear material as long as the associated radiation fields are relatively low.



Entrance to the TA-55 Plutonium Facility at the Los Alamos National Laboratory

Within the facility, there is a glovebox line (40 boxes) for fabrication of radioisotope heat sources and another series of connected glovebox functions as a development fuel line for ceramic fuels. This line is currently being used to fabricate research-scale quantities of MOX-type fuel pellets. At research-scale quantities, this line is capable of working with fuels containing neptunium and small quantities of americium. The line also has been used to fabricate fuels for space reactors and MOX fuels in support of the surplus weapons plutonium disposition program.

Space and Security Power Systems Facility

Location: Idaho National Laboratory
Research Priority(ies): Space and security missions
Operational status/current utilization: Fully operational

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

The Space and Security Power Systems Facility consists of an administrative building and a nuclear process building. The facility is located at Materials and Fuels Complex at the Idaho National Laboratory. The nuclear process building is a two-story, reinforced concrete building of approximately 10,000 gross ft^2. It is a security access-controlled facility surrounded by the Materials and Fuels Complex Perimeter Intrusion Detection and Assessment System. Modification of the administrative building and construction of the nuclear process building was completed in 2004.

Space and Security Power Systems Facility at the Idaho National Laboratory

The Space and Security Power Systems Facility provides the capability for assembly and testing of radioisotope power sources. These power sources, or batteries, convert the heat from plutonium-238 decay to electrical power for use in space applications or remote terrestrial locations. After a power source is assembled in one of the specialized gloveboxes in the facility, testing is performed to ensure the power source will work in the desired environment. Testing activities include the following: vibration testing to simulate lift-off conditions for space applications or vehicle transport conditions for terrestrial missions; mass properties determination for space and terrestrial applications; and thermal/vacuum testing that duplicates, as close as possible on earth, the conditions under which a space battery will be expected to operate.

Fluorinel Dissolution Process, CPP-666 Cell (FDP)

Location: Idaho National Laboratory
Research Priority(ies): Improving long-term management of fuel cycle and waste
Operational status/current utilization: Currently operational (waste packaging only – no ongoing spent fuel dissolution) Target date for closure is 2012 when all of the SNF is scheduled to be removed from the adjoining fuel storage area (6 large wet storage basins)

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, (bench/lab scale)	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements

FDP was constructed in 1984 as a second-generation reprocessing facility to perform head-end dissolution for zirconium-based fuel reprocessing. It was commissioned in 1985 and operated successfully between 1985 and 1988 to support the Navy. It houses a three-train dissolver system. Three small cells for sampling, waste load out, and neutron interrogation support cell operation. A pneumatic transfer system connects the sample cell with the Remote Analytical Laboratory.

This facility is contaminated from operations; some decontamination has occurred. FDP was designed to remotely remove and replace equipment multiple times before facility EOL. Recent missions have included remote waste packaging, and many support systems remain functional: remote maintenance systems, HVAC, shielded viewing windows.

Common enhancements would include tasks related to updating permits and SAR, reviewing security requirements, assessing improvements that may be needed for confinement systems (e.g., HVAC) as well as additional shielding barriers if new source terms exceed the design basis. The facility would likely operate as a hazards Category II and security Category II facility.

FDP (and Fuel Storage Facility), Idaho National Laboratory

Refurbishment would include complete upgrade/replacement of the control room and process control systems, possible repairs to sampling systems, assurance of double containment barriers for process solutions, and assessment of the remaining lifetime for the dissolver trains and process vessels. Enhancements could include modifications to confinement systems resulting from using different headend processes (fuel disassembly and pin chopping, voloxidation, hull treatment), hot cell space to conduct new waste treatment operations, additional remote handling capabilities to address LWR commercial fuel, and modifications to SNF transfer system for moving LWR SNF from the storage basins to the FDP cell. Modification of the head-end off-gas cleanup system may be required to demonstrate new technologies that are required for some of the candidate flowsheets

Fuel Processing Facility, CPP-691 (FPF)

Location: Idaho National Laboratory
Research Priority(ies):): Improving long-term management of fuel cycle and waste
Operational status/current utilization: FPF is currently operated as a storage facility with an annual cost of about $50,000 per year
Remarks: Newest aqueous production scale processing facility in DOE complex (construction stopped in 1992)

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale [1]	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale [2]
Waste form development [3]	Irradiated target processing	Fuel development	Assembly and test

[1] fully integrated, end-to-end; phased-targeted components
[2] only if no inert atmosphere is required
[3] engineering scale, phased-targeted components

Facility functionality/Needed/Planned Enhancements

FPF was designed to process SNF in pulsed columns and recover enriched uranium as an oxide product. Although intended to recover high-enriched uranium, alpha control features were designed into the facility because of the potential for plutonium contamination. Construction was halted in 1992 after enclosure of the structure was completed. Minimal heating and ventilation was installed for safety and investment protection. Most of the process equipment and balance of plant items (e.g., heating and ventilation, control room, and offices) were installed or completed. However, some of the more expensive items such as shielded viewing windows, remote manipulators, and emergency generator were purchased, but not installed. The facility is currently used as a storage warehouse.

FPF contains nine shielded, air-atmosphere process cells, each approximately 20 ft wide x 40 ft long x 40 ft high. These are located below grade and aligned next to a 200 ft long x 15 ft wide x 45 ft high “mini-canyon” pump-and-valve corridor. Remotely controlled sampling cells support process functions. The pump and valve corridor is stainless-steel lined and equipment within it can be remotely maintained. Three levels of operating corridors surround the process cells.

Cost data vary with selected mission (e.g., modifications to transition to full scale used fuel recycling are much lower than those needed for fuel fabrication.) Fuel fabrication would only be considered for a candidate fuel that did not require an inert atmosphere (most proposed future fast reactor fuels require an inert atmosphere). The utilities and HVAC for this facility need to be finished to the extent that it is safe to work in so it could be completed. There would be the costs related to completing the building in a manner that would be consistent with newly defined programmatic goals. These goals are generally synergistic with its original aqueous separation mission.

Fuel Processing Facility at the Idaho National Laboratory

Common enhancements to any of the FPF capabilities would include tasks related to updating permits and SARs, reviewing security requirements, assessing improvements that may be needed for confinement systems such as the HVAC, as well as additional shielding barriers if new source terms exceed the design basis. The facility would likely operate as a hazards Category II and security Category II facility. Facility enhancement costs would include tasks related to assurance of double containment barriers for process solutions, modifications to confinement systems that may result from using different process flowsheets, separating new by-products, remote rather than contact handled SNM vault storage, timely removal of decay heat, and hot cell space to conduct new waste treatment operations.

Fuel Storage Area, CPP-666 (FSA)

Location: Idaho National Laboratory
Research Priority(ies): Wet storage of all types of SNF and irradiated targets at engineering and production scale
Operational status/current utilization: Currently operational until the spent fuel is removed and placed in dry storage which is scheduled to be completed in 2012
Remarks: Most modern wet spent fuel storage pool in the DOE complex

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, (bench/lab scale)	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test
Facility functionality/needed/planned enhancements			

Built in 1985, the Fuel Storage Area, CP-666, includes six water storage basins, two of which are deep enough for commercial LWR fuel assemblies. A cart and inclined plane allows fuel to be transferred from the basins directly into the fuel-dissolution process cell. However, a cart modification would be needed to transfer full-length commercial assemblies into the fuel-dissolution process cell. Cask-handling capabilities accommodate commercial fuel transfer casks.

FSA (and Fluorinel Dissolution Process) at the Idaho National Laboratory

Cost data will vary with selected mission, but they are not expected to be significant relative to enhancements to refurbishment as the storage capabilities of the facility are likely to meet or exceed any new requirements and the facility is operating.

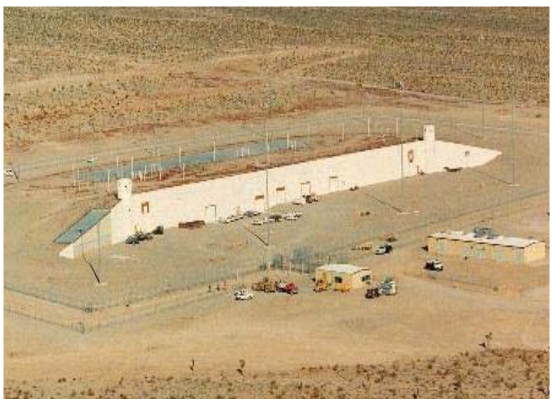
The facility would likely operate as a hazards Category II and security Category II facility. Common enhancements would include tasks related to updating permits and SARs, reviewing security requirements, assessing improvements that may be needed for confinement systems such as the HVAC, as well as additional shielding barriers if new source terms exceed the design basis.

Device Assembly Facility (DAF)

Location: Nevada Test Site
Research Priority(ies): Space and security missions
Operational status/current utilization: Operational; Critical experiments and national security work

Nuclear energy research capabilities for this facility are shaded			
Thermal irradiation	PIE	High level mechanical testing	Transient testing
Aqueous separations, bench/lab scale	Aqueous separations, engineering scale	Aqueous separations, integrated lab-scale testing	Electromechanical separations (engineering scale)
Fast irradiation, small samples	Fast irradiation testing, full size fuel and LTAs	Hot fuel fabrication, small test pins	Hot fuel fabrication, engineering scale
Waste form development	Irradiated target processing	Fuel development	Assembly and test

Facility functionality/needed/planned enhancements



Device Assembly Facility at the Nevada Test Site

The DAF at the Nevada Test Site supports activities related to nuclear test readiness and science-based stockpile stewardship, including assembly of subcritical experiments. The DAF is a relatively new facility that is capable of handling high activity alpha isotopes. As such, it is under consideration as a candidate for heat source production for radioisotope power systems.

DAF would require several modifications to prepare a portion of it for glove box operations to fabricate and test clad plutonium-238 fuel for space and defense applications.