

# ***Prioritized Safeguards and Security Issues for Extended Storage of Used Nuclear Fuel***

**Fuel Cycle Research & Development**

*Prepared for  
U.S. Department of Energy  
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Material Protection Accounting  
and Control Technologies*

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## ACRONYMS

BRC	Blue Ribbon Commission
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
DOE/NE	U.S. Department of Energy Office of Nuclear Energy
FCT	Fuel Cycle Technologies
FCRD	Fuel Cycle Research and Development
GAO	Government Accountability Office
HLW	High-level Waste
IAEA	International Atomic Energy Agency
ISFSI	Independent Spent Fuel Storage Installation
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LLW	Low-level Waste
MIT	Massachusetts Institute of Technology
MPACT	Material Protection Accounting and Control Technologies
MRS	Monitored Retrievable Storage
NAS	National Academy of Sciences
NRC	U.S. Nuclear Regulatory Commission
R&D	Research and Development
SNF	Spent Nuclear Fuel
SNL	Sandia National Laboratories
UFD	Used Fuel Disposition

# MATERIAL PROTECTION ACCOUNTING AND CONTROL TECHNOLOGIES PRIORITIZED SAFEGUARDS AND SECURITY ISSUES FOR EXTENDED STORAGE OF USED FUEL

## 1. INTRODUCTION

In light of the report, *The Blue Ribbon Commission (BRC) on America's Nuclear Future* [BRC 2012], lessons learned from the accident at Fukushima, and a variety of other factors, increased emphasis is being placed on extended storage of used fuel, especially dry storage, potentially for many decades. As part of this emphasis, technical analyses and guidance documents are needed to assure that the security risks associated with extended storage are understood and minimized, and that reliable and technically sound information is available to address any stakeholder concerns that may arise. In FY2012, the Material Protection Accounting and Control Technologies (MPACT) Campaign in the U.S. Department of Energy Office of Nuclear Energy (DOE/NE) Fuel Cycle Technologies (FCT) Program initiated activities to provide such technical analyses and guidance documents for safeguards and security of extended storage of used fuel.

To provide a context for this MPACT work, this report discusses prioritized safeguards and security issues for extended storage of used fuel. This work extends and complements used fuel security work in the Used Fuel Disposition (UFD) Campaign and was performed by technical staff from DOE national laboratories including Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Sandia National Laboratories (SNL).

The remainder of this section includes a background and overview of previous studies to address issues for the back end of the fuel cycle, including used fuel storage. Based on key recommendations from previous studies, as well as the work that has been done in the UFD Campaign and has been transitioned to continue in the MPACT Campaign, prioritize issues have been identified. These issues will be revisited to provide the basis for the MPACT used fuel safeguards and security R&D needs to be developed in FY2013.

### 1.1 Background

The DOE/NE FCT Program is conducting research and development (R&D) for alternative nuclear fuel cycles, including nuclear fuel recycling and waste management, within the Fuel Cycle R&D Program (FCRD). All fuel cycle alternatives include the production of used fuel and the need for its safe and secure storage. The uncertain future of the proposed Yucca Mountain Repository for final disposal of used fuel has caused a lack of a clearly identified disposal strategy for used fuel. The tactical strategy is to store used fuel at the utility sites in either pool or dry cask storage systems. This strategy will require extended storage of legacy fuel, used fuel being discharged from the current fleet of commercial reactors, as well as the potential of used fuel and process wastes discharged from alternative future nuclear fuel cycles.

Current practices for storage of used nuclear fuel include pool storage or dry storage on concrete pads at most operating commercial reactors. In addition, General Electric operates a storage pool at the Morris, IL, site that contains used fuel from several reactors [Andrews, 2004]. The U.S. Nuclear Regulatory

Commission (NRC) regulates both pool storage and dry surface storage of spent nuclear fuel (SNF) under Title 10 of the Code of Federal Regulations (CFR), Part 72 [USG, 2010]. Part 72 discusses licensing of both Independent Spent Fuel Storage Installations (ISFSIs) and Monitored Retrievable Storage (MRS) facilities. The term “ISFSI” refers to both wet (pool) and dry surface storage facilities. An MRS is a used (spent) fuel storage facility operated by the DOE pending shipment of the material to a high-level waste (HLW) repository. ISFSIs are currently licensed for 20 years; the current regulatory framework allows extensions for up to a total of 60 years. HLW and Greater-than-Class-C low-level waste, as well as used fuel can be stored at ISFSIs.

The time period for storage depends on the eventual availability of a disposition path or a geologic disposal option. The time period associated with extended storage is generally accepted to be well past the current 60-year licensing period. Although no time threshold has been defined, the current NRC recommendation for long-term used fuel management planning is 300 years [NRC, 2010]. This presents regulatory and technical issues with regard to both storage safety and security.

## 1.2 Overview of Previous Studies

Over the years, several studies have addressed the back end of the fuel cycle, including disposition of used (spent) fuel. One of the most recent is the study by the BRC to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle and recommend a new strategy [BRC, 2012]. To develop a prioritized safeguards and security issues for extended storage of used fuel for the MPACT Campaign, this effort has revisited those studies, including the following:

- The Government Accountability Office (GAO) study on *Spent Nuclear Fuel: Accumulating Quantities at Commercial Reactors, Present Storage and Other Challenges* [GAO, 2012]
- The BRC study on *America’s Nuclear Future* [BRC, 2012]
- The GAO study on *Commercial Nuclear Waste: Effects of a Termination of the Yucca Mountain Program and Lessons Learned* [GAO, 2011]
- The Massachusetts Institute of Technology (MIT) study on *The Future of the Nuclear Fuel Cycle* [MIT, 2011]
- The Report of the American Nuclear Society (ANS) President’s Special Committee on *Used Nuclear Fuel Management Options* [ANS, 2011]
- The Federation of American Scientists’ study on *The Future of Nuclear Power in the United States* [Ahearne et al., 2010]
- The GAO study on *Nuclear Waste Management: Key Attributes, Challenges, and Cost for the Yucca Mountain Repository and Two Potential Alternatives* [GAO, 2009]
- The National Academies of Science (NAS) study commissioned by Congress to evaluate issues related to the *Safety and Security of Commercial Spent Fuel Storage* [NAS, 2006]
- The International Atomic Energy Agency (IAEA) position paper on *The Long Term Storage of Radioactive Waste: Safety and Sustainability* [IAEA, 2003]
- The NAS study on *Improving the Scientific Basis for Managing DOE’s Excess Nuclear Materials and SNF* [NAS, 2003]
- The GAO study on *Spent Nuclear Fuel: Options Exist to Further Enhance Security* [GAO, 2003]
- The NAS study on the continuing challenges for disposition of HLW and SNF [NAS, 2001]

This effort under MPACT also considered current and previous efforts under the UFD Campaign to address security issues for long-term storage of used fuel [Durán et al., 2011, 2012]. The UFD storage

security efforts have focused on a regulatory assessment of applicable security requirements, including NRC regulations and DOE directives. In addition, three analyses have been performed to evaluate the reduction in the self-protection of used fuel that will result over the timeframe of extended storage and work is ongoing to implement a security risk assessment methodology for used fuel storage to address the changing conditions that might occur over the period of extended storage.

## **2. PRIORITIZED SAFEGUARDS AND SECURITY ISSUES FOR EXTENDED STORAGE OF USED FUEL**

This section reviews key recommendations from previous studies and then provides the basis for and a discussion of prioritized issues for safeguards and security for extended storage of used fuel.

### **2.1 Review of Key Recommendations from Previous Studies**

Generally, all of the previous studies to review used (spent) fuel storage are in agreement that the current methods for dry cask storage at current operating and shut down reactor site are safe and secure and likely to remain so for up to about 100 years. Many of the previous studies advocate a move from pool storage to dry cask storage. The more recent studies call for consolidated storage with a priority of moving stranded fuel from decommissioned reactors sites. There is also the expectation that safe and secure storage is required for many decades before a geologic repository would be operational, and then for many more decades after that for the long-term campaign to move used fuel from storage to disposal.

The BRC recommendations for a new strategy [BRC, 2012] include four elements relevant to spent fuel storage and transportation:

- Prompt efforts to develop one or more consolidated storage facilities as part of an integrated plan for managing the back end of the fuel cycle.
- Prompt efforts to prepare for the eventual large-scale transport of spent nuclear fuel and high-level waste to consolidated storage.
- Support for continued U.S. innovation in nuclear energy technology and for workforce development.
- Active U.S. leadership in international efforts to address safety, waste management, non-proliferation, and security concerns.

Specifically related to used fuel storage and transportation security, the BRC has recommended an assessment of lessons learned from the Fukushima accident and revisiting previous spent fuel storage security studies, continued R&D on vulnerability and terrorism, and an examination of the advantages and disadvantages of “hardened” storage options. In addition the BRC calls for the U.S. to work with others in the international community “to ensure that all spent fuel remains under effective and transparent control and does not become ‘orphaned’ anywhere in the world with inadequate safeguards and security” [p. xiv, BRC, 2012].

The MIT study [MIT, 2010] recommends consolidated storage for stranded fuel only, as an option to consolidate and reduce the operational costs, including significant security costs, from distributed shutdown sites and to avoid additional risks of transporting fuel from operating reactors where current storage remains safe and secure.

The NAS study [NAS, 2006] focused on potential safety and security risks of spent fuel presently stored in cooling pools at commercial reactor sites. Their recommendations include additional analysis to more fully understand the threats, vulnerabilities, and consequences for attacks on spent fuel pools and dry cask

storage. In addition, appropriate actions were recommended to address significant vulnerabilities, reduce potential consequences by moving used fuel from pools to dry storage, and to identify possible upgrades to dry casks to improve their resistance to terrorist attacks. Finally, the NAS recommended review and upgrades of security requirements for protecting individual spent fuel rods and portions of rods being stored in pools as well as an assessment of the effectiveness and adequacy of surveillance and security measures by an independent organization.

## 2.2 Prioritized Issues for MPACT Storage Safeguards and Security

The DOE/NE FCT Program has been conducting R&D for alternative nuclear fuel cycles, including nuclear fuel recycling and waste management. All of the fuel cycle alternatives include production of used fuel and the need for its safe and secure storage. More specifically, the FCR&D Program is working to develop options to current practices to enable the safe, secure, economic, and sustainable expansion of nuclear energy while reducing proliferation risks. The focus of the FCRD Program is on long term, science-based research and development of technologies with the potential to produce transformational changes to the way in which the nuclear fuel cycle, and particularly nuclear waste, is managed. The MPACT campaign is charged with R&D associated with nuclear materials protection, including safeguards and security.

In addition, the FCT program has been conducting R&D for storage, transportation and disposal of used fuel in the UFD Campaign. This work has included R&D to address used fuel security for storage and transportation. In FY2012, the used fuel safeguards and security efforts for extended storage have transitioned to the MPACT Campaign in the FCRD Program. Efforts will continued in the UFD Campaign focused on security issues for more near-term efforts on consolidated storage and transportation. The prioritized issues in the MPACT Campaign will focus on safeguards and security for extended storage and will be coordinated to complement work in the UFD Campaign and other FCT efforts to address the BRC report recommendations.

Based on key recommendations from previous studies, as well as the work that has been done in the UFD Campaign and has been transitioned to continue in the MPACT Campaign, the following prioritized issues are identified. Each priority level includes important significant work; the prioritization has been done on a relative basis.

### 2.2.1 Highest Priority Issues

This section discusses the basis and recommendations for three highest priority areas for R&D in safeguards and security for extended storage of used fuel.

#### **Vulnerabilities to and Risks of Sabotage and Terrorist Attacks**

The BRC, NAS, and GAO studies all recommend additional R&D efforts to address vulnerabilities to and risks of sabotage and terrorist attacks on used fuel storage sites. Extended storage will most likely be dry cask storage; therefore MPACT efforts in this area should focus on security risk assessment for dry cask storage facilities as a first step for the technical basis of recommendations for protection measures commensurate with the security risk. A key issue here is the need for an appropriate approach for evaluating the security risk of used fuel storage for the timeframe of extended storage, tens of decades to a couple of centuries. Efforts to address this issue have been initiated in the UFD Campaign and have been transitioned to the MPACT Campaign [Durán et al., 2011, 2012]. A framework has been established to characterize adversary attack scenarios and evaluate the difficulty of those attacks. In addition, self-protection analyses have been performed to characterize this used fuel characteristic over the timeframe of extended storage, methods have been developed to evaluate attractiveness of the used fuel materials and integrated with the security risk assessment, and a preliminary set of future adversary capabilities has been developed.

Additional efforts and related activities include the following:

- Review of previous classified NRC studies for data on consequences of sabotage and terrorist attacks. The BRC, NAS, and GAO have all recommended that NRC provide a process to allow researchers and reviewers with need-to-know more expeditious access to the reports for these studies.
- Further development of approaches to evaluate factors that change over the timeframe of extended storage, including self-protection, material attractiveness, adversary technologies (e.g., improved breaching tools, robotics), and aging containers and fuel.
- Restart of the international cask sabotage experiments to develop data on spent fuel dispersal.
- Evaluation of the hardened storage concept. A security risk evaluation would provide the basis for a cost/benefit analysis to determine if the security risk of extended storage warrants additional investment for hardened storage.
- Consideration of larger system characteristics that have impacts on vulnerabilities and security risks of extended storage. The BRC has recommended consolidated storage as part of an integrated plan for the back end of the fuel cycle. Efforts are underway in the UFD Campaign to take a larger systems approach for used fuel storage, transportation, and disposal, including consideration of alternative cask and canister concepts that might change key characteristics of the target material for security considerations.
- Continued review of NRC rulemaking for ISFSI security requirements. In 2009, NRC published for public comment a technical basis evaluation for a propose rule to revise security requirements for storing fuel away from a reactor. This evaluation included a proposal to establish a security-based dose limit that would require ISFSIs to develop site security strategies to protect against a potential radiological release that exceeds NRC's acceptable dose limits at a site boundary. NRC received public comments showing a preference for guarding against a specific threat rather than the dose-based approach. As a result, the NRC has delayed the proposed rule in order to gather more information regarding the public comments and plans additional studies to assess the situation and determine the appropriate security strategy [GAO, 2012].

### **Best Practices for Consolidated Storage**

The BRC, NAS, and GAO all recommend the development of one or more consolidated storage facilities. Early identification of best practices for the security design and secure operation of new facilities is critical. In addition, the BRC recommends active U.S. leadership in international efforts to address safety, waste management, non-proliferation, and security concerns. MPACT is planning an International Best Practices Workshop with the World Institute for Nuclear Security on Used Fuel Storage Security that would address both these recommendations. Because near-term efforts for consolidated storage will be addressed in the UFD storage security efforts, as part of the DOE/NE response to the BRC recommendations, the MPACT efforts in this area must be coordinated with and complementary to the UFD efforts and other FCT efforts to address the BRC report recommendations.

### **Surveillance and Security Measures for Individual Fuel Rods and Portions of Rods**

The BRC and NAS have recommended a review of the effectiveness and adequacy, and upgrades for surveillance and security measures for protecting fuel rods not contained in fuel assemblies. The MPACT Campaign R&D should investigate the need and technologies to improve protection of these used fuel materials.

## **2.2.2 Moderate Priority Issue**

This section discusses the basis and recommendations for one moderate priority area for R&D in safeguards and security for extended storage of used fuel.

### **Improved Safeguards for Monitoring, Accounting and Control of Used Fuel**

The BRC and NAS have recommended a review of the effectiveness and adequacy, and upgrades for surveillance and security measures for protecting used fuel, including an assessment by an independent organization. In addition to a review of surveillance and security measures, the MPACT Campaign R&D should investigate current approaches and the need for improved used fuel monitoring, accounting and control technologies that could be deployed for the timeframe of extended storage.

#### **2.2.3 Lower Priority Issue**

This section discusses the basis and recommendations for one lower priority area for R&D in safeguards and security for extended storage of used fuel.

#### **Issues for Pool Storage of Used Fuel**

Previous studies have discussed the issue of a zirconium cladding fire in a used fuel pool. This was a primary focus of the NAS study in 2006. Significant efforts have been taken to address and mitigate the possibility of a used fuel pool fire in response to this NAS study as well as to the Fukushima accident. Since Fukushima Daiichi, NRC has been engaged in ongoing initiatives related to items such as addressing a loss of off-site electricity and seismic hazard reevaluation. It has been conducting a study on the consequences of accident scenarios affecting spent fuel pools, is undertaking a probabilistic risk assessment to quantify spent fuel risk for a selected reactor site of interest, has had plants install monitoring equipment to remotely measure a wider, range of water levels in spent fuel pools, and has required plants to ensure the effectiveness of water mitigation measures [GAO, 2012]. In addition, as a response to Fukushima, spent fuel management alternatives for the U.S. nuclear fleet has been developed in the UFD Campaign to address additional fuel pool vulnerabilities. Finally, extended storage is expected to emphasize dry storage. As a result, R&D efforts to address issues associated with pool storage are a lower priority for the MPACT Campaign. Any efforts in this area in the MPACT Campaign must be coordinated with and complementary to those in the UFD Campaign and other FCT efforts to address the BRC report recommendations.

### **3. CONCLUSIONS**

The DOE/NE FCT Program has been conducting R&D for alternative nuclear fuel cycles, including nuclear fuel recycling and waste management. All of the fuel cycle alternatives include production of used fuel and the need for its safe and secure storage. More specifically the FCR&D Program is working to develop options to current practices to enable the safe, secure, economic, and sustainable expansion of nuclear energy while reducing proliferation risks. The focus of the FCRD Program is on long term, science-based research and development of technologies with the potential to produce transformational changes to the way in which the nuclear fuel cycle, and particularly nuclear waste, is managed. The MPACT campaign is charged with R&D associated with nuclear materials protection, including safeguards and security.

In addition, the FCT program has been conducting R&D for storage, transportation and disposal of used fuel in the UFD Campaign. This work has included R&D to address used fuel security for storage and transportation. In FY2012, the used fuel safeguards and security efforts for extended storage have transitioned to the MPACT Campaign in the FCRD Program. Efforts will continue in the UFD Campaign focused on security issues for more near-term efforts on consolidated storage and transportation. The prioritized issues in the MPACT Campaign will focus on safeguards and security for extended storage

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and will be coordinated to complement work in the UFD Campaign and other FCT efforts to address the BRC report recommendations.

Based on key recommendations from previous studies, as well as the work that has been done in the UFD Campaign and has been transitioned to continue in the MPACT Campaign, prioritize issues have been identified. These issues will be revisited to provide the basis for the MPACT used fuel safeguards and security R&D needs to be developed in FY2013.

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