Update of the Used Fuel Disposition Campaign Implementation Plan

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Used Fuel Disposition
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Appendix E
FCT Document Cover Sheet

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This deliverable was prepared in accordance with Sandia National Laboratories
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QA program which meets the requirements of
☒ DOE Order 414.1 ☐ NQA-1-2000

This Deliverable was subjected to:

☐ Technical Review	☐ Peer Review
Technical Review (TR)	**Peer Review (PR)**
Review Documentation Provided	**Review Documentation Provided**
☐ Signed TR Report or,	☐ Signed PR Report or,
☐ Signed TR Concurrence Sheet or,	☐ Signed PR Concurrence Sheet or,
☐ Signature of TR Reviewer(s) below	☐ Signature of PR Reviewer(s) below

Name and Signature of Reviewers

*Note: In some cases there may be a milestone where an item is being fabricated, maintenance is being performed on a facility, or a document is being issued through a formal document control process where it specifically calls out a formal review of the document. In these cases, documentation (e.g., inspection report, maintenance request, work planning package documentation or the documented review of the issued document through the document control process) of the completion of the activity along with the Document Cover Sheet is sufficient to demonstrate achieving the milestone. QRL for such milestones may be also be marked N/A in the work package provided the work package clearly specifies the requirement to use the Document Cover Sheet and provide supporting documentation.

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1. Table of Contents

I. Introduction

This Campaign Implementation Plan provides summary level detail describing how the Used Fuel Disposition Campaign supports achievement of the overarching Fuel Cycle Research and Development Program mission and objectives. Implementation of the Used Fuel Disposition Campaign will be sufficiently flexible to accommodate any of the potential fuel cycle options for used fuel management. As described in the DOE's *Nuclear Energy Research and Development Roadmap Report to Congress* (April 2010, http://www.ne.doe.gov/doclibrary/overview.html), the Fuel Cycle R&D Program's activities have been organized by grouping potential fuel cycle options into three broad categories.

- *Once-Through* – Nuclear fuel makes a single pass through a reactor after which the used fuel is removed, stored for some period of time, and then directly disposed in a geologic repository for long-term isolation from the environment. The used fuel will not undergo any sort of treatment to alter the waste form prior to disposal in this approach, eliminating the need for separations technologies that may pose proliferation concerns. Less than one percent of the mined uranium is utilized in the present once-through fuel cycle.
- *Modified Open Cycle* – The goal of this approach is to develop fuel for use in reactors that can increase utilization of the fuel resource and reduce the quantity of actinides that would be disposed in used fuel. This strategy is "modified" in that some limited separations and fuel processing technologies are applied to the used LWR fuel to create fuels that enable the extraction of much more energy from the same mass of material and accomplish waste management goals.
- *Full Recycle* – In a full recycle strategy, all of the actinides important for waste management are recycled in thermal- or fast-spectrum systems to reduce the radio-toxicity of the waste placed in a geologic repository while more fully utilizing uranium resources. In a full recycle system, only those elements that are considered to be waste (primarily the fission products) are intended for disposal, not used fuel. Implementing this system will require extensive use of separation technologies and the likely deployment of new reactors or other systems capable of transmuting actinides.

This implementation plan will be maintained as a living document and will be updated as needed in response to progress in the Used Fuel Disposition Campaign and the Fuel Cycle Research and Development Program and possible changes in policy such as might result from the recommendations of the Blue Ribbon Commission on America's Nuclear Future (BRC 2012, *Report to the Secretary of Energy,* (http://cybercemetery.unt.edu/archive/brc/20120620211605/http:/brc.gov//)

II. Fuel Cycle Research and Development Program Mission and Objectives

The *Mission* of the Fuel Cycle Research and Development Program is to:

Develop used nuclear fuel management strategies and technologies to support meeting federal government responsibility to manage and dispose of the nation's commercial used nuclear fuel and high-level waste; develop sustainable fuel cycle technologies and options that improve resource utilization and energy generation, reduce waste generation, enhance safety, and limit proliferation risk.

> What is a sustainable fuel cycle?
>
> With respect to the Fuel Cycle Research and Development program a sustainable fuel cycle is one that:
> - Improves uranium utilization
> - Improves energy utilization
> - Reduces waste generation
> - Improves safety
> - Limits proliferation risk

The *Vision* of the Fuel Cycle Research and Development Program is:

By mid-century, strategies and technologies for the safe long-term management and eventual disposal of U.S. commercial UNF and any associated nuclear wastes have been fully implemented. Advanced nuclear fuel and fuel cycle technologies that enhance the accident tolerance of light-water reactors and enable sustainable fuel cycles are demonstrated and deployed. Together, these technologies and solutions support the enhanced availability, affordability, safety, and security of nuclear-generated electricity in the United States.

The *Objectives* of the Fuel Cycle Research and Development Program are to:
In the near term,

- Address Blue Ribbon Commission on America's Nuclear Future recommendations.
- Develop a strengthened technical and scientific basis for extended UNF storage.
- Partner with industry to develop and demonstrate integrated solutions for storage of used nuclear fuel.
- Identify and test options to increase accident tolerance of the light water reactor fleet.
- Select preferred sustainable fuel cycle options for further development.
- Support the deployment of advanced enrichment technology to meet national energy and security objectives.

In the medium term,

- Conduct science-based, engineering-driven research for selected sustainable fuel cycle options.
- Partner with industry to deploy an integrated solution for the extended storage of used nuclear fuel.
- Develop the scientific basis for multiple disposal options for used nuclear fuel and high-level waste.

- Demonstrate and deploy technical and process enhancements that enhance the accident tolerance of the current reactor fleet.

By mid-century,

- Have implemented acceptable and safe options, strategies and solutions for management (including extended storage and long-term disposal) of used nuclear fuel and nuclear waste.
- Support affordable, safe, and secure nuclear-generated electricity by deploying advanced nuclear systems and facilities.
- Test and make available advanced technologies that enable sustainable fuel cycles.

III. Campaign Mission and Objectives

The safe management and disposition of used nuclear fuel and/or high-level nuclear waste is a fundamental aspect of the nuclear fuel cycle. The United States currently utilizes a once-through fuel cycle where used nuclear fuel is stored on-site in either wet pools or in dry storage systems with ultimate disposal in a deep mined geologic repository envisioned. Multiple disposal strategies and long interim storage at reactor sites are being considered. In addition, the Fuel Cycle R&D Program is investigating alternatives to the once-through fuel cycle and there is a need for a sound technical basis for managing radioactive wastes from any future nuclear fuel-cycle to provide acceptable disposition paths for all wastes regardless of origin. These disposition paths will involve both the storing of radioactive material for some period of time and the ultimate disposal of radioactive waste. As disposition paths evolve from the continuing research and development process, it is important that storage options for fuel cycle materials remain as flexible as possible in order to facilitate selected disposal options.

The storage and transportation of UNF has a stable regulatory basis, is technically mature, and operationally safe. However, two important recent factors have precipitated the need for R&D investment. First, there is a likely need for storage licenses to be extended beyond the regulatory time limit. Second, the utility industry has been maximizing plant efficiencies which have resulted in markedly higher average burnups for the fuel. To extend the license time period, data needs to be obtained that demonstrates used fuel behavior and characteristics over long periods of time. For high burnup fuels, data as well as modeling and simulation are needed to demonstrate fuel behavior and characteristics during extended storage, as well as during transportation. While the near term focus of the FCR&D Program is on used nuclear fuel, wastes from alternative fuel cycle technologies will also be addressed. For example, advanced transmutation systems will utilize fuels, and possibly targets, that are quite different than LWR fuel. Research will be needed to identify and develop practical storage systems for these materials, leveraging on the experience gained for developing LWR used fuel storage systems.

The disposal of radioactive waste of all classifications (low-, intermediate-, high-level waste, and used nuclear fuel) has been investigated world-wide since the inception of nuclear power. While significant progress has been made regarding disposal, the routine disposal of used nuclear fuel and radioactive waste remains problematic. Experience both in the US and internationally has illustrated the challenges of siting, characterizing, designing, and licensing a geologic repository. Progress has been demonstrated by the deployment of near-surface disposal facilities for low-level waste and the Waste Isolation Pilot Plant for the disposal of defense-related transuranic wastes. However, the capacity for disposing of low-level wastes is limited, potential disposal pathways for Greater Than Class C low-level waste (which is essentially intermediate level waste) have yet to be identified, and the disposal of used nuclear fuel and high-level waste has not been demonstrated. An expansion of nuclear energy in the United States, and world-wide, and the closing of the nuclear fuel cycle would require the availability of routine disposal pathways.

In January of 2012, the Blue Ribbon Commission on America's Nuclear Future published the *BRC Report to the Secretary of Energy*. Among the recommendations from the BRC specific to transportation, storage and disposal was a statement that the BRC "…*believes the general* *direction of the current DOE research and development (R&D) program is appropriate*…" and generally endorsed the approaches undertaken by the UFD campaign to continue R&D on generic nuclear facility sites.

Mission

To address these challenges, the Used Fuel Disposition Campaign will identify alternatives and conduct scientific research and technology development to enable storage, transportation, and disposal of used nuclear fuel and wastes generated by existing and future nuclear fuel cycles.

Campaign Challenge

To provide a sound technical basis for implementation of a new national policy for managing the back end of the nuclear fuel cycle, including the identification and evaluation of safe and secure options for storage, transportation, and permanent disposal of radioactive wastes resulting from existing and future fuel cycles.

Recognizing that the current system for managing nuclear waste is viable for several decades, the Used Fuel Disposition Campaign has established five near-term *objectives* and four long-term *objectives*; additional information regarding specific goals associated with these objectives are provided in Section VI below.

Near-Term Objectives

1. Provide technical expertise to inform policy regarding the management of used nuclear fuel and radioactive waste that would be generated under existing and potential future nuclear fuel cycles.
2. Develop a comprehensive understanding of the current technical bases for storing used nuclear fuel and high-level nuclear waste to identify long-term research and development needs.
3. Develop the technical basis for the retrievability and transportation of high burnup UNF.
4. Develop a comprehensive understanding of the current technical bases for disposing of used nuclear fuel, low-level nuclear waste, and high-level nuclear waste in a range of potential disposal environments to identify long-term research and development needs.
5. Continue model development, confirmed by experiment for the evaluation of disposal system performance in a variety of generic disposal system concepts and environments.

Long-Term Objectives

1. Develop a fundamental understanding of the performance of potential storage system concepts over many decades for a variety of used nuclear fuel types and radioactive waste forms based on simulation and experiment.
2. Initiate long-term storage strategies through a small-scale demonstration project that incorporates the technologies identified and developed from the near-term storage objectives.

3. Develop a fundamental understanding of disposal system performance in a range of environments for potential wastes that could arise from future nuclear fuel cycle alternatives through theory, simulation, testing, and experimentation.
4. Develop a computational modeling capability, confirmed by experiment, for the performance of storage, transportation, and disposal options for a range of fuel cycle alternatives.

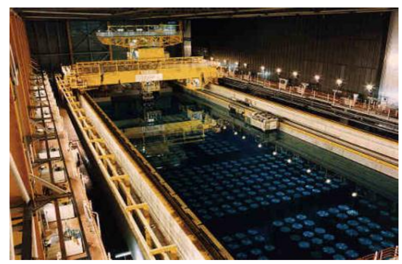
IV. Key Barriers and Technical Challenges

Storage

Used light water reactor fuel is being safely and securely stored in the United States, primarily at the locations where it was generated. It is initially stored in wet used fuel pools, but as these pools fill to capacity, the used fuel is transferred to dry canisters that are stored on-site. Used nuclear fuel is also transferred from wet pools to dry storage systems when a nuclear power plant is decommissioned, but the used fuel remains at the site of the reactor.

High-level nuclear waste, primarily vitrified borosilicate glass, generated from the reprocessing of used nuclear fuel is typically stored in vaults on site.

These storage systems provide radiation shielding and protection for both workers and the public, and dissipate heat emanating from radioactive decay of the waste. Security is provided both by physical barriers and the protective force present at the reactor site.



Neither wet nor dry storage systems offer a permanent solution for managing used nuclear fuel or high level nuclear waste. Rather, they are designed to be temporary with plans for ultimate removal of the material and subsequent disposition (i.e. disposal). The unavailability of disposition options, such as a permanent disposal facility, has resulted in the potential need for an extended storage period. Dry used fuel storage systems are typically licensed by the U.S. Nuclear Regulatory Commission for a 40-year period, although extended safe and secure storage for periods of up to 80 years is attainable. Safe and secure storage for even longer may be viable, although research and development is needed to determine how long safe and secure storage may be technically feasible.

Current policy is that the status quo is acceptable for long-term storage pending a decision on fuel cycle alternatives and final disposal. This approach is reasonable based on current economics, a stable regulatory environment, and sufficient land space to expand the on-site storage footprint, as needed. From a longer term strategic perspective, several issues arise that will need to be addressed:

- as UNF continues to be stockpiled in long-term storage, on-site storage space will become limited and there may be a drive to interim storage of UNF at one or more consolidated, independent used fuel storage facilities,
- there is a general security concern regarding this increasing stockpile of stored UNF at many different reactor sites,
- utilities are going to higher burnup fuels that will require additional safety and security assessments to verify their compatibility for storage under current regulatory and operational regimes,
- validation requirements for UNF integrity for transportation after long-term storage need to be developed, and

- experiments needed to obtain used fuel cladding material property data are inherently expensive and complex.

The 5- and 10-year Campaign Goals for storage are structured to address these issues so that all fuel cycle material will be stored in a safe and secure manner and in a way that will be

adaptable to selected disposal paths. In addition to the safety aspects associated with the storage and transportation of UNF, the high level of security maintained for current storage of used nuclear fuel will be continued in future storage, transportation, and disposal operations, and will be enhanced by advanced systems for intrusion detection, assessment, and response. Attempted diversion, theft, or sabotage of nuclear materials will be detected and prevented, and security will be assured throughout the used fuel management cycle. Current methods of accomplishing this objective are to employ intrusion detection technologies to alert Protective Force (PF) officers of an intruder and use physical barriers to delay the intruders long enough to ensure that the PF can neutralize and interdict the threat. This is the traditional "detect, delay, and respond" model. The security team will draw from design and installation experience and recent technologies utilized at DOE and DoD nuclear weapons sites.

As new options for nuclear fuel management are identified, there may be beneficial security characteristics that are inherent to the options being considered, such as configuration of material, weight, or storage location. For example, materials stored in large heavy containers, needed to meet safety or thermal dissipation requirements, will inherently provide delay. This element of delay which enhances the security represents an "intrinsically secure" feature of the option and comes at no additional cost for security. As new options are being developed, the security team will identify intrinsically secure features of each concept, which will factor into the systems analysis of the R&D options being proposed. In the initial stages of a concept there may be opportunities to "build in" security features that come at no additional cost, resulting in an intrinsically secure design.

Transportation

Significant R&D and operational experience exists related to the transportation of LWR used fuels. However, higher burnup fuels and advanced fuels developed as part of future fuel cycle options will likely require development of a materials properties database and may require new technologies to support their transportation. The following are the R&D topics associated with Safe and Secure Transportation activities:

Material Property Understanding. The safety associated with UNF extended storage and subsequent transportation must be justified through experimental data collection, associated modeling and simulation, and confirmatory demonstration. In particular, the focus on material property data will be on the cladding of high burnup UNF.

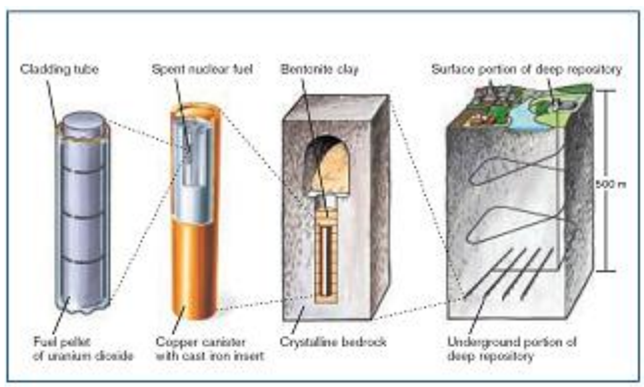
Risk-informed Qualification. As the nuclear fleet evolves and new fuel types are used, new and cost effective approaches are needed for cask qualification. Such approaches would require the development of advanced modeling capability supported by experimental data to predict the response of the shipping cask and its contents to accident conditions.

Radiological Consequences. The potential environmental consequences from intentional destructive events on shipping containers require complex characterization, in particular regarding how irradiated fuel will disperse following an attack. Existing R&D has focused on LWR fuels, and much is known about their behavior under these conditions. Additional research is needed, however, for higher burnup fuels and advanced fuels to develop the fundamental data on damage and dispersal phenomena including the coupling of the fuel-clad system. In addition, an evolving threat environment points to the need to improve analytical capabilities to support the estimation of potential consequences resulting from intentional destructive acts. The dynamics and extreme nature of these events dictate the use of unique experiments to support the development and validation of engineering consequence models. *Secure Transportation.* There is currently no commercial capability in the U.S. to transport Category I and II materials that require enhanced security. The DOE Safeguards Trailer (SGT) has been used on some shipments (e.g., Eurofab MOX fuel) in the U.S. However, the SGT cannot be relied on once routine commercial transport operations are required for Cat I/II shipments. As advanced fuel cycles are evolving in this country, there is a need to begin the development of a commercial capability to ship NRC-licensed Cat I/II nuclear and radioactive materials.

Disposal

Permanent disposal of used fuel and radioactive waste is only acceptable if sufficient isolation can be provided so that the risk of any potential exposure that may occur has been sufficiently reduced so that it meets regulatory requirements.

A variety of concepts for disposing of radioactive waste have been investigated extensively worldwide for several decades, since the inception of nuclear energy. These concepts address the disposal of low-level waste in shallow land burial facilities, disposal of intermediate-level waste in intermediate-depth facilities, and disposal of high-level waste and used nuclear fuel in deep mined geologic repositories,. In some cases, disposal facilities have been sited, licensed/permitted, constructed, and are in operation. In other cases, the siting-licensing-construction-operation process is underway. Other disposal concepts, such as deep borehole disposal, have also been considered and investigated, although not as in-depth or as extensively.



Crystalline Rock (Granite, SKB)

Safe disposal of radioactive wastes is accomplished by isolating the waste for sufficiently long time periods. Isolation is achieved by relying on the performance of the engineered and natural barriers of the disposal system under consideration. These natural and engineered barriers serve to isolate the waste, essentially resulting in no risk of exposure when these barriers are performing as expected. Over the long time periods necessary to isolate the wastes, the engineered barriers may degrade allowing some radionuclides still present in the waste to be released at a low rate into the natural system. The natural system will act to reduce and delay the subsequent migration of these released radionuclides to the accessible environment to very limited and acceptable levels. Understanding when radionuclides may begin to be released from the disposal system, the rate that they may be released, and how they might migrate through the natural system are the primary factors in demonstrating the safety of a disposal system concept.

When considering the safety of disposal systems, two primary barrier capabilities are essential.

- Completely isolating disposed wastes for as long as possible, after which;
- Limiting radionuclide releases to the accessible environment where radiation exposure could occur.

Geologic disposal concepts are typically complex systems with couplings between the disposed waste, engineered barrier materials, and the natural system. The long-term radionuclide isolation capabilities and characteristics of a waste disposal environment are dependent on the details of the site and the form and contents of the wastes to be disposed. Disposal facilities can be geographically large and the distance over which materials could potentially migrate can be long. Understanding how disposal systems could evolve over very large time scales, considering chemical and physical couplings and large length scales, is highly uncertain. Reducing this uncertainty, quantifying this uncertainty, and propagating this uncertainty through the safety assessments have been and continue to be challenges in demonstrating the viability of geologic disposal.

It must be recognized that uncertainty will never be eliminated, or may not even be reduced to a small level, due to the complexity of the disposal systems and the long time frames involved. However, research and development can be completed to understand a disposal system well enough to establish a reasonable expectation that it would be protective of public health and safety. Research and development focuses on gathering sufficient data (laboratory and field) and the development of computational models such that long-term disposal system performance can be evaluated and demonstrated.

V. Campaign Activities

Campaign Organization and Structure

The campaign structure is organized into three management groups:

1. Crosscutting (CX) activities. Activities that are campaign wide and may have effect on transportation, storage and disposal.
2. Storage and transportation (ST) research and development. Activities specifically associated with the storage and transportation of radioactive wastes.
3. Disposal research (DR) activities. Activities specifically associated with the disposal of radioactive wastes.

What follows is a summary of the activities in each of the campaign management groups.

CX-Campaign Management and Integration

This activity supports campaign management and integration activities. Specific responsibilities include ensuring technical R&D work throughout the campaign is of high quality and meets programmatic requirements; integrating R&D activities across the campaign and with other campaigns and industry participants in the Fuel Cycle R&D program; interacting with the Nuclear Energy Advisory Committee, the Nuclear Waste Technical Review Board, and other external advisory and review groups as needed; and supporting the DOE-NE University Programs as needed.

CX-Storage, Transportation and Disposal Interface Analysis

The objectives of this cross-cutting activity are to obtain both qualitative and quantitative information regarding the back-end of the nuclear fuel cycle (storage, transportation, and disposal) that can be used to inform future policy decisions regarding future nuclear fuel cycle deployment.

CX-International

The objective of this cross-cutting activity is to coordinate and facilitate international collaborative activities for the UFD campaign. Substantive technical work (i.e., modeling and analysis, experimental support) related to international collaboration is conducted within specific technical work packages in DR and ST.

ST-Field Demonstration

The objectives of the Field Demonstration activity are plan and deploy a confirmatory storage demonstration that will validate our understanding of component material degradation issues that are important to safety. This effort will be conducted in close collaboration with industry and the NRC. High priority storage component safety issues are identified in the Used Nuclear Fuel Storage and Transportation Data Gap Prioritization report (FCRD-USED-2012-000109). These issues include the collaboration with industry to plan for fielding a demonstration platform(s) under dynamic and constrained conditions. This work will specifically address potential paths to fielding a demonstration platform based on input from industry, the BRC recommendations, the DOE's strategy in response to the BRC recommendations, Congressional guidance, and other input as applicable.

ST-Storage and Transportation Experiments

The objectives of the Storage and Transportation Experiments activity are to conduct the separate effects tests (SET) and small-scale tests that have been identified in the Used Nuclear fuel Storage and Transportation Data Gap Prioritization report (FCRD-USED-2012-000109). As the experimental work evolves, new issues may arise as artifacts of the test programs. This activity will assess the impact on the developing technical basis as these new issues arise, and. will also closely coordinate with relevant regulatory progress to ensure that all R&D activities relate to eventual licensing.

ST-Transportation

The objectives of the Transportation activity are to address identified high priority technical issues associated with the retrieval and subsequent transportation of UNF. The focus will be on high burnup UNF (> 45 GWD/MTU).

ST-Storage and Transportation Engineering Analysis

The objectives of the Storage and Transportation Engineering Analysis activity are to conduct analyses, integrate experimental data, and develop the technical basis for extended long term storage and subsequent transportation of used fuel. Analyses will serve to augment the experimental work by addressing degradation phenomena not readily obtainable through experimentation, such as hydrided behavior in cladding land low temperature creep over very long periods of time.

ST-Security

The objectives of the Security activity are to assess the impact of the spent fuel standard over long storage periods, as well as how material attractiveness issues affect physical protection strategies and requirements. As the US NRC is currently in rule-making for storage security, this work will continue to integrate regulatory changes as they occur. In addition, planning for a systems approach to transportation security will be initiated to understand relative vulnerabilities various operational phases of transportation.

DR-Thermal Load Management and Design Concepts

The objectives of the Thermal Load Management and Design Concepts activity are to refine mined geologic disposal concepts for UNF and HLW, using published information, international experience, and original analysis, and to identify “enclosed” and "open" reference disposal concepts, and provide descriptive information including surface and underground facilities, waste packaging, thermal analysis for waste forms, and cost estimation.

DR-Generic Engineered Barrier System Evaluations

The objectives of the Generic Engineered Barrier System (EBS) evaluations activity are focused towards the identification and evaluation of important features and processes in the analysis of EBS design concepts and related materials for nuclear waste disposal in various types of repository environments in the near-field environment of disposal. A key aspect of EBS design concept evaluation is the development of flexible tools and methods to analyze disposal of various waste types and assess performance requirements in the process of EBS design optimization.

DR-Generic Natural System Evaluations

The objectives of the Generic Natural System Evaluations activity are aimed to develop experimental and computational capabilities and perform modeling analyses to support the development of disposal concepts in various geologic media (e.g. clay, granite, salt and deep borehole) in the far-field environment of disposal.

DR-Regional Geology

The objective of the Regional Geology activity is to develop a spatial (GIS) database to document fundamental geologic information on alternative geologic disposal options at the regional scale. The data acquired as part of this work will support the UFD site screening, Site selection, and site characterization decision points. Along with geologic data related to specific formations, the work captures spatial siting factors (seismic hazard, mineral resources, topography, population, infrastructure, etc.) important at the screening, selection and characterization stages of disposal system development.

DR-Generic Disposal System Level Modeling

The objective of the Generic Disposal System Level Modeling activity is to develop the necessary system model architecture to support the evaluation of post-closure risk at sufficient rigor to support intended use and maintain the flexibility in the system model architecture to meet the evolving needs of the DOE NE and UFD missions by providing the capability to produce risk information throughout the potential future phases of the mission, including prioritization of R&D needs, down selection of geologic disposal options, and site selection and screening.

DR-Advanced System Level Modeling

The objective of the Advanced System Level Modeling activity is to identify and begin development of a computational model framework capable of supporting both simple and complex integrated generic disposal system models in accordance with the requirements identified in FY12.

DR-Inventory

The objective of the Inventory activity is to provide estimates of primary and secondary waste streams from potential alternative fuel cycles. These estimates are intended to provide a common baseline for other UFD campaign efforts such as generic disposal system modeling and storage and transportation studies as well as tasks associated with other campaigns such as the Separations and Waste forms campaign and the Fuel Cycle Options campaign.

DR-Low Level Radioactive Waste Disposition

The objective of the Low Level Radioactive Waste Disposition activity is to evaluate low level radioactive waste (LLW) disposal options to ensure that LLW that would be generated from potential future advanced fuel cycles can be disposed of safely and in a cost-effective manner. Advanced nuclear fuel cycles could potentially generate LLW streams that differ from those being generated by the current once through nuclear fuel cycle. The waste streams could differ in regards to volume, waste form, radionuclide content and concentration, and chemical content and concentration. The disposition of these wastes could prove challenging.

DR-Deep Borehole Disposal

The objective of the Deep Borehole Disposal activity is to advance the deep borehole disposal technical basis needed to demonstrate the viability of this disposal concept and make progress towards implementing a full-scale demonstration.

DR-Salt R&D

The objective of the Salt R&D activity is based on the Salt Research Development Study Plan completed on March 23, 2012 and agreed upon by DOE-NE and DOE-EM. The study plan was developed in response to the agreement on the technical objectives and science-based scope of work for the study of salt geologic media for potential disposal of DOE-owned and civilian high-level waste and used nuclear fuel.

VI. Campaign Goals

G5-1 *2013 through 2015:* The focus during this period is on the development of science-based tools for evaluating storage, transportation, and disposal system performance using theory, experiments, and modeling. The tools will aim at understanding the fundamental processes in a variety of disposal environments, relying on information and data currently existing in the United States and international waste management programs. Improvements in storage and transportation systems for used LWR fuel will be explored and developed. Concepts will be developed for storing and transporting used fuels and waste generated from a range of advanced fuel cycles.

The specific objectives are:

Storage & Transportation:

- *Develop a comprehensive plan for a demonstration storage platform (complete March 2012)*
- *Collaborate with industry to select one storage demonstration system (2013)*
- *Conduct material property testing on high burnup used fuel cladding in a hot cell*
- *Conduct corrosion laboratory studies on SS storage canisters and continue industry collaboration to obtain in-situ data on storage canisters*
- *Develop advanced in-situ inspection techniques to monitor long term behavior of storage safety components*
- *Identify and develop criteria for verification of fuel integrity prior to shipment after long-term storage. (2015)*
- *Develop advanced analytical approaches that can be applied to safety and security scenarios for storage (2015)*
- *Develop Aging Management Plans to support re-licensing, extended storage, retrieval, and transportation (2015)*
- *Develop uncertainty quantification methods to support the technical basis for storage and transportation (2015)*
- *Conduct field testing of simulated used fuel in transportation environments to assess fuel robustness (2013)*
- *Develop a technical basis for licensing transportation systems designed to transport high burnup fuels (2015)*

Disposal Research and Campaign Cross-Cutting Activities:

- *Develop parameter uncertainty ranges for repository design concepts, thermal characteristics for engineered and natural materials (properties, temperature limits), and characteristics of the advanced waste streams selected for analysis (inventory, waste forms) (2015)*
- *Develop descriptions of repository surface facilities and other repository infrastructure needed for each reference design concept (2013)*
- *Develop refined estimates of disposal system costs including repository surface facilities, for all reference design concepts (2013)*

- *Evaluate coupled thermal, mechanical, and hydrological processes to support the assessment of long-term performance of reference design concepts(2015)*
- *Develop field testing and site characterization techniques for future site characterization activities(2014)*
- *Develop a framework of computational models, supported by experiments as appropriate, for evaluating disposal system performance for multiple disposal concepts (2013)*
- *Develop a catalog of potential disposal systems available in the US, with generic reference cases (2014)*
- *Compile current geologic and geographic data to support site screening and selection activities (2015)*
- *Use disposal performance modeling capability to prioritize the disposal R&D program (2014)*
- *Support fuel cycle options analyses using both storage/transportation/disposal interface and disposal performance modeling tools to help guide R&D for a range of alternative future fuel cycles*

G10-1 *2015 through 2025:* The focus during this period is primarily on continued development of the capability for understanding of disposal system performance through modeling and simulation and focused experimentation in the laboratory and field (i.e. underground research laboratories [URLs]). The URLs used will either be existing or constructed in the United States or those that could be accessed through international collaborations (for example, the Japanese, Korean, and European URLs), or a combination. Storage and transportation concepts for used fuel and wastes for an advanced fuel cycle will be selected and regulatory approval of these concepts will be initiated. *The specific objectives are:*

Storage & Transportation:

- *Collaborate with industry to field a full-scale NRC-licensed demonstration storage facility with monitoring/inspection capabilities to assess long term performance*
- *Validate advanced analytical approaches for evaluating storage options based on the five-year recommendations*
- *Complete the technical basis for licensing transportation systems designed to ship high burnup fuels*

Disposal Research and Campaign Cross-Cutting Activities

- *Support the development and implemention of integrated storage, transportation, and disposal concepts compatible with utility operational practices and timely underground emplacement of waste*
- *Develop advanced modeling capability for evaluating and demonstrating disposal system performance, confirmed by experiment.*
- *Conduct experimental programs to fill data needs and confirm advanced modeling approaches*
- *Continue to develop enhancements to disposal concepts, to achieve safe disposal while facilitating earlier, less costly, more efficient emplacement of hotter waste with fewer intermediate handling and processing steps.*

- *Use disposal system and subsystem modeling and experimental work to provide robust support for the selection of geologic disposal options and subsequent siting and licensing applications.*

VII. Performance Measures

Quantifiable performance measures for the Used Fuel Disposition Campaign are defined as milestones associated with the completion of documentation for each of the objectives described above. Most of the objectives listed above can be appropriately characterized as level 2 or 3 milestones, and will be defined in detail in control account and work package documentation.

VIII. Campaign Interfaces

Within the FCR&D Program, the Used Fuel Disposition Campaign is intimately linked with the Separations- Waste Form Campaign because that campaign is investigating the possible waste forms that could be used to isolate wastes generated under alternative fuel cycles. The Used Fuel Disposition Campaign is also linked with the Fuel Cycle Options Campaign by providing that campaign with information for evaluating waste management impacts within fuel cycle system analyses.

The Used Fuel Disposition Campaign interfaces with:

- The Storage and Transportation Planning Project because of the linkage between storage and transportation implementation in that project and Storage & Transportation R&D in the UFD Campaign.
- The DOE Office of Environmental Management because disposal options developed by the DOE Office of Nuclear Energy must accommodate the used nuclear fuel and high-level radioactive wastes, including those derived from defense-related programs that are currently managed by the DOE Office of Environmental Management;
- The MPACT campaign to integrate the specific activities related to security of storing used nuclear fuel with the broader MPACT mission of developing innovative technologies and analysis tools to enable next-generation nuclear material management for future U.S. nuclear fuel cycles;
- Industrial partners in both the disposal and storage areas. In the area of storage, the Campaign currently participates as a member of the Electric Power Research Institute's Extended Storage Collaboration Program and will collaborate with both nuclear utilities and dry storage vendors in the development of field demonstration programs; and,
- Universities directly and indirectly with them through the Nuclear Energy University Program (NEUP).

The Campaign also collaborates with resources from the industry with expertise related to geologic disposal to augment the knowledge base within the campaign. Additional disposal related industrial collaborations will likely occur.

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The Campaign participates extensively with international working groups and collaborates with Japan through the *U.S. – Japan Joint Nuclear Energy Action Plan, Waste Management Working Group* and the Republic of Korea through the *Joint Fuel Cycle Studies*, *Fuel Cycle Alternative Working Group* bilateral agreements.

The Campaign participates extensively with international working groups and collaborates with Japan through the *U.S. – Japan Joint Nuclear Energy Action Plan, Waste Management Working Group* and the Republic of Korea through the *Joint Fuel Cycle Studies, Fuel Cycle Alternative Working Group* bilateral agreements. The Campaign also supports active cooperation on disposal research in partnership with the DECOVALEX, the Mont Terri Project, and the Colloid Formation and Migration Project. DOE's formal membership in these multi-national initiatives provides access to field data and allows participation in ongoing field experiments.